

# PAPERmaking!



*The e-magazine for the Fibrous Forest Products Sector*

*(from the publishers of **Paper Technology International**)*



*Produced by:*

***The Paper Industry Technical Association***

**Volume 4 / Number 2 / 2018**



## CONTENTS:

### FEATURE ARTICLES:

1. **UK Industry**: Background on Industrial Decarbonisation Roadmap
2. **MFC Composite Films**: Properties of gelatine films containing MFC
3. **Waste Treatment**: Using fungi in waste treatment of Indian sites
4. **Antibacterial Paper**: Immobilised nano-silver
5. **Biorefining**: Major review on new generation biorefining
6. **Wood Panel**: Mat compression measurements on particleboards
7. **Carbon Fibre Rollers**: Using lightweight rollers in printing and papermaking
8. **Cultural Differences**: Examples of cultural difference in the workplace
9. **Networking**: How to survive networking events
10. **Conflict**: Dealing with conflict in the workplace
11. **Influencing**: Mastering the 3 ways to influence people
12. **Leadership**: Bridging the leadership gap
13. **Memory Skills**: Improve your memory

### SUPPLIERS NEWS SECTION:

**Products & Services:** Section 1 – PITA Corporate Members

**ABB / Archroma / Buckman / Jarshire / SchaeferRolls / Toscotec S.P.A.**

Section 2 – Other Suppliers

### DATA COMPILATION:

**Installations**: Overview of equipment orders and installations since May 2018

**Research Articles**: Recent peer-reviewed articles from the technical paper press

**Technical Abstracts**: Recent peer-reviewed articles from the general scientific press

**Events**: Information on forthcoming national and international events and courses

**Classified Advertising**: Latest recruitment opportunities

The Paper Industry Technical Association (PITA) is an independent organisation which operates for the general benefit of its members – both individual and corporate – dedicated to promoting and improving the technical and scientific knowledge of those working in the UK pulp and paper industry. Formed in 1960, it serves the Industry, both manufacturers and suppliers, by providing a forum for members to meet and network; it organises visits, conferences and training seminars that cover all aspects of papermaking science. It also publishes the prestigious journal *Paper Technology* and the *PITA Annual Review*, both sent free to members, and a range of other technical publications which include conference proceedings and the acclaimed *Essential Guide to Aqueous Coating*.



## Industrial decarbonisation of the pulp and paper sector: A UK perspective

Paul W. Griffin (1), Geoffrey P. Hammond (1,2), Jonathan B. Norman (1)

1) Department of Mechanical Engineering, University of Bath, Bath BA2 7AY, UK

2) Institute for Sustainable Energy and the Environment (I<sup>2</sup>SEE), University of Bath, Bath BA2 7AY, UK

The potential for reducing industrial energy demand and 'greenhouse gas' (GHG) emissions in the Pulp and Paper sector (hereinafter denoted as the paper industry) has been evaluated within a United Kingdom (UK) context, although the lessons learned are applicable across much of the industrialised world.

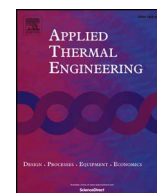
This sector gives rise to about 6% of UK industrial GHG emissions resulting principally from fuel use (including that indirectly emitted because of electricity use). It can be characterised as being heterogeneous with a diverse range of product outputs (including banknotes, books, magazines, newspapers and packaging, such as corrugated paper and board), and sits roughly on the boundary between energy-intensive (EI) and non-energy-intensive (NEI) industrial sectors.

This novel assessment was conducted in the context of the historical development of the paper sector, as well as its contemporary industrial structure. The findings of this study indicate that the attainment of a significant decline in GHG emissions over the long-term will depend critically on the adoption of a small number of key technologies [e.g., energy efficiency and heat recovery techniques, bioenergy (with and without CHP), and the electrification of heat], alongside a decarbonisation of the electricity supply. The present roadmaps help identify the steps needed to be undertaken by developers, policy makers and other stakeholders in order to ensure the decarbonisation of the UK paper sector.

*Applied Thermal Engineering*, Volume 134, April 2018, Pages 152-162. (Open Access)

<https://doi.org/10.1016/j.applthermaleng.2018.01.126>

The Paper Industry Technical Association (PITA) is an independent organisation which operates for the general benefit of its members – both individual and corporate – dedicated to promoting and improving the technical and scientific knowledge of those working in the UK pulp and paper industry. Formed in 1960, it serves the Industry, both manufacturers and suppliers, by providing a forum for members to meet and network; it organises visits, conferences and training seminars that cover all aspects of papermaking science. It also publishes the prestigious journal *Paper Technology* and the *PITA Annual Review*, both sent free to members, and a range of other technical publications which include conference proceedings and the acclaimed *Essential Guide to Aqueous Coating*.



## Research Paper

## Industrial decarbonisation of the pulp and paper sector: A UK perspective

Paul W. Griffin<sup>a,1</sup>, Geoffrey P. Hammond<sup>a,b,\*</sup>, Jonathan B. Norman<sup>a</sup><sup>a</sup> Department of Mechanical Engineering, University of Bath, Bath BA2 7AY, UK<sup>b</sup> Institute for Sustainable Energy and the Environment (I-SEE), University of Bath, Bath BA2 7AY, UK

## ARTICLE INFO

## Keywords:

Pulp and paper sector  
Industrial energy analysis and carbon accounting  
Enabling technologies  
Improvement potential  
Technology roadmaps  
United Kingdom

## ABSTRACT

The potential for reducing industrial energy demand and ‘greenhouse gas’ (GHG) emissions in the *Pulp and Paper* sector (hereinafter denoted as the *paper* industry) has been evaluated within a United Kingdom (UK) context, although the lessons learned are applicable across much of the industrialised world. This sector gives rise to about 6% of UK industrial GHG emissions resulting principally from fuel use (including that indirectly emitted because of electricity use). It can be characterised as being heterogeneous with a diverse range of product outputs (including banknotes, books, magazines, newspapers and packaging, such as corrugated paper and board), and sits roughly on the boundary between *energy-intensive* (EI) and *non-energy-intensive* (NEI) industrial sectors. This novel assessment was conducted in the context of the historical development of the *paper* sector, as well as its contemporary industrial structure. Some 70% of recovered or recycled fibre is employed to make *paper* products in the UK. Fuel use in *combined heat and power* (CHP) plant has been modelled in terms of so-called ‘auto-generation’. Special care was taken not to ‘double count’ auto-generation and grid decarbonisation; so that the relative contributions of each have been accounted for separately. Most of the electricity generated via steam boilers or CHP is used within the sector, with only a small amount exported. Currently-available technologies will lead to further, short-term energy and GHG emissions savings in *paper* mills, but the prospects for the commercial exploitation of innovative technologies by mid-21st century is speculative. The possible role of bioenergy as a fuel resource going forward has also been appraised. Finally, a set of low-carbon UK ‘technology roadmaps’ for the *paper* sector out to 2050 have been developed and evaluated, based on various alternative scenarios. These yield transition pathways that represent forward projections which match short-term and long-term (2050) targets with specific technological solutions to help meet the key energy saving and decarbonisation goals. The content of these roadmaps were built up on the basis of the improvement potentials associated with different processes employed in the *paper* industry. Under a *Reasonable Action* scenario, the total GHG emissions from the sector are likely to fall over the period 1990–2050 by almost exactly an 80%; coincidentally matching GHG reduction targets established for the UK economy as a whole. However, the findings of this study indicate that the attainment of a significant decline in GHG emissions over the long-term will depend critically on the adoption of a small number of key technologies [e.g., energy efficiency and heat recovery techniques, bioenergy (with and without CHP), and the electrification of heat], alongside a decarbonisation of the electricity supply. The present roadmaps help identify the steps needed to be undertaken by developers, policy makers and other stakeholders in order to ensure the decarbonisation of the UK *paper* sector.

## 1. Introduction

## 1.1. Background

The industrial sector in the *United Kingdom of Great Britain and Northern Ireland* (UK) accounts for 17% of total final energy consumption [1] and a corresponding 20% of carbon emissions [2] in 2015. There are large differences between industrial sub-sectors in the end-

use applications of energy, especially in terms of products manufactured, processes undertaken and technologies employed (see Fig. 1 [3]). It is clear that the pulp and paper subsector (hereinafter denoted as the *paper* industry) as seen in Fig. 1 gives rise to the sixth highest industrial energy consumption in the UK; caused by a combination of drying/separation processes (40%), low temperature heating processes (28%), compressed air requirements (10%), space heating (8%) and electrical motors (6%) [3]. UK industry overall has been found to

\* Corresponding author at: Department of Mechanical Engineering, University of Bath, Bath BA2 7AY, UK.

E-mail address: [G.P.Hammond@bath.ac.uk](mailto:G.P.Hammond@bath.ac.uk) (G.P. Hammond).<sup>1</sup> Present address: CDP – Global Environmental Reporting System, 71 Queen Victoria Street, London EC4V 4AY, UK.

## Nomenclature

### Abbreviations

|        |                                                                    |         |                                                                             |
|--------|--------------------------------------------------------------------|---------|-----------------------------------------------------------------------------|
| BAT    | Best Available Technology                                          | GB      | Great Britain                                                               |
| BCE    | before the ‘Common Era’                                            | GHG     | ‘greenhouse’ gas                                                            |
| BGS    | British Geological Survey                                          | GOS     | (the UK) Government Office of Science                                       |
| BPT    | Best Practice Technology                                           | H:P     | heat-to-power ratio                                                         |
| CCA    | Climate Change Agreements                                          | I&C     | industrial and commercial                                                   |
| CCL    | Climate Change Levy                                                | ICT     | information and communications technology                                   |
| CCS    | Carbon Capture and Storage                                         | IEA     | International Energy Agency                                                 |
| CCU    | Carbon Capture and Utilisation                                     | IOP     | Index of Production (ONS statistical bulletin)                              |
| CE     | (in the) ‘Common Era’                                              | IPPC    | Integrated Pollution Prevention and Control (EU regulatory data)            |
| CEPI   | Confederation of European Paper Industries                         | LA      | Low Action (scenario)                                                       |
| CHP    | Combined Heat and Power                                            | NEI     | non-energy-intensive                                                        |
| CPI    | Confederation of Paper Industries (in the UK)                      | NG      | natural gas                                                                 |
| CT     | (the UK) Carbon Trust                                              | NP RES  | ‘non-programmable’ renewable energy sources                                 |
| DECC   | (the former UK) Department of Energy and Climate Change            | ONS     | Office of National Statistics (for the UK)                                  |
| DNO    | Distribution Network Operator                                      | ORC     | organic Rankine cycle                                                       |
| DSF    | Demand-Side Flexibility                                            | PRODCOM | ‘Production Communautaire’ (Community Production – EU statistical database) |
| DSP    | Demand Side Participation                                          | PV      | (solar) photovoltaic (power generators)                                     |
| DSR    | Demand Side Response                                               | RA      | Reasonable Action (scenario)                                                |
| DUKES  | Digest of United Kingdom Energy Statistics (annual)                | RA-CCS  | Reasonable Action together with Carbon Capture & Storage (scenario)         |
| ECN    | Energy research Centre of the Netherlands                          | RCUK    | Research Councils UK                                                        |
| ECUK   | Energy Consumption in the UK (DECC annual statistical publication) | RT      | Radical Transition (scenario)                                               |
| EI     | energy-intensive                                                   | SEC     | specific energy consumption                                                 |
| EU     | European Union                                                     | SIC     | (UK) Standard Industrial Classification                                     |
| EU-ETS | EU Emissions Trading Scheme                                        | SRF     | solid recovered fuel                                                        |
|        |                                                                    | UED     | (the industrial) Usable Energy Database                                     |
|        |                                                                    | UK      | United Kingdom of Great Britain and Northern Ireland                        |
|        |                                                                    | UKERC   | UK Energy Research Centre                                                   |

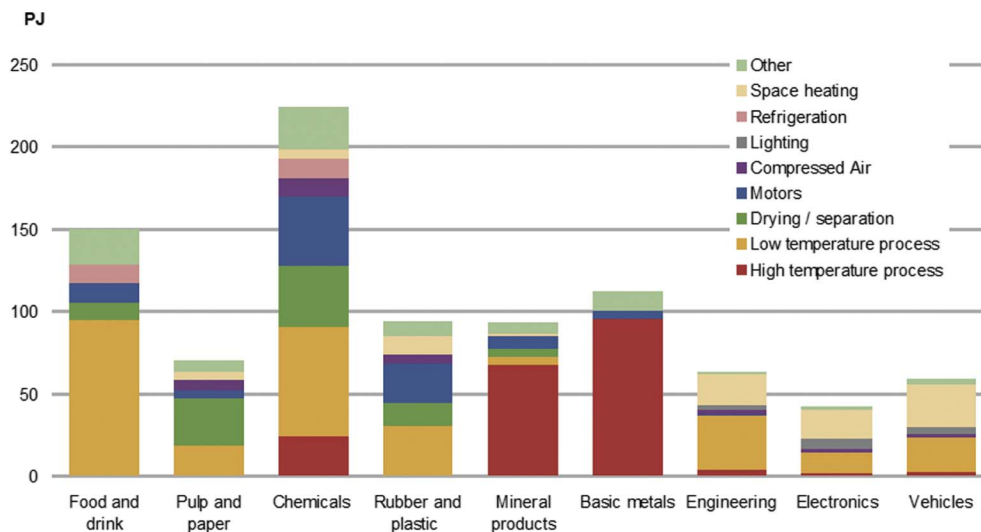


Fig. 1. Final UK energy demand by industrial subsector and end-use. Source: Norman [3].

consist of some 350 separate combinations of sub-sectors, devices and technologies [4,5]. Nevertheless, it is the only end-use energy demand sector in the UK that has experienced a significant fall of roughly 60% in final energy consumption over the period 1970–2015 [1]. This was in spite of a rise of over 40% in industrial output in value added terms. However, the aggregate reduction in energy intensity (MJ/£ of gross value added) fell by 38 per cent during 1990–2015 [1], but this masks several different underlying causes: *end-use efficiency* (accounting for around 80% of the fall in industrial energy intensity; largely induced by the price mechanism [4,5]); *structural changes in industry* [a move away from *energy-intensive* (EI) industries towards *non-energy-intensive* (NEI) ones, including services [4,5]]; and *fuel switching* (from coal and oil to natural gas and electricity that are cleaner, more readily controllable,

and arguably cheaper for the businesses concerned).

### 1.2. The issues considered

The present study builds on work by Dyer et al. [4], commissioned by the UK *Government Office of Science* (GOS), Hammond and Norman [6], and on a recent ‘Advanced Review’ by Griffin et al. [7]. In each case, a variety of assessment techniques for determining potential energy use and ‘greenhouse gas’ (GHG) reductions were discussed. Griffin et al. [7] then evaluated the wider UK industrial landscape with the aid of decomposition analysis [8] in order to identify the factors that have led to energy and carbon savings over recent decades. They consequently assessed the improvement potential in two sectors: ‘Cement’

and 'Food & Drink', which represent the EI and NEI industrial sectors respectively. Here the pulp and paper sector of UK industry is examined in terms of their energy use and GHG emissions, as well as its improvement potential. It can be characterised as being heterogeneous (having a diverse range of product outputs, including banknotes, books, magazines, newspapers and packaging, such as corrugated paper and board), and as sitting on the rough boundary between EI and NEI industries (see Fig. 2 [7]). [A high value in any of the measures shown in Fig. 2 suggests that a given sub-sector would be EI.] However, the *Confederation of Paper Industries* (CPI), the trade association, regards the industry as being EI. It accounts for some 6% of GHG emissions from UK industry as shown in Fig. 3 [7]. Notwithstanding the growth of electronic media, domestic consumers and businesses continue to make use of paper in all its many forms.

The opportunities and challenges to reducing industrial energy demand and carbon dioxide equivalent ( $\text{CO}_2\text{e}$ ) emissions (carbon dioxide is the principal GHG [5]) in the British *paper* industry have been evaluated, although the lessons learned are applicable across much of the industrialised world. The data here has been largely extracted from an industrial *Usable Energy Database* (UED) that was produced for the *UK Energy Research Centre* (UKERC) [actually an academic community or network funded by the *Research Councils UK (RCUK) Energy Programme*] by the present authors (see Griffin et al. [7,9,10]). A set of industrial decarbonisation 'technology roadmaps' out to 2050 are finally reported, based on various alternative scenarios: named *Low Action* (LA), *Reasonable Action* (RA), *Reasonable Action including Carbon Capture and Storage* (CCS) [RA-CCS], and *Radical Transition* (RT) respectively. Such roadmaps represent future projections that match short-term (say out to 2035) and long-term (2050) targets with specific technological solutions to help meet the key energy saving and decarbonisation goals. Their contents were built up in the present study on the basis of the improvement potentials associated with various processes employed in the *paper* industry and embedded in the UED [7,9,10]. They help identify the steps needed to be made by industrialists, policy makers and other stakeholders in order to ensure the decarbonisation of the UK *paper* sector.

## 2. The pulp and paper sector

### 2.1. Historical development of the paper industry

The historical context in which the various industrial sectors are viewed has changed over time. Sir Neil Cossons (an industrial archaeologist and former Director of the *Science Museum* in London, 1986–2000), for example, placed the *paper* sector under the broad umbrella of 'The Chemical Industries' [11]. This was because (at least since the 1870s) pulp - from which paper is produced - had to be boiled, along with a variety of acid and alkaline reagents, in order to purify or remove contaminants. But it was Arabic science from about 3500 BCE, based largely in Egypt and the Near East, that led to what is now recognised as chemicals [12,13]: the early smelting of metals [especially copper, gold and mercury (or 'quicksilver'), as well as alloys like bronze] gave rise to an understanding of the properties of their chemical compounds. The Egyptians had paper and ink with which to write [14]. They made paper from the pith of the papyrus reed, which was cut into strips and laid across each other at right angles, then pressed, dried, smoothed, and gummed together in order to form a roll. Ink was made from a lamp-black and gum solution, and their pens (used brush-wise at first, but later cut into quills) from rushes. Ancient Egypt had a monopoly on papyrus, but was obviously able to export it [14]. They had no need to resort to *cuneiform* writing [12]; first developed by the ancient Sumerians of Mesopotamia (c. 3500–3000 BCE). This term originally came from the Latin 'cuneus', whereby a wedge-shaped stylus was used to make impressions on a clay or similar surface. Egypt's hieroglyphic script meant that it provided a major stimulus to the spread of writing amongst its neighbours [14]; both to the east and

west. Indeed, the Islamic civilisation was in direct contact with the Far East by the *Early Middle Ages* (6th to the 10th Century CE) [12]. The Arabic world imported from the east valuable materials (including high-quality steel, paper, porcelain and silk) and other elements of knowledge, such as the Indian system of mathematical notation (which is still known today as 'Arabic numerals') [14].

The fruits of Arabic science and technology progressively migrated across Europe. But the only significant advance made in the Ancient Greek and Roman civilisations in terms of writing was in the replacement of papyrus by parchment [14]. This parchment was made from untanned leather, with the best quality ('vellum') being made from the skin of a very young calf or kid [15]. It was worked and soaked in lime to get rid of dirt and large amounts of natural grease; dried on a stretching-frame; shaped with a knife; and then smoothed to produce a perfect writing-surface [14]. (In the UK, *Acts of Parliament* are still printed on vellum for archival purposes.) However, parchment was mainly replaced by paper; the earliest paper being referred to as 'cloth parchment'. The invention of printing with movable type by Johannes Gutenberg (the German blacksmith, goldsmith, printer and publisher; c. 1398–1468) [16] and the increasing demand for books ultimately led to the development of good quality paper from rag pulp [15]. It was in fact produced from various raw materials of a fibrous nature, not just rags from linen or cotton, but also from straw or wood [14,17]. Pulp was manufactured by pulverising such cellulosic ingredients, highly diluted with water, in order to disperse the fibres [11,14,16], and then pouring the resulting thick liquid pulp into sieves (or 'moulds') [15]. This would ensure that the fibre retained the necessary shape from which it could be sequentially pounded in a vat and dried [15,17]. The rectangular mould - a screen or tray with a fine wire screen surrounded by a wooden frame (or 'deckle') across the bottom [11] - was dipped into the vat and then held up to drain. In the 15th Century there were about 11 wires to the cm, but this was gradually increased to produce finer paper [12]. The paper on the bottom of the tray was then placed onto woollen felt [14], and constructed as a 'quire' of some 144 sheets and felts [17]; prior to going under a screw press. Sheets of pressed paper would be separated from the felts, and subsequently laid out on drying racks in the atmosphere; typically in a loft [11,15]. Additives, such as china clay or gypsum, were mixed with the pulp to provide 'filling' and gloss, thereby improving the quality of the finished paper for artwork or illustrations [11,14,15]. Thus, by the age of the English literary writer Dr. Samuel Johnson (1709–1784) printing was already 300 years old and, from the perspective of the user (in contrast to the maker), the printed book was not fundamentally different from books today [14]. In 1700 there were around 100 paper mills in England; over half were in the South East (clustered around London), and the rest quite widely spread [17]. By this time water power was often used at paper mills to drive the machinery that pounded the rags into pulp [17]. A good supply of pure water was also essential for mixing with the rags.

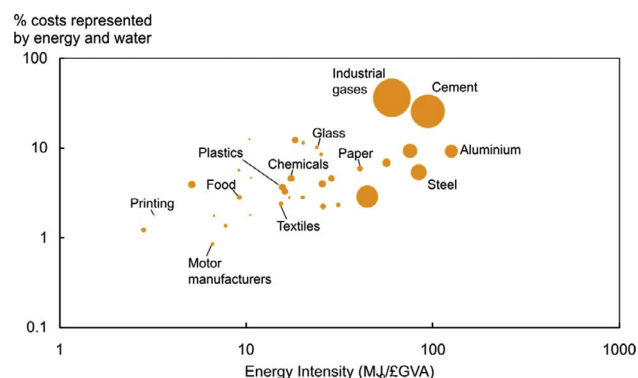


Fig. 2. Primary energy intensity, percentage of costs represented by energy and water, and mean primary energy use per enterprise (reflected by the area of the data points). Source: adapted from Griffin et al. [7].

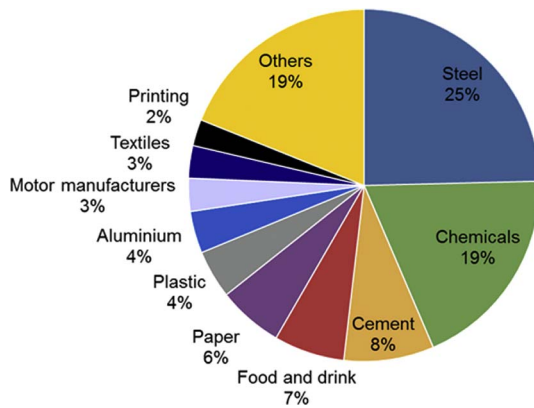


Fig. 3. Greenhouse gas (GHG) emissions from UK industry. Source: adapted from Griffin et al. [7].

Significant innovations in paper-making accompanied the so-called *Industrial Revolution* in the UK from about 1760 CE onwards [11,14,15] accompanying, for example, the discovery of ways of bulk-producing acids and alkalis. Such developments came about from a fusion of empirical ‘rules of thumb’ with the basic sciences [12]. The first steam engine to drive a paper mill was installed at Wilmington near Hull in about 1786, and there were several steam-powered mills located in various parts of Britain by 1815 [17]. Machines to make paper on an endless ‘web’ (similar to that patented by John Gamble in 1801) were built by the London inventor and engineer Bryan Donkin [17] in 1804 in order to replace the earlier batch type of process [11]. Pulp was poured onto a moving web (belt or cylindrical drum) from which it was drawn out as a continuous sheet, and then dried on rollers [15]. Variants of this design were installed by Henry and Sealy Fourdrinier in paper mills that continuously produced paper or board at Two Waters and Frogmore in Hertfordshire, and at St Neots in Huntingdonshire (see Fig. 4 [18]). Donkin subsequently developed a rotating type bed that came into practice in 1813 [17], and which further increased the speed of printing [14]. A dramatic rise in the reading public in the latter half of the 19th Century led to a significant increase in the consumption of paper, even before the excise duty was abolished in 1861 [14]. The provision of the first municipal libraries in Britain around 1850 generated interest in books and, after the newspaper tax was repealed (in 1855), the number of newspapers trebled in forty years [14]. This demand could not be met from linen and cotton rags and straw, and *Esparto* grass from Spain and North Africa began to be imported [14]. However, the real solution to this problem was the use of wood-pulp, which progressively replaced rags with cellulose fibre from coniferous trees [11,14]. The pulp was initially prepared by using grindstones immersed in water containing ready-cut logs. But this did not remove detrimental resin and other impurities, and from 1873 onwards chemical wood-pulp was employed by boiling wood chips with soda or sulphite solutions. This provided most of the input material for the great rolls needed by the emergent newspaper industry [14].

## 2.2. Structure of the modern pulp and paper sector

A modern paper-making machine is usually an enhanced version of the *Fourdrinier* type [11] (see again Fig. 4), which uses a specially woven plastic fabric mesh conveyor belt that is often several hundred metres long. The proportion of the machine involved in removing water from the web either by drainage or steam represents over 90% of the total length [11]. The speed at which paper, and more particularly multi-layer boards can be produced is determined by the rate at which the water can be removed from the webs [11]. An innovative development in the early 1960s was the ‘Inverform’ machine in which water is removed under gravity from below and with the aid of a vacuum box from above the webs [11]. This paper-making device can be used for

the manufacture of single or multi-ply grades of paper, and is capable of extremely high operating speeds. The contemporary *paper* industry is a relatively high technology sector that takes full advantage to modern developments in electronics and *Information and Communications Technology* (ICT), such as for the automatic control and monitoring of paper-making plants [19]. Wood-pulp for the British industry is now typically produced from resources obtained via the timber industries in Canada and Scandinavia, as well as from Scotland [15]. The UK *paper* sector has continued to innovate and has invested heavily, for example, in a modern newsprint machine (producing 400,000 tonnes of newsprint per year) and £300 M in a state-of-the-art containerboard machine to produce lightweight paper [19].

The consumption of paper and board products in the UK amounted to just over 10.5 Mt in 2010 (the baseline year for the present study) according to the national trade association: the *Confederation of Paper Industries* (CPI) [20]. There was a modest decline of some 2% per annum thereafter. Corrugated paper demand corresponded to around 2.15 Mt in 2010, which has risen modestly in recent years (to ~2.3 Mt in 2015) [20]. These demands were met with the aid of 3.8 Mt of recovered or recycled paper in the base year. Indigenous production of paper and board was about 4.3 Mt in 2010 from just over 50 paper mills of varying sizes and specialisms [20] (having ~9000 employees). Parent reel tissue production was only around 730 kt. These mills utilised 1.1 Mt of wood-pulp (0.9 Mt from indigenous sources and 0.2 Mt imported), as well as sawmill residues, like wood chips [20]. Timber extracted in the UK for pulp and paper production amounts to less than 5%, and comes typically via virgin wood fibre from sustainably managed and certified forests [19]. Recovered paper has steadily increased since the 1950s [19] to the current level of 3.75 Mt. Indeed, the British *paper* industry has a recycling rate of ~80% (collected from both households and businesses), which is the highest of any material. However, there are constraints on the quantity of paper fibre that can be recycled [19]. Around only 19% is not recyclable, because (i) it increasingly degrades as it goes through successive recycling phases (up to about a maximum of 7 times, although in Europe it now stands at 3.4 cycles); (ii) it is kept embodied in artistic works, books, photographs or wall paper; or (iii) it disintegrates when used in the form of cigarette or sanitary papers [19]. The UK was a significant exporter of recovered paper amounting to some 4.3 Mt that went to China (~75%), the *European Union* (EU) (~14%), India (~5%), Indonesia (~3%), and the Rest of the World (~3%) [20]. This helps reduce ‘carbon footprints’ of paper-making elsewhere around the world.

Fuel consumption in the UK paper and board sector is dominated by boiler and *combined heat and power* (CHP) or co-generation plants for process electricity and steam production. Energy is required to drive machinery and to generate heat to dry the paper produced [19]. Fuel demands are mostly met by natural gas (NG), although biomass is increasingly being utilised and presently accounts for about 15% of sector

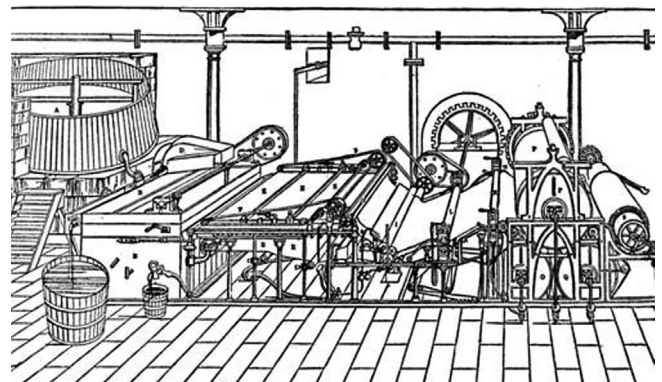


Fig. 4. The traditional Fourdrinier paper-making machine of the type built by Bryan Donkin. Source: adapted from the University of Michigan, 1920 [18].

fuel consumption. Paper is formed and dried from pulp, and finished into paper products. Just two mills were fully integrated pulp and paper operations. Final energy demand at typical mills is dominated by the dryer section in which steam-heated cylinders heat the paper fibres to around 100 °C [21]. The physical unit of production for the sector is *tonnes of paper and board* (tpb). UK sector energy demand in 2010 was 60 PJ; of which fuel demand was 53 PJ. Imported electricity was 8.5 PJ, whilst the corresponding power supplies exported was 1.5 PJ. The UK paper-making industry reduced its total energy consumption by 34% per tonne of paper made between 1990 and 2010 [19]. Production was 4.3 Mtpb in 2010; resulting in a direct *specific energy consumption* (SEC) of 12.2 GJ/tpb and primary SEC of about 19 GJ/tpb. Energy costs amount to about 30% of the total cost of paper-making [19]. Direct GHG emissions were some 2.3 MtCO<sub>2</sub>e; a reduction of 42% over the period 1990–2010, due to investment in lower carbon energy sources [19]. The corresponding total emissions, including those attributable to net electricity, were 3.3 MtCO<sub>2</sub>e. Large and complex paper mills typically take control of their energy supplies by building CHP plants that are more efficient than separate supply of electricity and heat, and reduce GHG emissions and generating costs [19]. A number of such CHP plants use biogenic (wood) waste, which is a renewable resource and gives rise to further reductions in GHG emissions. The UK paper sector is the largest user and producer of bioenergy in Europe [19].

### 3. Methods and materials

#### 3.1. A Hybrid top-down/bottom-up approach

There are two broad ways to modelling the industrial sector [7]: top-down and bottom-up approaches, as illustrated in Fig. 5 (adapted and elaborated from those presented by Dyer et al. [21] and Griffin et al. [7]). A top-down approach splits industry into sub-sectors, usually

based on available statistical data, and uses this data to determine energy use, output, energy intensity and other measures for which data is available. This approach has the advantage of covering a large proportion of energy demand, but it is limited by the level of disaggregation available from industry-wide statistical sources. Thus, the conclusions that can be drawn from such top-down studies are often only indicative in nature. In contrast, a bottom-up approach would typically focus on a single industrial sub-sector. Energy use can then be separated into lower order sub-sectors, processes or manufacturing plants. The data used for this type of bottom-up study typically comes from more specific information sources, such as trade associations, company reports, and case studies. Such a bottom-up study can therefore be useful in terms of presenting more accurate findings [22,23], although it will be limited in the breadth of its application.

An innovative hybrid approach was employed to develop the industrial *Usable Energy Database* (UED) [9,10], produced by the present authors for the whole of the UK industrial sector as part of the research programme of the *UK Energy Research Centre* (UKERC). Aspects of both top-down and bottom-up models were adopted, with detailed bottom-up studies set within a top-down framework. Using this novel approach would normally entail focusing on a number of sub-sectors for the bottom-up study [7], with the remainder of the sector being treated in a generic manner. Sub-sectors that use a large amount of energy are obviously prioritised for bottom-up studies. In addition, sub-sectors that use energy in a relatively homogeneous manner are easier to analyse, and this may also be considered when selecting appropriate sub-sectors. Sub-sectors that are not the subject of detailed bottom-up modelling require a focus on the potential reduction in emissions through widely used, ‘cross-cutting’ technologies can be useful [7,9,10].

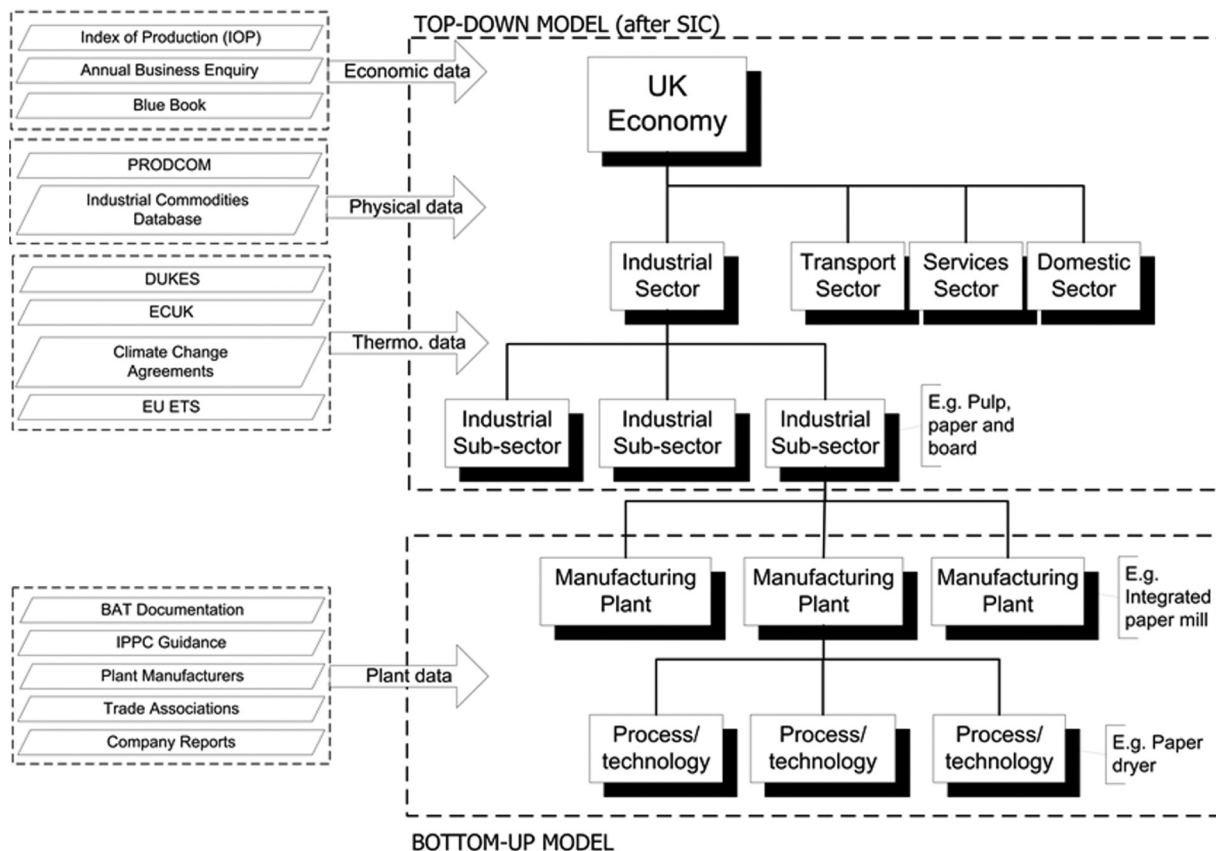


Fig. 5. Schematic representation of an integrated top-down and bottom-up modelling approach for the UK industrial sector. Source: elaborated from the diagrams presented in Dyer et al. [21] and Griffin et al. [7].

### 3.2. The baseline conditions

The energy inputs to the UED pulp and paper section were based on information from the trade association (David Morgan, CPI, private communication, 2013). This covers all paper mills (51 sites) in the UK (see the Sankey-type energy flow diagram presented in Fig. 6), but not the manufacture of “finished paper products” that use energy in a different manner. The information here covers the UK *Standard Industrial Classification* (SIC) Code (2007) 17.12 [24]. Their energy use covered around 50% of energy demand at the 3 digit SIC level (i.e., SIC 17.1 - *Manufacture of pulp, paper and paperboard*), according to the UK Government's former *Department of Energy and Climate Change* (DECC) [25]. Output from these mills was taken from the information submitted by industrial companies as a requirement of *Climate Change Agreements* (CCA) and collated by AEA [26]; what is now the consultancy *Ricardo Energy & Environment*. CCA are voluntary agreements between UK industry and the UK Government's *Environment Agency* aimed at delivering reductions in energy use and GHG emissions. Operators receive a discount on the *Climate Change Levy* (CCL), effectively a tax on energy delivered to UK non-domestic users, of 90% on electricity bills and 65% on other qualifying input fuels. The CCA for the *paper* sector is administered by a wholly-owned subsidiary of the CPI [27]; the *Paper Sector Climate Change Management Co. Ltd.* Direct GHG emissions come under the remit of the *EU Emissions Trading Scheme* (EU-ETS). SEC data is reported for the *paper* sector for some 46 UK paper mills in 2015 [27]. The basis of this information was again confirmed by the CPI (David Morgan, CPI, private communication, 2013), although the energy demand differed slightly from that reported under the CCA, due to the inclusion of renewable energy sources (that is not reported under CCA). Economic output was taken from the UK Government's *Annual Business Survey* [28].

Fuel use by CHP plants was based on reported auto-generated electricity (again via David Morgan, CPI, private communication, 2013), and sector heat-to-power (H:P) ratio was calculated from the *Digest of United Kingdom Energy Statistics* (DUKES) [29]. Similarly, the overall efficiency of CHP was taken from DUKES. Information on exported electricity from CHP was given by the CPI (Morgan, 2013). The fuel used in producing this exported electricity was calculated based on information from DUKES [29]. The Sankey diagram (shown in Fig. 6) depicts the 2010 baseline division of energy inputs (fuels and primary electricity) against comparative outputs (associated with the core paper machines and ancillary processes). The thickness of the ‘arrows’, ‘links’, or ‘lines’ is proportional to the quantity of energy. The major role of CHP plants in providing both heat and power is illustrated as an intermediate node or process. Non-CHP fuel input is assumed to be used in steam systems, based on a report by the UK *Carbon Trust* (CT) [30]. The SEC of the various processes was then based on information adopted from that study [30], although they were scaled to match the total electricity demand reported by the CPI (Morgan, 2013). Using the same scaling factor for steam use yielded a boiler efficiency of 82%. This is high in comparison to the average for the industrial sector, but not unreasonably so.

### 3.3. Improvement potential

#### 3.3.1. The overall context

Improvement potentials were initially extracted from the CT study [30], which particularly focuses on UK *paper* manufacturing rather than on the pulp sub-sector. This mainly covers short-term opportunities, and so was therefore supplemented by information from alternative (international) sources that cover opportunities that involve more major changes to the production process [21,31,32]. There may be some potential for greater use of the wastes from paper production as fuels, for example, and this was considered in the UED in terms of CHP gasification. However, there was insufficient technical information available to give greater consideration of this opportunity. Pulp production is comparatively small in the UK. The sector already uses both a substantial amount of recycling and imported pulp. Domestic pulp represents just ~6% of the sector input [30], with only two integrated mills in the UK that use mechanical pulping. They could technically convert to chemical pulping, and use the products produced (so-called ‘black liquor’) to become net zero GHG emitters. Thus, pulp production was not included in the UED.

#### 3.3.2. Fuel switching - towards a bio-economy

The *Confederation of European Paper Industries* (CEPI) [33], a Brussels-based non-profit-making organisation representing the European pulp and paper industry, has recommended the further conversion of industrial installations to low or zero carbon energy use, particularly from renewable sources. Bioenergy can be produced from either biomass (any purpose-grown material, such as crops, forestry or algae) or biogenic waste (including household, food and commercial waste, agricultural or forestry waste, and sewage sludge). Sustainable bioenergy is a renewable resource that is often low carbon, and potentially leads to ‘negative emissions’ when coupled to CCS facilities [34]. It has more recently been proposed in a Swedish context [35,36] to integrate a biorefinery with pulp and paper mills in order to produce high value chemical products [23] alongside conventional outputs. The UK Government's *UK and Global Bioenergy Resource Model* (an updated feedstock availability model) suggests that there is substantial quantities of indigenous biomass and biogenic waste available even accounting for the application of more stringent sustainability and land use criteria [37]. The total 2030 UK bioenergy resources might be equivalent to some 850–1120 PJ; with accessible resources of perhaps 580–672 PJ. But many industrial sectors will be competing for this resource alongside, for example, power generation. This is likely to, in any case, drive up biofuel prices. Nevertheless, the UK pulp and paper sector is already substantially invested in the use of biomass feedstock as both a raw material and fuel, although the CPI has advocated further government support for the expansion of UK agricultural land use for woody biomass. On-site residuals from *paper* production (such as ‘black liquor, waste fibre, bark and fines’) are used to generate a biogenic replacement (*syngas*) for natural gas via gasification. This can be obtained using a variety of feedstocks: *solid recovered fuel* (SRF), waste wood, and other waste materials. Unfortunately, in their stakeholder engagement with the UK Government, representatives of the *paper* industry (via the CPI)

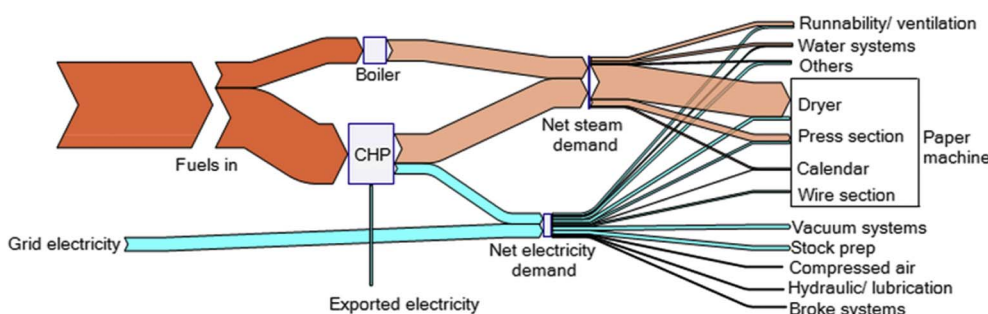


Fig. 6. Sankey energy flow diagram of the UK Pulp and Paper sector as modelled here; baseline data in 2010. Source: Griffin et al. [9].

noted that the costs of such gasification are high and rather unreliable. Presently all direct heat, around 13.5% of that is generated in the UK *paper* industry, is produced from the burning of NG. Some 2.2 TWh is produced from biofuels - constituting 23% of all fuels utilised in the sector. Indeed, the CPI have suggested to the UK Government that it could be a promising candidate for an above average share of biomass for electricity and heat (> 7% by 2030). That would be equivalent to a growth of biomass use of around 4% per annum, or some 22,000 tonnes of additional resource. According to the CPI, the main technological opportunities going forward are likely to be in the areas of CHP and, in the longer term, CCS. Residuals from paper-making can be employed as a new feedstock for low-quality paper, as a source of minerals, or else applied in the construction sector. A downside of paper waste utilisation is the production of ash from its incineration, which is contaminated with heavy metals from dyes, inks and surface treatments.

### 3.3.3. Energy efficiency and heat recovery

In meeting the twin challenges of climate change mitigation and energy security, the UK Government's *Carbon Plan* [38] set out a number of guiding principles. The first among them was to use less energy in the most cost-effective manner in industry as elsewhere. This central role for energy efficiency improvements were echoed at an international level by the *International Energy Agency* (IEA) [39], by the EU [40], and countries like Germany [41] and Sweden [42,43]. The IEA have attempted to capture the highest potential reduction in global emissions from efficiency measures in their clean energy pathways or roadmaps out to 2050 [39]. They argue that the cost savings accrued from reducing energy demand could outweigh additional costs by 2.5:1 and, after discounting future savings to present money with a 10% discount rate, save several trillion US dollars. The IEA suggest that the implementation of *Best Available Technologies* (BATs) - those that are proven technologies, but which may not yet be economically viable - could reduce energy consumption by 20% from current levels [39]. They argue that the BATs offer some of the most promising least-cost options for reducing energy consumption and GHG emissions in industry. But action is needed to invest in new facilities and to retrofit equipment that reach BAT levels, otherwise this capacity will be sub-optimal and very costly to upgrade.

Energy efficiency measures have therefore been widely recommended for the pulp and paper sector and other industries [38–43]. Likewise heat recovery opportunities are seen as having a significant improvement potential [21,26,30–32]. In the UK, Hammond and Norman [6] employed a database of the heat demand, heat recovery potential and location of industrial sites involved in the EU-ETS to estimate the potential application of different heat recovery technologies. The options considered for recovering the heat were recovery for use on-site (using heat exchangers); upgrading the heat to a higher temperature (via heat pumps); conversion of the heat energy to fulfill a cooling demand (employing absorption chillers); conversion of heat to electricity (adopting *organic Rankine cycle* (ORC) devices; see also Chen et al. [44]); and transport of the heat to fulfill an off-site heat demand. Similarly, the *Energy research Centre of the Netherlands* (ECN) have examined the potential of modern industrial heat pumps that could generate steam up to 200 °C utilising waste heat [45], including a test cell programme related to the particular needs of the *paper* industry. The UK analysis by Hammond and Norman [6] provided an indicative assessment of the overall potential for the various technologies. The greatest potential for reusing surplus heat was found to be recovery at low temperatures (via heat exchangers), and in its conversion to electrical power (mostly utilising ORC technology [44]). Both these technologies exist in commercial applications, but are not well established. Support for their further development and installation could therefore increase their take-up. A broad analysis of this type, which investigates a large number of sites, cannot accurately identify all site-level opportunities. Nonetheless, the overall heat recoverable in the UK using a combination of these technologies was estimated at 52 PJ/yr, saving over 2.0

MtCO<sub>2e</sub>/yr in comparison to supplying the energy outputs in a conventional manner [6]. A network and market for trading in heat, along with the wider use of district heating systems, could also open significant potential for exporting heat from industrial sites to other users. A range of *Best Practice Technologies* (BPTs) – those that represent the ‘best’ technologies, which are currently in use and therefore economically viable – for both energy efficiency improvements and heat recovery has been advocated for introduction into the pulp and paper sector in future [21,26,30–32].

### 3.3.4. Demand-side flexibility

*Demand-side flexibility* (DSF) is the ability to change electricity demand from an industrial plant or other user in response to an external signal from a power supplier [46,47]. The use of tools such as *Demand Side Response* (DSR) – where levels of electricity demand are increased, reduced or shifted – and on-site energy storage enable the optimisation of electricity usage and has major advantages in the context of an energy infrastructure designed to meet occasional peak demands. This will be particularly important in the transition towards a low-carbon future. *Demand Side Participation* (DSP) concepts are mainly short-term (minutes to hours) [48], whereas flexibility is needed over several days or more. The rigid patterns of power supply based on life-long experience of fossil-fuelled supplies make such flexibility challenging, but are important to explore. Fully automated DSR concepts, such as ‘smart’ controllers for EV charging and heat-pumps, have been studied in some detail. *Industrial and commercial* (I&C) customers can benefit financially by offering DSF services to market actors (e.g., the various ‘aggregators’ - companies who aggregate small loads and then participate in demand-side markets on behalf of customers - or the *National Grid*, the ‘System Operator’ for the Great Britain (GB)). *Distribution Network Operators* (DNOs), who run and maintain regional distribution systems, can employ DSF to manage local network restrictions. This can reduce stress at peak times, support planned or unplanned network outages, and defer or avoid the need for network reinforcement [46]. In both cases, the operators are motivated by the growing share of so-called ‘non-programmable’ renewable energy sources (NP RES) on the network [49]. The contribution of DSF in GB electricity markets is currently small and mainly for grid balancing on a second-by-second basis. It is therefore a largely ‘untapped’ resource. DSF will inevitably be required in future in order to manage the system and market risks [38]. *Smart power* innovations - a combination of interconnectors, storage and demand flexibility (or DSR) - could generate £8 bn per year of savings; according to a report for the recently-established UK *National Infrastructure Commission* [50].

The *National Grid* (NG) in GB aims to address various barriers to customer participation, and is initially focusing on interacting with I&C customers [46]. Those customers who offer *demand-side flexibility* generally do so to reduce their electricity costs and generate new revenue streams, enabled by new ICT (e.g., metering and automation). But pilot demonstrations will be necessary in order to overcome the fears of some I&C customers that disturbances to their production processes might lead to reduced outputs or quality. Many such customers work with ‘aggregators’, because current DSR markets in the UK are seen as complex, or their volumes are too small to access DSF tools directly [46]. On-site or ‘back-up’ generation provides much of the DSF today [46]. Nevertheless, leveraging further on-site CHP or co-generation plants from the *paper* industry will enable the sector to interact more easily with the energy market [49]. The *Confederation of European Paper Industries* (CEPI) has suggested that mechanical pulping, an electro-intensive process, can be used for ‘peak shaving’ programmes [33]. It can react at reasonably short notice, ranging from as short as 15 min up to one hour, depending on the frequency and schedule of interruptions. In some European countries (e.g., Austria, Belgium and Norway), the *paper* industry is also involved in ‘valley filling’ programmes, whereby the whole production process is shifted to the night or to the weekends so as to optimise baseload electricity generation [49]. But, in the paper-

making process, the flexibility margin is very small [49] and most of the energy required by the sector (steam and electricity) is generated on-site, therefore mostly ‘off-grid’. Nevertheless, the widespread geographical distribution of paper mills across Europe would permit the cost-effective absorption of excess electricity from NP RES, substantially reducing the need for costly investments in grid extensions [49]. Policy makers, and actors in the energy sector more broadly, envisage that the scale and value of DSF is likely to grow in the future as part of a *smarter* system and with technological advances [4]. DSP will necessarily require the adoption of an appropriate regulatory framework, clear market roles, and a standardisation of processes to reduce transaction costs for aggregators.

### 3.3.5. Emerging and breakthrough technologies

Carbon sequestration from forestry and vegetation is an important part of the Earth’s carbon cycle. Worldwide, carbon sequestration technologies capable of removing CO<sub>2</sub> from the flue gases of fossil fuel-fired power plants are now being investigated as a matter of some priority [26,32,51]. They are perhaps the key innovative technology in this area. The *paper* industry has long used biogenic process waste as an energy source, and over half of the energy utilised by the European industry is generated from biomass [52]. The UK industry, represented by the CPI [19], argues that paper production drives sustainable (and certified) forest growth. Here the IEA worked jointly with the ‘Carbon Sequestration Leadership Forum’ and the ‘Global CCS Institute’ [53]. They noted that the deployment of large-scale CCS demonstration projects is critical to the deployment of the technology. The IEA progress review [53] suggests that government and regional groups had made commitments to launch 19–43 such demonstrators by 2020. These developments were identified in the USA, the EU (“particularly the United Kingdom”), Canada and Australia. But the partners noted that implementation of such a programme would be challenging. The 2008 economic ‘downturn’, and the more recent *Eurozone* financial crisis, have both made the economic situation far more difficult in terms of potential public investments in large-scale energy projects of all kinds. If CCS facilities could be employed together with bioenergy, then it

would give rise to ‘carbon sinks’ or ‘negative emissions’. However, given the output produced and the size of sites this is considered by some to be unlikely to be realised [34], and have instead advocated *carbon capture and utilisation* (CCU) in order to use CO<sub>2</sub> to produce fuel, chemicals [23] and other materials [5]. The CEPI believe that other innovative (so-called ‘disruptive’) technologies could complement the GHG emissions reduction by some 3 MtCO<sub>2e</sub> in Europe by 2050 [33].

## 4. UK pulp and paper ‘technology roadmaps’ to a low carbon future by 2050

### 4.1. Background

A set of technology roadmaps have been developed in order to evaluate for the potential deployment of the identified paper sector technologies out to 2050. (Alternative modelling approaches have been adopted by the EU [54] and in the USA [55].) The extent of resource demand and GHG emissions reduction has been estimated here and projected forward. Such roadmaps represent future projections that match short-term (say out to 2035) and long-term (2050) targets with specific technological solutions to help meet key energy saving and decarbonisation goals. A bottom-up technology roadmap approach has been adopted, based on those that were initially used by Griffin et al. [7,23,56] to examine the impact of UK cement decarbonisation (for further details see Griffin [57]). Thus, their contents were built up on the basis of the improvement potentials associated with various processes employed in the *paper* industry and embedded in the UED [7,9,10].

### 4.2. Benchmark UK paper technology projections

The projected benchmark is affected by sector output, grid decarbonisation, and deployment of BPT/BAT. It is assumed that the GB grid will decarbonise by around 85% over the period 2010–2050. GHG emissions pathways of illustrative technology roadmaps for several of the smaller UK so-called energy intensive industrial sectors - pulp and

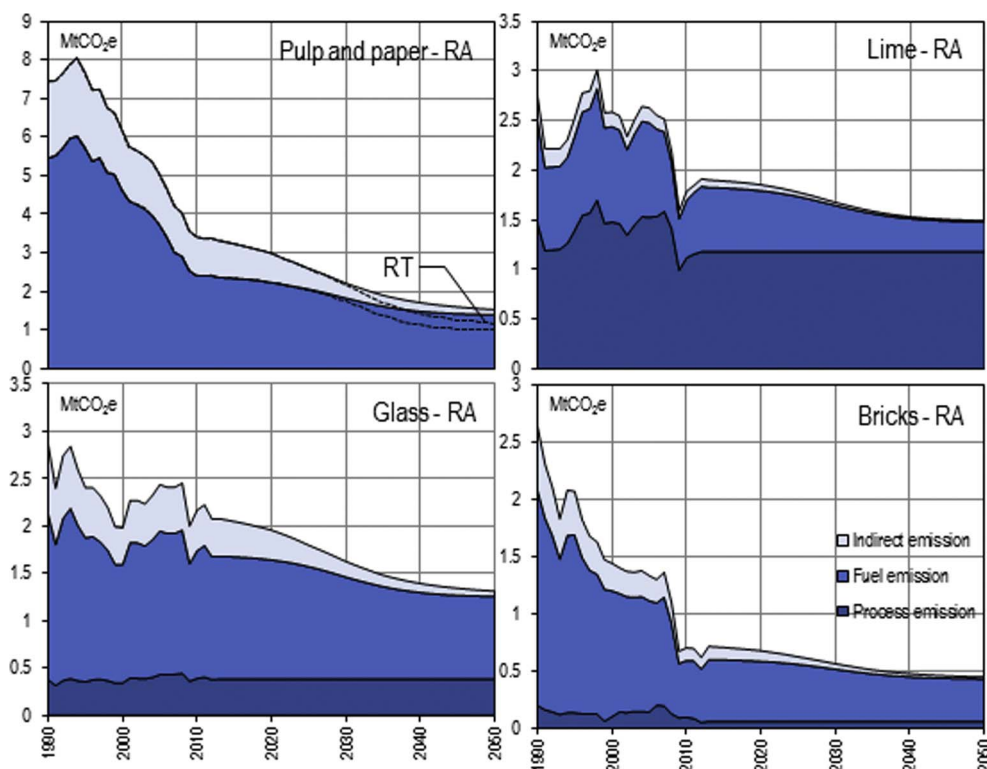


Fig. 7. Greenhouse gas (GHG) emissions splits of 2050 technology roadmaps of some UK energy-intensive industries under the Reasonable Action (RA) scenario: pulp and paper, lime, glass, and bricks. (The overall trend under a more Radical Transition (RT) scenario) is also depicted.) Source: Griffin [47].

paper, lime, glass, and bricks - over the period 1990–2050 are illustrated in Fig. 7. None of these sectors were identified as having viable CCS opportunities, and only the *paper* sector was identified as being open to radical process transition. Also shown are the trajectories of relevant GHG emission targets and caps. It was estimated that EU-ETS legislation in 2010 covered 94% of direct GHG emissions from energy-intensive industry. These four industrial sectors were determined via the bottom-up assessment of the relationship between SEC and physical output. Physical output was first obtained or estimated for each sector. For bricks, output was determined by moving the 2010 tonnage reported for the CCA scheme *pro rata* with the trend in numbers of brick produced according to the *British Geological Survey* (BGS) [57–60]. Glass output trend was back-calculated from raw material process emission estimated for the UK GHG Inventory [61], which assumes emissive raw material demand in the vast majority of glass product types and mass output [62]. The same approach is applied to estimate the production trends for lime (and ammonia; see Griffin [57]). Efficiency improvements via CHP plant were not directly assessed here, due largely to uncertainty about the impact of fuel switching.

#### 4.3. Scenario definition

The identified improvement technologies for the UK were incorporated into the *paper* technology roadmap framework through a series of scenarios. The baseline year for the framework was taken as 2010. Full details of the both the 2010 baseline and the BAT/BPT improvements can be found in the UKERC industrial UED [9,10]. Four future scenarios were devised in order to demonstrate this approach. The *paper* industry has been active in the area of technology roadmapping, particularly at the global level by the IEA [39], and ideas from such roadmaps were drawn on in constructing some of the scenarios detailed below [7,23,56,57]:

- **Low Action (LA).** This scenario describes a path of only slight improvements. No further investment is presumed to be made in additional process technology improvements and efficiency is only improved incidentally through the replacement of industrial facilities.

- **Reasonable Action (RA).** All identified efficiency technologies are presumed to be installed by 2025, and retired equipment are replaced with best practice ones by 2030.
- **Reasonable Action including CCS (RA-CCS).** This scenario is based on RA, but includes the potential impact of CCS. Biomass co-firing with CCS may, of course, mitigate upstream emissions on a full life-cycle basis, due to potential ‘negative emissions’ [63]; something that will need careful examination in future studies.
- **Radical Transition (RT).** This scenario explores a boosted or radical version of the reasonable action (without CCS) scenario [57].

#### 4.4. Alternative UK paper technology roadmaps

The various so-called ‘energy-intensive’ sectors considered include pulp and paper, lime, glass and bricks (with some reference given to the wider ceramics sector described by Griffin [57]). Background calculations and modelling are described there. For brick manufacture, present fuel mix was taken from a recent study by the *Carbon Trust* [60] and combined with the SEC reported for the sector CCA scheme [64]. SEC was linearly extrapolated to the level in 1980 as reported by Langley [65]. For glass, SEC was assumed to change with the trend in efficiency of glass furnaces reported by *British Glass* [66], which is likely to account for about 70% of sector energy demand. Fuel mix since 1990 is dominated by natural gas for both glass and bricks production, and was assumed to conform to the mix published by the UK *Office of National Statistics* (ONS) [67] for glass and other ceramic products (SIC 23.1–4 and 23.7–9). SEC of paper-making was backcasted linearly from the baseline (2010) to that reported in 1980, and fuel mix changes in renewable fuel requirements were informed by the CPI (David Morgan, CPI, private communication, 2013). It was not possible to extrapolate Lime SEC to an earlier time period, and so this was conservatively assumed to improve at a rate of 1% per annum from 1990 to the baseline date. The fuel mix was inferred from ONS data [67], which has stayed reasonably constant over the period, except for an increase in the use of waste fuels in recent years. Natural gas combustion is listed separately for ammonia production by the ONS, and this was used to represent energy demand for ammonia (see also Griffin et al. [23]).

GHG emission splits for the *Reasonable Action* (RA) roadmaps of

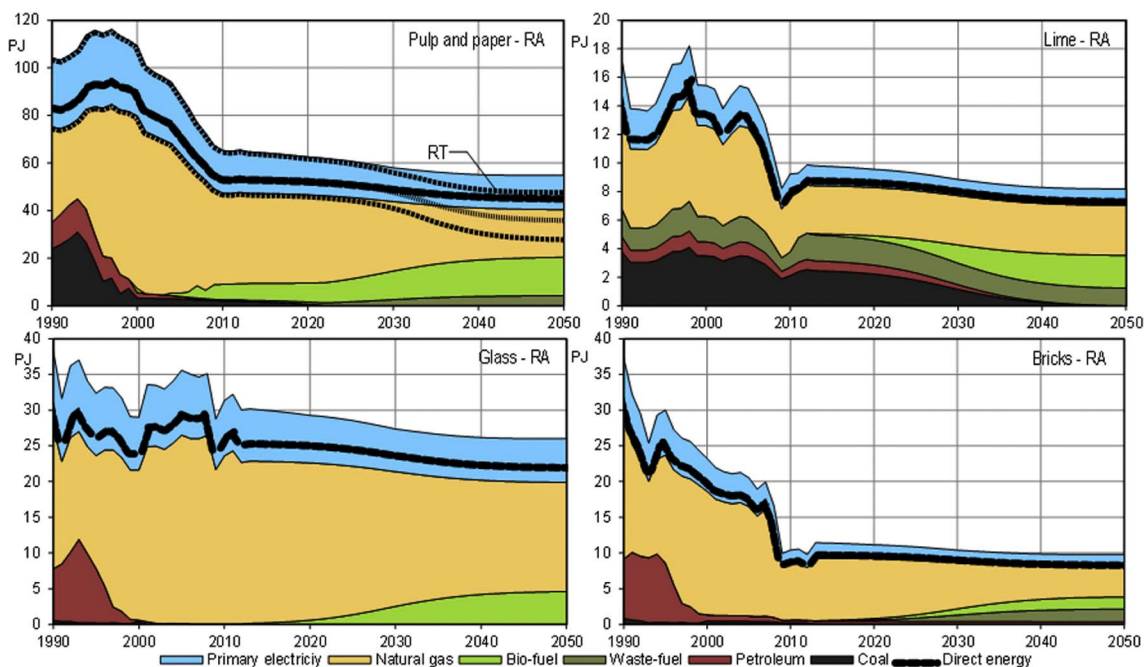


Fig. 8. Energy splits in the 2050 technology roadmaps of some UK energy-intensive industries under the *Reasonable Action* (RA) scenario: pulp and paper, lime, glass, and bricks. {The overall trend under a more *Radical Transition* (RT) scenario is also depicted.} Source: Griffin [47].

each of the energy-intensive industrial sectors modelled over the period 1990–2050 is depicted in Fig. 7. It can be seen that pulp and paper sector satisfies the 80% decarbonising target by 2050 compared to the emissions in 1990. This was established by both the UK Government for the economy overall [38], and by the CEPI for the European pulp and paper sector [33]. The CEPI believe it can be achieved alongside 50% more added value created by the industry. Fig. 7 indicates that, under the RA scenario, the total (fuel plus indirect) GHG emissions are likely to fall from about 7.5 MtCO<sub>2e</sub> in 1990 to 1.5 MtCO<sub>2e</sub> in 2050, i.e., coincidentally almost exactly an 80% reduction. The Radical Transition (RT) roadmap trend for pulp and paper is also shown in Fig. 7 for completeness, and displays an 85% fall. The associated energy splits are then displayed in Fig. 8. This suggests that, again under the RA scenario, natural gas is likely to contribute some 37% towards the total (fuel plus indirect) pulp and paper sectoral energy use by 2050, whilst biofuels and biogenic wastes similarly amount to 37%. Primary electricity [principally generated via nuclear power, onshore and offshore wind turbines, solar photovoltaic (PV) systems, and hydro-power] accounts for the remaining 26%. This is an energy mix with a much lower carbon content than the 2010 baseline made up of 56% NG, 28% primary electricity, 11% biofuels, and ~5% coal. With the application of a more *Radical Transition* (incorporated in the RT scenario), an energy saving of 56% is observed over 1990–2050 in comparison to that pertaining with just *Reasonable Action* (resulting from the RA scenario) of 47%. Energy demand for the *paper* industry remains fairly constant at about 55 PJ after 2030; only half that in 1990. Both the RA and RT scenarios presume a 15% process SEC improvement going forward. In the various energy-intensive industrial sectors illustrated in Fig. 8, the dramatic (negative) impact of the 2008 global ‘financial crisis’ on UK industry that resulted in a severe economic downturn or ‘recession’ can clearly be seen, particularly as reflected by the fall in energy consumption associated with construction-related artefacts and infrastructure projects (requiring the use of *Bricks* and *Lime*). That was due mainly to the decline in physical products from these sectors. The Sankey-type energy flow diagram shown above as Fig. 6 indicates the 2010 baseline division of inputs (fuels and primary electricity) to the UK *paper* industry against its outputs (the energy consumed by the paper machine and ancillary processes). The important role of CHP plants in providing both heat and power is depicted in Fig. 6 as an intermediate node or process between the ‘arrows’ or ‘links’ that represent the magnitude of the energy flows.

## 5. Concluding remarks

The potential for reducing industrial energy demand and ‘greenhouse gas’ (GHG) emissions in the *Pulp and Paper* sector has been evaluated within a UK context, although the lessons learned are applicable across much of the industrialised world. This sector gives rise to about 6% of UK industrial GHG emissions resulting principally from fuel use, as well as that indirectly emitted because of electricity use. It can be characterised as being heterogeneous with a wide range of product outputs (including banknotes, books, magazines, newspapers and packaging, e.g., fabricated from corrugated paper and board), and sits roughly on the boundary between energy-intensive (EI) and non-energy-intensive (NEI) industrial sectors as previously characterised by Griffin et al. [7] (see again Fig. 2). Some 70% of recovered or recycled fibre is employed to make *paper* products in the UK. Process energy requirements are dominated by a combination of drying/separation processes (40%), low temperature heating processes (28%), compressed air requirements (10%), space heating (8%) and electrical motors (6%) [3]. Fuel use in *combined heat and power* (CHP) plants has been modelled in terms of so-called ‘auto-generation’. Special care was taken not to ‘double count’ auto-generation and grid decarbonisation; so that the relative contributions of each have been accounted for separately. Most of the electricity generated via steam boilers or CHP is used within the sector, with only a small amount exported. Currently-available

technologies (BATs) will lead to further, short-term energy and GHG emissions savings in *paper* mills, but the prospects for the commercial exploitation of innovative technologies by mid-21st century is speculative. There are many non-technological barriers to the take-up of such technologies [7,22]. The possible role of bioenergy as a fuel resource going forward has also been appraised. Finally, UK roadmaps for the *paper* sector out to a low carbon future in 2050 have been evaluated. They exhibit quite large uncertainties, and the attainment of significant falls in GHG emissions over the long-term will depend critically on the adoption of a small number of key technologies [e.g., energy efficiency and heat recovery techniques, bioenergy (with and without CHP), and the electrification of heat], alongside a decarbonisation of the electricity supply. Thus, this novel technology assessment and associated roadmaps help identify the steps needed to be made by developers, policy makers and other stakeholders in order to ensure the decarbonisation of the UK *paper* industry.

## Acknowledgements

The work reported forms part of a programme of research at the University of Bath on the technology assessment of energy systems and transition pathways towards a low carbon future that has been supported by a series of UK research grants and contracts awarded by various bodies associated with the *Research Councils UK* (RCUK) *Energy Programme* for which the second author (GPH) was the holder. This programme is a cross council initiative led by the *Engineering and Physical Sciences Research Council* (EPSRC), and contributed to by the *Economic and Social Research Council* (ESRC), the *Natural Environment Research Council* (NERC), the *Biotechnology and Biological Sciences Research Council* (BBSRC) and *Science and Technology Facilities Council* (STFC). The research grants associated with industrial energy demand and carbon emissions reduction originally formed a part of the ‘core’ research programme of the *UK Energy Research Centre* (UKERC); Phase 2, 2009–2014 [under Grant NE/G007748/1]. The first author (PWG) and third author (JBN) undertook their contributions to the present work as part of a UKERC flexible funding project entitled ‘*Industrial Energy Use from a Bottom-up Perspective*’ [for which the second author (GPH) was the Principal Investigator]. During the preparation of this paper the second (GPH) and third (JBN) authors continued to work in the field of industrial energy use and carbon emissions reduction supported by the EPSRC ‘End Use Energy Demand’ (EUED) Programme, as part of the *Centre for Industrial Energy, Materials and Products* (CIE-MAP) [under Grant EP/N022645/1], as a Co-Director and Research Fellow respectively.

The authors' names are listed alphabetically.

## Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.applthermaleng.2018.01.126>.

## References

- [1] Department of Business, Energy and Industrial Strategy [BEIS], *Energy Consumption in the UK*, BEIS, London, 2016.
- [2] Department of Energy and Climate Change [DECC], *Updated Energy and Emissions Projections 2015*, DECC, London, 2016.
- [3] J.B. Norman, *Industrial Energy Use and Improvement Potential*, PhD Thesis University of Bath, Bath, UK, 2013.
- [4] C.H. Dyer, CH, G.P. Hammond, C.I. Jones, R.C. McKenna, Enabling technologies for industrial energy demand management, *Energy Policy* 36 (2008) 4434–4443.
- [5] G.P. Hammond, Industrial energy analysis, thermodynamics and sustainability (In memoriam: Willem van Gool), *Applied Energy* 84 (2007) 675–700.
- [6] G.P. Hammond, J.B. Norman, Heat recovery opportunities in UK industry, *Applied Energy* 116 (2014) 387–397.
- [7] P.W. Griffin, G.P. Hammond, J.B. Norman, Industrial energy use and carbon emissions reduction: A UK perspective, *WIREs Energy Environ.* 5 (2016) 684–714.
- [8] G.P. Hammond, J.B. Norman, Decomposition analysis of energy-related carbon

- emissions from UK manufacturing, *Energy* 41 (2012) 220–227.
- [9] P. Griffin, G. Hammond, J. Norman, Industrial Energy Use from a Bottom-Up Perspective: Developing the Usable Energy Database (Beta Version), Report UKERC/WP/ED/2013/002, UK Energy Research Centre, London, UK, 2013 [see [http://data.ukedc.rl.ac.uk/cgi-bin/dataset\\_catalogue/view.cgi.py?id=15](http://data.ukedc.rl.ac.uk/cgi-bin/dataset_catalogue/view.cgi.py?id=15)] (accessed 20 October 2014).
  - [10] P. Griffin, G. Hammond, J. Norman, Industrial Energy Use from a Bottom-Up Perspective: Usable Energy Database (Spreadsheet - Beta Version), UK Energy Research Centre, London, UK, 2013 [see [http://data.ukedc.rl.ac.uk/cgi-bin/dataset\\_catalogue/view.cgi.py?id=15](http://data.ukedc.rl.ac.uk/cgi-bin/dataset_catalogue/view.cgi.py?id=15)] (accessed 20 October 2014).
  - [11] N. Cossons, *The BP Book of Industrial Archaeology*, second ed., David & Charles, Newton Abbot, UK, 1987.
  - [12] S.T.S. Al-Hassani, E. Woodcock, R. Saoud (Eds.), *1001 Inventions: Muslim Heritage in Our World*, second ed., Foundation for Science Technology and Civilisation, Manchester, UK, 2005.
  - [13] J. Al-Khali, *Pathfinders: The Golden Age of Arabic Science*, Allen Lane, London, UK, 2010.
  - [14] T.A. Derry, T.I. Williams, *A Short History of Technology: From Earliest Times to A.D. 1900*, Oxford University Press, London, UK, 1960.
  - [15] R.A. Buchanan, *Industrial Archaeology of Britain*, Pelican Books, Harmondsworth, UK, 1972.
  - [16] N. MacGregor, *Germany: Memories of a Nation*, Allen Lane, London, UK, 2014.
  - [17] B. Trinder, *The Making of the Industrial Landscape*, J.M. Dent & Sons, London, UK, 1982.
  - [18] The University of Michigan. *Paper: Devoted to the Manufacture, Sale and Use of Pulp and Paper*, Volume 27, The University of Michigan, Ann Arbor, Michigan, USA, 1920.
  - [19] Confederation of Paper Industries [CPI], *Paper Myths and Facts: A Balanced View*, CPI, Swindon, UK, 2012.
  - [20] Confederation of Paper Industries [CPI], *Industry Facts 2015*, CPI, Swindon, UK, 2016.
  - [21] J. De Beer, E. Worrell, K. Blok, Long-term energy-efficiency improvements in the paper and board industry, *Energy* 23 (1998) 21–42.
  - [22] C.H. Dyer, G.P. Hammond, R.C. McKenna, Engineering sustainability: energy efficiency, thermodynamic analysis and the industrial sector, *The Environmental Engineer (Journal of Sustainability and Environmental Engineering, Institution of Engineers, Australia)* 9 (2008) [Winter], 17–22.
  - [23] P.W. Griffin, G.P. Hammond, J.B. Norman, Industrial energy use and carbon emissions reduction in the chemicals sector: A UK perspective, *Applied Energy*: available online 12th August (2017) [DOI: 10.1016/j.apenergy.2017.08.010].
  - [24] Office of National Statistics [ONS], *UK Standard Industrial Classification of Economic Activities 2007 (SIC 2007)*, Palgrave Macmillan, Basingstoke, UK, 2009.
  - [25] Office for National Statistics [ONS], *Energy Use by Industry - Source and Fuel 1990–2012*, ONS, London, UK, 2014 [Spreadsheet].
  - [26] AEA, *Analysing the Opportunities for Abatement in Major Emitting Industrial Sectors*, Report ED56379 for the UK Committee on Climate Change, AEA, Didcot, UK, 2010.
  - [27] Confederation of Paper Industries [CPI], *Climate Change Agreements, Revised Position Paper*, CPI, Swindon, UK, 2016.
  - [28] Office of National Statistics [ONS], *UK non-financial business economy: 2014 revised results (Annual Business Survey)*, Palgrave Macmillan, Basingstoke, UK, 2016.
  - [29] Department of Business, Energy and Industrial Strategy [BEIS], *Digest of United Kingdom Energy Statistics*, BEIS, London, UK, 2016 (annual).
  - [30] Carbon Trust (CT), *Industrial Energy Efficiency – Guide to the Paper Sector*, Report CTG059, CT, London, UK, 2011.
  - [31] N. Martin, N. Anglani, D. Einstein, M. Khrushch, E. Worrell, L.K. Price, Opportunities to Improve Energy Efficiency and Reduce Greenhouse Gas Emissions in the U.S. Pulp and Paper Industry, Report LBNL 46141, Lawrence Berkeley National Laboratory, Berkeley, CA, USA, 2000.
  - [32] N. Martin, E. Worrell, M. Ruth, L. Price, R.N. Elliott, A.M. Shipley, J. Thorne, *Emerging Energy-efficient Industrial Technologies*, Report LBNL 46990, Lawrence Berkeley National Laboratory, Berkeley, CA, USA, 2000.
  - [33] Confederation of European Paper Industries [CEPI], *The Forest Fibre Industry: 2050 Roadmap to a Low-carbon Bio-economy*, CEPI, Brussels, Belgium, 2011.
  - [34] Centre for Low Carbon Futures [CLCF], *Carbon Capture and Utilisation in the Green Economy: Using CO<sub>2</sub> to Manufacture Fuel, Chemicals and Materials*, CLCF, York, UK, 2011.
  - [35] M. Moshkelani, M. Marinova, M. Perrier, J. Paris, The forest biorefinery and its implementation in the pulp and paper industry: Energy overview, *Applied Thermal Eng.* 50 (2013) 1427–1436.
  - [36] T. Rafione, M. Marinova, L. Montastruc, J. Paris, The green integrated forest biorefinery: an innovative concept for the pulp and paper mills, *Appl. Therm. Engineering* 73 (2014) 74–81.
  - [37] Ricardo Energy & Environment, *Biomass Feedstock Availability*, Report ED 662421043 (for BEIS), Ricardo Energy & Environment, Harwell, Didcot, UK, 2017.
  - [38] HM Government, *The Carbon Plan: Delivering Our Low Carbon Future*, Department of Energy and Climate Change, London, UK, 2011.
  - [39] International Energy Agency [IEA], *Energy Technology Perspectives 2012: Pathways to a Clean Energy System*, second ed., IEA Publications, Paris, France, 2012.
  - [40] P.A. Pilavachi, The role of the European Union in promoting energy efficiency in the paper industry, *Appl. Therm. Eng.* 16 (1996) 539–548.
  - [41] T. Fleiter, D. Fehrenbach, E. Worrell, W. Eichhammer, Energy efficiency in the German pulp and paper industry – A model-based assessment of saving potentials, *Energy* 40 (2012) 84–99.
  - [42] K. Möllersten, J. Yan, M. Westermarck, Potential and cost-effectiveness of CO<sub>2</sub> reductions through energy measures in Swedish pulp and paper mills, *Energy* 28 (2003) 691–710.
  - [43] J. Blomberg, E. Henriksson, R. Lundmark, Energy efficiency and policy in Swedish pulp and paper mills: a data envelopment analysis approach, *Energy Policy* 42 (2012) 569–579.
  - [44] Q. Chen, G.P. Hammond, J.B. Norman, Energy efficiency potentials: contrasting thermodynamic, technical and economic limits for organic Rankine cycles within UK industry, *Applied Energy* 164 (2016) 984–990.
  - [45] A. Marina, S.F. Smeding, H.A. Zondag, A.K. Wemmers, A bottom-up approach for determining the European industrial heat pump potential, *Proc. 4th Sustainable Thermal Energy Management (SusTEM2017) International Conference*, Alkmaar, The Netherlands, 28–30 June 2017, 352–361.
  - [46] National Grid, *Power Responsive - Demand Side Flexibility Annual Report 2016*, National Grid, Warwick, UK, 2016.
  - [47] M. Paulus, F. Borggrete, The potential of demand-side management in energy-intensive industries for electricity markets in Germany, *Appl. Energy* 88 (2011) 432–441.
  - [48] J. Chilvers, T.J. Foxon, S. Galloway, G.P. Hammond, D. Infield, M. Leach, P.J.G. Pearson, N. Strachan, G. Strbac, M. Thomson, Realising transition pathways for a more electric, low carbon energy system in the UK: challenges, insights and opportunities, *Proc. Instn Mech. Engrs Part A: Journal of Power and Energy* 231 (2017) 440–477.
  - [49] N. Rega, *Thinking outside the box: new perspectives from the paper industry on demand-side flexibility*, The ICER Chronicle Edition 2 (2014) 54–58.
  - [50] G. Strbac, I. Konstantelos, M. Aunedi, M. Pollitt, R. Green, Delivering future-proof energy infrastructure, A Report for the National Infrastructure Commission, Imperial College London/University of Cambridge, London/Cambridge, UK, 2016 [ < [https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/507256/Future-proof\\_energy\\_infrastructure\\_imp\\_cam\\_feb\\_2016.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/507256/Future-proof_energy_infrastructure_imp_cam_feb_2016.pdf) > ] accessed 15 June 2016.
  - [51] G.P. Hammond, S.S. Onko Akwe, S. Williams, Techno-economic appraisal of fossil-fuelled power generation systems with carbon dioxide capture and storage, *Energy* 36 (2011) 975–984.
  - [52] Confederation of Paper Industries [CPI], *Biomass Sustainability, Revised Position Paper*, CPI, Swindon, UK, 2015.
  - [53] International Energy Agency [IEA], *Carbon Capture and Storage - Progress and Next Steps*, IEA/Organisation of Economic Co-operation and Development (OECD), Paris, France, 2010.
  - [54] A. Soria, J. Forsström, J.T. Keränen, E. Hytönen, A world model of the pulp and paper industry: demand, energy consumption and emission scenarios to 2030, *Environmental Sci. Policy* 12 (2009) 257–269.
  - [55] N. Ozalp, B. Hyman, Energy end-use model of paper manufacturing in the US, *Appl. Therm. Eng.* 26 (2006) 540–548.
  - [56] P.W. Griffin, G.P. Hammond, J.B. Norman, Prospects for emissions reduction in the UK cement sector, *Proc. Instn Civil. Engrs: Energy* 167 (2014) 152–161.
  - [57] P.W. Griffin, Radical change in energy intensive UK industry, PhD Thesis University of Bath, Bath, UK, 2013.
  - [58] British Geological Survey [BGS], *Brick Clay: Issues for Planning*, Commissioned Report CR/01/117N, HMSO, London, UK, 2001.
  - [59] British Geological Survey [BGS], *United Kingdom Minerals Yearbook 2002*, BGS, Nottingham, UK, 2003.
  - [60] Carbon Trust [CT], *Industrial Energy Efficiency Accelerator: Guide to the Brick Sector*, Report CTG043, CT, London, UK, 2011.
  - [61] J. MacCarthy, *National Atmospheric Emissions Inventory: Pivot Table Viewer for the UK GHG Inventory*, Department for Environment, Food and Rural Affairs, London, UK, 2014 [spreadsheet].
  - [62] N. Webb, M. Broomfield, L. Cardenas, J. MacCarthy, T. Murrells, Y. Pang, N. Passant, G. Thistlethwaite, A. Thomson, UK Greenhouse Gas Inventory 1990 to 2011: Annual Report for submission under the Framework Convention on Climate Change, Report Ricardo-AEA/R/3355, Ricardo-AEA, Didcot, UK, 2012.
  - [63] T. Kruger, R. Darton, Negative emissions technologies could become the world's largest industry, *Proc. Instn Civil. Engrs: Civil Eng.* 166 (2013) 51.
  - [64] J. World, P. Scott, *Climate Change Agreements: Results of the Fifth Target Period*, Report AEAT/ED43694/R1, AEA Technology, Didcot, UK, 2011.
  - [65] K. Langley, *Energy Use and Energy Efficiency in UK Manufacturing Industry up to the year 2000*, Volume 2: Sector Reports Containing the Detailed Analyses of the Industries, their Energy Use and Potential Energy Savings, HMSO, London, UK, 1984.
  - [66] British Glass [BG], *A Clear Future: UK Glass Manufacturing Sector Decarbonisation Roadmap to 2050*, BG, Sheffield, UK, 2014.
  - [67] Office for National Statistics [ONS], *Energy Use by Industry - Source and Fuel 1990–2012*, ONS, London, UK, 2014 [Spreadsheet].



## Effect of microfibrillated cellulose (MFC) on the properties of gelatine based composite films

Shuaishuai Yang (1), Haichao Li (1), Huizhen Sun (2)

1) College of Chemistry and Chemical Engineering, Qinghai Nationalities University, Xining 810007, China.

2) Center of Ecology Research, Northeast Forestry University, Harbin 150040, China

Properties of gelatine composite films (with 4% glycerol as plasticizer) with different concentrations of microfibrillated cellulose (MFC) (0.2-1.0%) were investigated. The composite films can be dissolved in hot water (95°C) in less than 6 minutes. However the addition of MFC had insignificant effect on heat shrinkage and light transmittance of the resultant films.

Journal of Bioresources and Bioproducts. 2018, 3(3) 107-111. (Open Access)

DOI: 10.21967/jbb.v3i3.157

The Paper Industry Technical Association (PITA) is an independent organisation which operates for the general benefit of its members – both individual and corporate – dedicated to promoting and improving the technical and scientific knowledge of those working in the UK pulp and paper industry. Formed in 1960, it serves the Industry, both manufacturers and suppliers, by providing a forum for members to meet and network; it organises visits, conferences and training seminars that cover all aspects of papermaking science. It also publishes the prestigious journal *Paper Technology* and the *PITA Annual Review*, both sent free to members, and a range of other technical publications which include conference proceedings and the acclaimed *Essential Guide to Aqueous Coating*.

# Effect of microfibrillated cellulose (MFC) on the properties of gelatin based composite films

Shuaishuai Yang<sup>a,\*</sup>, Haichao Li<sup>a,\*</sup>, Huizhen Sun<sup>b</sup>

a) College of Chemistry and Chemical Engineering, Qinghai Nationalities University, Xining 810007, China.

b) Center of Ecology Research, Northeast Forestry University, Harbin 150040, China.

\*Corresponding authors: [lihaichao@vip.163.com](mailto:lihaichao@vip.163.com); [sunhuizhen@hotmail.com](mailto:sunhuizhen@hotmail.com)

## ABSTRACT

Properties of gelatin composite films (with 4% glycerol as plasticizer) with different mass concentrations of microfibrillated cellulose (MFC) (0.2-1.0%) were investigated. The prepared composite films with 1.0 % MFC showed the highest tensile strength (12.32 MPa) with the lowest water absorption rate (391.1 %). The composite films can be dissolved in hot water of 95°C in less than 5 minutes. However, the addition of MFC had insignificant effect on the heat shrinkage and light transmittance of the resultant composite films.

**Keywords:** Gelatin films; Microfibrillated cellulose; Physicochemical properties

## 1. INTRODUCTION

Gelatin is a biodegradable polymer, which can be obtained by thermal denaturation or physical and chemical degradation of collagen.<sup>1</sup> Gelatin has excellent film-forming, biocompatible and biodegradable properties,<sup>2,3</sup> which make it have a potential application in food packing. However, Gelatin dissolves easily in the 40°C solution, and its mechanical properties are also poor. Therefore, it is a research direction to seek a modification method to improve their dissolving and mechanical properties at present.

The interest in gelatin has recently increased exponentially because of its biodegradable properties. Gelatin contains a large amount of hydroxyl, amino and carboxyl, which makes its modification method more diversified, such as physical,<sup>4,5</sup> chemical<sup>6,7</sup> and combining modification etc.<sup>8,9</sup> For example, the gelatin composite films were modified with starch at different temperature, the results indicated that the crystallinity of the gelatin composite films could be increased.<sup>10</sup> The effect of stearic acid and reaction time on the properties of gelatin films were also investigated, and the results showed that the tensile strength and water absorption of the gelatin films decreased with the increase of stearic acid content.<sup>11</sup> The gelatin was modified by cross-link with transglutaminase, and a bigger molecular weight could be obtained.<sup>12</sup> The modification of gelatin and gelatin-chitosan composite films with enzyme was also investigated, and the results showed that the viscosity modulus of gelatin-chitosan increased rapidly, and the effect on gelatin was not obvious.<sup>13</sup>

Over the past decades, the study of cellulose composites was the most active one in the science and technology field. Cellulose is the main component of plant's cell wall,<sup>14-18</sup> which is the most abundant natural organic matter all over

the world and inexhaustible resources.<sup>19,20</sup> It is a micromolecular polysaccharide, which is composed of D-glucose with  $\beta$ -1, 4-glycosidic bond. The chemical formula is  $(C_6H_{10}O_5)_n$  and the molecular-weight is about  $5.0 \times 10^4$ - $2.5 \times 10^6$ . Due to the existence of a large number of hydroxyl groups, which makes intermolecular and intramolecular of cellulose produce some strong hydrogen bond, and thus has an active effect on physical and chemical properties. In this paper, microfibrillated cellulose (MFC) was used to modify the dissolving and mechanical properties of gelatin composite films, and the effect of MFC on the tensile strength (TS), Elongation at break, thermal and water adsorption properties was studied in detail.

## 2. EXPERIMENTAL

### 2.1. Material

The gelatin was purchased from Tianjin Guangfu Fine Chemical Research Institute (Tianjin, China). MFC was procured from Sinopharm Chemical Reagent Co., Ltd (Shanghai, China). The glycerol was obtained from Tianjin Damao Reagent Factory (Tianjin, China). The gelatin was food grade and other agents were analytical grade, which were used without further purification.

### 2.2. Preparation of gelatin/MFC composite films

The gelatin/MFC composite films were prepared by solution casting method as described.<sup>21</sup> For the preparation of composite films, 5 g gelatin was added into pure water (50 mL) with stirring until it dissolved completely. Then, 4% glycerol and 0.2-1.0% MFC were added and continued to mix at 60°C for 60 min in digital temperature control

agitator (XH-50E, Xianghu Science and development Co. Ltd, Beijing, China). The film-forming solution was cast onto a rimmed silicone plate and dried at room temperature about 72 h. The films were kept in a constant temperature and humidity chamber (HE-WS-408D8, Haoen Testing Instrument Co., Ltd, Dongguan, China) at 25°C and 50% RH for 48 h before further tests.

### 2.3. Characterization of gelatin/MFC composite films

#### 2.3.1. Morphological observation

The microstructure of gelatin/MFC composite films was characterized by scanning electron microscopy (SEM) (JCM-6000 BENCHTOP SEM, JEOL, Japan) with an accelerating voltage of 15.0 kV.

#### 2.3.2. Mechanical properties

The tensile strength and elongation at break were determined by intelligent electronic tensile testing instrument (XLW, Blue Light Electrical and Mechanical Technology Co., Ltd, Jinan, China) according to ASTM D882-02 (ASTM, 1995a), and the thickness was measured by thickness indicator (MX-3, DAKOTA ULTRASONICS, Scott, USA). The composite film samples were cut into 2.30 × 10.0 cm, and kept at 50% relative humidity (RH) for 48 h before analysis. Then, the tensile strength (TS) and elongation at break (E) were calculated with the Eq. (1) and Eq. (2), respectively. Where  $\sigma$  and  $\varepsilon$  were tensile strength (TS) and elongation at break (EAB), respectively.  $F$ ,  $b$ , and  $d$  were tensile force and width and thickness of composite film, respectively.  $l_0$  and  $l_1$  were tensile elongation and original length, respectively.

$$\sigma = \frac{F}{b \times d} \times 100\% \quad (1)$$

$$\varepsilon = \frac{l_1}{l_0} \times 100\% \quad (2)$$

#### 2.3.3. Thermogravimetric and heat shrinkage analysis

The thermal analysis of the composite films was characterized by Thermogravimetric analyzer (IRPrestige21, shimadzu corporation, Kyoto, Japan). The composite film samples were about 8-10 mg, and kept at 50% relative humidity (RH) for several days before analysis. The samples were tested with a rate of heating of 10 °C/min, between 25 °C and 800 °C in an inert atmosphere (100 ml/min N<sub>2</sub>).

The heat shrinkage of composite films was characterized by heat shrinkage instrument (RSY-R2, Blue Light Electrical and Mechanical Technology Co., Ltd, Jinan, China). Film samples of 10 × 50 mm dimension were heat treated at 120 °C for twenty seconds.

#### 2.3.4. Optical properties

The optical properties of the composite films were determined using ultraviolet spectrophotometer (752N, INESA, shanghai, China). The films were cut into 10 × 50 mm size and tested between 400 nm and 800 nm.

#### 2.3.5. Water absorption properties

Dyr composite films were cut into 20 × 20 mm pieces, and soaked in distilled water until the maximum absorption was reached (the films' weight changed within 1%). The Water absorption was calculated with the Eq. (3). Where  $Q$  was Water absorption.  $m_0$  and  $m_1$  were the weights of dry and wet film, respectively.

$$Q = \frac{m_1 - m_0}{m_0} \times 100\% \quad (3)$$

## 3. RESULTS AND DISCUSSION

### 3.1. Morphology

The surface morphology and cross section of pure gelatin film and gelatin/MFC composite film using scanning electron microscopy are shown Fig.1. In the gelatin/MFC composite film, the surface was much smoother than the pure gelatin film was rough, and the cross section of gelatin/MFC composite film was denser, which might due to cross-linked reaction between gelatin and MFC.

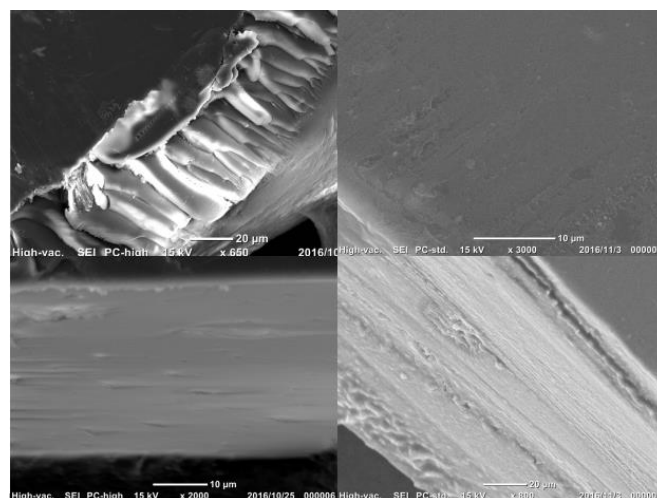


**Fig. 1.** SEM images of neat gelatin films and gelatin/MFC composite films (top: surface; bottom: cross section; left: neat gelatin films; right: gelatin/MFC composite films)

### 3.2. Mechanical properties

Fig.2 shows the mechanical properties of gelatin/MFC composite films. The tensile strength changed as the MFC mass concentration varied. Among them, the gelatin/MFC composite film of 1.0% MFC had the highest tensile

strength (12.32 MPa). However, the gelatin/MFC composite films showed a decreasing elongation at break, which can be attributed to the decrease of film-forming solution matrix mobility as the MFC content increased.<sup>22</sup> In general, the composite films had more improved mechanical properties than neat gelatin films.

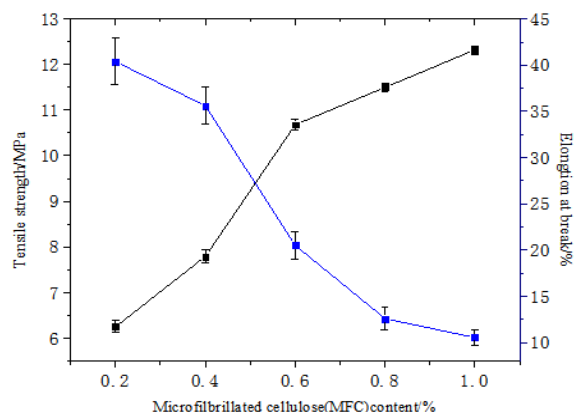


**Fig. 2.** Tensile strength (TS) and elongation at break (EAB) curves of gelatin/MFC composite films with various MFC mass concentrations: 0.2%, 0.4%, 0.6%, 0.8%, 1.0%.

### 3.3. Thermogravimetric and heat shrinkage analysis

Generally, the thermogravimetric curve of the biopolymer-based film has three stages: the loss of physically absorbed water, structured water and decomposition of biomolecules.<sup>23</sup> From Fig. 3a we can observe that the first stage of weight loss was about 150 °C, which mainly contained free water and volatile substance. However, gelatin/MFC composite film was more stable than pure gelatin film at about 270 °C (weight loss of less than 10%). Moreover, the Maximum weight loss of pure gelatin film and gelatin/MFC was about 500 °C and 600 °C, respectively. From heat shrinkage curves of gelatin/MFC composite films (Fig. 3b), the heat shrinkage of composite film decreased by adding MFC of various mass concentration, which was about 0.67%. All in all, MFC promoted the stability of gelatin film.

### 3.4. Optical properties

The light transmittance of pure gelatin films and gelatin/MFC composite films was illustrated in Fig. 4. At the center of the visible light 600 nm, which showed some differences between pure gelatin (86.5%) and five gelatin/MFC composite films with the date of 82.9%, 83.4%, 82.2%, 83.1% and 78.2%, respectively. The decrease in light transmittance was mainly due to the phenomenon of reflection or scattering at the interface between gelatin and MFC,<sup>24</sup> which might be confirmed by scanning electron microscopy (SEM). However, the

gelatin/MFC composite film still kept a much higher transmittance in general, which also reflected the good compatibility between gelatin and MFC.

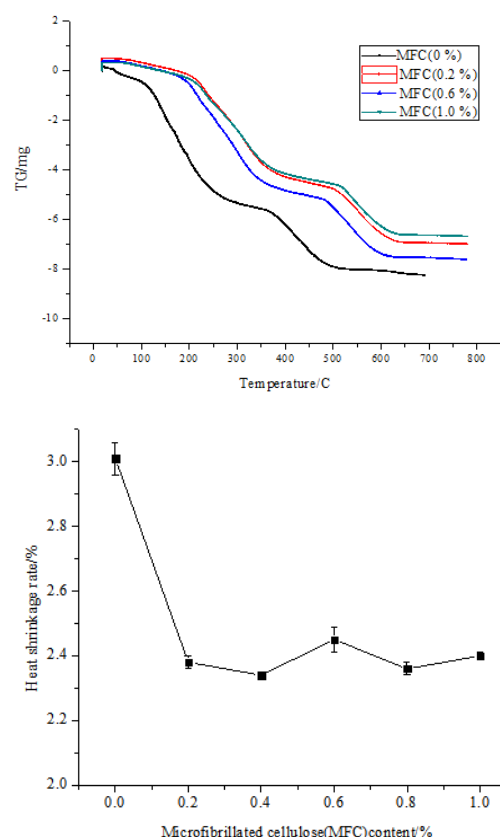


**Fig. 3.** TG and heat shrinkage curves of pure gelatin film and gelatin/MFC composite films with various MFC mass concentrations: 0.0 %, 0.2 %, 0.4 %, 0.6 %, 0.8 %, 1.0 %.

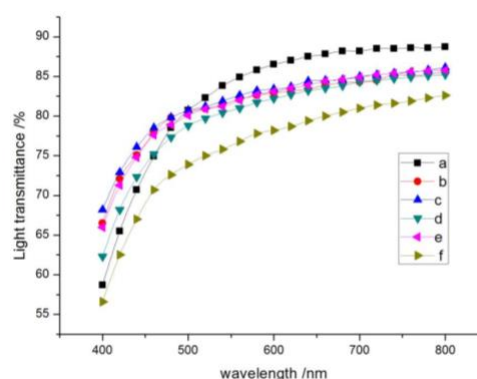


**Fig. 4.** Light transmittance curves of neat gelatin films and gelatin/MFC composite films with various MFC mass concentrations: 0.0% (a), 0.2% (b), 0.4% (c), 0.6% (d), 0.8% (e), 1.0% (f).

### 3.5. Water absorption properties

From Fig. 5 we can observe that the water absorption of the films emerged vast change in the first 2 hours. The curve didn't mark the water adsorption of the pure gelatin film for much damage in a few minutes. Moreover, the water adsorption of the composite film is lower than pure gelatin film, and the result showed that the water adsorption was decreasing with the raise of MFC (391.1% contain 1.0% MFC). Generally, the cross-linking of gelatin molecules would promote a reduction in the swelling of composite. The result illustrated MFC benefited the formation of more cross-linkage and net structure between gelatin and MFC.<sup>25</sup>

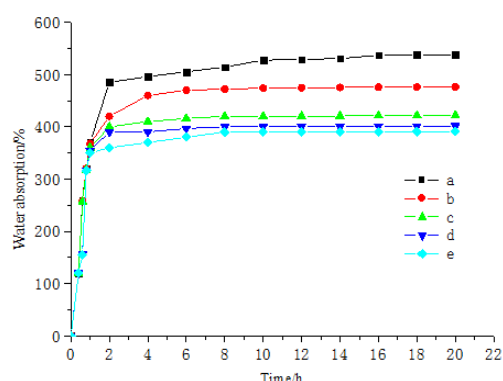


**Fig.5.** Water absorption curves of gelatin/MFC composite films with various MFC mass concentrations: 0.0% (a), 0.2% (b), 0.4% (c), 0.6% (d), 0.8% (e), 1.0% (f).

#### 4. CONCLUSIONS

Gelatin/MFC composite films with improved mechanical properties were fabricated by solution casting method with various MFC mass concentrations. With the addition of MFC, the tensile strength increased and the elongation at break decreased. MFC addition decreased the water adsorption and the light transmittance of the gelatin films.

#### ACKNOWLEDGMENTS

The authors are grateful for the support of the Natural Science Foundation of Qinghai Province, China, Grant No. 2015-ZJ-909.

#### REFERENCES

1. Veis A. The macromolecular chemistry of gelatin. New York: Academic Press, 1964.
2. Jiang M. K., Liu S. Y., Du X., et al. Physical properties and internal microstructures of films made from catfish skin gelatin and triacetin mixtures[J]. Food Hydrocolloids, 2010, 24: 105-110.

3. Jataru A. N., Danu M., Peptu C. A., et al. Ionically and covalently cross-linked hydrogels based on gelatin and chitosan[J]. Soft Ma-ter., 2013, 11: 45-54.
4. Zhai M., Zhao L., Yoshii F., et al. Study on antibacterial starch/chitosan blend film formed under the action of irradiation [J]. Carbohydrate Polymers, 2004, 57(1): 83-88.
5. Khandal D., Aggarwal M., Suri G., et al. Electron beam irradiation of maltodextrin and cinnamyl alcohol mixtures: Influence of glycerol on cross-linking [J]. Carbohydrate Polymers, 2015, 117: 150-159
6. Li C. S., Yang H. S. Effects of salt and sugar addition on the physicochemical properties and nanostructure of fish gelatin[J]. Food Hydrocolloids, 2015(45): 72-82.
7. Paulraj K., Jong W. R. Physicochemical properties of gelatin/silver nanoparticle antimicrobial composite films[J]. Food Chemistry, 2014, 148: 162-169.
8. Gholamreza K., Seyed M. M., Seyed M. A., et al. Investigation of gelatin/multi-walled carbon nanotube nanocomposite films as packaging materials[J]. Food Science & Nutrition, 2014, 2(1):65-73.
9. Gholamreza K., Seyed M. M., Amin M. P., et al. Antioxidant and antibacterial properties of gelatin films incorporated with carvacrol[J]. Journal of Food Safety, 2013, 33: 423-432.
10. Ioannis A., Atsuyoshi N., Sei-ichi A. Edible films made from hydroxypropyl starch and gelatin and plasticized by polyols and water[J]. Carbohydrate Polymers. 1998, 36(2-3) :105-119.
11. Karnnet S., Potiyaraj P., Pimpan V. Preparation and properties of biodegradable stearic acid-modified gelatin films [J]. Ploymer Degradation and Stability, 2005, 90(1): 106-110.
12. Ho J. B., Duncan O. D., Robert M. K., et al. Effects of transglutaminase-induced cross-linking on properties of fish gelatin-nanoclay composite film[J]. Food Chemsitry, 2009, 114(1): 180-189.
13. Chen T H, Embree H D, Brown E M, et al. Enzyme-catalyzed gel formation of gelatin and chitosan: potential for in situ applications. Biomaterials, 2003, 24(17): 2831-2841.
14. Kubicki, Vincent H. C., Linghao Z.. Cellulose Microfibril Twist, Mechanics and Implication for Cellulose Biosynthesis[J]. Journal of Physical Chemistry A, 2013, 117 (2): 2580-2589.
15. Persson, Bo N. J., Ganser, Christian, Schmied. Adhesion of cellulose fibers in paper[J]. Journal of Physics: Condensed Matter, 2013, 25 (4): 45002-45012.
16. Li X. G., Huang M. R., Hu L., et al. Cellulose derivative and liquid crystal blend membranes for oxygen enrichment [J]. European Polymer Journal, 1999, 35(1):157-166.
17. Xu B.H. Preparation and Analysis of Super Absorbent Resin from Cellulose[D]. Beijing: Beijing Forestry University, 2008.
18. Wu D. P. Biomedical Natural Polymer Fiber Material [J]. Foreign Silk, 2008, (3): 27-28.
19. Hubber M. A. Rojas O. J., Lucia L. A., et al. Bioresources. 2008, 3(3):929.
20. Cheng Q., Wang S., Rials T. G. Composites: Part A, 2009, 40(2): 218.
21. Umma H., Md S. I., Tawsif A., Siddique, Amalina M. A., Bee C. A. Adsorption and photocatalytic degradation of anionic dyes on Chitosan/PVA/Na-Titanate/TiO<sub>2</sub> composites

- synthesized by solution casting method[J]. Carbohydrate Polymers, 2016.
22. Adzaly N. Z., Jackson A., Villalobos-Carvajal R., Kang I., Almenar E. Development of novel sausage casing[J]. Journal of Food Engineering, 2015, 152: 24-31.
  23. Jose M. V., Tomas V., Dean D. R., Nyairo E. Fabrication and characterization of aligned and nanofibrous PLGA/Collagen blends as bone tissue scaffold[J]. Polymer, 2009, 50(15): 3778-3785.
  24. Fushou C. Study on the preparation and properties of cellulose nanofiber reinforced soybean protein isolate (SPI) transparent composites[D]. Fuzhou: Fujian normal university, 2009.
  25. Wenhong W., Yabin W., Xiaowei Z., Xiao W., Guixian G. Fabrication and characterization of microfibrillated cellulose and collagen composite film[J]. Journal of Bioresources and Bioproducts. 2016, 1(4): 162-168.



## Characterization and Isolation of Fungi for Removal of Color from Pulp and Paper Mill Effluent, Meerut (India)

Rajesh Kumar (1), Rajdeo Kumar (1), Ashish Chauhan (2), Manoj Kumar (3), Manish Kumar Goyal (2) and Thakur IS (1)

1) School of Environment Sciences, Jawaharlal Nehru University, New Delhi, India

2) National Institute of Pharmaceutical Education and Research, Mohali, India

3) Centre for Public Health, Punjab University, Chandigarh, India

In this research paper, use of biological agents for the treatment of effluent is more environmental friendly and can lead to the production of more value added products like biogas and compost etc. Pulp and paper mill is the major industrial hub in our country. The heavy demand for the paper helps in steady expansion of paper industries. Pulp and paper industry is one of the largest and most notorious sources of industrial pollution. The Ministry of Environment and Forest, Govt. of India has categorized the pulp and paper industry as one of the twenty most polluting industries.

J Environ Anal Toxicol 2015, 5:6. (Open Access)

DOI: 10.4172/2161-0525.1000324

The Paper Industry Technical Association (PITA) is an independent organisation which operates for the general benefit of its members – both individual and corporate – dedicated to promoting and improving the technical and scientific knowledge of those working in the UK pulp and paper industry. Formed in 1960, it serves the Industry, both manufacturers and suppliers, by providing a forum for members to meet and network; it organises visits, conferences and training seminars that cover all aspects of papermaking science. It also publishes the prestigious journal *Paper Technology* and the *PITA Annual Review*, both sent free to members, and a range of other technical publications which include conference proceedings and the acclaimed *Essential Guide to Aqueous Coating*.

# Characterization and Isolation of Fungi for Removal of Color from Pulp and Paper Mill Effluent, Meerut (India)

Rajesh Kumar<sup>1\*</sup>, Rajdeo Kumar<sup>1</sup>, Ashish Chauhan<sup>2</sup>, Manoj Kumar<sup>3</sup>, Manish Kumar Goyal<sup>2</sup> and Thakur IS<sup>1</sup>

<sup>1</sup>School of Environment Sciences, Jawaharlal Nehru University, New Delhi, India

<sup>2</sup>National Institute of Pharmaceutical Education and Research, Mohali, India

<sup>3</sup>Centre for Public Health, Punjab University, Chandigarh, India

## Abstract

In this research paper, use of biological agents for the treatment of effluent is more environmental friendly and can lead to the production of more value added products like biogas and compost etc. Pulp and paper mill is the major industrial hub in our country. The heavy demand for the paper helps in steady expansion of paper industries. Pulp and paper industry is one of the largest and most notorious sources of industrial pollution. The Ministry of Environment and Forest, Govt. of India has categorized the pulp and paper industry as one of the twenty most polluting industries.

**Keywords:** Effluent; Pulp and paper; Biogas; Industry; Pollution

## Introduction

India is one of the first ten industrialized countries in the world. We have good industrial infrastructure in core industries like chemicals, fertilizers, petroleum, pulp and paper mill and leather industries etc. Though three fourth volume of the waste water is generated from municipal sources, industrial waste water contribute over half of the pollution load and major portion of this originates from large and medium scale industries. Pulp and paper mill is the major industrial hub in our country. The heavy demand for the paper helps in steady expansion of paper industries. In 1951, there were 17 paper mills in country which producing 0.13 million tons paper per annum. The number has gone up to 406 in 2002 producing 1.9 million tons paper per annum. Pulp and paper mills are utilizing huge amount of lingo-cellulosic components of plants and using chemicals during manufacturing regarded as polluting industries because of huge amount of waste material enter into the environment.

Pulp production from wood ( $10^6$  metric tons day<sup>-1</sup> worldwide) not only requires large amount of fresh water but also is responsible for the discharge of a considerable volume of effluents (200 m<sup>3</sup>/ metric ton of pulp). Since the pulp production by plant materials corresponds to only about 40-50% of the original weight of the wood, these effluent are heavily loaded with organic material. Over 100 organic chemicals most of them chlorinated have been identified in spent bleaching liquor. These compounds are chlorinated lingnosulphonic acid, chlorinated resin acid, chlorinated phenol and chlorinated hydrocarbon. Although the pulp industry has made a considerable effort to reduce the residual organic matter but organic compounds generated during pulping and bleaching performed by using chlorine, chlorine dioxide and sometimes hydro chlorite formed recalcitrant xenobiotics which are not removed by treatment method [1-6].

Biological decolourisation methods use several classes of microorganism including bacteria, algae and fungi to degrade the polymeric lignin derived chromophoric material. Among these wood degrading white rot fungi have been shown to efficiently and completely degrade and metabolize lignin resulting in rapid decolourisation of the effluents. *Schizophyllum commune*, *Tinctoporia borbonica*, *Phanerochaete chrysosporium* and *Trametes versicolor* have been found to degrade lignin and metabolize it along with carbohydrates. *Aspergillus niger* with *Trichoderma sp.* one of the fungi are also capable of degrading lignin and decolourizing El stage effluent of hard wood pulp bleaching.

Bacterial cultures have been marketed for decolonization or kraft mill effluent. *Pseudomonas aeruginosa* is capable of reducing kraft mill effluent color by 26-54% or more under aerobic conditions. Color was primarily removed by adsorption with little depolymerization. During microbial attack of lignin a number of sample aromatic compound like vanilic acid, p-hydroxy benzoic acid, ferulic acid, syringic acid and coniferaldehyde are produced.

## Profile of the pulp and paper industry in India

The Pulp and paper industry is one of the largest and oldest industries in India. It has most notorious sources of industrial pollution. The Ministry of Environment and Forest, Govt. of India has categorized the pulp and paper industry as one of the twenty most polluting industries. The first paper mill was commissioned in 1812 in the eastern state of West Bengal. Today are about 406 pulp and paper industries with an annual installed capacity of 6.2 million tons. The capacity utilization is estimated at around 60-65% of the total installed capacity (Table 1).

## Pulp and paper industry and its status

Worldwide pulp production from wood is  $10^6$  metric tons per day which is also responsible for the discharge of considerable volume of effluent (200 m<sup>3</sup>/metric tons). The world population used over 214 million tons of paper and board products in 1987 and all estimates show that paper consumption is going to increase in the seeable future. In India, it is about 288 pulp and paper mill which manufacture  $27.5 \times 10^5$  tons of paper per year. Pulp and paper industry in India is quite old and it has an installed capacity of about 3.0 million ton per annum. The large paper mills with capacity greater than 55 tons per day and numbering 34 account for about 50 percent of total installed capacity.

**\*Corresponding author:** Rajesh Kumar, School of Environment Sciences, Jawaharlal Nehru University, New Delhi-110 067, India, Tel: +91-8591473231; E-mail: [rajdeo.kumar@rediffmail.com](mailto:rajdeo.kumar@rediffmail.com)

**Received** August 10, 2015; **Accepted** September 28, 2015; **Published** October 04, 2015

**Citation:** Kumar R, Kumar R, Chauhan A, Kumar M, Goyal MK, et al. (2015) Characterization and Isolation of Fungi for Removal of Color from Pulp and Paper Mill Effluent, Meerut (India). J Environ Anal Toxicol 5: 324. doi:10.4172/2161-0525.1000324

**Copyright:** © 2015 Kumar R, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

| State             | Number of mills | Installed capacity (tons per year-TPY) |
|-------------------|-----------------|----------------------------------------|
| Andhra Pradesh    | 22              | 414550                                 |
| Assam             | 2               | 220500                                 |
| Bihar             | 4               | 25000                                  |
| Gujarat           | 68              | 935800                                 |
| Haryana           | 15              | 149150                                 |
| Himachal Pradesh  | 6               | 53200                                  |
| Jammu and Kashmir | 1               | 5000                                   |
| Karnataka         | 14              | 34530                                  |
| Kerala            | 5               | 215600                                 |
| Madhya Pradesh    | 21              | 290650                                 |
| Maharashtra       | 71              | 1034050                                |
| Nagaland          | 1               | 33000                                  |
| Odisha            | 1               | 27050                                  |
| Pondichery        | 1               | 9000                                   |
| Punjab            | 37              | 375162                                 |
| Rajasthan         | 7               | 12195                                  |
| Tamil Nadu        | 31              | 639250                                 |
| Uttar pradesh     | 73              | 870780                                 |
| West Bengal       | 18              | 222600                                 |
| <b>Total</b>      | <b>406</b>      | <b>6121327</b>                         |

**Table 1:** Geographical spread of the pulp and paper mill in India.

The rest mills are small and have a production capacity of less than 30 tons per day of over 300 mills producing about 2.5 million tons of pulp about 10 percent is pulp for viscous rayon grade industry. The pollution potential of small paper mills is greater than that of large mills as they lack proper effluent treatment system and chemical recovery units.

### Characteristics of pulp and paper mill effluent

The paper making processes produces an effluent which contains a substantial quality of cellulose “fines” and others additives. This can be up to 50% of the total mass. This contaminated water is frequently referred to as “white water”. Reclamation of the effluent is economically essential as the gross usage of water in the industry is very high and cost of effluent treatment for all water assigned to drain would be too expensive and would also involve a loss of raw materials [6-13].

## Materials and Methods

### Sampling

Sampling was started for the purpose of isolation of fungal strains. The sediment was collected from the Kaccha nala outside the Centaury Pulp and Paper Mill (Ghanshyam Dham, Lalkuan, Nainital and Uttaranchal) premises. Second sampling was done near Anand Tissue Paper Mill, Meerut. Sediments samples were collected from the drain near the industry. The Sediment was collected in clean plastic containers and brought to the laboratory of the department and immediately stored in refrigerator at 4°C unit used for further analysis.

### Microbial community procurement

**Culture media:** The composition of the culture media which was used in the present investigation has been given as under:

**Potato Dextrose Agar (PDA):** The sterilized potato dextrose agar media used for culturing the fungal strains was used at the rate of 39 gm per liter of distilled water and the pH of the media was adjusted to  $5.0 \pm 1.0$ .

**Potato Dextrose Broth (PDB):** The sterilized potato dextrose broth

was used for the continuous enrichment of the fungal strain has been used at the rate of 24 gm per liter of distilled water. The pH of the media was adjusted to  $5.0 \pm 1.0$ .

**Minimal Salt Medium (MSM):** The sterilized minimal salt medium was used for the continuous enrichment of the microbial strains in this investigation. The composition is described above.

**Antibiotic:** Antibiotic strepto penicillin was used for the prevention of any contamination of the media used in the investigation. It has been used at the rate of 100 mg per liter sterilized media.

**Isolation of fungus from the sediments:** 1.0 gm of sediments was dissolved in 10 ml of autoclaved water. It was shaken vigorously to mix them properly. It was kept standing at room temperature for 2 hr. Then the supernatant was decanted and centrifuged at 1000 rpm for 5 minute. The same process was repeated with the sediments of both the industry. Serial dilution of the supernatant in the order of  $10^{-3}$ ,  $10^{-4}$ ,  $10^{-5}$  were done using 0.1 ml autoclaved double distilled water from each dilution was spread on the PDA plates and incubated at 30°C for 4 days. Spreading was done in triplicate.

**Preparation of fungal inoculums (Pellets):** For the preparation of fungal inoculums in the form of pellets initially the fungal isolates were individually grown on potato dextrose agar plates by incubation at 30°C for 4 days. Fungal mycelium disc (of about 1 cm diameter) were cut for the zone of active growth and inoculated at the rate of mycelia discs inn sterilized Erlenmeyer flasks containing potato dextrose broth (100 ml) and steriptopenicilliini (100 ml). The flasks were incubated at 30°C for 4 days under shake conditions in orbital shaker. The pellets of approximately 1.5-2.0 mm size were observed suspended in the medium ready for use in the treatment of pulp and paper mill effluent.

### Screening of potential strains

MSM effluent (150 ml) in a sterilized Erlenmeyer flasks inoculated with individual fungal isolates and a control were then inoculate with individual fungal isolates and a control were then incubated at 30°C in a rotary shaker for 15 days. The parameter such as color and lignin were observed and measured at an interval of 0, 1, 3, 5, 7, 10, 15 days. The experiment was repeated on the basis of comparative analysis of reduction percentage of different parameters studied by the individual isolates along with control; the potential strains were screened out.

### Decolonizing assay

Color was estimate by the method 212°C (APHA). The sample was filtered and then centrifuged at 10,000 rpm for 30 minutes to remove all the suspended matter. The supernatant was taken and volume of sample was maintained at 50 ml. The pH of the sample was adjusted to 7.0 with 2M NaOH. Then the absorbance was taken at the wavelength of 456 nm using Varian Cary Spectrophotometer. The value of color was calculated in coloring unit by making standard curve [3-8].

### Preparation of standard curve

Dissolved 1.246 gm of potassium chloroplatinate and 1.0 gm crystallized cobaltous chloride in ware with 100 ml core HCl and diluted to 1 liter. This stock solution has color of 500 CU. The suitable dilution was made from this stock solution to prepare standard curve.

### Measurement of Lignin

The lignin of the samples was estimated according to Pearl and Benson. In this method the sample was centrifuged at 10,000 rpm for 30 minutes to remove all the suspended matter. The pH of the

supernatant was then adjusted to 7.0 with 2M NaOH. The sample (50 ml) was mixed with 1 ml of  $\text{CH}_3\text{COOH}$  (10%) and 1 ml of  $\text{NaNO}_2$  (10%). After 15 minutes, 2 ml of  $\text{NH}_4\text{OH}$  was added. It was then left for five minutes and absorbance (OD) was measured at 430 nm. For blank, 1 ml of  $\text{CH}_3\text{COOH}$  (10%) was added in 50 ml of distilled water and 2 ml of  $\text{NH}_4\text{OH}$ . After 15 minutes, 1 ml of  $\text{NaNO}_2$  (10%) was added. After waiting for 5 minutes optical density (OD) was taken at 430 nm. The absorbance value was transformed into lignin content (ppm) using the following formulate [3-8].

$$\text{Lignin (ppm)} = \text{Absorbance} / 0.000247$$

### Enzyme analysis

Finally the three most potent strains were selected for enzyme analysis. Two enzymes Lignin *peroxidase* and Manganese *peroxidase* were studied [3-8].

**Lignin *peroxidase* (Lip):** Veratryl alcohol (VA) assay. Lip can be measured photometrically through the oxidation of VA to veratryl aldehyde at 310 nm. The reaction mixture will contain 2 mM VA, 35 mM sodium titrate buffer (pH 3.0) and enzyme. The reaction starts with the addition of 0.36 mM  $\text{H}_2\text{O}_2$ .

**Manganese *peroxidase* (MnP):** MnP activity can be measured directly through the oxidation of Mn (II) to Mn (III) at 270 nm. The reaction mixture consists of 0.5 mM  $\text{MnSO}_4 \cdot \text{H}_2\text{O}$  and enzyme, 45 mM sodium malonate buffer (pH-4.5) and enzyme. The reaction starts with the addition of 0.1 mM  $\text{H}_2\text{O}_2$ .

### Microscopic study and identification of fungal strains

In this the isolated fungal strains were grown on PDA plate. A very small amount of mycelium was picked up from plate and kept on clear glass slide having a drop of water. Then observing under microscope (2X) the mycelium was teased and the fungal hyphae were separated from each other. Finally this mycelium was transferred on second glass slide having a drop of water. The cover slip was placed to make a temporary slide. This slide was observed under a microscope, Olympus and Magnus MLX-TR at 40X and 100X having camera attached with it. Fungal mycelium, spores and the spore attachment was observed and photographs were taken for the purpose of identification.

## Results

### Isolation of fungal strains

Sampling was done from two industries namely as centrally pulp and paper mill, Lalkuan and Anand tissue paper mill, Meerut where sediment samples were collected. Fungal strains were isolated by serial dilution and grown on Potato Dextrose Agar (PDA) plates. Three fungal strains F1, F2 and F3 were isolated from century pulp and paper mill, Lalkuan and three fungal strains 1, 5 and 7 were isolated from Anand tissue paper mill, Meerut. One fungal strain AF3 was available in laboratory. Hence total seven fungal strains were used in this study. Figures 1 and 2 shows the isolated and purified fungal strains. The characteristics of these strains are given in the Tables 2 and 3 [1-4].

### Microscopic study of fungal strains 1, F1 and AF3

The fungal strains were inoculated on the PDA plates. They were allowed to mature and form spores. Then temporary slides were made and observed under microscope and photographs were taken for the purpose of identification. The morphological characteristics of the three fungal strains are in the Table 3, Figures 3-5.

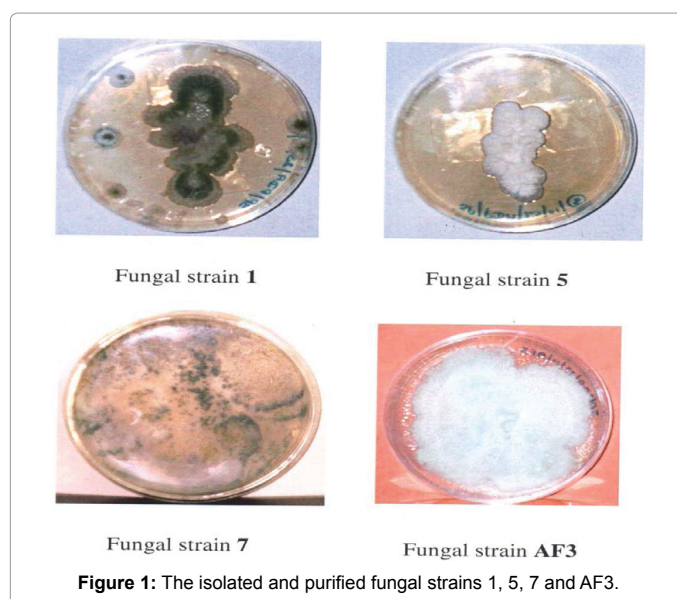


**Figure 1:** The isolated and purified fungal strains 1, 5, 7 and AF3.

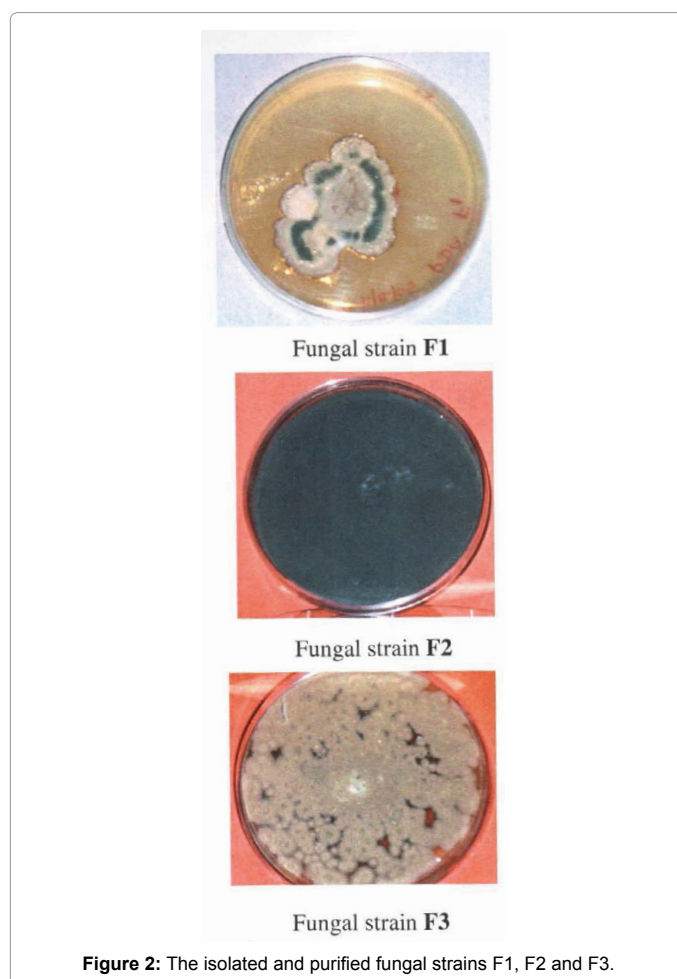


**Figure 2:** The isolated and purified fungal strains F1, F2 and F3.

The three fungi on the basis of their morphology have been identified as

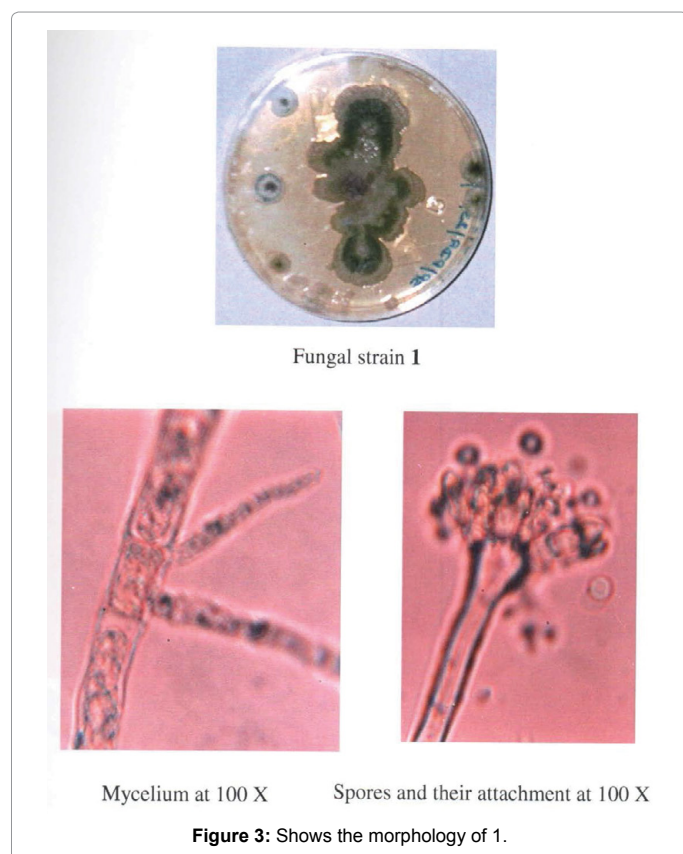
1: *Aspergillus* sp.

| Fungal Isolates | Source              | Growth | Characteristics                                                          |
|-----------------|---------------------|--------|--------------------------------------------------------------------------|
| 1               | Anand Paper Mill    | Slow   | White mycelia, light green spores                                        |
| 5               | Anand Paper Mill    | Slow   | White mycelium with dark colour spores, mycelia becomes dark from behind |
| 7               | Anand Paper Mill    | Fast   | White cottony mycelia with green spores                                  |
| AF3             | Previously isolated | Medium | White snowy cottony mycelia with yellowish pigmentation                  |
| F1              | Century Paper Mill  | Slow   | Dirty white mycelia with green spores                                    |
| F2              | Century Paper Mill  | Fast   | White mycelia with excess spores production of green color               |
| F3              | Century Paper Mill  | Fast   | White mycelia with light brown spores produced in excess                 |

**Table 2:** Source and characteristics of isolated fungal strains.

| Fungal isolate | Morphological characteristics                                                                                                                                                                                                             |
|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1              | White mycelium, light green spores, mycelium septate, branched mycelium, branching at right angles, spores spherical and single-cell attached on sporangiophore, sporangiophore bulbous bearing bottle shaped phialides spores in chain.  |
| F1             | White mycelium, green spores, mycelium septate, branched mycelium, branching at right angles, spores spherical and single cell, attached on sporangiophore, sporangiophore bulbous bearing bottled-shaped phialides, and spores in chain. |
| AF3            | White cottony mycelium, dirty yellow spores, septate, mycelium branched, uninucleate spore, spore globules, spores attached at the tip of mycelium.                                                                                       |

**Table 3:** Morphological characteristics of 1, F1 and AF3.

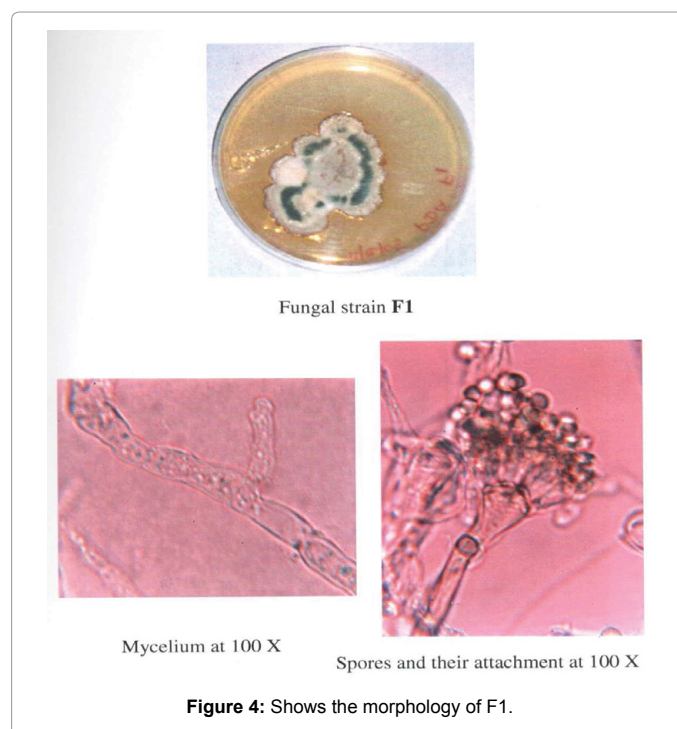


F1: *Aspergillus* sp.

AF3: *Basidioclamyces* sp.

### Enrichment of fungal isolated in potato dextrose broth

The fungal isolate were enriched for the preparation on fungal beads to be used as inoculums in the subsequent screening experiment. The purified fungal isolates in the form of disc of 1 cm<sup>2</sup> diameter cut from the active growth zone of the PDA plate was enriched in the PDB containing 100 ppm streptopenicilin and pH was adjusted to 5.2 ± 1. It was observed that beads like structure were formed after 3 days of incubation in shake flask condition at 30°C. The fungal beads

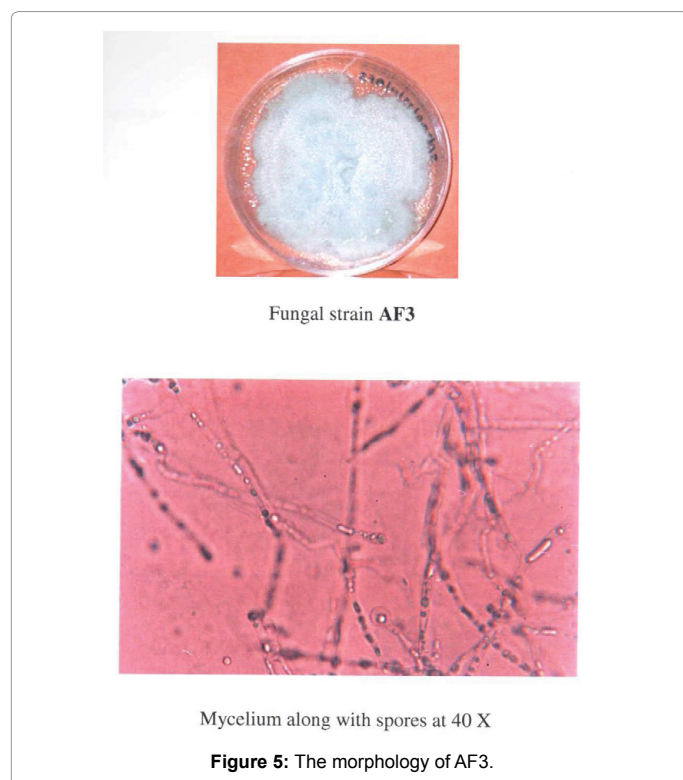


were used as inoculums at the rate of 10 percent (w/v) in experiments conducted.

### Screening experiment for decolourisation of pulp and paper mill effluent

The seven fungal isolates were purified and enriched in the PDB and were used to test their efficiency in the decolourisation of pulp and paper mill effluent. Pulp and Paper mill effluent is highly colored. The color is mainly due to lignin present in it. Hence, color and lignin content were used as parameters to evaluate the efficiency of different fungal isolates in decolorizing pulp and paper mill effluent.

Minimum salt medium of pulp and paper mill effluent was prepared. All seven fungal strains were screened for their capacity to decolorize effluent. Inoculums size was 10 percent (w/v). The experiment was set for 10 days. Regular sampling was done on zero hour, first day, second



day, third day, fifth day, seventh day and tenth day. The results are given in the Table 3.

### Confirmatory experiment and enzymatic study

It was found that fungal strain 1 and F1 were most efficient in decolourisation of pulp and paper mill effluent. AF3 was kept as a reference. The experiment was repeated with three fungal strains 1, F1 and AF3. Further, enzyme assay was done to check the presence of enzymes lignin *peroxidase* and manganese *peroxidase*. The results are given in Table 3. From Table 4, it is clear that 1 and F1 are quite efficient in decolourising pulp and paper mill effluent as compared to AF3. Among 1 and F1, F1 more efficient than 1. Lignin *peroxidase* was found in 1 and F1 but absent in AF3 and manganese *peroxidase* was absent in all three strains [8-13] (Table 5).

Where, changes in pH, Color (C.U.), Lignin (ppm), Lignin *peroxidase* and Manganese *peroxidase* by 1, F1 and AF3 fungal strains at different time intervals in Pulp and Paper mill effluent; ND: Not Detectable.

### Discussion

Fungal strains have been shown to be efficient in the decolourisation of pulp and paper mill effluent. Some of the popular fungi used are *Phanerachaete chrysosporium*, *Trametes versicolor*, *Aspegillus sp.*, *Cariolus cercicolor* etc.

All the fungal isolates were capable of decolourizing the pulp and paper mill effluent. However, the efficiency of decolourisation varied from fungi to fungi. Among all, F1 strain was most efficient in decolourisation and least effective was strain 7. Figure 4 shows the percentage decrease in the color content of the pulp and paper mill effluent by different fungal isolates. The relative efficiency of decolourization all the fungal strains is F1>1>F3>F2>AF3>5>7.

| Days   | Strains | pH   | Color (C.U.) | Lignin (ppm) |
|--------|---------|------|--------------|--------------|
| 0 Day  |         | 5.96 | 27806.63     | 75060.73     |
| 1 Day  | 1       | 6.17 | 15893.03     | 51983.81     |
| 1 Day  | 5       | 6.20 | 11611.58     | 54939.27     |
| 1 Day  | 7       | 6.29 | 14701.67     | 57489.88     |
| 1 Day  | F1      | 6.28 | 6271.17      | 33157.89     |
| 1 Day  | F2      | 6.32 | 10941.44     | 49190.28     |
| 1 Day  | F3      | 6.45 | 11537.12     | 44736.84     |
| 1 Day  | AF3     | 6.18 | 12505.10     | 53765.18     |
| 2 Day  | 1       | 6.80 | 4223.52      | 33562.75     |
| 2 Day  | 5       | 6.81 | 12393.41     | 49190.28     |
| 2 Day  | 7       | 6.81 | 13286.93     | 57975.71     |
| 2 Day  | F1      | 6.83 | 2659.86      | 28076.92     |
| 2 Day  | F2      | 6.20 | 9787.31      | 42550.61     |
| 2 Day  | F3      | 6.93 | 9452.24      | 44412.96     |
| 2 Day  | AF3     | 6.72 | 11983.88     | 52672.06     |
| 3 Day  | 1       | 6.90 | 3869.83      | 31133.60     |
| 3 Day  | 5       | 6.90 | 12132.80     | 44210.53     |
| 3 Day  | 7       | 6.90 | 12802.94     | 53036.44     |
| 3 Day  | F1      | 6.89 | 2492.32      | 25668.02     |
| 3 Day  | F2      | 6.09 | 10606.37     | 44858.30     |
| 3 Day  | F3      | 6.92 | 8298.11      | 41012.15     |
| 3 Day  | AF3     | 6.80 | 10941.44     | 47004.05     |
| 5 Day  | 1       | 6.94 | 4202.81      | 35991.90     |
| 5 Day  | 5       | 6.90 | 12616.79     | 46032.39     |
| 5 Day  | 7       | 6.90 | 11537.12     | 50080.97     |
| 5 Day  | F1      | 6.92 | 3309.29      | 25991.90     |
| 5 Day  | F2      | 6.14 | 9415.01      | 35587.04     |
| 5 Day  | F3      | 6.93 | 9340.55      | 40323.89     |
| 5 Day  | AF3     | 6.86 | 11946.65     | 43562.75     |
| 7 Day  | 1       | 7.03 | 9005.48      | 37287.45     |
| 7 Day  | 5       | 6.97 | 11648.81     | 45101.21     |
| 7 Day  | 7       | 6.94 | 9638.39      | 48623.48     |
| 7 Day  | F1      | 6.95 | 5133.56      | 31376.52     |
| 7 Day  | F2      | 6.20 | 10680.83     | 42145.75     |
| 7 Day  | F3      | 6.98 | 8558.72      | 37570.85     |
| 7 Day  | AF3     | 6.90 | 12207.26     | 45101.21     |
| 10 Day | 1       | 6.94 | 21589.22     | 55344.13     |
| 10 Day | 5       | 6.90 | 15334        | 50364.37     |
| 10 Day | 7       | 6.94 | 8968.25      | 46761.13     |
| 10 Day | F1      | 6.78 | 9750.08      | 37732.79     |
| 10 Day | F2      | 6.15 | 16451.48     | 45546.56     |
| 10 Day | F3      | 6.93 | 8744.87      | 41781.38     |
| 10 Day | AF3     | 6.90 | 20286.17     | 56599.19     |

**Table 4:** Changes in pH, Color (C.U.) and Lignin content (ppm) by different fungal strains at different time intervals in Pulp and Paper mill effluent.

The efficiency to remove lignin from the effluent was also observed in all the strains. Among all the strains F1 was most efficient in removing lignin and 7 were least effective. Figure 4 shows the percentage decrease in the lignin content of the pulp and paper mill effluent by different fungal isolates. The trend for lignin removal among different strains is F1>1>F3>F2>AF3>5>7.

The trend for lignin removal is similar to decolonization probably because the most important color causing compound in the pulp and paper mill effluent is lignin. Hence the removal of lignin is translated into color reduction of the effluent. The decolorizing capacity of different fungi is maximum in the beginning of the experiment, increase till 2<sup>nd</sup>

| Days    | Strains | pH   | Color (C.U.) | Lignin (ppm) | Lip   | MnP   |
|---------|---------|------|--------------|--------------|-------|-------|
| 0 hour  |         | 6.93 | 24493.16     | 65587.04     | ND    | ND    |
| 6 hours | 1       | 7.10 | 10308.53     | 45789.47     | ND    | ND    |
| 6 hours | F1      | 7.10 | 8521.48      | 42550.61     | 0.012 | ND    |
| 6 hours | AF3     | 7.09 | 11015.90     | 46518.22     | ND    | ND    |
| 1 Day   | 1       | 7.22 | 5096.33      | 36720.65     | 0.043 | ND    |
| 1 Day   | F1      | 7.26 | 4575.11      | 37004.05     | 0.075 | ND    |
| 1 Day   | AF3     | 7.25 | 7590.74      | 41578.95     | ND    | ND    |
| 2 Day   | 1       | 7.80 | 4537.88      | 28218.62     | 0.054 | ND    |
| 2 Day   | F1      | 7.84 | 3756.05      | 32348.18     | 0.091 | ND    |
| 2 Day   | AF3     | 7.90 | 6213.23      | 39797.57     | ND    | ND    |
| 3 Day   | 1       | 8.26 | 4351.73      | 30161.94     | ----- | ----- |
| 3 Day   | F1      | 8.39 | 3793.28      | 27854.25     | ----- | ----- |
| 3 Day   | AF3     | 8.25 | 4575.11      | 32105.26     | ----- | ----- |
| 5 Day   | 1       | 8.32 | 5692.01      | 33117.41     | 0.018 | ND    |
| 5 Day   | F1      | 8.46 | 4575.11      | 28380.57     | 0.01  | ND    |
| 5 Day   | AF3     | 8.48 | 8186.42      | 38016.19     | ND    | ND    |
| 7 Day   | 1       | 8.67 | 6920.60      | 35222.67     | ----- | ----- |
| 7 Day   | F1      | 8.76 | 7292.90      | 33360.32     | ----- | ----- |
| 7 Day   | AF3     | 8.56 | 14180.45     | 49190.28     | ----- | ----- |
| 10 Day  | 1       | 8.68 | 7516.28      | 35870.45     | 0.012 | ND    |
| 10 Day  | F1      | 8.76 | 6585.53      | 31700.40     | 0.007 | ND    |
| 10 Day  | AF3     | 8.63 | 10718.06     | 42348.18     | ND    | ND    |
| 15 Day  | 1       | 8.70 | 13361.39     | 48056.68     | ND    | ND    |
| 15 Day  | F1      | 8.87 | 10122.38     | 39635.63     | ND    | ND    |
| 15 Day  | AF3     | 8.74 | 12914.63     | 47246.9      | ND    | ND    |

**Table 5:** Changes at different time intervals in Pulp and Paper mill effluent.

day and then becomes almost constant till 5<sup>th</sup> day. After 5<sup>th</sup> day there is decrease in the efficiency. This may be due to the death and decay of the fungal mycelium. From these screening experiments two most efficient fungal strains F1 and 1 were selected for further experiments and AF3 was also used [8-13].

The experiment was repeated with F1, 1 and AF3. Results for the decolourisation and lignin reduction were same as above (Figure 4). F1 was most effective followed by 1 and finally AF3.

Enzyme assay was done for lignin *peroxidase* and manganese *peroxidase*. F1 and 1 produced lignin *peroxidase*. AF3 did not produce any of the enzymes. Manganese *peroxidase* was absent in all three. Maximum enzyme activity was observed on 2<sup>nd</sup> day of the experiment then it declined sharply till 5<sup>th</sup> day and finally become almost negligible (Figure 4). This shows that the lignin *peroxidase* plays an important role in the decolourization of effluent as the maximum reduction was found on 2<sup>nd</sup> day of experiment. In AF3, physical adsorption / absorption seems to play the major role. Physical adsorption/absorption also takes place with F1 and 1 as the fungal mycelium became colored at the end of the experiment [8-13] (Figures 6-10).

## Conclusions

The use of biological agent for the treatment of effluent is more environmental friendly and can lead to the production of more value added products like biogas, compost etc. Fungus has been shown to be efficient in the decolonization of the pulp and paper mill effluent. Among all the fungal isolates tested F1 is most efficient in decolorizing the pulp and paper mill effluent followed by 1. Both the strains performed better than AF3, a strain previously isolated. The maximum decolourization was on the 2<sup>nd</sup> day though the process of decolourization started within the 6 hours. Lignin *peroxidase* also seems to play an important role in

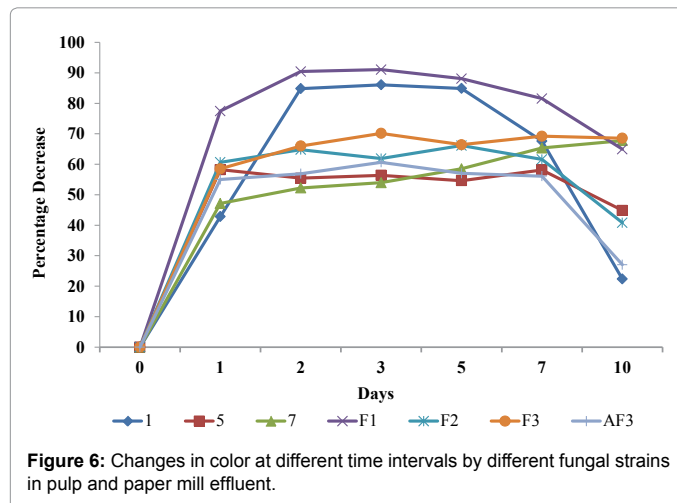


**Figure 6:** Changes in color at different time intervals by different fungal strains in pulp and paper mill effluent.

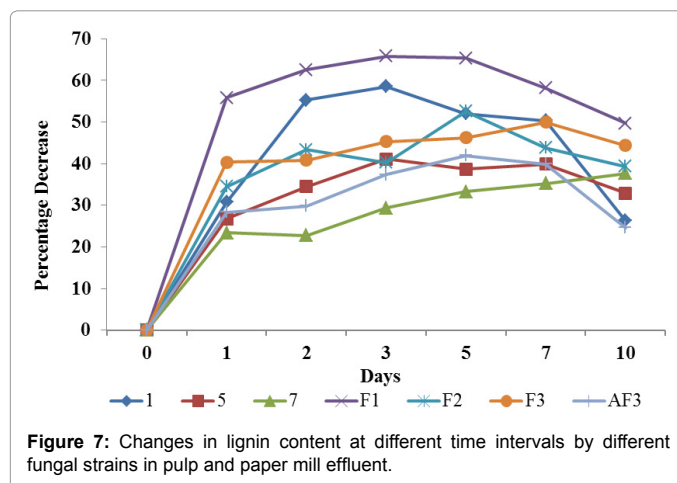


**Figure 7:** Changes in lignin content at different time intervals by different fungal strains in pulp and paper mill effluent.

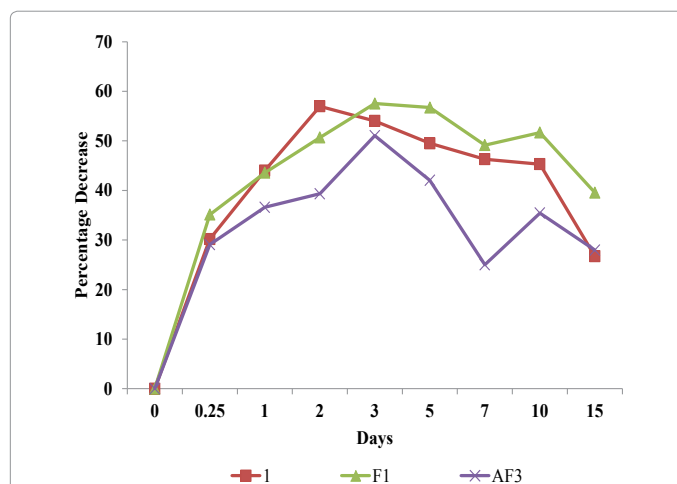


**Figure 8:** Changes in color at different time intervals by 1, F1 and AF3 fungal strains in pulp and paper mill effluent.

the decolourization of the pulp and paper mill effluent as it is produced by both F1 and 1. Manganese *peroxidase* was absent in the case of all three fungi that is 1, F1 and AF3. The quick response shown by two fungi 1 and F1 in the treatment of the effluent will reduce the retention time for the treatment which on applied on the industrial scale makes

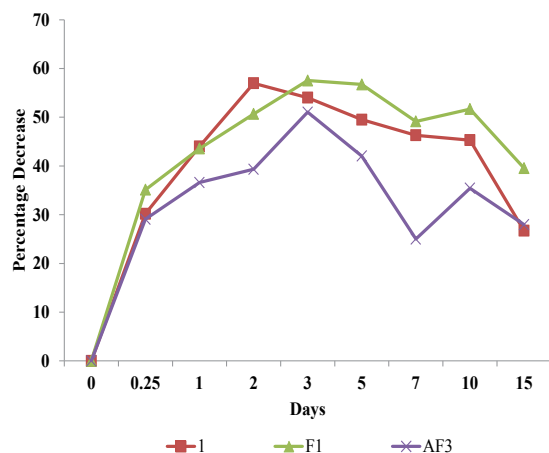


**Figure 9:** Changes in lignin content at different time intervals by 1, F1 and AF3 fungal strains in pulp and paper mill effluent.

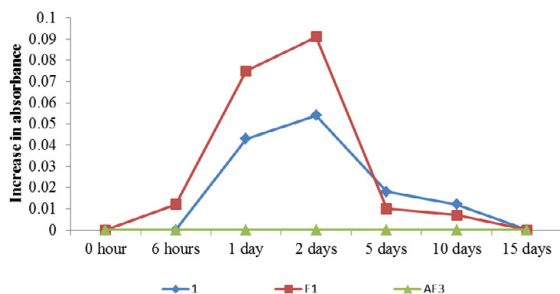


**Figure 10:** Increase in absorbance during the enzyme assay of lignin peroxidase present in pulp and paper mill effluent treated by 1, F1 and AF3 at different time intervals.

the process more feasible and economical. Thus the strains F1 and 1 has the potential for industrial application for decolourisation of pulp and paper mill effluent.

## Acknowledgements

Rajesh Kumar is highly thankful to the Vice-Chancellor of Jawaharlal Nehru University, New Delhi for his kind permission to publish this research articles. We also acknowledged the help of Mr. Nagendra Prasad for assistance.

## References

1. Bajpai P, Bajpai PK (1997) Reduction of organo-chlorine compounds in bleach plant effluents. Biotechnology in the Pulp and Paper Industry 57: 213-259.

2. Beulker S, Jekel (1993) Precipitation and coagulation of organic substances in bleaching effluents of pulp mills. Water Sci & Technol 27: 193-199.
3. Boominathan K, Reddy CA (1992) Fungal degradation of lignin: Biotechnological. In: Handbook of Applied Mycology. Arora DK, Elander RP, Mukharji KG, (eds) Vol 4 Fungal Biotechnology. Marcel Dekker, Inc., New York. pp: 763-822.
4. Deshpande VP, Godkari BP, Kaul SN (1999) Industrial waste water management. Journal of Indian Assoc for Environment Management 27: 28-30.
5. Gokhale S, Kapadnis BP, Patil SF (1992) Impact of paper and pulp industry effluents on environment. NIE J 10: 6-11.
6. Hossain KSK, Das M, Ibrahim SH (2001) Aerobic studies on pollution abatement of sulphite pulp bleaching effluent using Phanerochaete chrysosporium (MTCC-787). Journal of industrial Pollution Control 17: 191-200.
7. Joyce TW, Dubey GA, Webb AA (1979) The effect of biological treatment on the lime precipitation color removal process. TAPPI J 62: 107-109.
8. Kannan K, Oblisami G (1990) Decolorization of pulp and paper mill effluent by growth of Aspergillus niger. World J Microbiol Biotechnol 6: 114-116.
9. Rintala J, Martin JLS, Lettinga G (1991) Thermophilic anaerobic treatment of sulphate rich pulp and paper integrate process water. Water Sci Technol 24: 149-160.
10. Singh RS, Marwaha SS, Khanna PK (1996) Characterisation of pulp and paper mill effluents. J Ind Poll Cont 12: 163-172.
11. Subrahmanyam PVR (1975) Colour removal from kraft pulp and paper industry. J Indian Assoc Environ Manage 17: 79-94.
12. Tuhkanen T, Naukkarinen M, Blackburn S, Tanskanen H (1997) Ozonation of pulp mill effluent prior to activated sludge treatment. Environ Technol 18: 1045-1051.
13. Sundari S, Kanakarni MSP (2001) The effect of pulp unit effluent on Agriculture. J of Industrial poll Control 17: 83-97.



## Paper material containing Ag cations immobilised in faujasite: synthesis, characterisation and antibacterial effects

Roman J. Jedrzejczyk (1), Katarzyna Turnau (2), Damian K. Chlebda (3), Dominika Pawcenis (3), Przemysław J. Jodłowski (4), Piotr Przybysz (5), Tomasz Łojewski (6), Maciej Sitarz (6), Joanna Łojewska (3)

1) Malopolska Centre of Biotechnology, Jagiellonian, University, ul. Gronostajowa 7A, 30-387 Kraków, Poland

2) Institute of Environmental Sciences, Jagiellonian, University, ul. Gronostajowa 7, 30-387 Kraków, Poland

3) Faculty of Chemistry, Jagiellonian University, ul. Gronostajowa 2, 30-387 Kraków, Poland

4) Faculty of Chemical Engineering and Technology, Cracow University of Technology, ul. Warszawska 24, 30-155 Kraków, Poland

5) Natural Fibers Advanced Technologies, ul. Błękitna 42A, 93-322 Łódź, Poland

6) Faculty of Materials Science and Ceramics, AGH, University of Science and Technology, Al. Mickiewicza, 30, 30-059 Kraków, Poland

The study is devoted to manufacturing and characterising a new paper material with antimicrobial properties, as an alternative to paper containing silver nanoparticles (NPs) which are claimed to be harmful to the ecosphere. In place of silver NPs, the new material contains faujasite mineral (from the faujasite group) exchanged with silver cations which are firmly attached to the material's lattice. The material was obtained by typical ion exchange and additional elution with EDTA salt to dispose of the remaining silver oxide NPs. Thus, modified faujasite was then added to paper pulp. The new, modified paper showed better quality in terms of acidity, tensile strength and cellulose degree of polymerisation compared to paper containing Ag NPs. The visual quality of the paper is also better than that containing Ag NPs. The new material shows high potential for use in food and pharmaceuticals packaging.

Cellulose (2018) 25:1353–1364. (Open Access)

<https://doi.org/10.1007/s10570-017-1635-9>

The Paper Industry Technical Association (PITA) is an independent organisation which operates for the general benefit of its members – both individual and corporate – dedicated to promoting and improving the technical and scientific knowledge of those working in the UK pulp and paper industry. Formed in 1960, it serves the Industry, both manufacturers and suppliers, by providing a forum for members to meet and network; it organises visits, conferences and training seminars that cover all aspects of papermaking science. It also publishes the prestigious journal *Paper Technology* and the *PITA Annual Review*, both sent free to members, and a range of other technical publications which include conference proceedings and the acclaimed *Essential Guide to Aqueous Coating*.

# Paper material containing Ag cations immobilised in faujasite: synthesis, characterisation and antibacterial effects

Roman J. Jędrzejczyk  · Katarzyna Turnau  · Damian K. Chlebda  ·  
Dominika Pawcenis  · Przemysław J. Jodłowski  · Piotr Przybysz ·  
Tomasz Łojewski · Maciej Sitarz · Joanna Łojewska

Received: 8 July 2017 / Accepted: 18 December 2017 / Published online: 28 December 2017  
© The Author(s) 2017. This article is an open access publication

**Abstract** The study is devoted to manufacturing and characterising a new paper material with antimicrobial properties, as an alternative to paper containing silver nanoparticles (NPs) which are claimed to be harmful to the ecosphere. In place of silver NPs, the new material contains faujasite mineral (from the faujasite group) exchanged with silver cations which are firmly attached to the material's lattice. The material was obtained by typical ion exchange and additional elution with EDTA salt to dispose of the remaining

silver oxide NPs. Thus, modified faujasite was then added to paper pulp. The new, modified paper showed better quality in terms of acidity, tensile strength and cellulose degree of polymerisation compared to paper containing Ag NPs. The visual quality of the paper is also better than that containing Ag NPs. The new material shows high potential for use in food and pharmaceuticals packaging.

R. J. Jędrzejczyk (✉)  
Malopolska Centre of Biotechnology, Jagiellonian  
University, ul. Gronostajowa 7A, 30-387 Kraków, Poland  
e-mail: roman.jedrzejczyk@uj.edu.pl

K. Turnau  
Institute of Environmental Sciences, Jagiellonian  
University, ul. Gronostajowa 7, 30-387 Kraków, Poland  
e-mail: katarzyna.turnau@uj.edu.pl

D. K. Chlebda · D. Pawcenis · J. Łojewska  
Faculty of Chemistry, Jagiellonian University, ul.  
Gronostajowa 2, 30-387 Kraków, Poland  
e-mail: damian.chlebda@uj.edu.pl

D. Pawcenis  
e-mail: pawcenis@chemia.uj.edu.pl

J. Łojewska  
e-mail: lojewska@chemia.uj.edu.pl

P. J. Jodłowski  
Faculty of Chemical Engineering and Technology,  
Cracow University of Technology, ul. Warszawska 24,  
30-155 Kraków, Poland  
e-mail: jodlowski@chemia.pk.edu.pl

P. Przybysz  
Natural Fibers Advanced Technologies, ul. Błękitna 42A,  
93-322 Lodz, Poland  
e-mail: piotrprzybysz@interia.pl

T. Łojewski · M. Sitarz  
Faculty of Materials Science and Ceramics, AGH  
University of Science and Technology, Al. Mickiewicza  
30, 30-059 Kraków, Poland  
e-mail: lojewski@agh.edu.pl

M. Sitarz  
e-mail: msitarz@agh.edu.pl

**Keywords** Cellulose · Antimicrobial · Physicochemical properties · Silver

## Introduction

Zeolites and zeolite-based materials are biocompatible minerals that are commonly used in a variety of antibacterial and antifungal applications, such as medicine (Matsuura et al. 1997; Danilczuk et al. 2008), food packaging (Zagory 1995; Suslow and Crops 1997; Appendini and Hotchkiss 2002) and the clothing industry (Takai et al. 2002; Grancaric et al. 2012). According to the literature, there is still a need for intensive research into new materials that could offer additional features in comparison to those currently available (Zampino et al. 2011; Fang et al. 2014; Vukoje et al. 2014), and which may be used as active packaging for the safe storage of a great many types of goods. The antimicrobial properties of modified natural polymers are of great interest (Kukhareenko et al. 2014; Littunen et al. 2016), but the mobility and potential migration of silver in such materials can be problematic. The antimicrobial properties of different porous materials are also still being tested (Wang et al. 2006; Yang et al. 2009; Azócar et al. 2012; Nassar and Youssef 2012; Youssef et al. 2013), and zeolites seem to be the best alternative because of their mechanical resistivity, sorptive and catalytic properties which can eliminate or decrease the problem of environmental risks.

Packaging is defined as “active” if it can provide mechanical, chemical and antimicrobial protection for the items stored inside (Gutiérrez et al. 2009). Thus, active packaging should not only protect the stored objects, but also extend their shelf-life. Such functionalities can be secured by using packaging capable of the absorption of odours arising from the degradation of organic items, especially of compounds containing sulphur or other volatile organic compounds (Vermeiren et al. 1999).

Another valuable property of packaging materials is their antimicrobial activity against bacteria, fungi and viruses (Vermeiren et al. 1999). Silver has, since ancient times, been known as a biocide, a property that is today exploited by the addition of silver nanoparticles (NPs) to many everyday goods. The antimicrobial activity of silver has been confirmed on a wide

range of organisms, including bacteria, viruses and fungi (Russel and Hugo 1994; Damm et al. 2005). Simultaneously, concerns about the environmental impact of silver ions and particles have been growing in recent years, as expressed in literature (Böswald et al. 1999; Venous 1999; Kim et al. 2009; Marambio-Jones and Hoek 2010; Echegoyen and Nerín 2013; Cushen et al. 2014). The content of silver in everyday goods, and thus also in packaging, is not currently regulated either in the European Union or in the United States of America (Seaton et al. 2010; Langauer-Lewowicka and Pawlas 2015; Mackevica et al. 2016). Since the influence of silver particles on the environment and ecosystem is still a subject of intense scientific debate (Moore 2006; Bystrzejewska-Piotrowska et al. 2009; Giri 2014), and as it has already been established that they also have a detrimental effect on the cells of animals including human and eukaryotic organisms (AshaRani et al. 2009; Panyala et al. 2008), it seems important to look for alternative materials that exhibit equally good antimicrobial properties but are safe to human beings.

A solution to achieve this goal could be to trap silver ions or NPs in some kind of a solid matrix, which is one of the most important requirements of active packaging material because the contact of microbes and active agents should be selective and fully controlled, as described by Restuccia et al. (2010). Impregnation of silver cations onto the surface of the solid support could be a way to prevent silver migration. Another idea would be to use a solid of high surface area to enable contact with microbes. For this purpose, zeolite minerals seem a prospective media for silver anchoring, then used as an additive to other material such as paper (Baldevraj and Jagadish 2011).

The use of zeolite as a filler in polymeric materials has been reported in literature (Bastani et al. 2013). Some authors suggest that zeolites can enhance the antibacterial activity of thus prepared composite materials (Matsumura et al. 2003; Odabaş et al. 2011). The addition of zeolites to paper has a positive influence on its properties, such as change in acidity, permeability and resistance to hazardous compounds such as sulphur dioxide, nitrogen oxides and VOCs (Bishop et al. 2008; O’Connell et al. 2008).

The goal of this research is to develop innovative, environmentally friendly packaging material based on paper with high biocidal activity, mechanical resistance and stable chemical compositions, and with the

minimum silver content introduced into the zeolite structure. The material should also prevent the silver from migrating into the ecosphere.

## Experimental

### Zeolite preparation

Y-type zeolite (Faujasite, FAU) in powder form was purchased from Zeolyst International (CBV-100). After conditioning at 23.5 °C and RH = 50% for 12 h, the zeolite in sodium form was used further for ion exchange from silver nitrate solutions. Silver nitrate was obtained from Avantor Performance Materials. Disodium ethylenediaminetetraacetate dihydrate ( $\text{Na}_2\text{EDTA} \cdot 2\text{H}_2\text{O}$ ) from Sigma-Aldrich was used for another treatment to remove the external silver oxide NPs (those which were not exchanged with sodium cations).

Faujasite exchanged with silver (AgFAU) was used as an additive to paper pulp. AgFAU samples were prepared by suspending 1.00 g of zeolite in 100 cm<sup>3</sup> of 0.1 M  $\text{AgNO}_3$  solution in deionised water. Due to the light sensitivity of silver, suspensions were stirred in the darkness (300 rpm, 1 h). After ion exchange, AgFAU samples were filtered and washed with deionised water. After preparation, the obtained samples were dried in an oven at 60 °C for 8 h.

In order to remove the unexchanged (non-bonded) silver from the external surfaces of the zeolite, the prepared samples were washed with 10 cm<sup>3</sup> of 0.01 M  $\text{Na}_2\text{EDTA}$  solution and 10 cm<sup>3</sup> of deionised water (the procedure was repeated five times in total) for reference. The washing procedure was repeated until the concentration of silver cations in the eluent reached a minimum constant value. After each step, the zeolite suspension was centrifuged (4000 rpm).

The ion exchange capacity and EDTA washing efficiency were monitored by energy dispersive x-ray fluorescence spectroscopy (ED-XRF, ARL QUANT'X; Thermo Scientific, USA). Based on calibration, the Ag content in the zeolites was determined.

The silver that remained on the zeolite surface was analysed by x-ray photoelectron spectroscopy (XPS) using the ESCA Prevac spectrometer equipped with a hemispheric analyser of charged XPS and AES particles (VG Scienta R3000). The x-ray tube was

equipped with two anticathodes Mg/Al (power Mg/Al = 400/600 W), and the x-ray monochromator with the radiation source (single anticathode–Al). XPS spectra were calibrated to the carbon component C1 s binding (with energy of 285.0 eV). High resolution spectra were fitted using CasaXPS software.

Two types of analysis were performed, according to the AgNP characterisation. At first we monitored the de novo formation of Ag NPs by UV–Vis spectroscopy. We observed the characteristic band assigned for AgNPs, hence we were sure of the NPs' presence in suspension. This observation was confirmed by DLS experiments.

### Modified paper preparation

In order to obtain paper sheets containing AgFAU, cellulose from Whatman filter paper was used. Prior to preparation, the Whatman paper sheets were conditioned according to the ASTM D685 norm, and under these conditions they were cut into 4 × 4 cm pieces following disintegration in 400 cm<sup>3</sup> of deionised water using a dispersing instrument (IKA T18 Ultra-Turrax with stainless steel dispersing elements). Cellulose suspension (paper pulp) content is shown in Table 1.

Elemental analysis of the obtained paper was performed with an XRF spectrometer (Thermo Scientific ED-XRF, thick Cu filter,  $K\alpha = 22.36$  eV). Prior to XRF analysis, the obtained samples were digested in boiling 65% nitric acid for 15 min.

The paper sheets containing AgFAU, along with the reference materials (Ag NPs,  $\text{Ag}^+$ ), were formed on a custom-built papermaking vacuum table. Wet paper sheets (about 15 × 20 cm) were dried on the glass surface at ambient temperature. From these paper sheets, small circle samples were cut by hole punching, and then used for microbial tests.

Apart from the final samples of paper containing AgFAU washed with EDTA ( $\text{PZAg}^+_{\text{EDTA}}$ ), four kinds of reference samples were prepared:

- P—cellulose without additives
- $\text{PAg}^+$ —paper with  $\text{Ag}^+$  cations prepared from cellulose suspensions in 0.1 M  $\text{AgNO}_3$
- $\text{PAg}^0$ —paper with Ag NPs prepared from  $\text{AgNO}_3$  suspensions as above, but then treated by sonication (10 min) of the  $\text{AgNO}_3$  solution (0.1 M) containing a low amount of ethanol (1.5 vol.%).

**Table 1** The content of prepared paper materials

| Sample                  | Active material                                           | Description                                                               | Silver content in paper, wt% |
|-------------------------|-----------------------------------------------------------|---------------------------------------------------------------------------|------------------------------|
| P                       | n/a                                                       | n/a                                                                       | n/a                          |
| PAg <sup>0</sup>        | Silver nanoparticles                                      | 0.51 g of silver nitrate sonicated for 10 min and suspended in paper pulp | 0.5 ± 0.02                   |
| PAg <sup>+</sup>        | Silver cations                                            | 0.51 g of silver nitrate suspended in paper pulp                          | 0.3 ± 0.02                   |
| PZ0                     | Y-type zeolite (Na form)                                  | 1.77 g of zeolite suspended in paper pulp                                 | n/a                          |
| PZAg <sup>+</sup>       | Exchanged Y-type zeolite                                  | 1.77 g of zeolite suspended in paper pulp                                 | 1.5 ± 0.02                   |
| PZAg <sup>+</sup> _EDTA | Exchanged Y-type zeolite washed with Na <sub>2</sub> EDTA | 1.77 g of zeolite suspended in paper pulp                                 | 1.1 ± 0.02                   |

Prior to sonication, the suspensions were purged with an inert gas (Ar) for 60 min, after which ultrasound at a frequency of 20 kHz was applied (the average power of the ultrasound was equal to 90 W)

- PZAg<sup>+</sup>—paper with AgFAU prepared as described above but with no additional washing with Na<sub>2</sub>EDTA

#### Testing paper properties

##### Ageing

Ageing was carried out in a climatic chamber (MEMMERT HCP246) at 90 °C and with a relative humidity of 59%, for 12 days. All samples were aged under the same conditions.

##### pH measurements

The pH measurements of the paper samples were carried out according to the TAPPI T 529 om-88 norm using a flat plate electrode (Flatrode Hamilton, 809 Titrande from Metrohm). Samples were cut out from the prepared paper sheets, and a drop of water was placed on their surfaces. The electrode was then applied to each sample, and the pH was measured until a stable value was reached.

##### Mechanical properties

The zero-span breaking strength was measured according to the TAPPI T236 norm (TAPPI 1996). Before measurements, samples were conditioned

according to the D685 ASTM standard, at 23 °C and 50% RH.

##### Texture

Surface topology was analysed by optical microscopy (Leica DM2000) equipped with a digital camera. Imaging was carried out using reflected and transmitted light modes, respectively. To obtain representative images, imaging was carried out at five different places of the material (test of material homogeneity).

##### SEM analysis

The surface topography of the prepared materials was examined by using scanning electron microscopy (SEM) equipped with a probe for chemical analysis of specimens in microareas with energy dispersive X-ray spectroscopy. A scanning electron microscope (Nova Nano SEM 300 FEI Company) was used for high-quality magnification of the paper morphology.

##### Colour

Measurements were carried out using the Colour-QuestXE (HunterLab) colorimeter. Measurement conditions were as follows: measuring surface Ø = 9.5 mm, observer 2°, illuminant D65, specular reflection excluded.

##### Lightfastness

A micro fading tester was used to assess the lightfastness of the prepared paper samples. The micro fading

tester, a relatively novel device which can be used to obtain quick and non-destructive measurements of material colour change caused by incident light, was described in (Lerwill et al. 2008; Łojewski et al. 2011). The instrument was equipped with a high power xenon light source and VIS spectrometer, which allow induced colour changes to be monitored. Three lightfastness measurements were taken for each type of paper.

### Degree of polymerisation

The weight-averaged degree of polymerisation ( $DP_w$ ) of cellulose (cellulose triphenylcarbamate, CTC) was determined by size exclusion chromatography (SEC). The details concerning the analytical procedures used can be found elsewhere (Pawcenis et al. 2015). In brief, analysis of molecular mass distributions was carried out in tetrahydrofuran (THF) solvent used as a mobile phase, with double detection: (1) by multiple angle laser light scattering (MALLS, Waters), and (2) refractive index (RI). Both detectors worked at a light wavelength of 658 nm. In the measurements, a value of the specific increment of the refractive index equal to  $0.162 \text{ cm}^3/\text{g}$  was used.

The paper samples containing  $\text{Ag}^0$ ,  $\text{Ag}^+$  and zeolite were first defibred in a beaker in  $50 \text{ cm}^3$  of water (the process was aided by ultrasound waves). The standard procedure of preparing cellulose material was applied (Lauriol et al. 1987; Stol et al. 2002), using cellulose derivative CTC in THF solution. The AgFAU was removed from the CTC solutions by filtration through a Teflon syringe filter with pore diameter of  $0.45 \text{ }\mu\text{m}$ . The other additives were removed before derivatisation by washing.

### Antimicrobial properties

*Escherichia coli* from the culture collection of the laboratory of the Plant-Microbial Interaction Group of the Jagiellonian University (Kraków, PL) were used in the laboratory tests. A detailed description of the sample preparation and analytical procedure can be found in our previous work (Łojewska et al. 2015). The efficiency of the biocidal process on the prepared paper samples was checked using the test LuciPac Pen equipped with a lumitester (Kikkoman lumitester PD-20) (ATP + AMP, Hygiene Monitoring test kit from Kikkoman Corp., code 60331), in accordance with the

manufacturer's instructions. The test gives relative content of ATP, ADP and AMP (RLU—relative luminescence units).

## Results and discussion

### Quantitative evaluation of material

The progress of ion exchange was monitored by XRF analysis, the results of which are shown in Fig. 1. It can be noted that the time necessary to achieve saturation in ion exchange was around 2 h. For the assumed half exchange, a time of 1 h was chosen. The degree of ion exchange was then measured by the XRF method, by digesting the samples in concentrated  $\text{HNO}_3$ .

In order to dispose of the external unattached silver moieties, complexation using EDTA sodium salt was employed. The progress of elution with the EDTA solution of a given concentration was monitored by XRF analysis of eluate solutions. To check the efficiency of EDTA washing, the AgFAU samples were also treated with the same quantities of water. After repeated treatment with the same portions of EDTA, the amount of silver in the eluent solution stabilises and reaches a low constant value, which is 0.15% of the initial value. This was assigned as the completion of the removal process. The state and amount of silver on the zeolite surface at different stages of elution were also analysed with XPS, which indicated the presence of silver NPs on the initial sample. Semi-quantitative results are shown in Table 2.

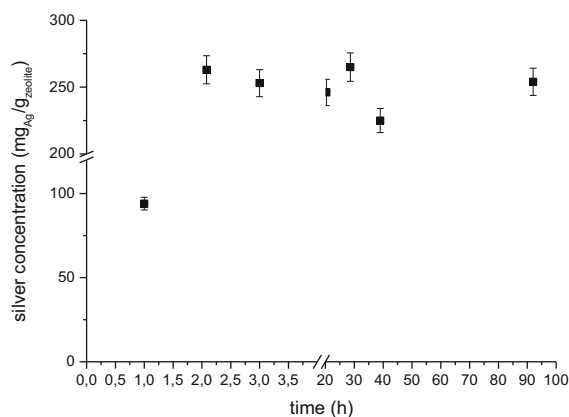


**Fig. 1** Silver ion exchange isotherm

**Table 2** XPS results of silver washing efficiency from AgFAU (PZAg<sup>+</sup>)

| EDTA concentration, mol/dm <sup>3</sup> | Portions of eluent, cm <sup>3</sup> |                      | XPS signal after spectra normalisation, a.u. |
|-----------------------------------------|-------------------------------------|----------------------|----------------------------------------------|
|                                         | 1st run                             | 2nd run              |                                              |
| –                                       | –                                   | –                    | 1.05 ± 0.05                                  |
| –                                       | 150 H <sub>2</sub> O                | 150 H <sub>2</sub> O | 1.19 ± 0.06                                  |
| 0.01                                    | 150 EDTA                            | 150 H <sub>2</sub> O | 1.25 ± 0.07                                  |
| 0.1                                     | 150 EDTA                            | 150 H <sub>2</sub> O | 0.29 ± 0.23                                  |
| 0.1                                     | 300 EDTA                            | 150 H <sub>2</sub> O | 0.31 ± 0.02                                  |

Corresponding with analysis of eluents, the amount of silver at the surface stabilises after treatment with the EDTA solution of higher concentration (> 0.01 M), and is around four times lower than for the initial sample. Neither the 0.01 M EDTA nor the water were able to remove external silver oxide particles from the zeolite samples. The remaining silver will be called stable silver attached to Al–O-groups in zeolite, impossible to remove by treatment with a chelating agent.

The content of silver present in the paper samples is shown in Table 1. For the final PZAg<sup>+</sup>\_EDTA, the amount of silver was measured as 1.5 wt%. It can be noted that, due to the washing procedure, the silver content in the PZAg<sup>+</sup>\_EDTA sample was 27% lower (1.5 wt% drops to 1.1 wt%) than in the PZAg<sup>+</sup> untreated sample. In the PAg<sup>+</sup> and the PAg<sup>0</sup> control samples, Ag content was from two to three times lower compared to the paper modified with the zeolite. The silver content in the paper was not controlled other than by the affinity of different additives (silver cations, silver NPs or AgFAU particles) to cellulose fibres, which varies from sample to sample.

As can be inferred from the optical images of the final paper sample PZAg<sup>+</sup>\_EDTA, the zeolite filler dispersed evenly within the paper pulp (Fig. 2a, b). The zeolite particles can be noted as black spots in the transmission image of the sample (Fig. 2a).

What is more, SEM analysis confirmed that zeolite is presented on the cellulose fibres. The back-scattered electron mode allowed silver-exchanged zeolite to be shown as brighter spots (Fig. 3). In the picture, there are also marked (as numbers) places where EDX analysis was performed. The average values of element content (Table 3) confirm the presence of elements typical for zeolite (Al, Si, O), as well as for silver which was introduced to zeolite.

### *The pH of paper*

The pH values (Fig. 4) of the paper samples containing silver in any form were lower than for the reference samples without silver; for P and PZ0, pH amounted to  $8.8 \pm 0.25$ ,  $9.4 \pm 0.08$ , respectively. The lowest value was observed for sample PAg<sup>+</sup> ( $4.7 \pm 0.11$ ). For samples which contained zeolites, both unmodified and modified, the pH values were higher,  $5.9 \pm 0.03$ ;  $7.00 \pm 0.04$ , respectively. Although, the addition of zeolite with trapped silver causes a decrease in the pH value, the decrease is much lower than for materials in which the active agent was presented in unbound form. It seems that the higher acidity of paper material designed for packaging is not an obstacle. In fact, in the long run the acidity of paper is responsible for the loss of the mechanical strength of paper or cellulose-based materials caused by hydrolysis of cellulose fibres (Chu 1981; Łojewski et al. 2010). Low pH of cellulose-based materials may result from, amongst other things, the manufacturing process, the presence of acids in the raw materials, or as products of cellulose degradation. In the presence of water molecules (atmospheric moisture, bound water) an acid hydrolysis reaction occurs. Therefore, hydrolytic cleavage of  $\beta(1-4)$  glycosidic bonds leads to shortening of cellulose chains. This process will be reflected in the consecutive decrease of average DP value, and possibly in loss of mechanical strength of cellulose fibres.

### *Mechanical properties and DP*

According to the results of zero-span breaking strength of the paper samples, of all tested materials the PZAg<sup>+</sup>\_EDTA was around 20% stronger than unmodified paper, and stronger than the rest of the samples

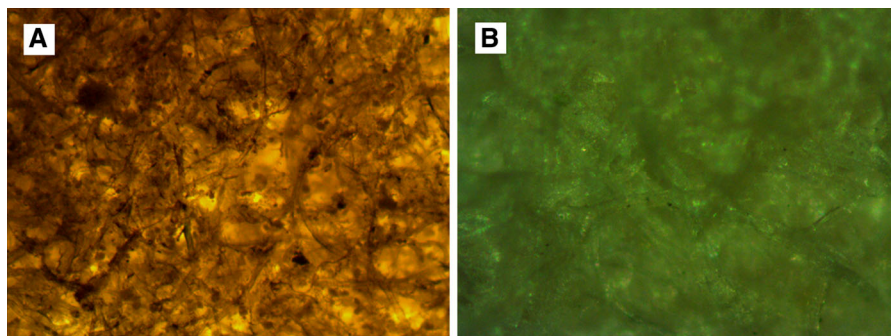


**Fig. 2** The microscopic images of the final paper sheets collected in: **a**—transmitted light, **b**—reflected light (for  $\text{PZAg}^+_{\text{EDTA}}$  sample)

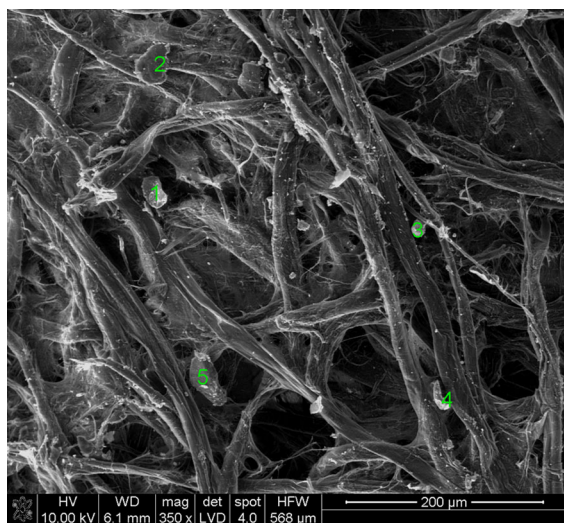


**Fig. 3** SEM image of the final paper material with silver-exchanged zeolite (1, 2, 3, 4, 5—places of EDX measurements)

**Table 3** The average values of EDX elemental analysis of paper doped with silver-exchanged zeolite

| Element | Wt%             |
|---------|-----------------|
| C       | $80 \pm 4$      |
| O       | $14.5 \pm 0.51$ |
| Al      | $0.50 \pm 0.04$ |
| Si      | $0.30 \pm 0.03$ |
| S       | $0.50 \pm 0.05$ |
| Cl      | $0.50 \pm 0.07$ |
| Ag      | $3.0 \pm 0.2$   |
| K       | $0.8 \pm 0.1$   |

(Fig. 5). The presence of silver or silver oxide crystallites in paper ( $\text{PAg}^+$ ,  $\text{PAg}^0$ ,  $\text{PZAg}^+$ ) weakens the strength of cellulose fibres in comparison with the pure paper sample P. This can be explained by the

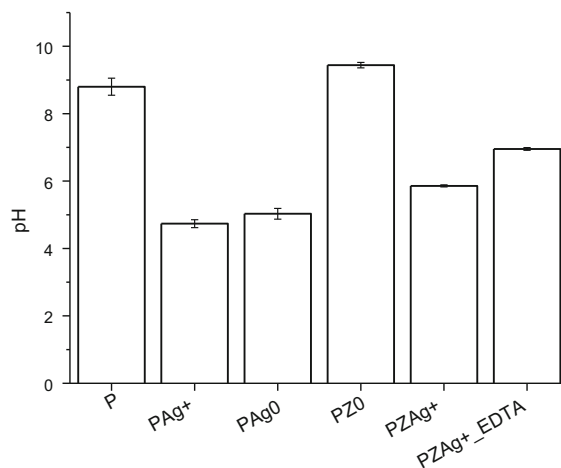


**Fig. 4** The pH values of the prepared paper sheets

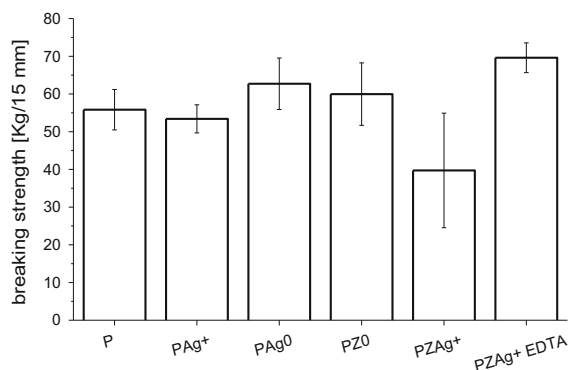


**Fig. 5** Mechanical endurance of paper expressed as zero-span tensile strength

modification of the hydrogen bonding network with silver cations, which interact directly with  $-\text{OH}$  groups in cellulose chains or are electrostatically attracted by them as high electronic density is located just on the

surface of the fibres due to the enrichment with  $-OH$  groups (He et al. 2003). Indeed, it has been documented that hydrogen bonding is responsible not only for the crystallinity of cellulose, but also for tensile strength (Chu 1981). Let us note that, even in the sample containing zero valent silver NPs ( $PZAg^0$ ), the presence of  $Ag^+$  cannot be excluded as the sonication process used for silver reduction proceeded with high but limited efficiency. In the paper sample  $PZAg^+$ , which was not eluted, the crystallites of silver oxide are still present. However, it has to be taken into account that the conclusions drawn from the results of the measurements of mechanical properties are not very firm, due to high experimental error.

The results of paper mechanical resistance are consistent with paper acidity (compare Figs. 4, 5). This means that paper acidity can be correlated with cellulose fibre strength and used as a gauge for predicting mechanical properties. In brief, paper sample  $PAg^0$ , containing silver NPs, demonstrated both much lower pH and breaking strength than the final material prepared by us containing silver-exchanged zeolite  $PZAg^+_EDTA$ . It can also be noted from the comparison of the  $PZAg^+$  and  $PZAg^+_EDTA$  samples that washing with EDTA improves both the acidity and mechanical properties of the modified paper material.

The degree of polymerisation ( $DP_w$ ) of the initial unaged and aged samples was assessed based on the SEC measurements of molecular mass distribution of cellulose. When comparing the unaged samples, all the initial values were similar and fell in the range 1200–1400  $DP_w$ , except the unaged sample containing zeolite  $PZAg^+$ , for which  $DP_w$  was about 1070. An important observation is also that the  $DP_w$  of the final sample ( $PZAg^+_EDTA$ ) is the highest among the studied samples – even up to around 100 units higher than for the reference paper sample (see Fig. 6). The same observation can be made for the initial  $PAg^0$  paper containing silver NPs. Upon thermal ageing, the decrease in  $DP_w$  values can be noted for all samples. The lowest degradation was measured for P samples, and there is almost no degradation at all for the pure zeolite-enriched paper sample PZ0. The highest drop in  $DP_w$  values was shown by the  $PAg^+$  and  $PAg^0$  samples with silver additives, indicating highly degraded cellulose chains of the 200  $DP_w$  value. There is a noteworthy difference between the  $PAg^0$  sample with silver NPs and the final sample of

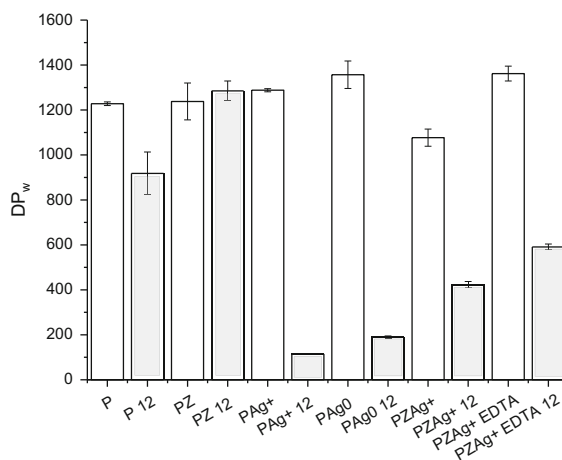


**Fig. 6** Degree of polymerisation ( $DP_w$ ) of cellulose in initial paper materials (white bars) and ageing for 12 days (indicated by grey bars)

$PZAg^+_EDTA$ , which confirms the conclusion about the positive influence of faujasite exchanged with silver on the condition of both cellulose chains and fibres in the paper material.

### Visual properties

The parameter  $L^*$  from the CIELab colour model was used as the measure of brightness— $L^*$  with a range from 0 (black) to 100 (white). The total colour change ( $\Delta E$ ) was calculated from the  $L^*$ ,  $a^*$ ,  $b^*$  values following the equation described in (Gulrajani 2010).

For the initial samples, regardless of the filler composition, no colour differences were noted among any sample containing silver, by either colour change indicator ( $L^*$  and  $\Delta E$ ) in comparison with the reference paper sample P. The results presenting the differences that occurred after 2 months of storage at

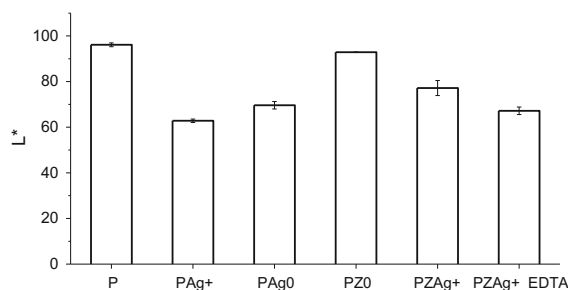


**Fig. 7** The brightness of the paper samples after 3 months of natural aging

23 °C and 50% RH are shown in Fig. 7. There, for all samples containing silver, an average drop of around 20% in the  $L^*$  values was observed in comparison with the reference paper sample P. An important observation is that there was almost no difference between paper samples with silver NPs ( $\text{PAg}^0$ ) and our final material ( $\text{PZAg}^+_{\text{-EDTA}}$ ).

Colour stability (lightfastness) over time was also measured by spot light ageing tests performed with a micro fading tester. The results are expressed by  $\Delta E$  values in Fig. 8. Again, the highest colour change values were noted for the samples containing silver, reaching 35 units for the  $\text{PAg}^+$  sample. The lightfastness of paper Ag NPs and the final sample  $\text{PZAg}^+_{\text{-EDTA}}$  is very much alike, with only three  $\Delta E$  units difference.

### Antimicrobial properties

The antimicrobial properties of the obtained final material and the reference samples are presented in Fig. 9. The tests were performed with respect to *E. coli* strains used typically as a representative to assess the biocidal properties of materials. The highest and comparable activity can be noted for both paper samples containing zeolites, as can be judged from the comparison of the ATP/ADP/AMP content in the samples (expressed as counts) in Fig. 9. The content of adenosine phosphates can be used as a direct measure of the bioactivity of the living organisms, especially if the bacterial strain is of the same identity (as discussed by Kwiatkowska et al. (2016) and references therein). The greatest drop in the values was observed for both

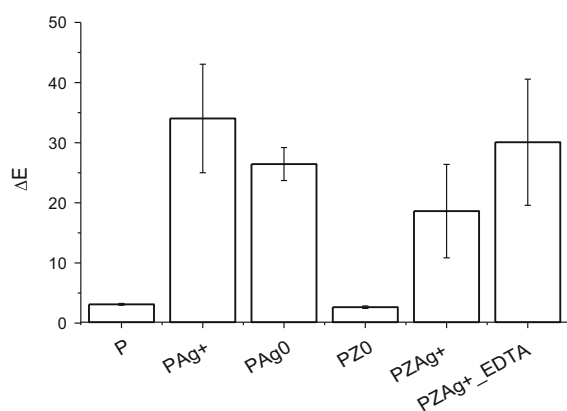


**Fig. 8** Total colour change ( $\Delta E$ ) obtained in micro fading tests for paper samples

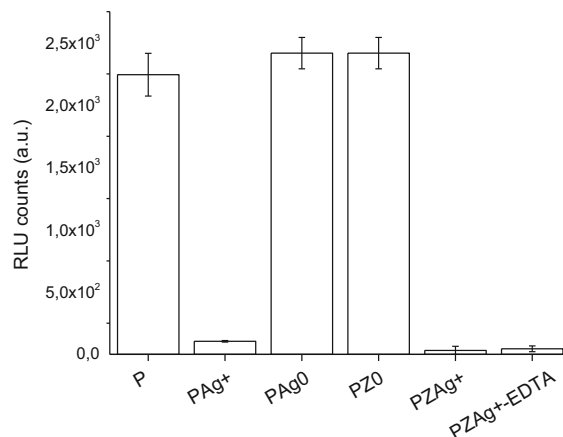


**Fig. 9** Antibacterial effects expressed as ATP/AFM ratio by RLU counts for reference and modified paper materials against *E. coli* strain

the samples containing zeolites,  $\text{PZAg}^+$  and the final  $\text{PZAg}^+_{\text{-EDTA}}$ , and slightly less so for the  $\text{PAg}^+$  sample. This indicates that in fact the active silver species in the mechanism of biocidal activity are silver cations and not silver zero valent NPs ( $\text{PAg}^0$ ), which respond comparably to the paper reference sample P, indicating no biocidal activity and a low concentration of  $\text{Ag}^+$ .

To illustrate the action of materials against *E. coli* strain, the inhibition zone is presented (Fig. 10). A halo, proving the antimicrobial behaviour of manufactured material, can be seen around the paper disc.

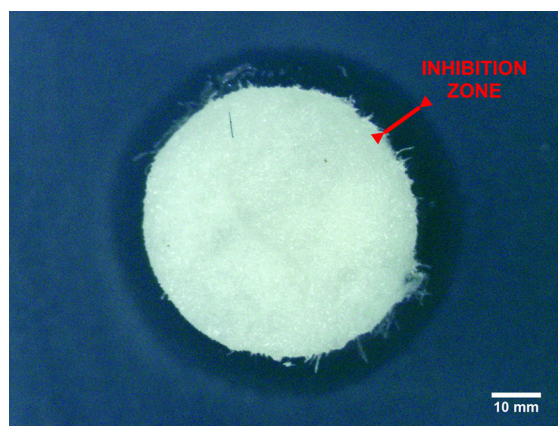


**Fig. 10** The image of the inhibition zone of prepared paper material

## Conclusions

A new paper material with antimicrobial activity was obtained as an alternative to materials containing silver NPs. The properties of the modified paper and reference samples were assessed by measurements of pH, tensile strength,  $DP_w$  and colour change. The antimicrobial properties were established for the *E. coli* strain, used as a standard testing microorganism.

The new paper material contains the faujasite mineral exchanged with silver cations, which is unique in that it contains exclusively the cations bound to faujasite mostly in its voids. This was achieved by the elution procedure elaborated for the material, which utilised a strong chelating agent ( $Na_2EDTA$ ) that is unable to penetrate the faujasite voids due to the size of the molecule. The other materials of this kind described in the literature (LEE et al. 2006; Taniguchi et al. 2006) also contain silver oxide NPs, which are formed during ion exchange in zeolites.

The new material shows greatly improved cellulose fibre quality in comparison with pure paper, and especially with paper containing silver NPs, as can be inferred from the tensile strength measurements and DP measurements of cellulose in paper. This observation corresponds to the pH of the material, which is higher than that measured for paper with silver NPs. The visual properties of the new material with the silver-exchanged faujasite are also better, as can be judged from the results of natural and accelerated light ageing tests.

Most importantly, the new material shows outstanding biocidal activity regarding *Escherichia coli*, typically used as a control strain of bacteria for antimicrobial tests. It must be emphasised that the reference paper sample with silver NPs showed no activity for this strain.

The new paper material shows potential for use as a packaging material in applications that demand sorptive and antimicrobial properties. The information included in this paper is protected by Polish and EU patent applications (Łojewska et al. 2015).

**Acknowledgments** The research was performed within grant SPB 811/N-COST/2010/0 from National Science Centre, Poland. The National Science Centre, Poland - project No. 2016/23/B/ST8/02024 is also acknowledged for additional analyses.

**Open Access** This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits unre-

stricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

## References

- Appendini P, Hotchkiss JH (2002) Review of antimicrobial food packaging. *Innov Food Sci Emerg Technol* 3:113–126
- AshaRani PV, Mun GLK, Hande MP, Valiyaveetil S (2009) Cytotoxicity and genotoxicity of silver nanoparticles in human cells. *ACS Nano* 3:279–290
- Azócar I, Vargas E, Duran N et al (2012) Preparation and antibacterial properties of hybrid-zirconia films with silver nanoparticles. *Mater Chem Phys* 137:396–403
- Baldevraj RSM, Jagadish RS (2011) Incorporation of chemical antimicrobial agents into polymeric films for food packaging. In: *Multifunctional and nanoreinforced polymers for food packaging*. pp 368–420
- Bastani D, Esmaili N, Asadollahi M (2013) Polymeric mixed matrix membranes containing zeolites as a filler for gas separation applications: a review. *J Ind Eng Chem* 19:375–393
- Bishop KD, Bilodeau MA, Mackay SG, Ruthven DM (2008) Zeolite composite materials for waste odor control. US Patent No. 20080293614 A1
- Böswald M, Mende K, Bernschneider W et al (1999) Biocompatibility testing of a new silver-impregnated catheter in vivo. *Infection* 27:38–42
- Bystrzejewska-Piotrowska G, Golimowski J, Urban PL (2009) Nanoparticles: their potential toxicity, waste and environmental management. *Waste Manag* 29:2587–2595
- Chu CC (1981) Hydrolytic degradation of polyglycolic acid sutures. *Trans Annu Meet Soc Biomater Conjoint Int* 4:1727–1734
- Cushen M, Kerry J, Morris M et al (2014) Evaluation and simulation of silver and copper nanoparticle migration from polyethylene nanocomposites to food and an associated exposure assessment. *J Agric Food Chem* 62(6):1403–1411
- Damm C, Neumann M, Münstedt H (2005) Properties of nanosilver coatings on polymethyl methacrylate. *Soft Mater* 3:71–88
- Danilczuk M, Długopolska K, Ruman T, Pogocki D (2008) Molecular sieves in medicine. *Mini Rev Med Chem* 8:1407–1417
- Echegoyen Y, Nerín C (2013) Nanoparticle release from nanosilver antimicrobial food containers. *Food Chem Toxicol* 62:16–22
- Fang W, Ma L, Zheng J, Chen C (2014) Fabrication of silver-loaded hollow mesoporous aluminosilica nanoparticles and their antibacterial activity. *J Mater Sci* 49:3407–3413
- Giri S (2014) Nanotoxicity: aspects and concerns in biological systems. In: Das S (ed) *Microbial Biodegradation and Bioremediation*, 1st edn. Elsevier, London, pp 55–83
- Grancaric AM, Prlic I, Tarbuk A, Marovic G (2012) Activated natural zeolites on textiles: protection from radioactive contamination. Springer, Netherlands, pp 157–176

- Gulrajani ML (2010) Colour measurement principles, advances and industrial applications. Elsevier, Amsterdam
- Gutiérrez L, Sánchez C, Batlle R, Nerin C (2009) New antimicrobial active package for bakery products. *Trends Food Sci Technol* 20:92–99
- He J, Kunitake T, Nakao A (2003) Facile in situ synthesis of noble metal nanoparticles in porous cellulose fibers. *Chem Mater* 15:4401–4406
- Kim S, Choi JE, Choi J et al (2009) Oxidative stress-dependent toxicity of silver nanoparticles in human hepatoma cells. *Toxicol in Vitro* 23:1076–1084
- Kukhareenko O, Bardeau J, Zaets I et al (2014) Promising low cost antimicrobial composite material based on bacterial cellulose and polyhexamethylene guanidine hydrochloride. *Eur Polym J* 60:247–254
- Kwiatkowska M, Ważny R, Turnau K, Wójcik A (2016) Fungi as deterioration agents of historic glass plate negatives of Brandys family collection. *Int Biodeterior Biodegrad* 115:133–140
- Langauer-Lewowicka H, Pawlas K (2015) Nanocząstki srebra - zastosowanie i zagrożenie dla zdrowia i środowiska. *Med Środowiskowa* 18:7–11
- Lauriol J-M, Froment P, Pla F, Robert A (1987) Molecular weight distribution of cellulose by on-line size exclusion chromatography—low angle laser light scattering part I: basic experiments and treatment of data. *Holzforschung* 41:109–113
- Lee JS, Jeong NC, Yoon KB (2006) Method for preparing composites of zeolite-fiber substrate. US Patent No. 20060199724
- Lerwill A, Townsend JH, Liang H et al (2008) A portable micro-fading spectrometer for versatile lightfastness testing. *e-Preserv Sci* 5:17–28
- Littunen K, Snoei J, Castro D et al (2016) Synthesis of cationized nanofibrillated cellulose and its antimicrobial properties. *Eur Polym J* 75:116–124
- Łojewska J, Jedrzejczyk RJ, Łojewski T, et al (2015) Modified nanocomposite material, method for its production and its application. WO Patent No. 2015170303 A1
- Łojewski T, Zięba K, Knapik A et al (2010) Evaluating paper degradation progress. Cross-linking between chromatographic, spectroscopic and chemical results. *Appl Phys A* 100:809–821
- Łojewski T, Thomas J, Gołąb R et al (2011) Note: light ageing with simultaneous colorimetry via fibre optics reflection spectrometry. *Rev Sci Instrum* 82:76102
- Mackevica A, Olsson ME, Hansen SF (2016) Silver nanoparticle release from commercially available plastic food containers into food simulants. *J Nanoparticle Res* 18:1–11
- Marambio-Jones C, Hoek EMV (2010) A review of the antibacterial effects of silver nanomaterials and potential implications for human health and the environment. *J Nanoparticle Res* 12:1531–1551
- Matsumura Y, Yoshikata K, Kunisaki S-I, Tsuchido T (2003) Mode of bactericidal action of silver zeolite and its comparison with that of silver nitrate. *Appl Environ Microbiol* 69:4278–4281
- Matsuura T, Abe Y, Sato Y et al (1997) Prolonged antimicrobial effect of tissue conditioners containing silver-zeolite. *J Dent* 25:373–377
- Moore MN (2006) Do nanoparticles present ecotoxicological risks for the health of the aquatic environment? *Environ Int* 32:967–976
- Nassar MA, Youssef AM (2012) Mechanical and antibacterial properties of recycled carton paper coated by PS/Ag nanocomposites for packaging. *Carbohydr Polym* 89:269–274
- O’Connell DW, Birkinshaw C, O’Dwyer TF (2008) Heavy metal adsorbents prepared from the modification of cellulose: a review. *Bioresour Technol* 99:6709–6724
- Odabaş ME, Çinar Ç, Akça G et al (2011) Short-term antimicrobial properties of mineral trioxide aggregate with incorporated silver-zeolite. *Dent Traumatol* 27:189–194
- Panyala NR, Peña-Méndez EM, Havel J (2008) Silver or silver nanoparticles: a hazardous threat to the environment and human health? *J Appl Biomed* 6:117–129
- Pawcenis D, Thomas JL, Łojewski T et al (2015) Towards determination of absolute molar mass of cellulose polymer by size exclusion chromatography with multiple angle laser light scattering detection. *J Chromatogr A* 1409:53–59
- Restuccia D, Spizzirri UG, Parisi OI et al (2010) New EU regulation aspects and global market of active and intelligent packaging for food industry applications. *Food Control* 21:1425–1435
- Russel AD, Hugo W (1994) Antimicrobial activity and action of silver. *Prog Med Chem* 31:351–370
- Seaton A, Tran L, Aitken R et al (2010) Nanoparticles, human health hazard and regulation. *J R Soc Interface* 7(Suppl 1):S119–S129
- Stol R, Pedersoli JL, Poppe H, Kok WT (2002) Application of size exclusion electrochromatography to the microanalytical determination of the molecular mass distribution of celluloses from objects of cultural and historical value. *Anal Chem* 74:2314–2320
- Suslow T, Crops V (1997) Performance of zeolite based products in ethylene removal. *Perish Handl Q* (92):32–33
- Takai K, Ohtsuka T, Senda Y et al (2002) Antibacterial properties of antimicrobial-finished textile products. *Microbiol Immunol* 46:75–81
- Taniguchi A, Miyake K, Kurihara Y (2006) Antibacterial zeolite and antibacterial resin composition. WO Patent No. 2007037195 A1
- TAPPI (1996) Tappi T 231 cm-96: Zero-span breaking strength of pulp (dry zero-span tensile). 1–11
- Venous A (1999) Antimicrobial-impregnated central venous. *N Engl J Med* 340:1761–1762
- Vermeiren L, Devlieghere F, Van Beest M et al (1999) Developments in the active packaging of foods. *Trends Food Sci Technol* 10:77–86
- Vukoje ID, Džunuzović ES, Vodnik VV et al (2014) Synthesis, characterization, and antimicrobial activity of poly(GMA-co-EGDMA) polymer decorated with silver nanoparticles. *J Mater Sci* 49:6838–6844
- Wang JX, Wen LX, Wang ZH, Chen JF (2006) Immobilization of silver on hollow silica nanospheres and nanotubes and their antibacterial effects. *Mater Chem Phys* 96:90–97
- Yang FC, Wu KH, Liu MJ et al (2009) Evaluation of the antibacterial efficacy of bamboo charcoal/silver biological protective material. *Mater Chem Phys* 113:474–479

- Youssef AM, Kamel S, El-Samahy MA (2013) Morphological and antibacterial properties of modified paper by PS nanocomposites for packaging applications. *Carbohydr Polym* 98:1166–1172
- Zagory D (1995) Ethylene-removing packaging. *Active Food Packaging*. Springer, Boston, pp 38–54
- Zampino D, Ferreri T, Puglisi C et al (2011) PVC silver zeolite composites with antimicrobial properties. *J Mater Sci* 46:6734–6743



## Green and Sustainable Separation of Natural Products from Agro-Industrial Waste: Challenges, Potentialities, and Perspectives on Emerging Approaches

Vânia G. Zuin (1,2), Luíze Z. Ramin (1)

1) Department of Chemistry, Federal University of São Carlos, Rod. Washington Luís, km 235, São Carlos 13565-905, Brazil

2) Green Chemistry Centre of Excellence, University of York, North Yorkshire YO10 5DD, UK

*New generations of biorefinery combine innovative biomass waste resources from different origins, chemical extraction and/or synthesis of biomaterials, biofuels, and bioenergy via green and sustainable processes. From the very beginning, identifying and evaluating all potentially high value-added chemicals that could be removed from available renewable feedstocks requires robust, efficient, selective, reproducible, and benign analytical approaches. With this in mind, green and sustainable separation of natural products from agro-industrial waste is clearly attractive considering both socio-environmental and economic aspects. In this paper, the concepts of green and sustainable separation of natural products will be discussed, highlighting the main studies conducted on this topic over the last 10 years. The principal analytical techniques (such as solvent, microwave, ultrasound, and supercritical treatments), by-products (e.g., citrus, coffee, corn, and sugarcane waste) and target compounds (polyphenols, proteins, essential oils, etc.) will be presented, including the emerging green and sustainable separation approaches towards bioeconomy and circular economy contexts.*

Top Curr Chem (Z) (2018) 376:3. (Springer Open Choice)

<https://doi.org/10.1007/s41061-017-0182-z>

The Paper Industry Technical Association (PITA) is an independent organisation which operates for the general benefit of its members – both individual and corporate – dedicated to promoting and improving the technical and scientific knowledge of those working in the UK pulp and paper industry. Formed in 1960, it serves the Industry, both manufacturers and suppliers, by providing a forum for members to meet and network; it organises visits, conferences and training seminars that cover all aspects of papermaking science. It also publishes the prestigious journal *Paper Technology* and the *PITA Annual Review*, both sent free to members, and a range of other technical publications which include conference proceedings and the acclaimed *Essential Guide to Aqueous Coating*.



# Green and Sustainable Separation of Natural Products from Agro-Industrial Waste: Challenges, Potentialities, and Perspectives on Emerging Approaches

Vânia G. Zuin<sup>1,2</sup> · Luíze Z. Ramin<sup>1</sup>

Received: 30 August 2017 / Accepted: 26 December 2017 / Published online: 17 January 2018  
© The Author(s) 2018. This article is an open access publication

**Abstract** New generations of biorefinery combine innovative biomass waste resources from different origins, chemical extraction and/or synthesis of biomaterials, biofuels, and bioenergy via green and sustainable processes. From the very beginning, identifying and evaluating all potentially high value-added chemicals that could be removed from available renewable feedstocks requires robust, efficient, selective, reproducible, and benign analytical approaches. With this in mind, green and sustainable separation of natural products from agro-industrial waste is clearly attractive considering both socio-environmental and economic aspects. In this paper, the concepts of green and sustainable separation of natural products will be discussed, highlighting the main studies conducted on this topic over the last 10 years. The principal analytical techniques (such as solvent, microwave, ultrasound, and supercritical treatments), by-products (e.g., citrus, coffee, corn, and sugarcane waste) and target compounds (polyphenols, proteins, essential oils, etc.) will be presented, including the emerging green and sustainable separation approaches towards bioeconomy and circular economy contexts.

**Keywords** Green and sustainable extraction · Sustainable separation · Green analytical techniques · Biomass waste · Biorefinery · Bioeconomy and circular economy

---

Chapter 8 was originally published as Zuin, V. G. & Ramin, L. Z. Top Curr Chem (Z) (2018) 376: 3. <https://doi.org/10.1007/s41061-017-0182-z>.

---

✉ Vânia G. Zuin  
[vaniaz@ufscar.br](mailto:vaniaz@ufscar.br); [vania.zuin@york.ac.uk](mailto:vania.zuin@york.ac.uk)

<sup>1</sup> Department of Chemistry, Federal University of São Carlos, Rod. Washington Luís, km 235, São Carlos 13565-905, Brazil

<sup>2</sup> Green Chemistry Centre of Excellence, University of York, North Yorkshire YO10 5DD, UK

# 1 Introduction

Currently, it can be observed that global sustainability challenges are all closely interconnected, such as pollution, climate change, biodiversity loss, poverty, energy, and food security. As stated by Liu et al. [1], only holistic and disruptive approaches integrating various components of human and natural systems are effective in identifying and proposing suitable solutions for these challenges, especially those related to research, development, and innovation (RD&I) in interdisciplinary and transdisciplinary studies. To exemplify this systemic view, Fig. 1 illustrates the Earth surface that, based on the “Dymaxion map” (the Fuller Projection Map), shows the planet as a continuum without splitting any continents, seas, and oceans, where cycles are integrated through flows of matter, energy, and information [1, 2]. Here, Brazil, China, the Caribbean, and Africa interact across space, time, and organizational levels in many ways. For instance, the expansion of soybean production aggravates deforestation in Brazil, but also provides food and feedstock to China. The food trade between both countries also affects other areas, including the Caribbean and Africa. Dust particles from the Sahara Desert, also increased due to unbalanced agricultural practices, can reach the Caribbean and have an impact on coral reefs and soil fertility, diminishing tourism in this region. In addition, nutrient-rich particles from Africa can reach Brazil, improving its forest productivity.

According to the Director-General of the Food and Agriculture Organization (FAO) of the United Nations [3], after years of progress, world hunger has increased since 2015. Around 60% of the world’s starving people are from countries affected by conflict and climate change, including northeast Nigeria, Somalia, South Sudan, and Yemen with 20 million people, often suffering extreme climatic events such as droughts and floods. Not surprisingly, some of the FAO’s top priorities for the next

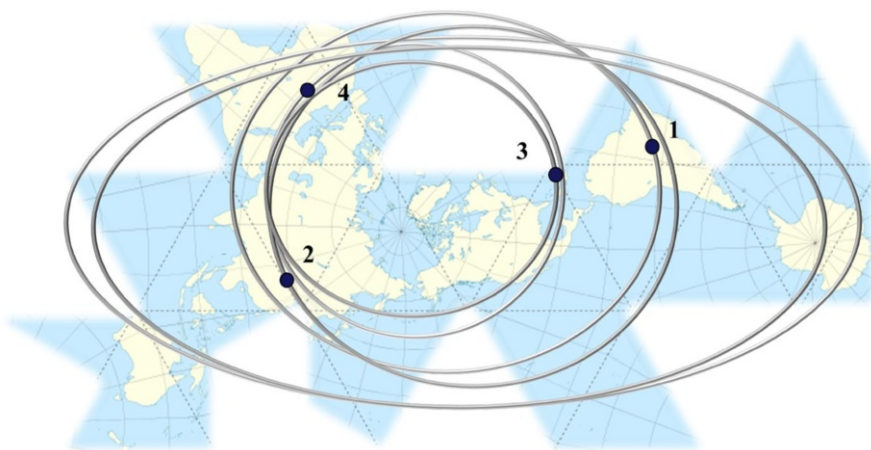


**Fig. 1** Representation of an integrated planetary flow system based on the Dymaxion map, emphasizing some coupled cycles related to food production and socio-environmental impacts among (1) Brazil, (2) China, (3) the Caribbean, and (4) the Sahara Desert. Adapted from [1]

2 years include topics such as sustainable agriculture, climate change mitigation and adaptation, water scarcity and support of subsistence rural practices, and fisheries and forestry [3, 4]. The challenges related to this demanding context can be intensified and better understood when taking into account that the world population is expected to increase by about 30% over the next 35 years, reaching more than 9.5 billion people in 2050 and 11.2 billion in 2100 [5].

As pointed out by Xia et al. [6], the global food waste of approximately 1.3 billion tons per year is shocking in this context and, although it should be avoided or minimized, it cannot be completely prevented nowadays. Primary and secondary processing generates unpreventable food supply chain waste. This can be due to a number of factors along the supply chain, differing by the commodity and country in question. In general terms, developing countries such as some African countries suffer the greatest loss during the early, upstream part of the primary processing, corresponding to 75% of food losses during production and postharvest. Various initiatives, e.g., building better infrastructure through knowledge transfer (more efficient storage and transport technologies) and improving collaboration and market opportunities in the food supply chain could have a positive role. In industrialized countries, waste occurs especially in the consumption stage, accounting for 50% of overall loss of crops in some countries of North America, Europe, and Oceania. In this case, together with educational and cultural actions, other aspects such as developing legislation to make date labels more user-friendly for consumers (sell-by, best-before, and consume-by), redesigning packaging characteristics (avoiding the “buy 1 get 2” offers) and retailer marketing strategies should be considered [7].

It is estimated that around 140 billion tons of biomass from the agricultural sector are generated every year in the world [8, 9], and a considerable part is recognized as waste and not conflicting with food availability, e.g., leaves, roots, stalks, bark, bagasse, straw residues, seeds, wood and animal residues. Using alternative strategies to avoid additional losses and produce several high value-added chemicals could minimize the volume of non-renewable materials used today (i.e., roughly 50 billion tons of fossil fuels), enough to greatly reduce greenhouse gas emissions and dependence on non-sustainable resources. Therefore, considering their available volume and practically low costs locally and globally, associated to rich function, structure and chemical heterogeneity, all agro-industrial waste should also be considered for their chemical and material potential, as well as a source of energy [10–13].

An important proposal related to waste hierarchy as a framework for residue management can be seen in Fig. 2 [14, 15], which was reformulated to include agro-industrial waste. In this case, the agro-industrial waste hierarchy has a different meaning from top to bottom, since all biomass is valued as raw material. ‘Prevention’ is an intrinsic part of optimized processes, avoiding overproduction. Therefore, the least probable option is ‘disposal’ as the supply chain is designed to attend sustainable consumption, using all bio-based material generated. Here, sustainable production also includes eco-efficiency, cleaner and green productivity, whereas sustainable consumption allows greener choices to be made by individuals based on eco-procurement, supply chain management, waste minimization, recycling, and resource efficiency measures. Both sustainable production and consumption comprises ‘life-cycle thinking’, aiming at preventing problems shifting from one

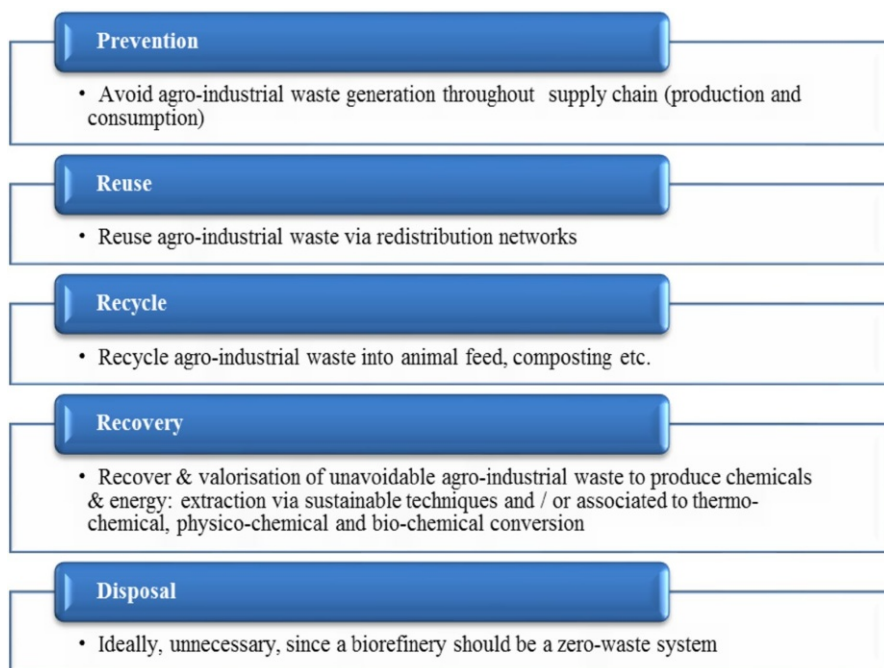


**Fig. 2** The agro-industrial waste hierarchy modified from [15]. The main idea is to promote sustainable production and consumption systems through zero-waste biorefinery

life-cycle stage to another, one geographical area or environmental compartment to another.

One of the most important and cited references highlighting the advances in genetics, biotechnology, process chemistry, and engineering that has helped establish a new manufacturing concept to convert renewable biomass into valuable fuels and products, known as biorefinery, was published by Ragauskas and collaborators in the mid-2000s [16]. According to these authors and other researchers [16, 17], integrating biomass and biorefinery technologies has the potential to develop sustainable bio-based energy and materials leading to a new manufacturing paradigm (Fig. 3).

In fact, this paradigm is currently connected to other strong concepts, i.e., bio-economy and circular economy; the latter is described as an industrial system that is restorative by intention and design. This idea replaces the end-of-life notion with regeneration, focusing on the use of renewable energy, elimination of toxic chemicals, reutilization, return and eradication of “waste through the superior design of materials, products, systems, and business models” [18, 19].

As can be noted, new generations of biorefinery combine innovative biomass resources from different origins, chemical extraction and purification and/or synthesis of biomaterials, biofuels and bioenergy via benign processes. From the very beginning, the identification and quantification of all potentially high value-added

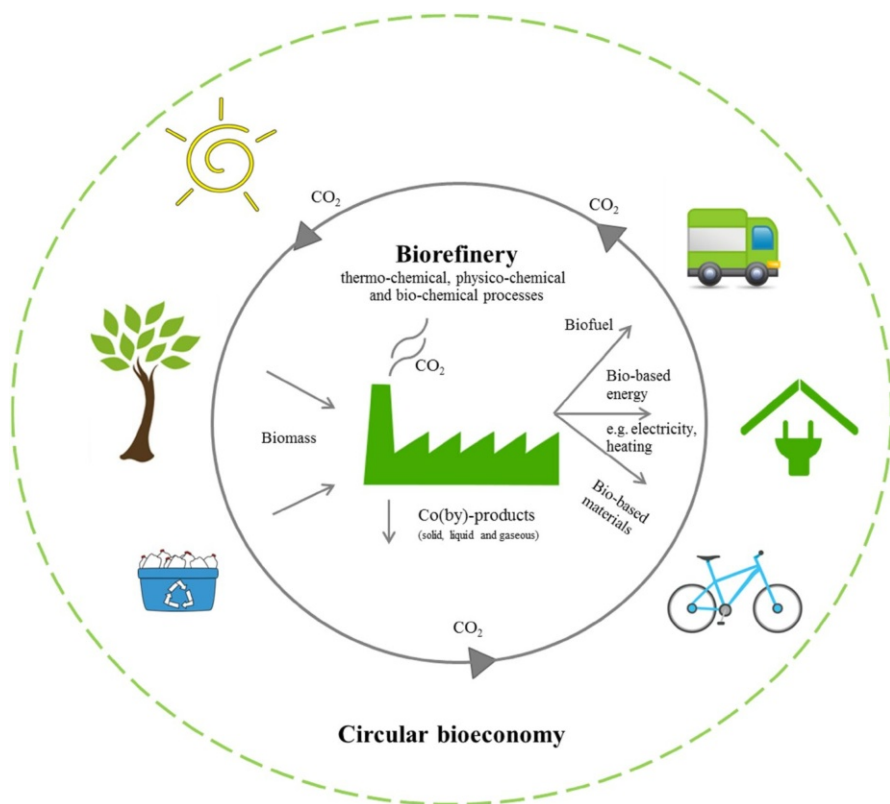


**Fig. 3** Holistic biorefinery model integrating biomass, biofuel, biomaterials and bioenergy cycle, based on green and sustainable technologies in the scope of bioeconomy and circular economy. Updated and expanded from [16, 17]

compounds that could be removed from the available renewable feedstocks requires another analytical approach, also connected to green chemistry [20, 21].

## 2 From Green to Sustainable Separation: Towards Holistic, Flexible, and Zero-Waste Biorefineries

More recently, green extraction and purification have been presented as methods based on establishing processes that reduce energy consumption, using solvents and renewable materials, as well as ensuring a safe and high-quality fraction/product [22]. The aim of their application is to obtain natural products from industrial waste, which is considered a highly attractive initiative [23].

However, a more adequate term for such extraction and purification processes towards vanguard biorefineries could be sustainable separation, adding to the previous green definition, the notion of innovation across all sectors that allows for

increased value in a wide sense, enhancing human and environment benefits and providing economically accessible technologies also advantageous to industry and large scale processing systems. It includes another dimension related to the generation of more creative and healthy jobs, contributing to the construction of a positive long-term sustainability agenda, encompassing bio-circular economy, environmental and social justice [24–27].

Sustainable separation can be defined as a holistic approach grounded on the circular and flexible design and application of renewable benign materials and auxiliaries (including bio-derived solvents, solid phases, membranes) and processes [rooted on green analytical techniques and sustainability metrics and indices, e.g., life cycle analysis (LCA), chemometrics, and other interdisciplinary indicators]. The aim is to optimize the tuneable use of energy, time, reagents, devices, scale, yield and number of steps to extract, fractionate, purify or even modify the components of interest from bio-derived waste during these *in situ* processes, ensuring analytical reproducibility, efficiency, selectivity robustness and scalability, with online evaluation regarding measurable objectives to create safer, healthier, and more efficient products, processes, and services under fair conditions, commercially available at accessible and just prices [28–30].

Natural products are among the most attractive value-added chemicals to be considered, which can be classified as organic compounds formed by living systems divided into three main categories: (1) compounds that occur in all cells and have a central role in their metabolism and reproduction (nucleic acids, amino acids, and sugars), also known as primary metabolites; (2) high-molecular polymeric materials which form cellular structures (cellulose, lignins, and proteins) and; (3) chemicals which are characteristic of a limited number of species, called secondary metabolites [22, 30]. Many of these bioactive compounds (e.g., alkaloids, terpenoids, and phenols) have been extensively used as medicine, nutraceuticals, flavors, fragrances, cosmetics, food additives, antimicrobials, bio-pesticides, etc. However, among the biggest challenges for biomass utilization is establishing benign methods to separate, purify and modify it into chemicals, fuels, and new materials. This is partially due to, with rare exceptions, the small amounts which are lower than 0.01% of the dry weight of vegetal, associated to possible product inhibition issues, large raw material variability, feed detoxification (when necessary), instability of the target compound (or fractions) and its presence in a complex mixture [23, 30].

It is well known that the separation steps, especially extraction, correspond up to 40–80% of the total costs of most common chemical processes currently used. From the point of view of a holistic biorefinery, separation has attracted more and more attention [31]. For instance, for natural products, solvent-based extraction is one of the best options nowadays considering the nature of many bio-based chemicals and matrices, and also the fact that other separation methods, such as those based on chromatography or membranes, do not have the same advantages taking into account commercial scales [32].

It is expected that high value-added components from biomass waste such as essential oils, polyphenols, and other food or medicinal-related products are extracted first, followed by polysaccharides, lignocelluloses or waxes via advanced separation and depolymerization processes. Among them, green solvents in general,

supercritical CO<sub>2</sub>, subcritical water, microwave (MW)-assisted acidolysis and gas-expanded liquids have been mentioned [33]. Green solvents offer important separation advantages, including near-supercritical or supercritical fluids, which have outstanding mass transport properties, polarity, and easiness of solvent removal after extracting the compound of interest [34]. Another interesting solvent is water, but the range of compounds that are soluble in this medium is quite limited. Nevertheless, the use of subcritical water has been demonstrated to be advantageous for organic modification to depolymerize, hydrolyze, gasify, and carbonize biomass to produce bioactive compounds, sugars, biogas, and other valuable solids [16, 35].

Integrating two or more green techniques combining different strategies has played an important role in overcoming the main drawbacks of a single technique towards sustainable separation. For instance, for high-pressure solvent extraction in which the extractants do not reach supercritical conditions, the temperature, time, and solvent consumed can be dramatically reduced associating ultrasound-assisted treatment [28, 36]. In fact, more attention has been paid to green extraction, purification, or modification of natural products derived from agro-industrial waste nowadays, opening up new opportunities for sustainable approaches designed for bioeconomy and circular economy models. The aim of this paper is to present an overview of the design and application of green and sustainable separation of natural products for vanguard zero-waste biorefineries. The main analytical techniques and procedures described over the last 10 years will be described in detail, showing the potentialities, challenges, and perspectives in this topical and emergent scenario.

### 3 High Value-Added Approaches for Green and Sustainable Separation of Natural Products from Waste: What can be Observed from the Literature?

More recently, trends in green and sustainable extraction, fractionation and purification techniques have largely focused on minimizing the use of solvents, energy and materials that are intrinsically benign to human health and the environment [37]. In order to analyze the *status quo* and perspectives related to natural product separation from waste, a systematic literature review was conducted using the ISIS Web of Knowledge platform (reviews and papers) from 2006 to 2017, combining the descriptors “natural product” and “green extraction/separation” (or “sustainable extraction/separation” or “eco-friendly extraction/separation”) and “waste” (or “residue”). Figure 4 shows the number of publications during this period. There were more than 160 research papers and reviews that, to the best of our knowledge, are reasonably representative to show the strongest tendencies in this field over the last decade. It can be clearly observed that there has been an increase in the number of manuscripts over the last 10 years, covering the principles, advances, and applications of these green methods.

The obtained data reflect the growing interest and potential of green and sustainable methods to separate natural products from waste. One tendency observed in particular was the innovative ways to remove (integrating extraction, purification and/or modification in the same integrated system) and use such compounds in more

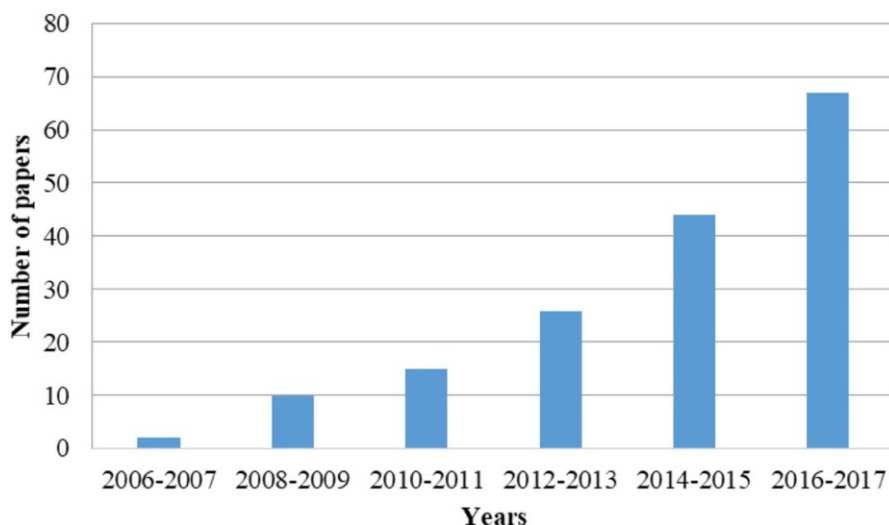


**Fig. 4** Number of publications per year focusing on green and sustainable separation (extraction, fractionation and purification) of natural products from waste (ISIS Web of Knowledge, January 2006 to December 2017)

contemporary sectors, promoting human and environmental health instead of general and old-fashioned remediation [19, 38]. As a result, new applications for food, nutraceutical, and agricultural sectors have been further explored, based on their advantageous properties as natural colorants, flavors, aromas, antioxidants, antifungals, bioformulations (bio-pesticides) or simply their use as precursors to generate other compounds for similar uses. Some details related to patents, (non-) clinical trials, sustainable indicators, scaling-up, regulatory, agro-industrial variability and availability, traceability, seasonality, good laboratory and manufacturing practices, additional economical and marketing issues have also been discussed.

Table 1 presents the research papers and reviews published during this period, highlighting their main focus, the green or sustainable techniques/approaches adopted, raw materials (mostly agro-industrial waste) and target compounds studied. The most common raw materials described as chemical feedstocks were waste derived from plants, for instance, food, mainly fruits (citrus, mango, papaya, grape, passiflora, banana, tomato, olive), grains (corn, soybean, sunflower, coffee) and other abundant materials (sugarcane bagasse, tea, wood bark, rice and wheat straw). Additional issues that affect the quality of the final products were also discussed, namely the procedure used for waste collection, selection, storage, drying, matrix characteristics (particle size, shape, specific surface area and porosity). The latter aspects play an important role in extraction efficiency due to the mass and heat transfer processes. Understanding the nature of raw material is crucial to avoid negative influences impacting the quality and yield during the removal of the target compounds, e.g., caused by co-extracted contaminants or due to the presence of some

**Table 1** Research papers and reviews focusing on green and sustainable separation of natural products from agro-industrial waste published from January 2006 to December 2017 (ISIS Web of Knowledge)

| Year | Crop                            | Waste stream         | Target compounds                      | Geographical location | Green or sustainable separation approach                                                                                                                             | References                                                                                                                                                           |
|------|---------------------------------|----------------------|---------------------------------------|-----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2017 | Olives                          | Olive kernels        | Phenolic compounds and oil            | France and Spain      | Aqueous liquid solid extraction (LSE), mechanical expression (ME), supercritical CO <sub>2</sub> (SC-CO <sub>2</sub> ) and gas-assisted mechanical expression (GAME) | Gas-assisted mechanical expression (GAME) for the selective recovery of lipophilic and hydrophilic compounds from olive kernel [145]                                 |
| 2017 | Figs                            | Leaves               | Bioactive compounds                   | China                 | Deep eutectic solvent with microwave and ultrasound extraction<br>Time: 10 min (MW) and 60 min (US)<br>Temperature: 40–80 °C<br>Power: 250 W (MW) and 700 W (US)     | Enhanced and green extraction polyphenols and furanocoumarins from Fig ( <i>Ficus carica</i> L.) leaves using deep eutectic solvents [136]                           |
| 2017 | <i>Polygonum multiflorum</i>    | Herbal raw materials | Stilbene glycoside and anthraquinones | China                 | Ionic liquids with ultrasonic extractor<br>Time: 1–120 min<br>Power: 40–120 W                                                                                        | Sequential extraction and separation using ionic liquids for stilbene glycoside and anthraquinones in <i>Polygonum multiflorum</i> [131]                             |
| 2017 | Several sources                 | Not defined          | Mostly bioactive compounds            | Spain                 | Review<br>Critical overview about the greenness of water as extraction solvent                                                                                       | Water as green extraction solvent: Principles and reasons for its use [146]                                                                                          |
| 2017 | Pomelo                          | Flavored             | Essential oil                         | China                 | Microwave irradiation<br>Power: 240–700 W<br>Time: 24 min                                                                                                            | A process to preserve valuable compounds and acquire essential oils from pomelo flavedo using a microwave irradiation treatment [52]                                 |
| 2017 | <i>Selaginella doederleinii</i> | Not defined          | Biflavonoids                          | China                 | Ionic liquids and microwave-assisted extraction<br>Power: 300–700 W<br>Time: 30–50 min<br>Temperature: 40–60 °C                                                      | Optimization of ionic liquid-assisted extraction of biflavonoids from <i>Selaginella doederleinii</i> and evaluation of its antioxidant and antitumor activity [132] |

**Table 1** (continued)

| Year | Crop                                  | Waste stream                               | Target compounds                                                     | Geographical location | Green or sustainable separation approach                                                                                                                                                  | References                                                                                                                                                                  |
|------|---------------------------------------|--------------------------------------------|----------------------------------------------------------------------|-----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2017 | <i>Pogostemon cablin</i>              | Leaves                                     | Essential oils                                                       | Indonesia             | Microwave-assisted hydrodistillation (MAHD) and solvent-free microwave extraction (SFME)<br>Power: 600 W (MAHD) and 264 W (SFME)<br>Time: 66 min (MAHD) and 45 min (SFME); solvent: water | Comparison of conventional and microwave-assisted distillation of essential oil from <i>Pogostemon cablin</i> leaves; analysis and modeling of heat and mass transfer [147] |
| 2017 | <i>Juglans regia</i> L.               | Fresh male flowers and unripe walnut seeds | Phenolic content and water-soluble polyphenols                       | Italy                 | Microwave-assisted extraction<br>Frequency: 2.45 GHz<br>Max. power: 500 W<br>Solvent: ethanol/water<br>Temperature: 60–100 °C<br>Time: 6–30 min                                           | Process intensification by experimental design application to microwave-assisted extraction of phenolic compounds from <i>Juglans regia</i> L. [148]                        |
| 2017 | Walnuts                               | Walnut de-pellicle                         | Flavonoids                                                           | China                 | Macroporous resins<br>Pretreated with 5% HCl and 5% NaOH solutions                                                                                                                        | Recovery of flavonoids from walnuts de-pellicle wastewater with macroporous resins and evaluation of antioxidant activities in vitro [149]                                  |
| 2017 | Ginseng                               | Roots                                      | Bioactive compounds                                                  | Brazil                | Sequential extraction system using ethanol followed by water<br>Temperature: 333 K<br>Time: 5–240 min                                                                                     | Techno-economic evaluation of obtaining Brazilian ginseng extracts in potential production scenarios [150]                                                                  |
| 2017 | Food ingredients and natural products | Not defined                                | Nutraceuticals, cosmetic, pharmaceutical, and bioenergy applications | France                | Review<br>current knowledge on ultrasound-assisted extraction                                                                                                                             | Ultrasound-assisted extraction of food and natural products. Mechanisms, techniques, combinations, protocols and applications. A review [151]                               |

**Table 1** (continued)

| Year | Crop                                                                                     | Waste stream                          | Target compounds                                                                                                           | Geographical location | Green or sustainable separation approach                                                                                                                                             | References                                                                                                                                                                          |
|------|------------------------------------------------------------------------------------------|---------------------------------------|----------------------------------------------------------------------------------------------------------------------------|-----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2017 | Coffee                                                                                   | Coffee chaff                          | Antioxidants                                                                                                               | Portugal              | Solid-liquid extraction and multi-frequency multimode modulated (MMM)<br>Frequency: 19.8 kHz<br>Power: 250 and 500 W<br>Time: 60–600 s                                               | Multi-frequency multimode modulated technology as a clean, fast, and sustainable process to recover antioxidants from a coffee by-product [152]                                     |
| 2017 | Apples                                                                                   | Wild apple fruit dust                 | Bioactive compounds, polyphenolic antioxidants                                                                             | Serbia                | Microwave-assisted extraction<br>Time: 15–35 min<br>Ethanol conc.: 40–80%<br>Irradiation power: 400–800 W                                                                            | Microwave-assisted extraction of wild apple fruit dust production of polyphenol-rich extracts from filter tea factory by-products [153]                                             |
| 2017 | Wood                                                                                     | Wood biomass                          | Lignin oligomers                                                                                                           | China                 | Microwave-assisted treatment with deep eutectic solvent<br>Solvent: choline chloride and oxalic acid dehydrate<br>Temperature: 80 °C<br>Power: 800 W<br>Time: 3 min                  | Efficient cleavage of lignin-carbohydrate complexes and ultrafast extraction of lignin oligomers from wood biomass by microwave-assisted treatment with deep eutectic solvent [137] |
| 2017 | Wood                                                                                     | Oak wood from cooperative by-products | Furanic compounds, <i>cis</i> - and <i>trans</i> -B-methyl-γ-octalactones, terpenes and norisoprenoids, benzenic compounds | Spain                 | Pressurized liquid extraction<br>Solvent: water, ethanol/water (80:20) and ethyl lactate<br>Temperature: 60–120 °C<br>Pressure: 10.34 MPa<br>Flush volume: 60%<br>Purging time: 80 s | Extraction of natural flavorings with antioxidant capacity from cooperative by-products by green extraction procedure with subcritical fluids [154]                                 |
| 2017 | <i>P. armeniaca</i> , <i>P. persica</i> , <i>P. domestica</i> , <i>Triticum aestivum</i> | Fruit and vegetables seeds and peels  | Phenolic compounds                                                                                                         | Pakistan              | Ultrasonic water bath<br>Solvent: 65% (v/v) ethanol (methanol and acetone)<br>Extraction time: 30 min<br>Temperature: 50 °C                                                          | Extraction and quantification of phenolic compounds from <i>Prunus armeniaca</i> seed and their role in biotransformation of xenobiotic compounds [71]                              |

**Table 1** (continued)

| Year | Crop                     | Waste stream                                               | Target compounds                                                                                              | Geographical location    | Green or sustainable separation approach                                                                                                   | References                                                                                                                                                |
|------|--------------------------|------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|--------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2017 | Lignocellulose materials | Lignocellulosic biomass such as crops or forestry residues | High value-added bio-based products (e.g., bioethanol, biogas, acetic acid, acetic acid, or activated carbon) | Mexico and Pakistan      | Review<br>Focus on transformation based on syngas platform (thermochemical platform) and sugar platform (biochemical platform)             | Lignocellulose: a sustainable material to produce value-added products with zero-waste approach [155]                                                     |
| 2017 | Olives                   | Olive by-product (paté)                                    | Fatty acids and phenolic compounds                                                                            | Spain and Italy          | Soxhlet extraction (percolation with petroleum ether, under reflux)                                                                        | Macro and micro functional components of a spreadable olive by-product (paté) generated by new concept of two-phase decanter [156]                        |
| 2017 | Tucumã palm fruit        | Tucumã's endocarp                                          | Cellulose                                                                                                     | Brazil and USA           | Alkaline extraction (135 °C, autoclave, 2 bar, 2 min, 20% of aqueous NaOH, 1:30 straw to liquor (g/ml), 30 min)                            | New approach for extraction of cellulose from tucumã's endocarp and its structural characterization [115]                                                 |
| 2017 | Grapes                   | Seeds                                                      | Resveratrol                                                                                                   | China                    | Subcritical water extraction<br>Pressure: 0.5–1.5 MPa<br>Time: 20–30 min<br>Temperature: 130–170 °C                                        | Optimization of subcritical water extraction of resveratrol from grape seeds by response surface methodology [100]                                        |
| 2017 | Mango, rambutan, santol  | Peels                                                      | Antioxidant activity                                                                                          | Thailand                 | Solid–liquid extraction<br>Ethanol (95%)                                                                                                   | Study effect of natural extracts on the antioxidant activity in pork balls [157]                                                                          |
| 2017 | Tomatoes                 | Pericarps without seeds                                    | Nutrient-rich antioxidant ingredients                                                                         | Portugal, Spain, Ireland | Microwave extraction (600 rpm, 200 W)<br>Time: 0–20 min<br>Temperature: 60–180 °C<br>Ethanol conc.: 0–100%<br>Solid/liquid ratio: 5–45 g/l | Valorization of tomato wastes for development of nutrient-rich antioxidant ingredients: a sustainable approach towards the needs of today's society [158] |

**Table 1** (continued)

| Year | Crop                                                                                                                    | Waste stream                               | Target compounds                                                                       | Geographical location         | Green or sustainable separation approach                                                                                                                  | References                                                                                                                                                                              |
|------|-------------------------------------------------------------------------------------------------------------------------|--------------------------------------------|----------------------------------------------------------------------------------------|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2017 | <i>Citrus latifolia</i> ,<br><i>Rubus</i> sp.,<br><i>Origanum vulgare</i><br>and <i>Heterotheca</i><br><i>inuloides</i> | Peel and broken down<br>vegetable material | Fatty acids and antioxidants<br>compounds                                              | Mexico, Belgium               | SC-CO <sub>2</sub><br>Extraction time: 1 h<br>Flow: 25 g/min<br>Pressure: 10–40 MPa<br>Temperature: 35–60 °C<br>Co-sol.: 0–8 g/min<br>Percent flow: 0–32% | Thermodynamics and statistical<br>correlation between supercritical<br>CO <sub>2</sub> fluid extraction and bioactivity<br>profile of locally available Mexican<br>plant extracts [159] |
| 2017 | Pomegranates                                                                                                            | Peels                                      | Carotenoids                                                                            | Greece                        | Ultrasound-assisted extraction<br>(139 W, 20 kHz); solvents:<br>vegetable oils<br>Extraction time: 10–60 min<br>Temperature: 20–60 °C                     | Green ultrasound-assisted extraction<br>of carotenoids from pomegranate<br>wastes using vegetable oils [72]                                                                             |
| 2017 | Pomegranates                                                                                                            | Both edible and non-<br>edible parts       | Polyphenols                                                                            | Greece                        | Semi-automatic extractor<br>Solvents: H <sub>2</sub> O, $\beta$ -CD, HP- $\beta$ -CD<br>Extraction time: 363 min<br>Temperature: 25 °C                    | Green extraction of polyphenols from<br>whole pomegranate fruit using<br>cyclodextrins [121]                                                                                            |
| 2016 | Quince                                                                                                                  | Leaves                                     | Natural dyes and bioactive<br>compounds                                                | Romania                       | Aqueous extraction<br>Extraction time: 60–240 min<br>Temperature: 4–100 °C                                                                                | Dyeing and antibacterial properties<br>of aqueous extracts from quince<br>( <i>Cydonia oblonga</i> ) leaves [160]                                                                       |
| 2016 | Corn                                                                                                                    | Steep liquor                               | Vanillic acid, <i>p</i> -coumaric<br>acid, ferulic acid, sinapic<br>acid and quercetin | Spain, Portugal, and<br>Italy | Liquid–liquid extraction<br>Solvents: chloroform (56 °C,<br>60 min)<br>Ethyl acetate (25 °C, 45 min)                                                      | A multifunctional extract from<br>corn steep liquor: antioxidant and<br>surfactant activities [161]                                                                                     |
| 2016 | Palm                                                                                                                    | Oil palm empty fruit<br>bunches            | Cellulose with polypro-<br>pylene as biocomposite<br>material                          | Malaysia, Pakistan            | Ultrasonic treatment (40 kHz)<br>solvent: hydrogen peroxide<br>Extraction time: 1–3 h<br>Room temperature                                                 | Autoclave and ultra-sonication<br>treatments of oil palm empty<br>fruit bunch fibers for cellulose<br>extraction and its polypropylene<br>composite properties [73]                     |
| 2016 | Tomatoes                                                                                                                | Seeds and peels                            | Carotenoids/proteins                                                                   | Tunisia and Germany           | Supercritical CO <sub>2</sub> extraction<br>80 °C, 400 bar, 4 g CO <sub>2</sub> /min for 2 h                                                              | Biorefinery cascade processing for<br>creating added value on tomato<br>industrial by-products from Tunisia<br>[82]                                                                     |

**Table 1** (continued)

| Year | Crop          | Waste stream               | Target compounds                                 | Geographical location | Green or sustainable separation approach                                                                                                                                                                                                                                                                                              | References                                                                                                                                                                    |
|------|---------------|----------------------------|--------------------------------------------------|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2016 | Black tea     | Black tea processing waste | Antioxidant and antimicrobial phenolic compounds | Turkey and USA        | Solvent extraction<br>Solvents: H <sub>2</sub> O, ethanol<br>Extraction time: 2 h<br>Temperature: 70 °C                                                                                                                                                                                                                               | Black tea processing waste as a source of antioxidant and antimicrobial phenolic compounds [46]                                                                               |
| 2016 | Rapeseed      | Rapeseed oil cakes         | Protein- and lignin-rich fractions               | France                | Ultrasonic milling and electrostatic separation<br>Solvents: NaOH, diethylether, hexane<br>Extraction time: 5 h<br>Temperature: 60 °C                                                                                                                                                                                                 | Chemical- and solvent-free mechanical fractionation of biomass induced by tribo-electrostatic charging: separation of proteins and lignin [139]                               |
| 2016 | Sunflower     | Seeds                      | Sunflower protein-based ingredients              | USA                   | Review<br>Green pigmentation associated with the interaction of sunflower protein and oxidized chlorogenic acid (CGA) by outlining the sunflower oil and protein meal market, CGA reactions contributing to greening, methods for CGA extraction, and the effect of processing on sunflower protein quality and the greening reaction | Chlorogenic acid oxidation and its reaction with sunflower proteins to form green-colored complexes [162]                                                                     |
| 2016 | Passion fruit | Peels                      | Pectin                                           | Malaysia              | Acidic and enzymatic extraction<br>Citric solution, cellulase<br>Extraction time: 30–120 min<br>Temperature: 35–85 °C                                                                                                                                                                                                                 | Comparison of acidic and enzymatic pectin extraction from passion fruit peels and its gel properties [107]                                                                    |
| 2016 | Red grape     | Pomace                     | Polyphenols and anthocyanin pigments             | Greece                | Ultrasound-assisted extraction<br>(140 W, 37 kHz)<br>Solvent: aqueous glycerol<br>Extraction time: 60 min<br>Temperature: 45 °C                                                                                                                                                                                                       | Development of a green process for the preparation of antioxidant and pigment-enriched extracts from winery solid wastes using response surface methodology and kinetics [74] |

**Table 1** (continued)

| Year | Crop                                     | Waste stream                        | Target compounds             | Geographical location | Green or sustainable separation approach                                                                                                              | References                                                                                                                                                                  |
|------|------------------------------------------|-------------------------------------|------------------------------|-----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2016 | Orange and lemon                         | Fresh and waste peel                | Pectin and D-limonene        | Portugal and Italy    | Microwave<br>Solvent: water<br>Extraction time: 1 h<br>Temperature: 80 °C                                                                             | Eco-friendly extraction of pectin and essential oils from orange and lemon peels [53]                                                                                       |
| 2016 | Coffee                                   | Spent coffee grounds                | Oil                          | China                 | Ultrasonication extraction<br>Solvent: hexane<br>Extraction time: 15–75 min                                                                           | Effect of oil extraction on properties of spent coffee grounds-plastic composites [98]                                                                                      |
| 2016 | Tomato                                   | Waste of tomato paste plants        | Lycopene                     | Iran and Canada       | Microemulsion technique (MET)<br>Solvents: water, saponin; glycerol, surfactant: lycopene<br>Extraction time: 30 min<br>Temperature: 25 °C            | Enhanced lycopene extraction from tomato industrial waste using microemulsion technique: optimization of enzymatic and ultrasound pre-treatments [163]                      |
| 2016 | Red capsicum ( <i>Cap-sicum annuum</i> ) | Processing residue                  | Carotenoids                  | India                 | Enzymatic liquefaction<br>Pectinase, visczyme L, cellulose extraction<br>Time: 1 h<br>Temperature: 60 °C                                              | Enzyme-assisted extraction of carotenoid-rich extract from red capsicum ( <i>Capsicum annuum</i> ) [108]                                                                    |
| 2016 | Rice                                     | Husk                                | Cellulose                    | India                 | Eco-friendly method<br>montmorillonite, LiOH, H <sub>2</sub> O <sub>2</sub><br>Extraction time: 6 h<br>Temperature: 80 °C                             | Extraction of cellulose from agricultural waste using montmorillonite K-10/LiOH and its conversion to renewable energy: biofuel by using <i>Myrothecium gramineum</i> [122] |
| 2016 | Tea (yarrow and rose hip)                | By-products from filter-tea factory | Chlorophylls and carotenoids | Serbia                | Supercritical fluid extraction<br>Extraction time: 5 h<br>Temperature: 40 and 60 °C<br>Pressure: 100–300 bar<br>CO <sub>2</sub> flow rate: 0.194 hl/h | Extraction of minor compounds (chlorophylls and carotenoids) from yarrow-rose hip mixtures by traditional versus green technique [83]                                       |

**Table 1** (continued)

| Year | Crop                                                                 | Waste stream                     | Target compounds                      | Geographical location             | Green or sustainable separation approach                                                                                                                                                                                                                                                                                   | References                                                                                                                                 |
|------|----------------------------------------------------------------------|----------------------------------|---------------------------------------|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| 2016 | Corn, sugarcane, sorghum, pearl millet, green gram, groundnut sesame | Bagasse, stover, stalk and shell | <i>Para</i> -coumaric acid (pCA)      | India and USA                     | Alkaline hydrolysis<br>pH 3, alkali conc.: 0.5–4 M<br>Hydrolysis duration: 4–24 h<br>Sugaring-out for separation of pCA from hydrolysate                                                                                                                                                                                   | Extraction of <i>p</i> -coumaric acid from agricultural residues and separation using 'sugaring out' [116]                                 |
| 2016 | Winery                                                               | Grape wastes and by-products     | Antioxidant compounds and polyphenols | Denmark, China, France and Brazil | Review<br>Conventional (solid liquid extraction, heating, grinding, etc.) and non-conventional (pulsed electric fields, high voltage electrical discharges, pulsed ohmic heating, ultrasounds, microwave-assisted extractions, sub- and supercritical fluid extractions, as well as pressurized liquid extraction) methods | Green alternative methods for the extraction of antioxidant bioactive compounds from winery wastes and by-products: a review [164]         |
| 2016 | 1st to 3rd generation biodiesel feedstocks                           | Mostly microalgae                | Biodiesel                             | Malaysia and Japan                | Review<br>Integration of enzymatic reactors with supercritical fluid technology                                                                                                                                                                                                                                            | Green biodiesel production: a review on feedstock, catalyst, monolithic reactor, and supercritical fluid technology [84]                   |
| 2016 | <i>Jatropha curcas</i> , oil palm                                    | Seeds, empty fruit bunch         | Bio-oil                               | Malaysia                          | Microwave extraction<br>Solvent: water<br>Extraction time: 60–140 min<br>Power: 200–700 W                                                                                                                                                                                                                                  | Green bio-oil extraction for oil crops [54]                                                                                                |
| 2016 | Green tea                                                            | Green tea residue                | Protein                               | The Netherlands                   | Alkaline protein extraction<br>Solvent: NaOH<br>Extraction time: 2 h<br>Temperature: 95 °C                                                                                                                                                                                                                                 | Improving yield and composition of protein concentrates from green tea residue in an agri-food supply chain: effect of pre-treatment [117] |

**Table 1** (continued)

| Year | Crop                                       | Waste stream                          | Target compounds                                   | Geographical location | Green or sustainable separation approach                                                                                                                                                                                                                                                                                                                         | References                                                                                                                            |
|------|--------------------------------------------|---------------------------------------|----------------------------------------------------|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| 2016 | Eucalyptus wood                            | Eucalyptus chips                      | Hemicelluloses                                     | Uruguay               | Green liquor extraction<br>Solvents: water and green liquor ( $\text{Na}_2\text{CO}_3$ , $\text{Na}_2\text{S}$ , and $\text{NaOH}$ )<br>extraction time: 30–150 min<br>temperature: 100–160 °C<br><br>Microfiltration, diafiltration, reverse osmosis<br>$\alpha\text{-Al}_2\text{O}_3$ membranes T1-70 (35 °C)<br>Polyamide composite membranes (35 °C, 60 bar) | Integrated forest biorefineries: green liquor extraction in eucalyptus wood prior to kraft pulping [123]                              |
| 2016 | Watermelons                                | Juice                                 | Lycopene                                           | Brazil                |                                                                                                                                                                                                                                                                                                                                                                  | Integrated membrane separation processes aiming to concentrate and purify lycopene from watermelon juice [140]                        |
| 2016 | Larch wood                                 | Sapwood, heartwood, bark and branches | Phenolic compounds                                 | Slovenia              | Pressurized hot water<br>Extraction time: 30 min<br>Temperature: 100 °C                                                                                                                                                                                                                                                                                          | Isolation of phenolic compounds from larch wood waste using pressurized hot water: extraction, analysis and economic evaluation [165] |
| 2016 | Tomatoes                                   | Pomace                                | Lycopene                                           | Iran                  | Microemulsion technique<br>$\text{H}_2\text{O}$ and surfactants<br>Extraction time: 30 min<br>Temperature: 35 °C                                                                                                                                                                                                                                                 | Microemulsion-based lycopene extraction: effect of surfactants, co-surfactants, and pretreatments [166]                               |
| 2016 | Melons                                     | Rind                                  | Carbohydrates, phenolic compounds, and fatty acids | Spain                 | Solvent extraction<br>Solvent: cyclohexane, ethanol<br>Extraction time: 2 h<br>Microwave radiation: 190 °C, 20 min, 200 W                                                                                                                                                                                                                                        | Microwave heating for the catalytic conversion of melon rind waste into biofuel precursors [167]                                      |
| 2016 | Tomatoes, fungus <i>Blakeslea trispora</i> | Processing waste                      | Lycopene                                           | Greece                | Review<br>Emphasis on final product safety and ecofriendly processing (solvent extraction, SFE, MAE, high-pressure processing, ultrasound, electrical methods)                                                                                                                                                                                                   | Natural origin lycopene and its “green” downstream processing [168]                                                                   |

Table 1 (continued)

| Year | Crop                                                | Waste stream                                              | Target compounds          | Geographical location | Green or sustainable separation approach                                                                                                           | References                                                                                                                                                                                          |
|------|-----------------------------------------------------|-----------------------------------------------------------|---------------------------|-----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2016 | Oranges                                             | Peel                                                      | Pectin                    | Italy                 | Conventional hydrodistillation, MAE, US<br>Solvents: water<br>Extraction time: 5–155 min<br>Temperature: 90–333 °C                                 | Novel configurations for a citrus waste based biorefinery: from solventless to simultaneous ultrasound and microwave-assisted extraction [55]                                                       |
| 2016 | Lemons, olives, onion, red grape, coffee, and wheat | Peel, leaves, solid wastes, pomace, spent filter and bran | Polyphenolic compounds    | Greece                | Ultrasound extraction (140 W, 37 kHz) eutectic mixtures<br>Extraction time: 90 min<br>Temperature: 80 °C                                           | Novel glycerol-based natural eutectic mixtures and their efficiency in the ultrasound-assisted extraction of antioxidant polyphenols from agri-food waste biomass [75]                              |
| 2016 | Potatoes                                            | Peels                                                     | Polyphenolic antioxidants | Greece                | Ultrasound extraction (140 W, 37 kHz)<br>Solvents: ethanol and glycerol<br>Extraction time: 90 min<br>Extraction temperature: 50–80 °C             | Optimization of a green ultrasound-assisted extraction process for potato peel ( <i>Solanum tuberosum</i> ) polyphenols using bio-solvents and response surface methodology [76]                    |
| 2016 | Grapes                                              | Seeds                                                     | Grape seed oil            | Croatia               | Supercritical CO <sub>2</sub><br>Extraction time: 90 min<br>Temperature: 35–64 °C<br>Pressure: 158–441 bar<br>CO <sub>2</sub> flow rate: 1.94 kg/h | Optimization of supercritical CO <sub>2</sub> extraction of grape seed oil using response surface methodology [85]                                                                                  |
| 2016 | <i>Crocus sativus</i>                               | Petals (underutilized bulk agro-waste)                    | Phenolic compounds        | Iran                  | Subcritical water extraction<br>Extraction time: 20–60 min<br>Temperature: 120–160 °C                                                              | Optimization of the subcritical water extraction of phenolic antioxidants from <i>Crocus sativus</i> petals of saffron industry residues: Box–Behnken design and principal component analysis [101] |
| 2016 | Bananas                                             | Peels                                                     | Antioxidants              | Malaysia and Turkey   | Solvent extraction<br>Solvents: acetone, ethanol, hexane, methanol, H <sub>2</sub> O<br>Extraction time: 1–5 h                                     | Optimization of extraction parameters on the antioxidant properties of banana waste [47]                                                                                                            |

**Table 1** (continued)

| Year | Crop                                                       | Waste stream                     | Target compounds                                                                                                                                                                     | Geographical location           | Green or sustainable separation approach                                                                                                        | References                                                                                                                                                                       |
|------|------------------------------------------------------------|----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2016 | Pea vine                                                   | Pea vine waste                   | Potential platform molecules (5-hydroxy furfural; ethanoic acid); sugars (levoglucosenone, rhamnose, xylose, fructose); biopolymer with pectinaceous and starch-like characteristics | United Kingdom                  | Pseudo-subcritical water extraction<br>Temperature: 125–175 °C<br>Pressure: 20–60 bar<br>Flow rate: 1–5 ml/min                                  | Potential utilization of unavoidable food supply chain wastes-valorization of pea vine wastes [6]                                                                                |
| 2016 | Keratin-containing products stored in large waste deposits | Processing waste                 | Keratin                                                                                                                                                                              | Romania                         | Review<br>Keratins solubilization (protected and unprotected methods) followed by dehydro-thermal, physical-type bonding or chemical treatments | Practical ways of extracting keratin from keratinous wastes and by-products: a review [169]                                                                                      |
| 2016 | <i>Taxus baccata</i> L.                                    | Case study based on European yew | 10-deacetylbaecatin III (10-DAB)                                                                                                                                                     | Germany                         | Review<br>Theoretical approach in thermodynamics and process modelling as an alternative process design                                         | Process design for integration of extraction, purification and formulation with alternative solvent concepts [170]                                                               |
| 2016 | Olives                                                     | Olive mill waste water           | Biophenols (hydroxytyrosol and tyrosol)                                                                                                                                              | Italy                           | Liquid-liquid extraction<br>Solvents: <i>n</i> -hexane, EtOAc                                                                                   | Quick assessment of the economic value of olive mill waste water [171]                                                                                                           |
| 2016 | Olives                                                     | Olive mill waste water           | Tyrosol                                                                                                                                                                              | Spain, United Kingdom and Spain | Hydrophobic ionic liquids<br>Solvents: ILs<br>Extraction time: 2 h<br>Temperature: 303–323 K                                                    | Recovery of tyrosol from aqueous streams using hydrophobic ionic liquids: a first step towards developing sustainable processes for olive mill wastewater (OMW) management [133] |
| 2016 | Cupuassu                                                   | Seeds                            | Cupuassu butter (phenolic content/tocopherols/fatty acids)                                                                                                                           | Brazil                          | Supercritical CO <sub>2</sub> extraction<br>Temperature: 50 and 70 °C<br>Pressures: 20–40 MPa                                                   | Supercritical CO <sub>2</sub> extraction of cupuassu butter from defatted seed residue: experimental data, mathematical modeling and cost of manufacturing [86]                  |

**Table 1** (continued)

| Year | Crop                                                                                                 | Waste stream                                                                                                | Target compounds                                                        | Geographical location      | Green or sustainable separation approach                                                                                                                              | References                                                                                                                                                  |
|------|------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2016 | Coffee                                                                                               | Spent coffee grounds                                                                                        | Oil fraction                                                            | Portugal, Brazil, Portugal | Supercritical CO <sub>2</sub><br>Extraction time: 1 h<br>Temperature: 55 °C<br>Pressure: 250 bar<br>Flow rate: 15 kg/h                                                | The green generation of sunscreens: using coffee industrial sub-products [87]                                                                               |
| 2016 | Ginger                                                                                               | Not defined                                                                                                 | Essential oil, phenolics, fibers and phenolic acids                     | France                     | Microwave hydrodiffusion and gravity processing (MHG) and UAE<br>Solvents: water<br>Extraction time: 83 and 90 min<br>Temperature: up to 100 and 50 °C                | Towards a “dry” bio-refinery without solvents or added water using microwaves and ultrasound for total valorization of fruit and vegetable by-products [56] |
| 2016 | Passion fruit                                                                                        | Passion fruit seeds and passion fruit seed cake (the residue from the seed oil production by cold pressing) | Oil and extract with promising antioxidant and antimicrobial activities | Brazil and USA             | SFE, LPE, MAC, UE<br>Solvents: sCO <sub>2</sub> , hexane, ethyl acetate, ethanol, H <sub>2</sub> O<br>Extraction time: 45 min–7 days<br>temperature: room temp.–50 °C | Valorization of passion fruit ( <i>Passiflora edulis</i> sp.) by-products: sustainable recovery and biological activities [88]                              |
| 2016 | Wood                                                                                                 | Broken pallets, crates, and waste timber from building and demolition works                                 | Renewable energy source                                                 | Romania                    | Review<br>Overview of the technical and economic opportunity of using wood waste as a renewable energy source                                                         | Wood waste as a renewable source of energy [172]                                                                                                            |
| 2015 | Plants of spontaneous flora, cultivated plant, and wastes resulted in agricultural and food industry | General bio-derived materials                                                                               | Polyphenols                                                             | Romania                    | Review<br>Microwave-assisted extraction (MAE), supercritical fluid extraction (SFE), and ultrasound-assisted extraction (UAE)                                         | A comparative analysis of the ‘green’ techniques applied for polyphenols extraction from bioresources [173]                                                 |

**Table 1** (continued)

| Year | Crop                                                                                                                    | Waste stream                                                                                | Target compounds                                                    | Geographical location | Green or sustainable separation approach                                                                         | References                                                                                                                                                                                                       |
|------|-------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|---------------------------------------------------------------------|-----------------------|------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2015 | Onion                                                                                                                   | Onion solid wastes                                                                          | Polyphenol- and pigment-enriched extracts with antioxidant activity | Greece                | Ultrasound extraction (140 W, 37 kHz)<br>Extraction time: 60 min<br>Temperature: 45 °C                           | A green ultrasound-assisted extraction process for the recovery of antioxidant polyphenols and pigments from onion solid wastes using Box–Behnken experimental design and kinetics [174]                         |
| 2015 | Six types of plant fibers (bast, leaf, seed, straw, grass, and wood) and animal fibers and regenerated cellulose fibers | Seed (coir) and animals (chicken feather) as they are secondary or made from waste products | Fibers                                                              | Sweden                | Review<br>Dew, stand, cold and warm water, steam, enzyme, mechanical, ultrasound chemical and Surfactant retting | A review of natural fibers used in biocomposites: plant, animal and regenerated cellulose fibers [175]                                                                                                           |
| 2015 | Non edible vegetables                                                                                                   | Seeds                                                                                       | Biodiesel                                                           | Egypt                 | Review                                                                                                           | A review on green trend for oil extraction using subcritical water technology and biodiesel production [102]                                                                                                     |
| 2015 | Neem                                                                                                                    | Neem seed cake (NSC)                                                                        | Neem Protein (NP)                                                   | USA                   | Alkaline extraction<br>Solvents: H <sub>2</sub> O and NaOH<br>Extraction time: 60 min<br>Temperature: 75 °C      | Bio-based polymeric resin from agricultural waste, neem ( <i>Azadirachta indica</i> ) seed cake, for green composites [118]                                                                                      |
| 2015 | Oranges                                                                                                                 | Peel                                                                                        | Essential oil, polyphenols and pectin                               | Algeria and France    | MHG, UAE, MAE<br>Solvents: “in situ” water<br>Extraction time: 25 and 3 min<br>Temperature: 59 °C                | Bio-refinery of orange peels waste: a new concept based on integrated green and solvent free extraction processes using ultrasound and microwave techniques to obtain essential oil, polyphenols and pectin [57] |

**Table 1** (continued)

| Year | Crop                                                                                                   | Waste stream                                                   | Target compounds                                                                                                                    | Geographical location | Green or sustainable separation approach                                                                      | References                                                                                                                                                                 |
|------|--------------------------------------------------------------------------------------------------------|----------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|-----------------------|---------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2015 | Corn, sugarcane, sorghum, soybean, rice, barley, potato, other lignocellulose, vegetable oils, oilseed | By-products (bagasse, straw, cobs, stalks, stover, grass etc.) | Biofuel, 1,3-propanediol, succinic acid, adhesives, solvents, surfactants, ethyl lactate, erucic acid, amylase ethers, among others | Denmark               | Review<br>Focus on integrating sustainability assessment procedures and tools (LCA and evaluation approaches) | Biorefining in the prevailing energy and materials crisis: a review of sustainable pathways for biorefinery value chains and sustainability assessment methodologies [144] |
| 2015 | Agro-industrial products                                                                               | Agro-industrial co-products                                    | Phenolic compounds                                                                                                                  | Brazil                | Solid-state fermentation, even as friendly enzyme-assisted extractions                                        | Biotransformation and bioconversion of phenolic compounds obtained: an overview [176]                                                                                      |
| 2015 | Cashew-nut                                                                                             | Husk                                                           | Natural dyes                                                                                                                        | India                 | Enzyme-assisted extraction cellulase and pectinase<br>Solvent: water<br>Extraction time: 60–180 min<br>pH 9.5 | Cashew-nut husk natural dye extraction using Taguchi optimization: green chemistry approach [109]                                                                          |
| 2015 | Beet                                                                                                   | Sugar beet pulp                                                | Monosaccharides present in hydrolyzed SBP pectin: L-rhamnose, L-arabinose, D-galactose and D-galacturonic acid                      | United Kingdom        | Centrifugal partition chromatography ascending mode, 1000 rpm<br>Mobile phase flow rate: 8 ml/min             | Centrifugal partition chromatography in a biorefinery context: separation of monosaccharides from hydrolyzed sugar beet pulp [141]                                         |
| 2015 | Mangoes ( <i>Mangifera indica</i> L.) and rye grains ( <i>Secale cereals</i> L.)                       | Peels and grains                                               | Alk(en)ylresorcinols (ARs)                                                                                                          | Germany               | Ultrasound-assisted extraction<br>Solvent: dichloromethane<br>Extraction time: 15 s cooled in ice bath        | Development and validation of an HPLC method for the determination of alk(en)ylresorcinols using rapid ultrasound-assisted extraction of mango peels and rye grains [78]   |

**Table 1** (continued)

| Year | Crop                              | Waste stream                    | Target compounds                                                                                                                                                              | Geographical location               | Green or sustainable separation approach                                                                                                                                                                                                             | References                                                                                                                                                                                                   |
|------|-----------------------------------|---------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2015 | Olives                            | Waste from olive oil production | High-added value compounds (polyphenols, fatty acids, coloring pigments (chlorophylls and carotenoids), tocopherols, phytosterols, squalene, volatile and aromatic compounds) | Spain, France, Morocco and Portugal | Review<br>Conventional (solvent, heat, grinding) and non-conventional methodologies (ultrasound, microwaves, sub- and supercritical fluid extractions, pressurized liquid extraction, pulsed electric fields and high voltage electrical discharges) | Emerging opportunities for the effective valorization of wastes and by-products generated during olive oil production process: non-conventional methods for the recovery of high-added value compounds [142] |
| 2015 | Asparagus                         | Dried segments (residues)       | Antioxidant compounds                                                                                                                                                         | China                               | Solid-liquid extraction<br>Solvents: acetone, methanol or ethanol<br>Extraction time: 2 h<br>Temperature: 70 °C                                                                                                                                      | Extraction and analysis of antioxidant compounds from the residues of <i>Asparagus officinalis</i> L. [177]                                                                                                  |
| 2015 | Grapes                            | Skin                            | Anthocyanins                                                                                                                                                                  | Korea                               | Deep eutectic solvents (DESS)<br>Extraction time: 45 min room temperature                                                                                                                                                                            | Highly efficient extraction of anthocyanins from grape skin using deep eutectic solvents as green and tunable media [138]                                                                                    |
| 2015 | Green tea                         | Green tea leaf residue          | HG pectin, RGII pectin, organic acids, cellulose and hemi-cellulose                                                                                                           | The Netherlands                     | Alkaline extraction<br>Solvents: 0.1 M NaOH<br>Extraction time: 2 h (protein), 5 min–24 h (carbohydrates or lignin)<br>Temperature: 95 °C                                                                                                            | How does alkali aid protein extraction in green tea leaf residue: a basis for integrated biorefinery of leaves [119]                                                                                         |
| 2015 | Papaya ( <i>Carica papaya</i> L.) | Processing waste                | Lycopene                                                                                                                                                                      | China                               | Ultrasound extraction (600 W, 40 kHz)<br>Solvents: ethanol/ethyl acetate<br>Extraction time: 15–40 min<br>Temperature: 20–70 °C                                                                                                                      | Optimization of ultrasound-assisted extraction of lycopene from papaya processing waste by response surface methodology [77]                                                                                 |

**Table 1** (continued)

| Year | Crop                                     | Waste stream                                                                                                                           | Target compounds                          | Geographical location | Green or sustainable separation approach                                                                                                         | References                                                                                                                                                             |
|------|------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|-----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2015 | Carrots, green beans, leeks and celeriac | Vegetable waste streams (rejected carrots, carrot steam peels, green beans cutting waste, leek cutting waste and celeriac steam peels) | Pectin                                    | Belgium               | Alcohol insoluble residue<br>Solvents: ethanol and acetone                                                                                       | Pectin characterization in vegetable waste streams: a starting point for waste valorization in the food industry [178]                                                 |
| 2015 | Berries of <i>A. mel-anocarpa</i>        | Black chokeberry wastes                                                                                                                | Antioxidants                              | France                | Extraction-adsorption process<br>Extraction time: 2–8 h<br>Temperature: 22 °C                                                                    | Pilot scale demonstration of integrated extraction-adsorption eco-process for selective recovery of antioxidants from berries wastes [179]                             |
| 2015 | Cashew nuts (CNS)                        | Shells                                                                                                                                 | Anacardic acid                            | Tanzania              | Review<br>Focus on natural anacardic acids from CNS and other plants and their semi-synthetic derivatives as possible lead compounds in medicine | Potential biological applications of bio-based anacardic acids and their derivatives [180]                                                                             |
| 2015 | Soy, sugarcane, tea                      | Soy sauce residues, sugarcane bagasse and tea dregs                                                                                    | Hemicelluloses                            | China                 | Ionic liquid<br>Solvents: ionic liquids<br>Extraction time: 1–5 h<br>Temperature: 70–100 °C                                                      | Quantitative industrial analysis of lignocellulosic composition in typical agro-residues and extraction of inner hemicelluloses with ionic liquid [134]                |
| 2015 | Tomatoes                                 | Processing tomato                                                                                                                      | Nutritional bioactive compounds, lycopene | Italy                 | Biocompatible technology extraction                                                                                                              | Recovery of tomato bioactive compounds through a biocompatible and eco-sustainable new technology for the production of enriched “nutraceutical tomato products” [181] |

**Table 1** (continued)

| Year | Crop                                                                    | Waste stream                                                                                   | Target compounds                                                                                                    | Geographical location    | Green or sustainable separation approach                                                                                                     | References                                                                                                                                |
|------|-------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| 2015 | <i>Citrus sinensis</i> (Hamlin, Valencia, Pera riu and Pera Natal)      | Albedo and flavedo                                                                             | Flavanone                                                                                                           | Brazil                   | Enzymatic process tannase, pectinase and cellulase<br>Extraction time: 30 h<br>Temperature: 40 °C<br>pH 5                                    | Simultaneous extraction and biotransformation process to obtain high bioactivity phenolic compounds from Brazilian citrus residues [110]  |
| 2015 | Sunflower                                                               | Seeds                                                                                          | Oil- (fatty acids and their antioxidant capacities) and water-soluble phase (proteins, carbohydrates and phenolics) | Slovenia                 | Subcritical water extraction<br>Extraction time: 5–120 min<br>Temperature: 60–160 °C<br>Pressure: 30 bar                                     | Simultaneous extraction of oil- and water-soluble phase from sunflower seeds with subcritical water [103]                                 |
| 2015 | Cereals, root crops, fruits, vegetables, oilseeds, meat, dairy products | Food waste                                                                                     | Nutritionally interesting compounds, chemicals and biofuels                                                         | Brazil                   | Review<br>Sub- and supercritical technologies                                                                                                | Sub- and supercritical fluid technology applied to food waste processing [89]                                                             |
| 2015 | Agricultural biomass                                                    | By-products such as durian peel, mango peel, corn straw, rice bran, corn shell and potato peel | Bio-fuel, water soluble sugars and phenolic compounds                                                               | Malaysia and Nigeria     | Review<br>Sub-critical water                                                                                                                 | Sub-critical water as a green solvent for production of valuable materials from agricultural waste biomass: a review of recent work [182] |
| 2015 | Sugarcane                                                               | Sugarcane waste (rind, leaf and bagasse)                                                       | Wax/long-chain aldehydes and <i>n</i> -policosanols (nutraceutical compounds) triterpenoids                         | UK and Brazil            | Supercritical CO <sub>2</sub> (scCO <sub>2</sub> )<br>Extraction time: 4 h<br>Temperature: 50 °C<br>Pressure: 350 bar<br>Flow rate: 40 g/min | Sugarcane waste as a valuable source of lipophilic molecules [183]                                                                        |
| 2015 | Mangoes                                                                 | Peel                                                                                           | Pectin                                                                                                              | Germany and Saudi Arabia | Hot-acid extraction<br>Extraction time: 90 min<br>pH 1.5                                                                                     | The arabinogalactan of dried mango exudate and its co-extraction during pectin recovery from mango peel [184]                             |
| 2015 | Coffee                                                                  | Spent coffee grounds                                                                           | Tannin compounds                                                                                                    | Malaysia                 | Alkaline extraction<br>Solvent: NaOH<br>Extraction time: 30–90 min<br>Temperature: 60–100 °C                                                 | The influence of extraction parameters on spent coffee grounds as a renewable tannin resource [185]                                       |

**Table 1** (continued)

| Year | Crop                            | Waste stream                                          | Target compounds                                                                                                                                         | Geographical location   | Green or sustainable separation approach                                                                                                   | References                                                                                                                                                 |
|------|---------------------------------|-------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2014 | <i>Eucalyptus globulus</i> wood | Trimblings of <i>Eucalyptus globulus</i> wood veneers | Phenolic compounds                                                                                                                                       | Spain                   | Aqueous two-phase extraction<br>PEG 2000 and ammonium sulphate<br>Extraction time: 30–390 min<br>Temperature: 25–65 °C                     | Aqueous two-phase systems for the extraction of phenolic compounds from <i>eucalyptus</i> ( <i>Eucalyptus globulus</i> ) wood industrial wastes [124]      |
| 2014 | Pomegranates                    | By-products after winemaking of pomegranate           | (poly)phenolic compounds                                                                                                                                 | Spain, Mexico and Italy | Extraction with MeOH 70% (v/v) and sonication                                                                                              | Assessment of pomegranate wine lees as a valuable source for the recovery of (poly)phenolic compounds [186]                                                |
| 2014 | Citrus                          | Peel, pulp and seeds                                  | Several value-added products, such as essential oils, pectin, enzymes, single cell protein, natural antioxidants, ethanol, organic acids, and prebiotics | Greece and Sweden       | Review                                                                                                                                     | Biotransformation of citrus by-products into value added products [187]                                                                                    |
| 2014 | Olives                          | Olive solid waste                                     | Natural dye                                                                                                                                              | Tunisia                 | Aqueous extraction in closed flasks<br>Solvent: NaOH<br>Extraction time: 15–120 min<br>Temperature: 30–90 °C                               | Development and optimisation of a non-conventional extraction process of natural dye from olive solid waste using response surface methodology (RSM) [125] |
| 2014 | Coffee                          | Waste coffee grounds                                  | Biodiesel production                                                                                                                                     | United Kingdom          | Suspended in fresh heptane room temperature                                                                                                | Effect of the type of bean, processing, and geographical location on the biodiesel produced from waste coffee grounds [188]                                |
| 2014 | Grapevine and hazelnut          | Grapevine waste and hazelnut skins                    | Polyphenols content                                                                                                                                      | Italy and France        | UAE and MAE<br>Solvents: ethanol, methanol, acetone, butanone, $\beta$ -cyclodextrin<br>Extraction time: 5–40 min<br>Temperature: 20–60 °C | Efficient green extraction of polyphenols from post-harvested agro-industry vegetal sources in Piedmont [58]                                               |
| 2014 | Bamboo                          | Raw bamboo culm                                       | Lignin                                                                                                                                                   | Malaysia                | Review<br>Chemical and steam explosion methods                                                                                             | Extraction and preparation of bamboo fibre-reinforced composites [189]                                                                                     |

**Table 1** (continued)

| Year | Crop                                                                              | Waste stream                                                                                                                 | Target compounds       | Geographical location | Green or sustainable separation approach                                                                                                                                          | References                                                                                                                                                                         |
|------|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|------------------------|-----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2014 | Spruce                                                                            | Spruce sawdust                                                                                                               | Carboxylic acids       | Finland               | Alkaline extraction<br>Solvents: $\text{Na}_2\text{CO}_3$ or $\text{Na}_2\text{S}_2\text{O}_8$<br>Extraction time: 30 min + 30 min;<br>Temperature: 80 °C up to 160 °C and 210 °C | Production of carboxylic acids from alkaline pretreatment byproduct of softwood [120]                                                                                              |
| 2014 | Variety of biomass sources (rapeseed, soybean, palm oil and nonedible feedstocks) | Preferably 2nd–4th generation feedstock (non-edible materials as bagasse, oil waste, microalgae, cyanobacteria and microbes) | Biodiesel              | Malaysia              | Review<br>Supercritical fluid process and catalytic in situ or reactive extraction process                                                                                        | Integration of reactive extraction with supercritical fluids for process intensification of biodiesel production: prospects and recent advances [90]                               |
| 2014 | Cherries                                                                          | Cherry seeds                                                                                                                 | Total phenolic content | Brazil and France     | Pressurized fluid extraction (PFE)<br>Solvent: anhydrous ethanol<br>Extraction time: 2–10 min<br>Temperature: 40–80 °C                                                            | Isolation by pressurized fluid extraction (PFE) and identification using CPC and HPLC/ESI/MS of phenolic compounds from Brazilian cherry seeds ( <i>Eugenia uniflora</i> L.) [190] |
| 2014 | Corn                                                                              | Corn stover                                                                                                                  | Lignin                 | USA                   | Protic ionic liquid (PIL)<br>Extraction time: 24 h<br>Temperature: 90 °C                                                                                                          | Lignin extraction from biomass with protic ionic liquids [135]                                                                                                                     |
| 2014 | Oranges                                                                           | Peel                                                                                                                         | D-limonene             | United Kingdom        | Microwave-assisted extraction<br>200 W, closed vessel<br>Solvent: hexane<br>Temperature: 70–110 °C                                                                                | Microwave-assisted extraction as an important technology for valorising orange waste [59]                                                                                          |
| 2014 | Sweet Limes                                                                       | Peel                                                                                                                         | Antioxidant phenolics  | Pakistan              | Enzymatic treatment<br>Incubation time: 30–120 min<br>Temperature: 30–75 °C<br>pH 5 to 8                                                                                          | Optimization of enzyme-assisted revalorization of sweet lime ( <i>Citrus limetta</i> Risso) peel into phenolic antioxidants [111]                                                  |

**Table 1** (continued)

| Year | Crop                                      | Waste stream                                                                     | Target compounds                                                                          | Geographical location | Green or sustainable separation approach                                                                             | References                                                                                                                                                   |
|------|-------------------------------------------|----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-----------------------|----------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2014 | Artichoke                                 | Artichoke scraps                                                                 | Phenolic compounds                                                                        | Italy                 | Ultrasound-assisted extraction (UAE)<br>Time: 60 min<br>Solvent: water                                               | Phenols and antioxidant activity in vitro and in vivo of aqueous extracts obtained by ultrasound-assisted extraction from artichoke by-products [79]         |
| 2014 | <i>Cachrys pungens</i> Jan (Umbelliferae) | Aerial parts of <i>Cachrys pungens</i> Jan (Umbelliferae)                        | Bioactive compounds                                                                       | Italy                 | Solvent extraction<br>Solvents: methanol<br>Extraction time: 72 h room temperature dark conditions                   | Phytotoxic activity of <i>Cachrys pungens</i> Jan, a Mediterranean species: separation, identification and quantification of potential allelochemicals [191] |
| 2014 | Wheat                                     | Wheat straw                                                                      | Major organic components (e.g., <i>N</i> -heterocycles, fatty acids, phenols and lignins) | Canada                | Fast pyrolysis steel shots 475 °C                                                                                    | Wheat straw biomass: a resource for high-value chemicals [192]                                                                                               |
| 2013 | Cranberries                               | Cranberry juice and pomace                                                       | Polyphenolics                                                                             | Canada and Mexico     | Pilot scale methods<br>Solvents: ethanol<br>Extraction time: 24 h                                                    | Bioactivities of pilot-scale extracted cranberry juice and pomace [48]                                                                                       |
| 2013 | Fruits, vegetables, eggs, shrimp          | Plant residues, industrial and post-harvest materials                            | Carotenoids                                                                               | Mexico                | Review<br>Novel environmentally friendly solvents (e.g., ethyl lactate, bioethanol, vegetal oil, commercial enzymes) | Carotenoids extraction and quantification: a review [193]                                                                                                    |
| 2013 | Tomatoes                                  | Peels                                                                            | Lycopene                                                                                  | Italy                 | Enzymatic-assisted extraction<br>Temperature: 45 and 60 °C<br>pH 4–5 and 9–10.5                                      | Environmentally friendly lycopene purification from tomato peel waste: enzymatic-assisted aqueous extraction [112]                                           |
| 2013 | Coffee                                    | Coffee residue left after the preparation of the brew (spent coffee grounds—SCG) | Polysaccharides                                                                           | Portugal              | Alkali extraction<br>Solvent: H <sub>2</sub> O and 4 M NaOH<br>Extraction time: 3 h<br>Temperature: 20–120 °C        | Extractability and structure of spent coffee ground polysaccharides by roasting pre-treatments [194]                                                         |

Table 1 (continued)

| Year | Crop            | Waste stream                    | Target compounds                                                | Geographical location | Green or sustainable separation approach                                                                                                                                                                                                        | References                                                                                                                         |
|------|-----------------|---------------------------------|-----------------------------------------------------------------|-----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| 2013 | Coffee          | Spent coffee grounds            | Lipids, oil                                                     | Iran                  | Soxhlet, UAE, MAE, SFE<br>Solvents: petroleum benzene and <i>n</i> -hexane<br>Soxhlet: 6 h, boiling temperature<br>UAE: 45 min, ambient conditions<br>MAE: 30 s, 200 and 800 W<br>SFE: 200–250 bar, 40–60 °C, modifier (water, ethanol, hexane) | Extraction of lipids from spent coffee grounds using organic solvents and supercritical carbon dioxide [60]                        |
| 2013 | Forest Industry | Forest residues, including bark | Bioactive molecules                                             | Canada                | Review<br>Green alternatives for the design, formulation, and manufacture of new products with applications in various markets (cosmetics, natural health products, biocides, adhesives, coatings)                                              | Forest extracts, the 4th pathway of the forest biorefinery concept [195]                                                           |
| 2013 | Coffee          | Spent coffee grounds (SCG)      | Lipid fraction                                                  | Portugal and Brazil   | Supercritical carbon dioxide<br>Extraction time: 1 h<br>Temperature: 55 °C<br>Pressure: 250 bar<br>CO <sub>2</sub> flow rate: 15 kg/h                                                                                                           | From coffee industry waste materials to skin-friendly products with improved skin fat levels [91]                                  |
| 2013 | Walnuts         | Green husk                      | Natural compounds with antioxidant and antimicrobial properties | Spain and Portugal    | Solvent extraction<br>Solvents: water, methanol, ethanol<br>Extraction time: 45 min room temperature                                                                                                                                            | Influence of solvent on the antioxidant and antimicrobial properties of walnut ( <i>Juglans regia</i> L.) green husk extracts [49] |
| 2013 | Coffee          | Spent coffee                    | Antioxidants                                                    | Spain                 | Soxhlet, SPE, filter coffeemaker<br>Solvents: water, ethanol, methanol<br>Extraction time: 6–165 min<br>Temperature: 80–100 °C                                                                                                                  | Influence of extraction process on antioxidant capacity of spent coffee [50]                                                       |

**Table 1** (continued)

| Year | Crop                                                  | Waste stream                         | Target compounds                                                                                                     | Geographical location | Green or sustainable separation approach                                                                    | References                                                                                                                                                     |
|------|-------------------------------------------------------|--------------------------------------|----------------------------------------------------------------------------------------------------------------------|-----------------------|-------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2013 | Tomatoes                                              | Peel                                 | Fatty acids                                                                                                          | France                | Depolymerization 1.5 M KOMe overnight treatment at room temperature                                         | Interfacial properties of functionalized assemblies of hydroxy-fatty acid salts isolated from fruit tomato peels [196]                                         |
| 2013 | Coffee                                                | Spent coffee grounds (SCG)           | Polysaccharides                                                                                                      | Portugal              | Microwave superheated water extraction<br>Extraction time: 5 min<br>Temperature: 200 °C                     | Microwave superheated water extraction of polysaccharides from spent coffee grounds [61]                                                                       |
| 2013 | Turkish red pine timber                               | Waste barks                          | Natural dye                                                                                                          | Turkey                | Natural dyestuff extraction machine<br>Solvents: water and ethanol<br>Extraction time: 24 h (osmosis)       | Natural dye extraction from waste barks of Turkish red pine ( <i>Pinus brutia</i> Ten.) Timber and eco-friendly natural dyeing of various textile fibers [126] |
| 2013 | Cotton, jute, flax, hemp, ramie and natural colorants | Wastes and manufacturing by-products | Fibres, polysaccharides, dyes and pigments, polyphenols, oils and other biologically active compounds                | India                 | Review<br>Conventional maceration, soxhlet, MAE, SFE, ultrasonic extraction                                 | Perspectives for natural product based agents derived from industrial plants in textile applications: a review [197]                                           |
| 2013 | Coffee                                                | Spent coffee grounds                 | Natural antioxidants                                                                                                 | Italy                 | Solvent extraction<br>Solvents: H <sub>2</sub> O, ethanol,<br>Extraction time: 30 min<br>Temperature: 60 °C | Recovery of natural antioxidants from spent coffee grounds [198]                                                                                               |
| 2013 | Feijoa fruits                                         | Primarily skin and some flesh        | Total soluble solids (TSS), pectin fibre content, total extractable PP content (TEPC) and total antioxidant activity | New Zealand           | Accelerated solvent extraction<br>Solvents: (acidified) water, ethanol<br>Temperature: 20 or 50 °C          | Utilisation potential of feijoa fruit wastes as ingredients for functional foods [127]                                                                         |
| 2012 | Green tea                                             | Green tea waste                      | Noncaffeine tea polyphenols                                                                                          | China                 | Water bath<br>20 min<br>90 °C                                                                               | A novel way of separation and preparation non-caffeine tea polyphenols from green tea waste [199]                                                              |

**Table 1** (continued)

| Year | Crop      | Waste stream                                              | Target compounds                                 | Geographical location | Green or sustainable separation approach                                                                                                       | References                                                                                                                                  |
|------|-----------|-----------------------------------------------------------|--------------------------------------------------|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| 2012 | Larch     | Larch wood-derived lignocellulosic residue                | Arabinogalactan, pectin, and crystalline glucose | Russia                | Water extraction<br>Extraction time: 2–3 h<br>Temperature: 60–80 °C                                                                            | An eco-friendly technology for polysaccharide production from logging and sawing waste [128]                                                |
| 2012 | Olives    | Olive leaves                                              | Oleuropein                                       | Greece                | SFE and PLE<br>SFE: 30 MPa, 50 °C, 9.6 kg/h<br>PLE: 10.34 MPa, 10 min, 40–150 °C<br>Solvents: H <sub>2</sub> O and EtOH                        | Development of a green extraction procedure with super/subcritical fluids to produce extracts enriched in oleuropein from olive leaves [92] |
| 2012 | Wood      | Wood barks, obtained from pulp mills as industrial wastes | Natural phenolic polymers of tannins and lignin  | France                | Aqueous extraction<br>urea and sulfite used as water-additives<br>Extraction time: 1 h under reflux<br>Temperature: 75 °C                      | Development of green adhesives for fibreboard manufacturing, using tannins and lignin from pulp mill residues [129]                         |
| 2012 | Wheat     | Wheat milling by-products                                 | High quality oil and vitamin E                   | Italy                 | Review<br>Solvent extraction, mechanical pressing or the eco-friendly supercritical carbon dioxide (SC-CO <sub>2</sub> ) extraction technology | Durum wheat by-products as natural sources of valuable nutrients [200]                                                                      |
| 2012 | Tree bark | Waste product from paper pulp industries                  | Antioxidants                                     | Sweden                | SFE, PFE, SLE<br>Solvents: scCO <sub>2</sub> , ethanol, H <sub>2</sub> O<br>Extraction time: 30 min–24 h<br>Temperature: 70–180 °C             | Extraction of antioxidants from spruce ( <i>Picea abies</i> ) bark using eco-friendly solvents [93]                                         |
| 2012 | Timber    | Empty fruit bunches                                       | Fiber                                            | Malaysia              | Perspective paper                                                                                                                              | Fiber resin matrix composites: nature's gift [201]                                                                                          |
| 2012 | Oranges   | Peel                                                      | Essential oil                                    | United Kingdom        | Steam distillation and microwave irradiation<br>SD: water, 1 h<br>MW: 12.5 min, 200 °C, power gradient from 400 to 1200 W                      | <i>p</i> -cymenesulphonic acid: an organic acid synthesized from citrus waste [202]                                                         |

**Table 1** (continued)

| Year | Crop                          | Waste stream                                        | Target compounds                         | Geographical location | Green or sustainable separation approach                                                                                                      | References                                                                                                                                                        |
|------|-------------------------------|-----------------------------------------------------|------------------------------------------|-----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2012 | Black tea                     | Black tea wastes                                    | Pancreatic lipase-inhibiting polyphenols | Japan                 | Hot-compressed water (HCW) ion-exchange water extraction temperature: 100–200 °C                                                              | Polyphenols extracted from black tea ( <i>Camellia sinensis</i> ) residue by hot-compressed water and their inhibitory effect on pancreatic lipase in vitro [203] |
| 2012 | Green tea                     | Green tea waste                                     | Polyphenols                              | China                 | Liquid–liquid extraction<br>Solvents: H <sub>2</sub> O, glyceryl, triacetate, <i>n</i> -butanol, ethyl acetate<br>Extraction time: 12 h + 2 h | Recovery of tea polyphenols from green tea waste by liquid–liquid extraction [204]                                                                                |
| 2012 | Citrus                        | Peels                                               | Polymethoxy flavonoids                   | China                 | Solvent extraction<br>Solvents: methanol and ethanol<br>Extraction time: 1–3 h<br>Temperature: 65–85 °C                                       | Study on the extraction technique of poly-methoxyflavonoids from citrus peels by using response surface methodology [205]                                         |
| 2011 | Coffee                        | Husks                                               | Caffeine                                 | Spain                 | Supercritical CO <sub>2</sub><br>Extraction time: 20 min<br>Temperature: 323 K<br>Pressure: 60 bar<br>CO <sub>2</sub> flow rate: 2–3 g/min    | Extraction of caffeine from Robusta coffee ( <i>Coffea canephora</i> var. Robusta) husks using supercritical carbon dioxide [94]                                  |
| 2011 | Oranges                       | Peel                                                | Essential oils                           | France and Tunisia    | Microwave steam diffusion (MSDf)<br>Extraction time: 12 min<br>Temperature: 100 °C                                                            | Microwave steam diffusion for extraction of essential oil from orange peel: kinetic data, extract's global yield and mechanism [62]                               |
| 2011 | Grape                         | Skins                                               | Anthocyanins                             | Spain                 | Microwave-assisted extraction<br>Solvents: H <sub>2</sub> O, methanol<br>Extraction time: 5–20 min<br>Temperature: 50–100 °C                  | Microwave-assisted extraction of anthocyanins from grape skins [63]                                                                                               |
| 2011 | Tea (green, oolong and black) | Tea residues (green, oolong and black tea residues) | Phenolic compounds                       | Japan                 | Microwave-assisted extraction water under autohydrolytic conditions<br>Extraction time: 2 min<br>Temperature: 110–230 °C                      | Microwave-assisted extraction of phenolic compounds from tea residues under autohydrolytic conditions [64]                                                        |

**Table 1** (continued)

| Year | Crop                                          | Waste stream                                                   | Target compounds                                                                                      | Geographical location | Green or sustainable separation approach                                                                                                            | References                                                                                                                                                |
|------|-----------------------------------------------|----------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|-----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2011 | Sea Buckthorn ( <i>Hippophae rhamnoides</i> ) | By-Products of juice production                                | Flavonoids                                                                                            | France                | Solvent-free microwave hydrodiffusion and gravity (MHG) without addition of solvent or water atmospheric pressure                                   | Solvent free microwave-assisted extraction of antioxidants from sea buckthorn ( <i>Hippophae rhamnoides</i> ) food by-products [206]                      |
| 2011 | Wheat                                         | Wheat straw                                                    | Energy and CO <sub>2</sub> secondary metabolites including fatty acids, wax esters and fatty alcohols | England               | Supercritical CO <sub>2</sub> extraction Temperature: 40–100 °C Pressure: 100–300 bar CO <sub>2</sub> flow rate: 40 g/min                           | Use of green chemical technologies in an integrated biorefinery [95]                                                                                      |
| 2011 | Olives                                        | By-products generated during storage of extra virgin olive oil | Phenolic compounds, hydroxytyrosol, tyrosol, decarboxymethyl oleuropein aglycone, and luteolin        | Italy and Spain       | Solid-liquid and liquid-liquid extraction<br>Solvents: n-hexane, methanol, H <sub>2</sub> O<br>Extraction time: 1 h                                 | Wastes generated during the storage of extra virgin olive oil as a natural source of phenolic compounds [207]                                             |
| 2010 | Tomatoes                                      | Ground tomatoes without seeds                                  | Lycopene                                                                                              | France and Algeria    | Solvent extraction<br>Solvent: D-limonene                                                                                                           | Carotenoid extraction from tomato using a green solvent resulting from orange processing waste [208]                                                      |
| 2010 | Tea plant                                     | Tea stalk and fiber wastes                                     | Caffeine                                                                                              | Turkey                | Supercritical CO <sub>2</sub> ethanol as co-solvent<br>Extraction time: 1–5 h<br>Temperature: 50–70 °C<br>Pressure: 250 bar<br>semi-continuous flow | Effect of ethanol content on supercritical carbon dioxide extraction of caffeine from tea stalk and fiber wastes [96]                                     |
| 2010 | Portuguese elderberry                         | Pomace                                                         | Anthocyanins                                                                                          | Portugal              | Supercritical CO <sub>2</sub> extraction<br>Solvents: CO <sub>2</sub> , water, ethanol<br>Extraction time: 40 min<br>Temperature: 313 K             | Effect of solvent (CO <sub>2</sub> /ethanol/H <sub>2</sub> O) on the fractionated enhanced solvent extraction of anthocyanins from elderberry pomace [97] |
| 2010 | Green tea                                     | Green tea waste                                                | Polyphenols, total catechins, and reducing sugars                                                     | South Korea and USA   | Solvents: cold water (25 °C), hot water (90 °C), sulfuric acid, hydrochloric acid and methanol<br>Extraction time: 20 min<br>250 rpm                | Effects of cellulase from <i>Aspergillus niger</i> and solvent pretreatments on the extractability of organic green tea waste [130]                       |

**Table 1** (continued)

| Year | Crop                                | Waste stream                                  | Target compounds                                                                                     | Geographical location | Green or sustainable separation approach                                                                                                        | References                                                                                                                     |
|------|-------------------------------------|-----------------------------------------------|------------------------------------------------------------------------------------------------------|-----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| 2010 | Tea                                 | Tea waste                                     | Caffeine                                                                                             | Iran                  | Subcritical water extraction<br>Temperature: 100–200 °C<br>Pressure: 20–40 bar<br>water flow rate: 1–4 g/min                                    | Isolation of caffeine from tea waste using subcritical water extraction [104]                                                  |
| 2010 | <i>Citrus sudachi</i>               | Peels                                         | Flavones                                                                                             | Japan                 | Microwave-assisted extraction<br>Solvents: methanol<br>extraction time: 10 to 12 min                                                            | Microwave-assisted extraction and methylation of useful flavones from waste peels of <i>Citrus sudachi</i> [209]               |
| 2010 | Mate ( <i>Ilex paraguariensis</i> ) | Mate residue                                  | Compounds with anti-oxidant properties, such as phenolic acids and methylxanthines, such as caffeine | Brazil                | Solvent extraction<br>Solvent: methanol, H <sub>2</sub> O, ethanol<br>sonication for 15 min room temperature                                    | Phenolic acids and methylxanthines composition and antioxidant properties of mate ( <i>Ilex paraguariensis</i> ) residue [210] |
| 2010 | Rice                                | Rice bran                                     | Phenolic compounds as well as other valuable materials                                               | Japan                 | Subcritical water<br>Preheated oil: 100–180 °C, 10 min<br>Preheated water bath: 180–360 °C, 10 min and 220 °C for 2–30 min                      | Production of phenolic compounds from rice bran biomass under subcritical water conditions [105]                               |
| 2009 | <i>Citrus</i>                       | Peels                                         | Essential oil                                                                                        | France and Algeria    | Microwave hydrodiffusion gravity<br>Extraction time: 15 min<br>atmospheric pressure 500 W                                                       | A new process for extraction of essential oil from citrus peels: microwave hydrodiffusion and gravity [65]                     |
| 2009 | Kiwifruit                           | By-products derived from kiwifruit processing | Phenolics and pectin polysaccharides                                                                 | New Zealand           | Solvent extraction<br>Solvents: water, ethanol<br>Extraction time: 1 h room temperature                                                         | Evaluation of the extraction efficiency for polyphenol extracts from by-products of green kiwifruit juicing [211]              |
| 2009 | Palm                                | Black liquor of oil palm waste                | Lignin                                                                                               | Malaysia              | Solvent extraction<br>Chemical extractions: di-ethyl ether, alcohol-benzene mixture treatment with H <sub>2</sub> SO <sub>4</sub> for 30–45 min | Exploring the antioxidant potential of lignin isolated from black liquor of oil palm waste [212]                               |

**Table 1** (continued)

| Year | Crop                                                 | Waste stream                                                                                                 | Target compounds                                                                              | Geographical location | Green or sustainable separation approach                                                                                                | References                                                                                        |
|------|------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|-----------------------|-----------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| 2009 | Turkish tea plants                                   | Tea stalk and fiber wastes                                                                                   | Caffeine                                                                                      | Turkey                | Supercritical carbon dioxide<br>Extraction time: 1–10 h<br>Temperature: 55–75 °C increasing pressure up to 250 bar semi-continuous flow | Extraction of caffeine from tea stalk and fiber wastes using supercritical carbon dioxide [99]    |
| 2009 | Rice                                                 | Rice bran                                                                                                    | Oil (value-added materials such as amino acids, organic acids, and water-soluble saccharides) | Japan                 | Subcritical water preheated oil bath: 100–180 °C<br>Preheated salt bath: 200–360 °C<br>Reaction time: 5 min                             | Sub-critical water treatment of rice bran to produce valuable materials [106]                     |
| 2009 | Several biomass                                      | Residues rich in ligno-celluloses                                                                            | Bio-based chemicals (e.g., succinic, lactic, fumaric L-malic, L-aspartic acids)               | England               | Review<br>Focus on green chemical conversion of lignin into higher value chemicals                                                      | The integration of green chemistry into future biorefineries [21]                                 |
| 2009 | Apple                                                | Industrially generated apple pomace                                                                          | Antioxidants and poly-phenols                                                                 | Ireland               | Pressurized liquid extraction accelerated solvent extractor static extraction of 5 min<br>Temperature: 75–193 °C                        | The optimization of extraction of antioxidants from apple pomace by pressurized liquids [213]     |
| 2008 | Chicory, citrus, cauliflower, endive, and sugar beet | Plant by-products (chicory roots, citrus peel, cauliflower florets and leaves, endive, and sugar beet pulps) | Pectins                                                                                       | France and Finland    | Enzymatic extraction<br>Extraction time: 4 h<br>Temperature: 50 °C                                                                      | Extraction of green labeled pectins and pectic oligosaccharides from plant by-products [113]      |
| 2008 | Tea (green, oolong, and black)                       | Green, oolong, and black tea residues                                                                        | Polysaccharides, polyphenols, arabinose, galactose, xylose, catechins                         | Japan                 | Microwave heating<br>Solvent: water<br>Temperature: 110–230 °C                                                                          | Microwave heating of tea residue yields polysaccharides, polyphenols, and plant biopolyester [66] |
| 2008 | Plant lipids                                         | Plant oils and other natural lipidic phases                                                                  | Phytosterols, vitamins                                                                        | Czech Republic        | Review<br>Enzymes as efficient natural catalysts                                                                                        | Plant products for pharmacology: application of enzymes in their transformations [114]            |

**Table 1** (continued)

| Year | Crop     | Waste stream   | Target compounds     | Geographical location | Green or sustainable separation approach                                                      | References                                                                                                                                             |
|------|----------|----------------|----------------------|-----------------------|-----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2007 | Broccoli | Broccoli seeds | Natural sulforaphane | China and Australia   | Liquid–liquid and solid-phase extraction<br>Solvents: ethanol, hexane, ethyl acetate          | Separation and purification of sulforaphane from broccoli seeds by solid phase extraction and preparative high-performance liquid chromatography [214] |
| 2006 | Tea      | Tea waste      | Caffeine             | Turkey                | Solid–liquid extraction<br>solvents: hot water and chloroform<br>Temperature: 370 K and 293 K | Solid–liquid extraction of caffeine from tea waste using battery type extractor; process optimization [215]                                            |

components in these matrices, such as water or high molecular weight compounds [39].

The decision concerning the best method to separate the compounds of interest from the raw material is dependent on several aspects, such as the characteristics of the target extracts and raw material (physical–chemical properties), available technology, required purity, selectivity, stability and, more importantly here, the greenness of the whole process. As can be seen in Fig. 5, the most cited techniques in these research papers were based on solvent/maceration (25% of the total), microwave (19%), ultrasonication (14.7%) and supercritical fluid processing (13%), followed by methods using ionic liquids (7%), enzymatic and subcritical fluid treatment (6%), as well as the association of two or more techniques.

According to the literature, the most widespread approaches for separating natural products from a number of matrices are based on liquid–liquid or solid–liquid extraction (LLE and SLE). Several greener alternatives have been proposed by replacing toxic or non-renewable organic solvents, as well as the extraction times. In some cases, solid-phase extractions (SPE) were also carried out and decreased both the amount of solvent and the number of extraction cycles, offering high enrichment factors [39, 40]. Actually, the mass transfer enhancement for SLE has been largely studied and applied, contributing to technology innovation, process intensification and integration, and energy saving, especially important for microwave, ultrasound, and high-pressure processing, for instance [41]. An overview of these techniques and related examples will be discussed in this section.

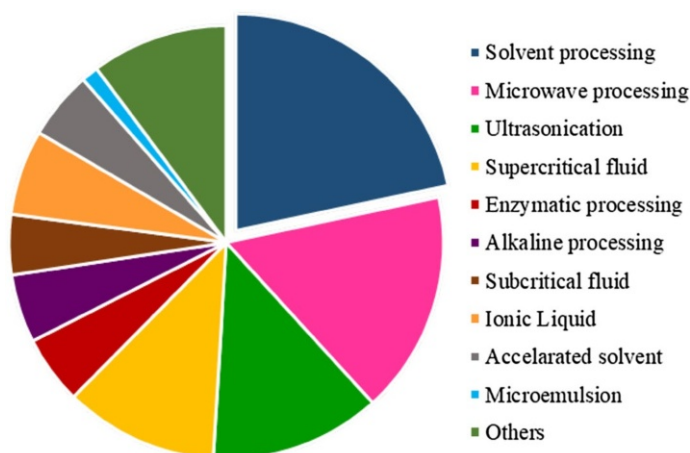


**Fig. 5** Main green and sustainable techniques used to separate natural products from waste described in research papers (ISIS Web of Knowledge, January 2006 to December 2017)

### 3.1 From Conventional Solvent Separation to Enhancement Processing Approaches Over the Last 10 Years

Solvent processing is one of the most traditional methods to remove natural products from bio-derived materials. In this extraction approach, the raw material in adequate size is exposed to different solvents, mostly organic, which remove soluble components of interest. The samples are then usually centrifuged and filtered to separate the solid residue, and the extract is used in this way (as a food supplement or for preparing functional foods, for example) or treated after this step. Solvent extraction is attractive compared to other methods due to low cost and simplicity. However, this method does not always use benign solvents; it frequently requires an evaporation/concentration step for recovery, it usually demands large amounts of solvent and needs a long time to be carried out. Additionally, the possibility of thermal degradation of natural bioactive components is also possible due to the high temperatures used during the extraction process [42]. Despite this, it is largely used in industries, where solvent reuse is of great economic importance. In general, the raw material (in its liquid or solid form) is mixed with a solvent, and the separation kinetic of the target compounds is influenced by parameters such as the solvent ratio, pH, and temperature and, for SLE, the particle size. The solvent should be atoxic, non-flammable and stable at working conditions, ideally renewable and cheap, with low viscosity and an adequate boiling point, allowing for easier solvent removal from the extract/fraction [43]. Recently, several models have been proposed to predict the best solvents to be used in a specific case, which do not only take into account physical descriptors, such as enthalpy of vaporization, dielectric constant, refractive index, boiling point, etc., but also empirical descriptors to evaluate, for instance, intermolecular forces (specific and non-specific solute–solvent interactions, e.g., hydrogen bond donor and/or hydrogen bond acceptor, Van der Waals and ion/dipole forces). Purely theoretical descriptors have been also introduced, offering the most important advantage of not requiring any experiments, as is the case of the model known as quantitative structure property relationship (QSPR), able to predict 127 polarity scales for more than 700 solvents [44].

The solvent selection also depends on the physical–chemical proprieties of the compounds of interest, considering principally the selectivity and greenness degree of the process, aiming at obtaining high recoveries and the integrity of the target compounds. In general, the raw material stays in contact with the solvent for a certain period (from minutes to days), when the soluble compounds are transferred from the matrix to the extractor phase, usually by shaking the system. For SLE, the dispersion of the particles in the solvent is facilitated agitating them, optimizing their contact and accelerating the separation process. Traditionally, solvent treatment is performed at room temperature, although heating can promote higher recoveries to these compounds that are not thermosensitive. In some cases, LLE and SLE can be time-consuming, demanding further purification and concentration steps, which are their main drawbacks [41, 45].

Maceration using green and non-toxic solvents for the separation of natural products from plant-derived waste has been described over the last years (e.g., to remove dyes from quince leaves or catechins, theaflavins, gallic acid, and antioxidants in

general from walnut green husk, cranberry pomace, black tea and banana processing waste). According to these studies, using water, methanol, ethanol or a mixture of them at 70–100 °C can be a low-cost, benign alternative for the recovery of high added-value compounds derived from residual biomass [46–49]. Scaling-up was also studied, whose results showed to be useful in determining industrial process feasibility and the economic value of polyphenols for commercial use, increasing the overall profitability of the cranberry industry [48].

Whenever possible, higher temperatures allow for higher mass transfer in a shorter time with lower energy consumption in general, resulting in better recovery efficiency than conventional systems [50]. As observed in Fig. 5, the second most cited green and sustainable separation process is based on microwave heating and can be considered a non-conventional technique nowadays. Heating is based on non-ionizing electromagnetic waves. Those between 0.915 and 2.45 GHz are used for industrial, scientific and medical applications. The overall principle of heating is rooted in its direct impact with polar materials/solvents and is dependent on ionic conduction and dipole rotation, occurring simultaneously in most cases. The increased temperature can overcome the natural product-matrix interaction caused by Van der Waals forces, dipole attraction, hydrogen bonding of the compounds of interest and active sites in the matrix. Therefore, thermal energy can disrupt both solute–solute and solute–matrix interactions, providing the activation energy required for the desorption process. The mass transfer of the compounds from the raw material to the solvent is also accomplished by convection and diffusion mechanisms, causing the explosion of plant cells and releasing their content into the liquid phase [51].

The eco-friendly removal of essential oils, pectin and polyphenols from a number of plant raw materials mediated by microwave irradiation has been described over the last years, paying special attention to citrus waste [52–66]. In fact, the orange juice processing industry can be considered more than a good case study. This sector is highly wasteful, generating 50% of waste from the total fruit/starting material (e.g., peel, bagasse, seeds and yellow water). Around 20 million tonnes of orange peel per year are produced worldwide, which consist of water (80%) and sugars, cellulose, hemicellulose, pectin and D-limonene (20%). Recently, it was shown using a mathematical model that D-limonene extraction consisted of a two stage diffusion process for a microwave (MW) heating approach: initial extraction from the exterior of cells followed by trans-membrane diffusion. Compared to other conventional extraction methods, it was found that the microwave treatment was more efficient, resulting in a higher overall yield due to the access to a higher amount of D-limonene [59].

The successful microwave-assisted solvent-free modification of pectin derived from citrus waste has also been reported [53]. These approaches not only allow for the separation of the major components of citrus peel, but they also add further value through the production of other high value-added products, such as pectin, D-limonene and a rare form of mesoporous cellulose which are produced in a single step, without added acid [67]. Along these lines, the concept of dry-biorefinery is gaining momentum, since valuable products can be recovered from plant by-products without adding solvents or water, using green processes such as MW [56].

Innovation relies on the separation of the target compounds from raw materials, which are rich in water, achieved without adding solvents or water, illustrating a circular systemic process; i.e., all materials and resources could be reintegrated into the integrated and zero-waste biorefinery [19]. Although very attractive, as expected, the design and use of real MW industrial scale equipment requires additional studies related to safety, corrosion and maintenance intervals [68].

The combination of two or more extraction/concentration methods is quite common in the literature (Table 1). As described by Boukroufa et al. [56], the removal of essential oil, polyphenols and pectin from orange waste was conducted using microwave and ultrasound technology, without adding any solvents. Essential oil separation was performed by Microwave Hydrodiffusion and Gravity (MHG), and thereafter the remaining water of this process was used as a solvent for the subsequent extraction of flavonoids and pectin. For polyphenol separation, ultrasound-assisted extraction (UAE) was used, and response surface methodology (RSM) using the central composite design (CCD) approach was used to investigate the influence of some variables. The CCD revealed that the optimized conditions of ultrasound power and temperature were 0.956 W/cm<sup>2</sup> and 59.83 °C giving a polyphenol yield of 50.02 mg GA/100 g dm, which, compared to conventional extraction, promoted an increase of 30% in the yield. Pectin was extracted by microwave-assisted extraction, resulting in a maximal yield of 24.2% for microwave power of 500 W (3 min), whereas traditional extraction provides 18.32% (120 min). As can be seen, the combination of microwave, ultrasound and recycled water resulted in higher recoveries of the compounds of interest in a shorter time, so that a systemic loop/cycle could be closed using only the resources generated in the plant. This makes the whole process optimized in terms of time, energy savings, cleanliness and reduced amount of waste.

As can be noted, ultrasound has been widely utilized for helping to extract target components from waste plant-derived sources, reducing separation time, solvents, energy consumption and improving the product quality. The effectiveness of ultrasound is attributed to the cavitation phenomenon, assisting the solubilization of the compounds of interest into the solvent, enhancing their removal from the bulk raw material [69]. According to Chemat [70], the ultrasound waves (from 20 kHz to 10 MHz) pass through an elastic medium, inducing a longitudinal displacement of particles resulting in a succession of compression and rarefaction phases in this medium. Every medium has a critical molecular distance and, below this critical point, the liquid remains intact. However, above this distance, the liquid would break down, creating voids (cavitation bubbles) in the liquid. When the size of these bubbles reaches a critical point they collapse, releasing a large amount of energy. The estimated temperature and pressure at this time are estimated at 5000 and 2000 K atmospheres. This creates hotspots that accelerate the chemical reactivity into the medium, generating microjets directed towards the solid surface, also responsible for the general higher effectiveness of this technique, as the high pressure and temperature involved in the process destroy the cell walls of the plant matrices and their content can be released into the medium more easily.

Some new process aiming at agro-industrial waste application in food industries based on ultrasound-assisted extraction of natural products have been reported

[71–79], as is the case of carotenoid separation from pomegranate peels using different vegetable oils as solvents [72]. Sunflower and soybean oils were used as solvents and parameters such as time, temperature, solid/oil ratio used were analyzed considering the yield. It was found that the optimum mild operating conditions were: extraction temperature, 51.5 °C; peel/solvent ratio, 0.10; amplitude level, 58.8%; solvent, sunflower oil. Additionally, a subsequent separation of oil and carotenoids was not necessary, since the pigmented oil can be used as a carotenoid source in different commercial products in this format.

The green recovery of cellulose from oil palm bunches by autoclave-based and ultrasonication pre-treatments were successfully developed to replace the non-green chlorite method [73]. An ultrasonic process with hydrogen peroxide yielded 49% cellulose with 9.13% alpha-cellulose content and 68.7% crystallinity, as compared to 64% cellulose with an autoclave treatment. The cellulose/polypropylene composites generated with high tensile strength, high thermal stability, and low water and diesel sorption showed great potentials for conversion into eco-composite products such as polymeric material insulated cables for high voltage engineering, automotive parts, sports tools and other household or office items.

Another highly cited green and sustainable technique to isolate organic compounds from bio-based waste is based on supercritical fluid processing (Fig. 5). It is widely known that substances at temperatures and pressures near or above their critical points have exceptional solvent characteristics for analytical purposes. These supercritical fluids possess liquid-like solvating and gas-like diffusivity power, and other tuneable properties that can be adjusted varying temperature, pressure and the addition of other components acting as a modifier. Due to its gas-like low viscosity and high diffusivity, the supercritical fluid can easily penetrate into plant materials with a fast mass transfer rate. Possibly, the most important property of supercritical fluids for separation processes is diffusion, obtaining solubility and diffusion good enough to provide quantitative extraction yield [80, 81]. Carbon dioxide (scCO<sub>2</sub>) is the fluid most widely used for extractions, with critical parameters of 31.1 °C and 73 atm (7.39 MPa), at relatively low operating conditions. It behaves as a nonpolar or polarizable solvent and low molar mass alcohols (co-solvents) are often added in small quantities to modify the solvent polarity. Because carbon dioxide can be depressurized to the gaseous state, the solvent is easily removed and supercritical fluid-based separation methods are easily coupled with subsequent analysis. Therefore, scCO<sub>2</sub> provides miscibility to the majority of natural products, availability and low cost, reliably high purity, negligible toxicity, facility for removal and reuse, resulting in many advantages for downstream processing in terms of product purification and/or catalyst recycling [80].

The approach using scCO<sub>2</sub> has been widely used for isolation and purification of chlorophylls, carotenoids, lipids, alkaloids, antioxidants from matrices such as filter tea, spruce bark, tomato and elderberry pomace, grape, passiflora, coffee and cupuassu seed waste [82–99]. In addition to the optimization of the separation process, some studies also aim to evaluate the techno-economic viability of large-scale commercial production, for example, to obtain cupuassu butter from cold-pressed seed residues, also evaluating the influence of thermodynamic and kinetic variables of yield, chemical composition and production costs of the extracts [86]. Optimal

conditions related to extraction kinetics, chemical composition and production costs were 30–35 MPa and 50 °C. It was shown that the phenolic content (0.47–2.82 mg/g) was lower than those commonly found using other methods (20–23 mg/g). The high contents of tocopherols, as well as the unsaturated fatty acids (48%) compared to the saturated fatty acids (52%) present in the butter obtained by scCO<sub>2</sub> demonstrated its great potential as an ingredient in food, pharmaceutical and cosmetic industries. In addition, process intensification for biodiesel production involving supercritical fluids has been reported [84, 90]. Such approaches can allow biodiesel production without any addition of catalyst, or via catalytic in situ or reactive extraction process, combining the extraction and reaction phase together in a single operation unit. These studies also discuss both processes towards the future bio-refinery setup and more efficient use of all waste produced.

The use of fluids different to CO<sub>2</sub> has been described in the literature, but as they are usually organic solvents, they do not show any distinct advantages and often have high critical temperatures. Despite having a very high critical temperature, water shows unique properties in the subcritical region (200–300 °C), as a reduction in dielectric constant (20–30) and density (0.7–0.8 g/cm<sup>3</sup>) compared to water at room temperature, improving its ability to dissolve nonpolar organic and inorganic compounds. Under these conditions, the water dissociation constant into hydroxide and hydrogen ions are more than three orders of magnitude higher, so that near-critical water acts as a self-neutralizing acid or base catalyst, avoiding salt waste generation. Moreover, using subcritical and supercritical water conditions greatly simplifies the product purification step in some cases, since nonpolar products are insoluble in water in lower temperatures [80, 100–106].

Other potential scalable approaches have been described, such as enzymatic [107–114], alkaline [115–120] and based on different types of aqueous media (e.g., cyclodextrins, montmorillonite K-10/LiOH, green liquor) [121–130]; ionic liquids [131–135], deep eutectic solvents [136–138], constituting alternative methods for the recovery of high added-value compounds from agro-industrial waste aiming at obtaining the best analytical, economical and socio-environmental compromise [139–142].

Based on the investigated literature [143], Table 2 summarizes the advantages and disadvantages of the four most cited green and sustainable techniques.

## 4 Conclusions

The establishment of vanguard biorefineries for bioeconomy and circular economy urgently demands innovation in green and sustainable separation for the recovery of natural products from agro-industrial by-products all over the world. Sustainable separation includes the idea of integrated valorization not only in an economic sense, but also strengthens other social and environmental dimensions, from small to large producing scales. According to the literature over the last decade, the number of studies in this field has grown significantly in recent years. New approaches incorporating holistic extraction and/or purification techniques, also integrating systemic chemical transformation through the design and use of renewable materials

**Table 2** Advantages and disadvantages of different technologies that were most cited as green and sustainable techniques over the last 10 years

| Advantages           |                                                                                                                                                                                                                                                                                                                                                                                                                             | Disadvantages                                                                                                                                                                                                   |
|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Solvent processing   | Inexpensive and simplicity; allows for solvent reuse                                                                                                                                                                                                                                                                                                                                                                        | Does not always uses benign solvents; frequently requires an evaporation/concentration step for recovery; usually demands large amounts of solvent and long extraction time; possibility of thermal degradation |
| Microwave processing | Reduced extraction time; reduced solvent usage; improved extraction yield; simple and inexpensive                                                                                                                                                                                                                                                                                                                           | Not good when either target compounds or solvents are non-polar or volatiles                                                                                                                                    |
| Ultrasonication      | Inexpensive, simple and efficient; can reduce the operating temperature (good for thermolabile compounds); can be used with any solvent                                                                                                                                                                                                                                                                                     | Its efficiency may be linked to the nature of plant matrix; the active part of ultrasound inside the extractor is restricted to a zone located in the vicinity of the ultrasonic emitter                        |
| Supercritical fluid  | Moderate extraction temperature (good for thermolabile compounds); rapid mass transfer (larger extraction rate); solubility of a chemical in a supercritical fluid can be manipulated; can eliminate concentration process; the solutes can be separated from supercritical fluids without losing volatiles due to its extreme volatility; additional filtration or centrifugation to remove solid residue is not necessary | Onerous operating conditions                                                                                                                                                                                    |

and optimized processes should combine the best green analytical figures of merit with online evaluation of the whole production chain. These approaches should generate healthier and more efficient products, methods and processes at an affordable and fair cost.

Overall, solvent processing and its modification towards the enhancement of mass transfer to remove the compounds of interest from selected waste have been widely used (25%), also on industrial scales. Alternative extraction or purification methods have shown increasingly more applications, such as for microwave, ultrasonication and supercritical fluid processing. It was shown that a wide range of natural products and their derivatives are used mainly in food (as dyes, aromas, flavors) in medicines or green formulations in agriculture. According to the data available, one paradigmatic case largely studied is the valorization of citrus waste, representing more than 10% of all residues considered in the research papers.

Moreover, an emergent challenging topic is to evaluate biorefinery processing alternatives, i.e., sustainability assessment tools, for example LCA, which include parameters such as feedstock supply (to verify the suitability and adequacy of a potential biomass feedstock for the separation or transformation treatment), process performance (to assess the input–output balance of material and energy flows) and bio-based chemical production [144]. Therefore, the decision about the best separation approach takes into account various fundamental aspects and is based on green and sustainable assessment tools, considering the type of agro-industrial waste (e.g., quantity, periodicity, chemical variability, water amount, distance to the processing unit), the natural target products (chemical quality, purity, humidity, costs etc.) and available technologies.

Using sustainability indicators and tools will be increasingly demanded in this field, contributing to the greenness or sustainability of the whole processing system. The development of a sustainable separation method which provides better recovery efficiency will not only add value to the agro-industrial waste, reducing the overall manufacturing costs and the use of synthetic chemicals, but will also aggregate value to the whole production chain, including its final products. The emergence of bio-based industries is changing the current status of the producing systems, contributing to the current biomass residual losses. Based on the literature, the scenario for future research and innovation in green and sustainable separation for the recovery of agro-industrial waste is truly beginning, bringing together various areas and sectors towards more efficient and circular systems.

**Acknowledgements** The authors wish to thank FAPESP (13/12052-5, 14/50827-1), Capes (2032/2014-07), EPSRC-UK (EP/M028763/1) and Mateus Segatto.

**Open Access** This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

## References

1. Liu J, Mooney H, Hull V, Davis SJ, Gaskell J, Hertel T, Lubchenco J, Seto KC, Gleick P, Kremen C, Li S (2015) Systems integration for global sustainability. *Science* 347:12588320–12588329
2. Kiser B (2016) Circular economy: getting the circulation going. *Nature* 53:443–446
3. Food and Agriculture Organization of the United Nations. World hunger on the rise again, reversing years of progress. <http://www.fao.org/news/story/en/item/902489/icode/>. Accessed 03 Jul 2017
4. Godfray HCJ, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, Pretty J, Robinson S, Thomas SM, Toulmin C (2010) Food security: the challenge of feeding 9 billion people. *Science* 327(5967):812–818
5. United Nations (2015) World Population prospects: the 2015 revision and key findings and advance tables. United Nations, New York. [https://esa.un.org/unpd/wpp/publications/files/key\\_findings\\_wpp\\_2015.pdf](https://esa.un.org/unpd/wpp/publications/files/key_findings_wpp_2015.pdf). Accessed 20 Oct 2016
6. Xia H, Houghton JA, Clark JH, Matharu AS (2016) Potential utilization of unavoidable food supply chain wastes—valorization of pea vine wastes. *ACS Sustain Chem Eng* 4(11):6002–6009
7. Aschemann-Witzel J (2016) Waste not, want not, emit less. *Science* 2978(6284):408–409
8. Perlatti B, Forim MR, Zuin VG (2014) Green chemistry, sustainable agriculture and processing systems: a Brazilian overview. *Chem Biol Technol Agric* 1:5–9
9. Foster-Carneiro L, Berni MD, Dorileo IL, Rostagno MA (2013) Biorefinery study of availability of agriculture residues and wastes for integrated biorefineries in Brazil. *Resour Conserv Recycl* 77:78–88
10. Tuck CO, Perez E, Horvath IT, Sheldon RA, Poliakoff M (2012) Valorization of biomass: deriving more value from waste. *Science* 337:695–699
11. Lin CSK, Pfaltzgraff LA, Herrero-Davila L, Mubofu EB, Abderrahim S, Clark JH, Koutinas AA, Kopsahelis N, Stamatelatos K, Dickson F, Thankappan S, Mohamed Z, Brocklesby R, Luque R (2013) Food waste as a valuable resource for the production of chemicals, materials and fuels. Current situation and global perspective. *Energy Environ Sci* 6(2):426–464
12. Lin CSK, Koutinas AA, Stamatelatos K, Mubofu EB, Matharu AS, Kopsahelis N, Pfaltzgraff LA, Clark JH, Papanikolaou S, Kwan TH, Luque R (2014) Current and future trends in food waste valorization for the production of chemicals, materials and fuels: a global perspective. *Bioprod Biorefin Biofuels* 8(5):686–715
13. Lin CSK, Luque R (2014) Renewable resources and biorefineries. Royal Society of Chemistry, Cambridge
14. Papargyropoulou E, Lozano R, Steinberger J, Wright N, Zb Ujang (2014) The food waste hierarchy as a framework for the management of food surplus and food waste. *J Clean Prod* 76:106–115
15. European Parliament Council. Directive 2008/1/EC of the European Parliament and of the council of 15 January 2008 concerning integrated pollution prevention and control
16. Ragauskas AJ, Williams CK, Davison BH, Britovsek G, Cairney J, Eckert CA, Frederick WJ, Hallett JP, Leak DJ, Liotta CL, Mielenz JR, Murphy R, Templer R, Tschaplinski T (2006) The path forward for biofuels and biomaterials. *Science* 311:484–489
17. Mohan SV, Nikhil GN, Chiranjeevi P, Reddy CN, Rohit MV, Kumar AN, Sarkar O (2016) Waste biorefinery models towards sustainable circular bioeconomy: critical review and future perspectives. *Bioresour Technol* 215:2–12
18. Clark JH, Deswarte F (2015) Introduction to chemicals from biomass, 2nd edn. John Wiley and Sons Ltd., Chichester
19. Zuin VG (2016) Circularity in green chemical products, processes and services: innovative routes based on integrated eco-design and solution systems. *Curr Opin Green Sustain Chem* 2:40–44
20. Anastas PT (1999) Green chemistry and the role of analytical methodology development. *Crit Rev Anal Chem* 29:167–175
21. Clark JH, Deswarte FEI, Farmer TJ (2009) The integration of green chemistry into future biorefineries. *Biofuels Bioprod Biorefin* 3:72–90
22. Chemat F, Avian M, Cravotto G (2012) Green extraction of natural products: concept and principles. *Int J Mol Sci* 13:8615–8627
23. Clark JH, Budarin V, Deswarte FEI, Hardy JJE, Kerton FM, Hunt AJ, Luque R, Macquarrie DJ, Milkowski K, Rodriguez A, Samuel O, Tavener SJ, White RJ, Wilson AJ (2006) Green chemistry and the biorefinery: a partnership for a sustainable future. *Green Chem* 8:853–860

24. Sustainable Chemistry (2017) The Organisation for Economic Co-operation and Development (OECD). Paris. <http://www.oecd.org/chemicalsafety/risk-management/sustainablechemistry.htm> Accessed 07 Jul 2017
25. Sustainable chemistry (2017) Umweltbundesamt, Dessau-Roßlau Germany. <http://www.umweltbundesamt.de/en/topics/chemicals/chemicals-management/sustainable-chemistry#textpart-1>. Accessed 07 Jul 2017
26. Campbell SD (2016) The planner's triangle revisited: sustainability And the evolution of a planning ideal that can't stand still. JAPA 82(4):388–397
27. Hanson JR (2003) Natural products: the secondary metabolites. RSC, Cambridge
28. Armenta S, Garrigues S, de la Guardia M (2015) The role of green extraction techniques in Green Analytical Chemistry. TrAC Trends Anal Chem 71:2–8
29. Zuin VG (2016) Green sample preparation of complex matrices: towards sustainable separations of organic compounds based on the biorefinery concept. Pure Appl Chem 88:29–36
30. Zuin VG, Budarin VL, De Bruyn M, Shuttleworth PS, Hunt AJ, Pluciennik C, Borisova A, Dodson JR, Parker H, Clark J (2017) Polysaccharide-derived mesoporous materials (Starbon®) for sustainable separation of complex mixtures. Faraday Discuss 196:1–9
31. Jessop PG (2016) The use of auxiliary substances (e.g. solvents, separation agents) should be made unnecessary wherever possible and innocuous when used. Green Chem 18:2577–2578
32. Kiss AA, Lange J-P, Schuur B, Brilman DWF, van der Ham AGJ, Kersten SRA (2016) Separation technology: making a difference in biorefineries. Biomass Bioenergy 95:296–309
33. Long Z, Budarin V, Jiajun F, Sloan R, MacQuarrie DJ (2017) Efficient method of lignin isolation using microwave-assisted acidolysis and characterisation of the residual lignin. ACS Sustain Chem Eng 5:3768–3774
34. Abou-Shehada S, Clark JH, Paggola G, Sherwood J (2016) Tunable solvents: shades of green. Chem Eng Process 99:88–96
35. Lachos-Perez D, Brown AB, Mudhoo A, Martinez J, Timko MT, Rostagno MA, Forster-Carneiro T (2017) Applications of subcritical and supercritical water conditions for extraction, hydrolysis, gasification, and carbonization of biomass: a critical review. Biofuels 14:611–626
36. Filly A, Fabiano-Tixier AS, Louis C, Fernandez X, Chemat F (2016) Water as a green solvent combined with different techniques for extraction of essential oil from lavender flowers. C R Chim 19:707–717
37. Chemat F, Strube J (2015) Green extraction of natural products. Wiley, Weinheim
38. Costa ES, Perlatti B, Silva EM, Matos AP, Silva MFGF, Fernandes JB, Zuin VG, Silva CMP, Forim MR (2017) Use of lignins from sugarcane bagasse for assembling microparticles loaded with *Azadirachta indica* extracts for use as neem-based organic insecticides. J Braz Chem Soc 28:126–135
39. Guardia M, Garrides S (2012) Handbook of green analytical chemistry. Wiley, New York
40. Braga EM, Seabra IJ, Dias AMA, Sousa HC (2013) Recent trends and perspectives for the extraction of natural products. In: Rostagno M, Prado J (eds) Natural product extraction. RSC, Cambridge
41. Both S, Strube J, Cravatto G (2015) Mass transfer enhancement for solid–liquid extractions. In: Chemat F, Strube J (eds) Green extraction of natural products: theory and practice. Wiley, Weinheim
42. Kumar K, Yadav AN, Kumar V, Vyas P, Dhaliwal HS (2017) Food waste: a potential bioresource for extraction of nutraceuticals and bioactive compounds. Bioresour Bioprocess 4(1):18
43. Regulation (EC) No 1907/2006 (2006) European Parliament and of the council concerning the registration, evaluation, authorisation and restriction of chemicals (REACH). European Commission, Luxembourg. <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02006R1907-20140410> Accessed 21 Jul 2017
44. Chemat F, Vian MA (2014) Alternative solvents for natural products extraction. Springer, Heidelberg
45. Ibanez E, Cifuentes A (2017) Green extraction techniques: principles, advances and applications. Elsevier, Amsterdam
46. Güçlü Üstündağ Ö, Erşan S, Özcan E, Özcan G, Kayra N, Ekinci FY (2016) Black tea processing waste as a source of antioxidant and antimicrobial phenolic compounds. Eur Food Res Technol 242:1523–1532
47. Toh PY, Leong FS, Chang SK, Khoo HE, Yim HS (2016) Optimization of extraction parameters on the antioxidant properties of banana waste. Acta Sci Pol Technol Aliment 15:65–78

48. Harrison JE, Oomah BD, Diarra MS, Ibarra-Alvarado C (2013) Bioactivities of pilot-scale extracted cranberry juice and pomace. *J Food Process Preserv* 37:356–365
49. Fernández-Agulló A, Pereira E, Freire MS, Valentao P, Andrade PB, González-Álvarez J, Pereira JA (2013) Influence of solvent on the antioxidant and antimicrobial properties of walnut (*Juglans regia* L.) green husk extracts. *Ind Crops Prod* 42:126–132
50. Bravo J, Monente C, Juárez I, De Peña MP, Cid C (2013) Influence of extraction process on antioxidant capacity of spent coffee. *Food Res Int* 50:610–616
51. Clodoveo ML, Dipalmo T, Rizzello CG, Corbo F, Crupi P (2016) Emerging technology to develop novel red winemaking practices: an overview. *Innov Food Sci Emerg Technol* 38:41–56
52. Liu Z, Zu Y, Yang L (2017) A process to preserve valuable compounds and acquire essential oils from pomelo flavedo using a microwave irradiation treatment. *Food Chem* 224:172–180
53. Fidalgo A, Ciriminna R, Carnaroglio D, Tamburino A, Cravotto G, Grillo G, Ilharco L, Pagliaro M (2016) Eco-friendly extraction of pectin and essential oils from orange and lemon peels. *ACS Sustain Chem Eng* 4:2243–2251
54. Zainab H, Nurfatirah N, Norfaezah A, Othman H (2016) Green bio-oil extraction for oil crops. *IOP Conf Ser Mater Sci Eng* 133:12053
55. González-Rivera J, Spepi A, Ferrari C, Duce C, Longo I, Falconieri D, Piras A, Tinè MR (2016) Novel configurations for a citrus waste based biorefinery: from solventless to simultaneous ultrasound and microwave-assisted extraction. *Green Chem* 18:6482–6492
56. Jacotet-Navarro M, Rombaut N, Deslis S, Fabiano-Tixier AS, Pierre FX, Bily A, Chemat F (2016) Towards a “dry” bio-refinery without solvents or added water using microwaves and ultrasound for total valorization of fruit and vegetable by-products. *Green Chem* 18:3106–3115
57. Boukroufa M, Boutekedjiret C, Petigny L, Rakotomanomana N, Chemat F (2015) Bio-refinery of orange peels waste: a new concept based on integrated green and solvent free extraction processes using ultrasound and microwave techniques to obtain essential oil, polyphenols and pectin. *Ultrason Sonochem* 24:72–79
58. Alexandru L, Binello A, Mantegna S, Boffa L, Chemat F, Cravotto G (2014) Efficient green extraction of polyphenols from post-harvested agro-industry vegetal sources in Piedmont. *C R Chim* 17:212–217
59. Attard TM, Watterson B, Budarin VL, Clark JH, Hunt AJ (2014) Microwave-assisted extraction as an important technology for valorising orange waste. *N J Chem* 38:2278–2283
60. Ahangari B, Sargolzaei J (2013) Extraction of lipids from spent coffee grounds using organic solvents and supercritical carbon dioxide. *J Food Process Preserv* 37:1014–1021
61. Passos CP, Coimbra MA (2013) Microwave superheated water extraction of polysaccharides from spent coffee grounds. *Carbohydr Polym* 94:626–633
62. Farhat A, Fabiano-Tixier A-S, El Maataoui M, Maingonnat JF, Romdhane M, Chemat F (2011) Microwave steam diffusion for extraction of essential oil from orange peel: kinetic data, extract's global yield and mechanism. *Food Chem* 125:255–261
63. Liazid A, Guerrero RF, Cantos E, Palma M, Barroso CG (2011) Microwave-assisted extraction of anthocyanins from grape skins. *Food Chem* 124:1238–1243
64. Tsubaki S, Sakamoto M, Azuma J (2010) Microwave-assisted extraction of phenolic compounds from tea residues under autohydrolytic conditions. *Food Chem* 123:1255–1258
65. Bousbia N, Vian MA, Ferhat MA, Meklati BY, Chemat F (2009) A new process for extraction of essential oil from Citrus peels: microwave hydrodiffusion and gravity. *J Food Eng* 90:409–413
66. Tsubaki S, Iida H, Sakamoto M, Azuma J (2008) Microwave heating of tea residue yields polysaccharides, polyphenols, and plant biopolyester. *J Agric Food Chem* 56:11293–11299
67. Balu AM, Budarin V, Shuttleworth PS, Pfaltzgraff LA, Waldron K, Luque R, Clark JH (2012) Valorisation of orange peel residues: waste to biochemicals and nanoporous materials. *Chemsuschem* 5:1694–1697
68. Chemat F, Cravotto G (2013) Microwave-assisted extraction for bioactive compounds: theory and practice. Springer, Heidelberg
69. Preece KE, Hooshyar N, Krijgsman AJ, Fryer PJ, Zuidam NJ (2017) Pilot-scale ultrasound-assisted extraction of protein from soybean processing materials. *J Food Eng* 206:1–12
70. Chemat F, Huma Z, Khan MK (2011) Applications of ultrasound in food technology: processing, preservation and extraction. *Ultrason Sonochem* 18:813–835
71. Bibi I, Sultan A, Kamal S, Nouren S, Safa Y, Jalani K, Sultan M, Atta S, Rehman F (2017) Extraction and quantification of phenolic compounds from *Prunus armeniaca* seed and their role in bio-transformation of xenobiotic compounds. *Korean J Chem Eng* 34(2):392–399

72. Goula AM, Ververi M, Adamopoulou A, Kaderides K (2017) Green ultrasound-assisted extraction of carotenoids from pomegranate wastes using vegetable oils. *Ultrason Sonochem* 34:821–830
73. Abdullah MA, Nazir MS, Raza MR, Wahjoedi BA, Yussof AW (2016) Autoclave and ultra-sonication treatments of oil palm empty fruit bunch fibers for cellulose extraction and its polypropylene composite properties. *J Clean Prod* 126:686–697
74. Trasanidou D, Apostolakis A, Makris DP (2016) Development of a green process for the preparation of antioxidant and pigment-enriched extracts from winery solid wastes using response surface methodology and kinetics. *Chem Eng Commun* 203:1317–1325
75. Mouratoglou E, Malliou V, Makris DP (2016) Novel glycerol-based natural eutectic mixtures and their efficiency in the ultrasound-assisted extraction of antioxidant polyphenols from agri-food waste biomass. *Waste Biomass Valoriz* 7:1377–1387
76. Paleologou I, Vasiliou A, Grigorakis S, Makris DP (2016) Optimisation of a green ultrasound-assisted extraction process for potato peel (*Solanum tuberosum*) polyphenols using bio-solvents and response surface methodology. *Biomass Convers Biorefin* 6:289–299
77. Li A-N, Li S, Xu D-P, Xu X-R, Chen Y-M, Ling W-H, Chen F, Li H-B (2015) Optimization of ultrasound-assisted extraction of lycopene from papaya processing waste by response surface methodology. *Food Anal Methods* 8:1207–1214
78. Geerkens CH, Matejka AE, Carle R, Schweiggert RM (2015) Development and validation of an HPLC method for the determination of alk(en)ylresorcinols using rapid ultrasound-assisted extraction of mango peels and rye grains. *Food Chem* 169:261–269
79. Punzi R, Paradiso A, Fasciano C, Trani A, Faccia M, de Pinto MC, Gambacorta G (2014) Phenols and antioxidant activity in vitro and in vivo of aqueous extracts obtained by ultrasound-assisted extraction from artichoke by-products. *Nat Prod Commun* 9:1315–1318
80. Guardia M, Garrides S (2011) Challenges in green analytical chemistry. RSC, Cambridge
81. Khaw K-Y, Parat M-O, Shaw PN, Falconer JR (2017) Solvent supercritical fluid technologies to extract bioactive compounds from natural sources: a review. *Molecules* 22:1186–1208
82. Kehili M, Schmidt LM, Reynolds W, Zammel A, Zetzi C, Smirnova I, Allouche N, Sayadi S (2016) Biorefinery cascade processing for creating added value on tomato industrial by-products from Tunisia. *Biotechnol Biofuels* 9:261
83. Pavlić B, Đurković AV, Vladić J, Gavarić A, Zeković Z, Tepić A, Vidović S (2016) Extraction of minor compounds (chlorophylls and carotenoids) from yarrow-rose hip mixtures by traditional versus green technique. *J Food Process Eng* 39:418–424
84. Gumba RE, Saallah S, Misson M, Ongkudon CM, Anton A (2016) Green biodiesel production: a review on feedstock, catalyst, monolithic reactor, and supercritical fluid technology. *Biofuel Res J* 3:431–447
85. Jokić S, Bijuk M, Aladić K, Bilić M, Molnar M (2016) Optimisation of supercritical CO<sub>2</sub> extraction of grape seed oil using response surface methodology. *Int J Food Sci Technol* 51:403–410
86. Cavalcanti RN, Albuquerque CLC, Meireles MAA (2016) Supercritical CO<sub>2</sub> extraction of cupuassu butter from defatted seed residue: experimental data, mathematical modeling and cost of manufacturing. *Food Bioprod Process* 97:48–62
87. Marto J, Gouveia LF, Chiari BG, Paiva A, Isaac V, Pinto P, Simões P, Almeida AJ, Ribeiro HM (2016) The green generation of sunscreens: using coffee industrial sub-products. *Ind Crops Prod* 80:93–100
88. Oliveira DA, Angonese M, Gomes C, Ferreira SRS (2016) Valorization of passion fruit (*Passiflora edulis* sp.) by-products: sustainable recovery and biological activities. *J Supercrit Fluids* 111:55–62
89. Viganó J, da Machado APF, Martínez J (2015) Sub- and supercritical fluid technology applied to food waste processing. *J Supercrit Fluids* 96:272–286
90. Lee KT, Lim S, Pang YL, Ong HC, Chong WT (2014) Integration of reactive extraction with supercritical fluids for process intensification of biodiesel production: prospects and recent advances. *Prog Energy Combust Sci* 45:54–78
91. Ribeiro H, Marto J, Raposo S, Agapito M, Isaac V, Chiari BG, Lisboa PF, Paiva A, Barreiros S, Simões P (2013) From coffee industry waste materials to skin-friendly products with improved skin fat levels. *Eur J Lipid Sci Technol* 115:330–336
92. Xynos N, Papaefstathiou G, Psychis M, Argyropoulou A, Aliogiannis N, Skaltsounis AL (2012) Development of a green extraction procedure with super/subcritical fluids to produce extracts enriched in oleuropein from olive leaves. *J Supercrit Fluids* 67:89–93
93. Co M, Fagerlund A, Engman L, Sunnerheim K, Sjöberg PJ, Turner C (2012) Extraction of antioxidants from Spruce (*Picea abies*) bark using eco-friendly solvents. *Phytochem Anal* 23:1–11

94. Tello J, Viguera M, Calvo L (2011) Extraction of caffeine from Robusta coffee (*Coffea canephora* var. Robusta) husks using supercritical carbon dioxide. *J Supercrit Fluids* 59:53–60
95. Budarin VL, Shuttleworth PS, Dodson JR, Hunt AJ, Lanigan B, Marriott R, Milkowski KJ, Wilson AJ, Breeden SW, Fan J, Sin EHK, Clark JH (2011) Use of green chemical technologies in an integrated biorefinery. *Energy Environ Sci* 4:471–479
96. İçen H, Gürü M (2010) Effect of ethanol content on supercritical carbon dioxide extraction of caffeine from tea stalk and fiber wastes. *J Supercrit Fluids* 55:156–160
97. Seabra IJ, Braga MEM, Batista MT, de Sousa HC (2010) Effect of solvent ( $\text{CO}_2/\text{ethanol}/\text{H}_2\text{O}$ ) on the fractionated enhanced solvent extraction of anthocyanins from elderberry pomace. *J Supercrit Fluids* 54:145–152
98. Wu H, Hu W, Zhang Y, Huang L, Zhang J, Tan S, Cai X, Xal Liao (2016) Effect of oil extraction on properties of spent coffee ground–plastic composites. *J Mater Sci* 51:10205–10214
99. İçen H, Gürü M (2009) Extraction of caffeine from tea stalk and fiber wastes using supercritical carbon dioxide. *J Supercrit Fluids* 50:225–228
100. Tian Y, Wang Y, Ma Y, Zhu P, He J, Lei J (2017) Optimization of subcritical water extraction of resveratrol from grape seeds by response surface methodology. *Appl Sci* 7(4):321
101. Ahmadian-Kouchaksaraie Z, Niazmand R, Najafi MN (2016) Optimization of the subcritical water extraction of phenolic antioxidants from *Crocus sativus* petals of saffron industry residues: Box–Behnken design and principal component analysis. *Innov Food Sci Emerg Technol* 36:234–244
102. Abdelmoez W, Ashour E, Naguib SM (2015) A review on green trend for oil extraction using subcritical water technology and biodiesel production. *J Oleo Sci* 64:467–478
103. Ravber M, Knez Ž, Škerget M (2015) Simultaneous extraction of oil- and water-soluble phase from sunflower seeds with subcritical water. *Food Chem* 166:316–323
104. Shalmashi A, Abedi M, Golmohammad F, Eikani MH (2009) Isolation of caffeine from tea waste using subcritical water extraction. *J Food Process Eng* 33:701–711
105. Pourali O, Asghari FS, Yoshida H (2010) Production of phenolic compounds from rice bran biomass under subcritical water conditions. *Chem Eng J* 160:259–266
106. Pourali O, Asghari FS, Yoshida H (2009) Sub-critical water treatment of rice bran to produce valuable materials. *Food Chem* 115:1–7
107. Liew SQ, Chin NL, Yusof YA, Sowndhararajan K (2016) Comparison of acidic and enzymatic pectin extraction from passion fruit peels and its gel properties. *J Food Process Eng* 39:501–511
108. Nath P, Kaur C, Rudra SG, Varghese E (2016) Enzyme-assisted extraction of carotenoid-rich extract from red capsicum (*Capsicum annuum*). *Agric Res* 5:193–204
109. Patil PD, Rao CR, Wasif AI, Anekar SV, Nagla JR (2015) Cashew-nut husk natural dye extraction using Taguchi optimization: green chemistry approach. *J Sci Ind Res (India)* 74:512–517
110. Madeira JV, Macedo GA (2015) Simultaneous extraction and biotransformation process to obtain high bioactivity phenolic compounds from Brazilian citrus residues. *Biotechnol Prog* 31:1273–1279
111. Mushtaq M, Sultana B, Bhatti HN, Asgher M (2014) Optimization of enzyme-assisted revalorization of sweet lime (*Citrus limetta* Risso) peel into phenolic antioxidants. *BioResources* 9:6153–6165
112. Cuccolini S, Aldini A, Visai L, Daglia M, Ferrari D (2013) Environmentally friendly lycopene purification from tomato peel waste: enzymatic-assisted aqueous extraction. *J Agric Food Chem* 61:1646–1651
113. Zykwinska A, Boiffard MH, Kontkanen H, Buchert J, Thibault JF, Bonnin E (2008) Extraction of green labeled pectins and pectic oligosaccharides from plant byproducts. *J Agric Food Chem* 56:8926–8935
114. Zarevúcka M, Wimmer Z (2008) Plant products for pharmacology: application of enzymes in their transformations. *Int J Mol Sci* 9:2447–2473
115. Manzato L, Rabelo LCA, de Souza SM, da Silva CG, Sanches EA, Rabelo D, Mariuba LAM, Simonsen J (2017) New approach for extraction of cellulose from tucumã's endocarp and its structural characterization. *J Mol Struct* 1143:229–234
116. Dhamole PB, Chavan S, Patil RG, Feng H, Bule M, Kinninge P (2016) Extraction of p-coumaric acid from agricultural residues and separation using “sugaring out”. *Korean J Chem Eng* 33:1860–1864
117. Zhang C, Van Krimpen MM, Sanders JPM, Bruins ME (2016) Improving yield and composition of protein concentrates from green tea residue in an agri-food supply chain: effect of pre-treatment. *Food Bioprod Process* 100:92–101

118. Rahman MM, Ho K, Netravali AN (2015) Bio-based polymeric resin from agricultural waste, neem (*Azadirachta indica*) seed cake, for green composites. *J Appl Polym Sci* 132:1–11
119. Zhang C, Sanders JPM, Xiao TT, Bruins ME (2015) How does alkali aid protein extraction in green tea leaf residue: a basis for integrated biorefinery of leaves. *PLoS One* 10:e0133046
120. Mudassar HR, Melin K, Koskinen J (2014) Production of carboxylic acids from alkaline pretreatment byproduct of softwood. *Cellul Chem Technol* 48:835–842
121. Diamanti AC, Igoumenidis PE, Mourtziolos I, Yannakopoulou K, Karathanos VT (2017) Green extraction of polyphenols from whole pomegranate fruit using cyclodextrins. *Food Chem* 214:61–66
122. Das AM, Hazarika MP, Goswami M, Yadav A, Khound P (2016) Extraction of cellulose from agricultural waste using Montmorillonite K-10/LiOH and its conversion to renewable energy: biofuel by using *Myrothecium gramineum*. *Carbohydr Polym* 141:20–27
123. Cabrera MN, Arrosbide MF, Franzoni P, Cassella N (2016) Integrated forest biorefineries: green liquor extraction in eucalyptus wood prior to kraft pulping. *Biomass Convers Biorefin* 6:465–474
124. Xavier L, Freire MS, Vidal-Tato I, González-Álvarez J (2014) Aqueous two-phase systems for the extraction of phenolic compounds from eucalyptus (*Eucalyptus globulus*) wood industrial wastes. *J Chem Technol Biotechnol* 89:1772–1778
125. Elksibi I, Haddar W, Ticha MB, Gharbi R, Mhenni MF (2014) Development and optimisation of a non conventional extraction process of natural dye from olive solid waste using response surface methodology (RSM). *Food Chem* 161:345–352
126. Avinc O, Celik A, Gedik G, Yavas A (2013) Natural dye extraction from waste barks of Turkish red pine (*Pinus brutia* Ten.) timber and eco-friendly natural dyeing of various textile fibers. *Fibers Polym* 14:866–873
127. Sun-Waterhouse D, Wang W, Waterhouse GIN, Wadhwa SS (2013) Utilisation potential of feijoa fruit wastes as ingredients for functional foods. *Food Bioprocess Technol* 6:3441–3455
128. Babkin VA, Malkov YA, Medvedeva EN, Trofimova NN, Ivanova NV (2012) An eco-friendly technology for polysaccharide production from logging and sawing waste. *Russ J Gen Chem* 82:955–962
129. Bertaud F, Tapin-Lingua S, Pizzi A, Navarrete P, Petit-Conil M (2012) Development of green adhesives for fibreboard manufacturing, using tannins and lignin from pulp mill residues. *Cellul Chem Technol* 46:7–8
130. Kim JH, Pan JH, Heo W, Lee H, Kwon EG, Lee H-G, Shin DH, Liu RH, Kim YJ (2010) Effects of cellulase from *Aspergillus niger* and solvent pretreatments on the extractability of organic green tea waste. *J Agric Food Chem* 58:10747–10751
131. Feng X, Song H, Dong B, Yang Y, Yao S (2017) Sequential extraction and separation using ionic liquids for stilbene glycoside and anthraquinones in *Polygonum multiflorum*. *J Mol Liq* 241:27–36
132. Li D, Qian Y, Tian YJ, Yuan SM, Wei W, Wang G (2017) Optimization of ionic liquid-assisted extraction of biflavonoids from *Selaginella doederleinii* and evaluation of its antioxidant and anti-tumor activity. *Molecules* 22(4):586
133. Larriba M, Omar S, Navarro P, García J, Rodríguez F, Gonzalez-Miquel M (2016) Recovery of tyrosol from aqueous streams using hydrophobic ionic liquids: a first step towards developing sustainable processes for olive mill wastewater (OMW) management. *RSC Adv* 6:18751–18762
134. Yao S, Yang Y-Y, Song H, Wang Y, Wan H-Q (2015) Quantitative industrial analysis of lignocellulosic composition in typical agro-residues and extraction of inner hemicelluloses with ionic liquid. *J Sci Ind Res (India)* 74:58–63
135. Achinivu EC, Howard RM, Li G, Gracz H, Henderson WA (2014) Lignin extraction from biomass with protic ionic liquids. *Green Chem* 16:1114–1119
136. Wang T, Jiao J, Gai QY, Wang P, Guo N, Niu LL, Fu YJ (2017) Enhanced and green extraction polyphenols and furanocoumarins from Fig (*Ficus carica* L.) leaves using deep eutectic solvents. *J Pharm Biomed Anal* 145:339–345
137. Liu Y, Chen W, Xia Q, Guo B, Wang Q, Liu S, Liu Y, Li J, Yu H (2017) Efficient cleavage of lignin-carbohydrate complexes and ultrafast extraction of lignin oligomers from wood biomass by microwave-assisted treatment with deep eutectic solvent. *Chemoschem* 10(8):1692–1700
138. Jeong KM, Zhao J, Jin Y, Heo SR, Han SY, Yoo DE, Lee J (2015) Highly efficient extraction of anthocyanins from grape skin using deep eutectic solvents as green and tunable media. *Arch Pharm Res* 38:2143–2152

139. Basset C, Kedidi S, Barakat A (2016) Chemical—and solvent-free mechanophysical fractionation of biomass induced by tribo—electrostatic charging: separation of proteins and lignin. *ACS Sustain Chem Eng* 4:4166–4173
140. Oliveira CS, Gomes FS, Constant LS, Silva LF, Godoy RL, Tonon RV, Cabral LM (2016) Integrated membrane separation processes aiming to concentrate and purify lycopene from watermelon juice. *Innov Food Sci Emerg Technol* 38:149–154
141. Ward DP, Cárdenas-Fernández M, Hewitson P, Ignatova S, Lye GJ (2015) Centrifugal partition chromatography in a biorefinery context: separation of monosaccharides from hydrolysed sugar beet pulp. *J Chromatogr A* 1411:84–91
142. Roselló-Soto E, Koubaa M, Moubarik A, Lopes RP, Saraiva JA, Boussetta N, Grimi N, Barba FJ (2015) Emerging opportunities for the effective valorization of wastes and by-products generated during olive oil production process: non-conventional methods for the recovery of high-added value compounds. *Trends Food Sci Technol* 45:296–310
143. Wang L, Weller CL (2006) Recent advances in extraction of nutraceuticals from plants. *Trends Food Sci Technol* 17(6):300–312
144. Parajuli R, Dalgaard T, Jørgensen U, Adamsen APS, Knudsen MT, Birkved M, Gylling M, Schjöring JK (2015) Biorefining in the prevailing energy and materials crisis: a review of sustainable pathways for biorefinery value chains and sustainability assessment methodologies. *Renew Sustain Energy Rev* 43:244–263
145. Koubaa M, Lepreux L, Barba FJ, Mhemdi H, Vorobiev E (2017) Gas-assisted mechanical expression (GAME) for the selective recovery of lipophilic and hydrophilic compounds from olive kernel. *J Clean Prod* 166:387–394
146. Castro-Puyana M, Marina ML, Plaza M (2017) Water as green extraction solvent: principles and reasons for its use. *Curr Opin Green Sustain Chem* 5:31–36
147. Kusuma HS, Mahfud M (2017) Comparison of conventional and microwave-assisted distillation of essential oil from *Pogostemon cablin* leaves: analysis and modelling of heat and mass transfer. *J Appl Res Med Aromat Plants* 4:55–65
148. Rosa R, Tassi L, Orteca G, Saladini M, Villa C, Veronesi P, Leonelli C, Ferrari E (2017) Process intensification by experimental design application to microwave-assisted extraction of phenolic compounds from *Juglans regia* L. *Food Anal Methods* 10(3):575–586
149. Zhu Y, Song H, Zhang X, Chen C, Zhao S, Ge F, Liu D (2017) Recovery of flavonoids from walnuts de-pellicle wastewater with macroporous resins and evaluation of antioxidant activities in vitro. *J Food Process Eng* 40:1
150. Vardanega R, Carvalho PI, Albarelli JQ, Santos DT, Meireles MAA (2017) Techno-economic evaluation of obtaining Brazilian ginseng extracts in potential production scenarios. *Food Bioprod Process* 101:45–55
151. Chemat F, Rombaut N, Sicaire AG, Meullemiestre A, Fabiano-Tixier AS, Abert-Vian M (2017) Ultrasound-assisted extraction of food and natural products. Mechanisms, techniques, combinations, protocols and applications. A review. *Ultrason Sonochem* 34:540–560
152. Puga H, Alves RC, Costa AS, Vinha AF, Oliveira MBP (2017) Multi-frequency multimode modulated technology as a clean, fast, and sustainable process to recover antioxidants from a coffee by-product. *J Clean Prod* 168:14–21
153. Pavlić B, Naffati A, Hojan T, Vradić J, Zeković Z, Vidović S (2017) Microwave-assisted extraction of wild apple fruit dust—production of polyphenol-rich extracts from filter tea factory by-products. *J Food Process Eng* 40:4
154. Alañón ME, Alarcón M, Marchante L, Díaz-Maroto MC, Pérez-Coello MS (2017) Extraction of natural flavorings with antioxidant capacity from cooperage by-products by green extraction procedure with subcritical fluids. *Ind Crops Prod* 103:222–232
155. Arevalo-Gallegos A, Ahmad Z, Asgher M, Parra-Saldivar R, Iqbal HM (2017) Lignocellulose: a sustainable material to produce value-added products with a zero waste approach—a review. *Int J Biol Macromol* 99:308–318
156. Lozano-Sánchez J, Bendini A, Di Lecce G, Valli E, Gallina Toschi T, Segura-Carretero A (2017) Macro and micro functional components of a spreadable olive by-product (pâté) generated by new concept of two-phase decanter. *Eur J Lipid Sci Technol* 119:1
157. Klinjapo R, Klinjapo R, Areerat K, Areerat K, Sutthirak P, Sutthirak P (2017) Study effect of natural extracts on the antioxidant activity in pork balls. *Br Food J* 119(10):2217–2228

158. Pinela J, Prieto MA, Barreiro MF, Carvalho AM, Oliveira MBP, Curran TP, Ferreira IC (2017) Valorisation of tomato wastes for development of nutrient-rich antioxidant ingredients: a sustainable approach towards the needs of the today's society. *Innov Food Sci Emerg Technol* 41:160–171
159. García-Pérez JS, Robledo-Padilla F, Cuellar-Bermudez SP, Arévalo-Gallegos A, Parra-Saldivar R, Zavala-Yoe R, Ramirez-Mendoza RA, Iqbal HMN (2017) Thermodynamics and statistical correlation between supercritical-CO<sub>2</sub> fluid extraction and bioactivity profile of locally available Mexican plants extracts. *J Supercrit Fluids* 122:27–34
160. Cerempei A, Mureşan EI, Cimpoeşu N, Carp-Cărare C, Rimbu C (2016) Dyeing and antibacterial properties of aqueous extracts from quince (*Cydonia oblonga*) leaves. *Ind Crops Prod* 94:216–225
161. Rodríguez-López L, Vecino X, Barbosa-Pereira L, Moldes AB, Cruz JM (2016) A multifunctional extract from corn steep liquor: antioxidant and surfactant activities. *Food Funct* 7:3724–3732
162. Wildermuth SR, Young EE, Were LM (2016) Chlorogenic acid oxidation and its reaction with sunflower proteins to form green-colored complexes. *Compr Rev Food Sci Food Saf* 15:829–843
163. Amiri-Rigi A, Abbasi S, Scanlon MG (2016) Enhanced lycopene extraction from tomato industrial waste using microemulsion technique: optimization of enzymatic and ultrasound pre-treatments. *Innov Food Sci Emerg Technol* 35:160–167
164. Barba FJ, Zhu Z, Koubaa M, Sant'Ana AS, Orlie V (2016) Green alternative methods for the extraction of antioxidant bioactive compounds from winery wastes and by-products: a review. *Trends Food Sci Technol* 49:96–109
165. Ravber M, Knez Ž, Škerget M (2015) Isolation of phenolic compounds from larch wood waste using pressurized hot water: extraction, analysis and economic evaluation. *Cellulose* 22:3359–3375
166. Amiri-Rigi A, Abbasi S (2016) Microemulsion-based lycopene extraction: effect of surfactants, co-surfactants and pretreatments. *Food Chem* 197:1002–1007
167. Lucas-Torres C, Lorente A, Cabañas B, Moreno A (2016) Microwave heating for the catalytic conversion of melon rind waste into biofuel precursors. *J Clean Prod* 138:59–69
168. Papaioannou EH, Liakopoulou-Kyriakides M, Karabelas AJ (2016) Natural origin lycopene and its “green” downstream processing. *Crit Rev Food Sci Nutr* 56:686–709
169. Rajabinejad H, Bucîşcanu I-I, Maier S-S (2016) Practical ways of extracting keratin from keratinous wastes and by-products: a review. *Environ Eng Manag J* 15:1131–1147
170. Sixt M, Koudous I, Strube J (2016) Process design for integration of extraction, purification and formulation with alternative solvent concepts. *C R Chim* 19:733–748
171. Delisi R, Saiano F, Pagliaro M, Ciriminna R (2016) Quick assessment of the economic value of olive mill waste water. *Chem Cent J* 10:63
172. Suteu D, Zaharia C, Popovici C, Malutan T, Rusu L, Tabacaru L (2016) Wood waste as a renewable source of energy. *Environ Eng Manag J* 15:665–673
173. Talmaciu AI, Volf I, Popa VI (2015) A comparative analysis of the “green” techniques applied for polyphenols extraction from bioresources. *Chem Biodivers* 12:1635–1651
174. Katsampa P, Valsamedou E, Grigorakis S, Makris DP (2015) A green ultrasound-assisted extraction process for the recovery of antioxidant polyphenols and pigments from onion solid wastes using Box–Behnken experimental design and kinetics. *Ind Crops Prod* 77:535–543
175. Ramamoorthy SK, Skrifvars M, Persson A (2015) A review of natural fibers used in biocomposites: plant, animal and regenerated cellulose fibers. *Polym Rev* 55:107–162
176. Madeira Junior JV, Teixeira CB, Macedo GA (2015) Biotransformation and bioconversion of phenolic compounds obtainment: an overview. *Crit Rev Biotechnol* 35:75–81
177. Fan R, Yuan F, Wang N, Gao Y, Huang Y (2015) Extraction and analysis of antioxidant compounds from the residues of *Asparagus officinalis* L. *J Food Sci Technol* 52:2690–2700
178. Christiaens S, Uwibambe D, Uytendaele M, Van Droogenbroeck B, Van Loey AM, Hendrickx ME (2015) Pectin characterisation in vegetable waste streams: a starting point for waste valorisation in the food industry. *LWT Food Sci Technol* 61:275–282
179. Vauchel P, Galván D'Alessandro L, Dhulster P, Nikov I, Dimitrov K (2015) Pilot scale demonstration of integrated extraction–adsorption eco-process for selective recovery of antioxidants from berries wastes. *J Food Eng* 158:1–7
180. Hamad F, Mubofu E (2015) Potential biological applications of bio-based anacardic acids and their derivatives. *Int J Mol Sci* 16:8569–8590
181. Sandei L, Bandini M, Del Rio D (2015) Recovery of tomato bioactive compounds through a biocompatible and eco-sustainable new technology for the production of enriched “nutraceutical tomato products”. *Acta Hort* 1081:345–351

182. Shitu A, Izhar S, Tahir TM (2015) Sub-critical water as a green solvent for production of valuable materials from agricultural waste biomass: a review of recent work. *Glob J Environ Sci Manag* 1:255–264
183. Attard TM, McElroy CR, Rezende CA, Polikarpov I, Clark JH, Hunt AJ (2015) Sugarcane waste as a valuable source of lipophilic molecules. *Ind Crops Prod* 76:95–103
184. Nagel A, Mix K, Kuebler S, Bogner H, Kienzle S, Elstner P, Carle R, Neidhart S (2015) The arabinogalactan of dried mango exudate and its co-extraction during pectin recovery from mango peel. *Food Hydrocoll* 46:134–143
185. Low JH, Rahman WAWA, Jamaluddin J (2015) The influence of extraction parameters on spent coffee grounds as a renewable tannin resource. *J Clean Prod* 101:222–228
186. Mena P, Ascacio-Valdés JA, Gironés-Vilaplana A, Del Rio D, Moreno DA, García-Viguera C (2014) Assessment of pomegranate wine lees as a valuable source for the recovery of (poly) phenolic compounds. *Food Chem* 145:327–334
187. Mamma D, Christakopoulos P (2014) Biotransformation of citrus by-products into value added products. *Waste Biomass Valoriz* 5:529–549
188. Jenkins RW, Stageman NE, Fortune CM, Chuck CJ (2014) Effect of the type of bean, processing, and geographical location on the biodiesel produced from waste coffee grounds. *Energy Fuels* 28:1166–1174
189. Zakikhani P, Zahari R, Sultan MTH, Majid DL (2014) Extraction and preparation of bamboo fibre-reinforced composites. *Mater Des* 63:820–828
190. Oliveira AL, Destandau E, Fougère L, Lafosse M (2014) Isolation by pressurised fluid extraction (PFE) and identification using CPC and HPLC/ESI/MS of phenolic compounds from Brazilian cherry seeds (*Eugenia uniflora* L.). *Food Chem* 145:522–529
191. Araniti F, Marrelli M, Lupini A, Mercati F, Statti GA, Abenavoli MR (2014) Phytotoxic activity of *Cachrys pungens* Jan, a Mediterranean species: separation, identification and quantification of potential allelochemicals. *Acta Physiol Plant* 36:1071–1083
192. Schnitzer M, Monreal CM, Powell EE (2014) Wheat straw biomass: a resource for high-value chemicals. *J Environ Sci Heal Part B* 49:51–67
193. Arvayo-Enríquez H, Mondaca-Fernández I, Gortáñez-Moroyoqui P, López-Cervantes J, Rodríguez-Ramírez R (2013) Carotenoids extraction and quantification: a review. *Anal Methods* 5:2916
194. Simões J, Nunes FM, Domingues MR, Coimbra MA (2013) Extractability and structure of spent coffee ground polysaccharides by roasting pre-treatments. *Carbohydr Polym* 97:81–89
195. Royer M, Kinuani N, Diouf PN (2013) Forest extractives, the 4th pathway of the Forest biorefinery concept. *J FOR* 3:32–41
196. Fameau A-L, Gaillard C, Marion D, Bakan B (2013) Interfacial properties of functionalized assemblies of hydroxy-fatty acid salts isolated from fruit tomato peels. *Green Chem* 15:341–346
197. Shahid-ul-Islam Shahid M, Mohammad F (2013) Perspectives for natural product based agents derived from industrial plants in textile applications—a review. *J Clean Prod* 57:2–18
198. Panusa A, Zuorro A, Lavecchia R, Marrosu G, Petrucci R (2013) Recovery of natural antioxidants from spent coffee grounds. *J Agric Food Chem* 61:4162–4168
199. Tan HP, Li HP, Song H, Xu WP, Guan C, Ran LP (2012) A novel way of separation and preparation noncaffeine tea polyphenols from green tea waste. *Adv Mater Res* 550–553:1875–1880
200. Durante M, Lenucci MS, Rescio L, Mita G, Caretto S (2012) Durum wheat by-products as natural sources of valuable nutrients. *Phytochem Rev* 11:255–262
201. Liew MS, Shamsuddin AH, Yew GZ (2011) Fiber resin matrix composites: nature's gift. *WIT Trans Ecol Environ* 148:131–140
202. Clark JH, Fitzpatrick EM, Macquarrie DJ, Pfaltzgraff LA, Sherwood J (2012) *p*-Cymenesulphonic acid: an organic acid synthesised from citrus waste. *Catal Today* 190:144–149
203. Yuda N, Tanaka M, Suzuki M, Asano Y, Ochi H, Iwatsuki K (2012) Polyphenols extracted from black tea (*Camellia sinensis*) residue by hot-compressed water and their inhibitory effect on pancreatic lipase in vitro. *J Food Sci* 77:H254–H261
204. Li ZJ, Wei Z, Xiao W, Wang J, Wu FA (2012) Recovery of tea polyphenols from green tea waste by liquid–liquid extraction. *Adv Mater Res* 396–398:1592–1595
205. Li CP, Wang LL, Jin ZS, Tang L (2012) Study on the extraction technique of poly-methoxyflavonoids from citrus peels by using response surface methodology. *Adv Mater Res* 560–561:544–549
206. Périno-Issartier S, Zill-e-Huma Abert-Vian M, Chemat F (2011) Solvent free microwave-assisted extraction of antioxidants from sea buckthorn (*Hippophae rhamnoides*) food by-products. *Food Bioprocess Technol* 4:1020–1028

207. Lozano-Sánchez J, Giambanelli E, Quirantes-Piné R, Cerretani L, Bendini A, Segura-Carretero A, Fernández-Gutiérrez A (2011) Wastes generated during the storage of extra virgin olive oil as a natural source of phenolic compounds. *J Agric Food Chem* 59:11491–11500
208. Chemat-Djenni Z, Ferhat MA, Tomao V, Chemat F (2010) Carotenoid extraction from tomato using a green solvent resulting from orange processing waste. *J Essent Oil Bear Plants* 13:139–147
209. Tsukayama M, Sasaki T, Yamamoto K, Kawamura Y, Ichikawa R (2010) Microwave-assisted extraction and methylation of useful flavones from waste peels of citrus sudachi. *Nippon Shokuhin Kagaku Kogaku Kaishi* 57:427–433
210. Vieira MA, Maraschin M, Pagliosa CM, Podestá R, De Simas KN, Rockenbach II, Amboni RDMC, Amante ER (2010) Phenolic acids and methylxanthines composition and antioxidant properties of mate (*Ilex paraguariensis*) residue. *J Food Sci* 75:C280–C285
211. Sun-Waterhouse D, Wen I, Wibisono R, Melton LD, Wadhwa S (2009) Evaluation of the extraction efficiency for polyphenol extracts from by-products of green kiwifruit juicing. *Int J Food Sci Technol* 44:2644–2652
212. Bhat R, Khalil HPSA, Karim AA (2009) Exploring the antioxidant potential of lignin isolated from black liquor of oil palm waste. *C R Biol* 332:827–831
213. Wijngaard H, Brunton N (2009) The optimization of extraction of antioxidants from apple pomace by pressurized liquids. *J Agric Food Chem* 57:10625–10631
214. Liang H, Li C, Yuan Q, Vriesekoop F (2007) Separation and purification of sulforaphane from broccoli seeds by solid phase extraction and preparative high-performance liquid chromatography. *J Agric Food Chem* 55:8047–8053
215. Senol A, Aydin A (2006) Solid-liquid extraction of caffeine from tea waste using battery type extractor: process optimization. *J Food Eng* 75:565–573



## Mat Compression Measurements During Low-Density Particleboard Manufacturing

Piotr Boruszewski, Piotr Borysiuk, Mariusz Mamiński, and Joanna Czechowska

Faculty of Wood Technology, Warsaw University of Life Sciences - SGGW, Nowoursynowska Str. 159, 02-776 Warsaw, Poland

*This study regards the effect of technological aspects on mat compression during the manufacturing of low-density particleboards made of two low density species - i.e. poplar and pine. Using these materials, three-layer low-density particleboards (500 kg/m<sup>3</sup>) were prepared. Three series were manufactured: (1) neat pine, (2) poplar-pine (face layer and core layer, respectively) and (3) neat poplar boards. Measurements of real-time variations in mat core temperature, pressure, and mat thickness allowed for the analysis of the mat compaction. Selected mechanical properties (modulus of rupture, modulus of elasticity, and internal bonding) of the manufactured particleboards were determined. Raw material of lower density used for particleboard manufacturing required either prolonged pressing time or more intense heat transfer into the mat core. The highest strength values were obtained for the poplar-pine particleboards.*

BioResources 11(3), 6909-6919. (Open Access)

DOI: [10.15376/biores.11.3.6909-6919](https://doi.org/10.15376/biores.11.3.6909-6919)

The Paper Industry Technical Association (PITA) is an independent organisation which operates for the general benefit of its members – both individual and corporate – dedicated to promoting and improving the technical and scientific knowledge of those working in the UK pulp and paper industry. Formed in 1960, it serves the Industry, both manufacturers and suppliers, by providing a forum for members to meet and network; it organises visits, conferences and training seminars that cover all aspects of papermaking science. It also publishes the prestigious journal *Paper Technology* and the *PITA Annual Review*, both sent free to members, and a range of other technical publications which include conference proceedings and the acclaimed *Essential Guide to Aqueous Coating*.

## Mat Compression Measurements During Low-Density Particleboard Manufacturing

Piotr Boruszewski,\* Piotr Borysiuk, Mariusz Mamiński, and Joanna Czechowska

This study regards the effect of technological aspects on mat compression during the manufacturing of low-density particleboards made of two low density species - *i.e.* poplar and pine. Using these materials, three-layer low-density particleboards (500 kg/m<sup>3</sup>) were prepared. Three series were manufactured: (1) neat pine, (2) poplar-pine (face layer and core layer, respectively) and (3) neat poplar boards. Measurements of real-time variations in mat core temperature, pressure, and mat thickness allowed for the analysis of the mat compaction. Selected mechanical properties (modulus of rupture, modulus of elasticity, and internal bonding) of the manufactured particleboards were determined. Raw material of lower density used for particleboard manufacturing required either prolonged pressing time or more intense heat transfer into the mat core. The highest strength values were obtained for the poplar-pine particleboards.

*Keywords:* Particleboard; Low density; Poplar; Pine; Pressing process; Raw material

*Contact information:* Faculty of Wood Technology, Warsaw University of Life Sciences - SGGW, Nowoursynowska Str. 159, 02-776 Warsaw, Poland; \*Corresponding author: [piotr\\_boruszewski@sggw.pl](mailto:piotr_boruszewski@sggw.pl)

### INTRODUCTION

The development of the furniture industry is connected with the implementation of innovative solutions in particleboard technology. There is a deficiency of wood results in the intensified research on alternative raw material resources (Papadopoulos *et al.* 2002; Abdul Khalil *et al.* 2010; Nicewicz *et al.* 2012; Gatani *et al.* 2013; Varanda *et al.* 2013). Waste wood, annual crops, and fast-growing species have recently become valuable raw materials for particleboard manufacturers (Strauss *et al.* 2004; West 2006; Carle and Holmgren 2009). To adopt alternative low-density materials for existing technology, the proper analysis and characterization of the variations in process parameters as well as the phenomena taking place in the mat are required. One of the most important parameters is mat compression ratio.

Switching to non-classical raw materials allows maintenance of the growth and competitiveness of the wood-based panel industry. The use of annual crops and low-density fast-growing species in manufacturing of novel types of composites for the furniture industry has increased in the last decade. The increase comes from the market needs, and introduction of new materials to the market is most welcomed (Sellers *et al.* 1993; Wang and Sun 2002; Xu *et al.* 2004; Meinlschmidt *et al.* 2008). The main advantage of new types of panels over the old ones is a lowered density. It is known from the literature that the density of woody material affects the compression ratio of a mat, which subsequently determines the properties of the final product (Buschbeck *et al.* 1961a,b; Moslemi 1974; Grigoriu 1981; Clad 1982; Xu *et al.* 2004; Haelvoet and Medved 2009). The reduced panel density renders a decrease in mechanical strength.

Thus, pressing the mats formed from low-density chips requires altered process parameters (*i.e.*, pressure and temperature regimes) (Moslemi 1974). An effectively modified pressing scheme (temperature, pressure, and time) should provide a proper cross-sectional density profile and expected mechanical performance, while overall panel density is decreased. It is recognized that reduced pressure imposes a prolonged pressing time and yields more uniform density profile. On the other hand, an increased pressure results in a higher compression ratio for face layers and a lower one for the core layers of a panel (Keylwerth 1958; Plath 1971; Wong *et al.* 1999; Dunky 2001).

Phenomena occurring during pressing of particleboards play a crucial role in their manufacturing, as the applied regimes determine the final properties of the product. Thus, better recognition and description of variables makes easier optimization of processes possible and, as a result, minimizes production costs, so that implementation of new technologies or products becomes easier.

It is commonly agreed that pressing is necessary for the compression of a mat to the target thickness and for the proper development of adhesive interactions between wood particles. The compression is primarily affected by (1) the pressure and amount of binder, which determine the contact area between chips; and (2) the temperature governing the curing of the binder and development of bondlines (Moslemi 1974). Other factors affecting mat compression process include time, press closing rate, target density of the product, type and amount of binder, as well as characteristics of the material subjected to bonding: chip dimensions, density, and moisture content.

Although there are numerous reports regarding the effect of the factors mentioned above on the compression process during manufacturing of wood-based composites (Kelly 1977; Steffen *et al.* 1999; Miyamoto *et al.* 2002; Dai *et al.* 2004; Nemli *et al.* 2007; Cai *et al.* 2009), none of them considers the compression of low-density particleboards. Therefore, in this paper, some aspects of low-density mat compression are discussed. Particleboards made of softwood, hardwood, and their mixtures are compared.

## EXPERIMENTAL

A total of 15 three-layer particleboards of density 500 kg/m<sup>3</sup> with dimensions of 320 x 320 x 18 mm<sup>3</sup> were made. 5 panels were prepared in each series: (1) industrial poplar chips, (2) industrial pine chips, and (3) both poplar (face layers) and pine (core layer) chips. The moisture contents were as follows: poplar 3.5% (face layer) and 2.9% (core layer); pine 5.0% (face layer) and 4.5% (core layer). Wood densities were 450 and 520 kg/m<sup>3</sup>, respectively, for poplar and pine.

A commercial urea-formaldehyde (UF) resin was used as a binder, hardened with 10% aqueous ammonium sulfate solution (3% for face layers, 4% for core layer (based on resin solids). Glue rates were as follows: face layer 12% and core layer 8%. A paraffin emulsion was used as a hydrophobic agent (1% based on dry wood).

All the mats were cold pre-pressed at 0.5 MPa pressure for 30 s. The difference in bulk density of pine and poplar chips, resulted in variations in the final thickness of the mats subjected to hot-pressing. In order to achieve comparable board density, the weight of the respective mats was constant. Hot pressing parameters were adopted from industrial conditions and from the literature (Moslemi 1974). Maximum unit pressure upon board pressing was set at 2.5 MPa, however the true momentary pressure was computer-controlled as follows: (1) increased until target thickness is achieved and then

(2) reduced. Other hot pressing parameters were as follows: platen temperature of 180 °C, pressing factor 18 s/mm, press closing rate 2 mm/s, time 324 s. The mat compression process was performed using a computer-controlled press.

Variables (mat core temperature with accuracy  $\pm 0.01$  °C, pressure with accuracy  $\pm 0.01$  MPa, and mat thickness with accuracy  $\pm 0.01$  mm) were monitored in real time throughout the pressing process for each batch, using the computer controller. Temperature measurement inside the mat was carried out using a Fe-CuNi thermocouple, fixed in the mat core during its formation.

Prior to testing, the boards were conditioned at  $20 \pm 2$  °C and  $65 \pm 5\%$  RH for seven days. The modulus of rupture (MOR) and modulus of elasticity (MOE) were tested according to European standard EN 310 (1993), and the internal bond strength (IB) was determined according to European standard EN 319 (1993). All mechanical tests were conducted using an electromechanical testing machine Instron model 3369 (Instron Corp., Norwood, MA). Ten specimens were tested in each series. Density profiles were measured on an X-ray density analyzer GreCon Da-X (Fagus-Grecon Greten GmbH & Co. KG, Alfeld-Hannover, Germany) at a scanning speed of 0.5 mm/s.

Statistical analysis was performed using STATISTICA version-12 software (StatSoft, Inc., Tulsa, OK). Statistical analysis for all stages of the research was performed at a significance level of 0.05.

## RESULTS AND DISCUSSION

As Fig. 1 indicates, the compression processes can be differentiated for the respective series of boards. The temperature (Fig. 1a), mat thickness curves (Fig. 1b), and pressure (Fig. 1c) were varied. Assuming a constant press-closing rate (2 mm/s), the main factor determining the locus and shape of the pressure curve was the mat thickness, which was affected by the properties of the material. The obtained initial uncompressed mat thickness was as follows: 80 mm for poplar ( $450 \text{ kg/m}^3$ ), 60 mm for pine ( $520 \text{ kg/m}^3$ ), and 70 mm for the mixed poplar-pine mats. The different initial mat thickness comes from the variable chip bulk density. We assumed manufacturing boards of same density, so in case of a “heavier” material, its amount was smaller.

The shortest time (21 s) and the lowest pressure (1.38 MPa) necessary for the mat to be compressed to the target thickness (18 mm) were observed for pine, while for poplar mat, the respective values were 38 s and 1.57 MPa, while midway values were recorded for the mixed poplar-pine mats, *i.e.*, 26 s and 1.61 MPa, respectively. Despite the differences in mat compressing (Fig. 1b), their pressure curves were similar (Fig. 1c). It should be noted that at the moment the mat reached the target thickness (18 mm), the initial temperature was still observed in the core layer. The temperature in the core began to increase gradually but not before the 40<sup>th</sup> second of the pressing process. Unlike the poplar and poplar-pine boards, the temperature increased above 80 °C in the pine mat core and then slowed, which might be caused by the evaporation of the volatile organic compounds present in pine wood (McDonald *et al.* 1999a,b).

As Fig. 1a indicates, the target temperature of 100 °C in the mat core was achieved after 200, 135, and 143 s, respectively, for poplar, pine, and poplar-pine boards. It was also found that when the mat core temperature reached 100 °C, at which partial plasticizing of the chips occurred, the pressure required for mat thickness control

remained at a low level of approximately 1 MPa and was comparable regardless of the series.

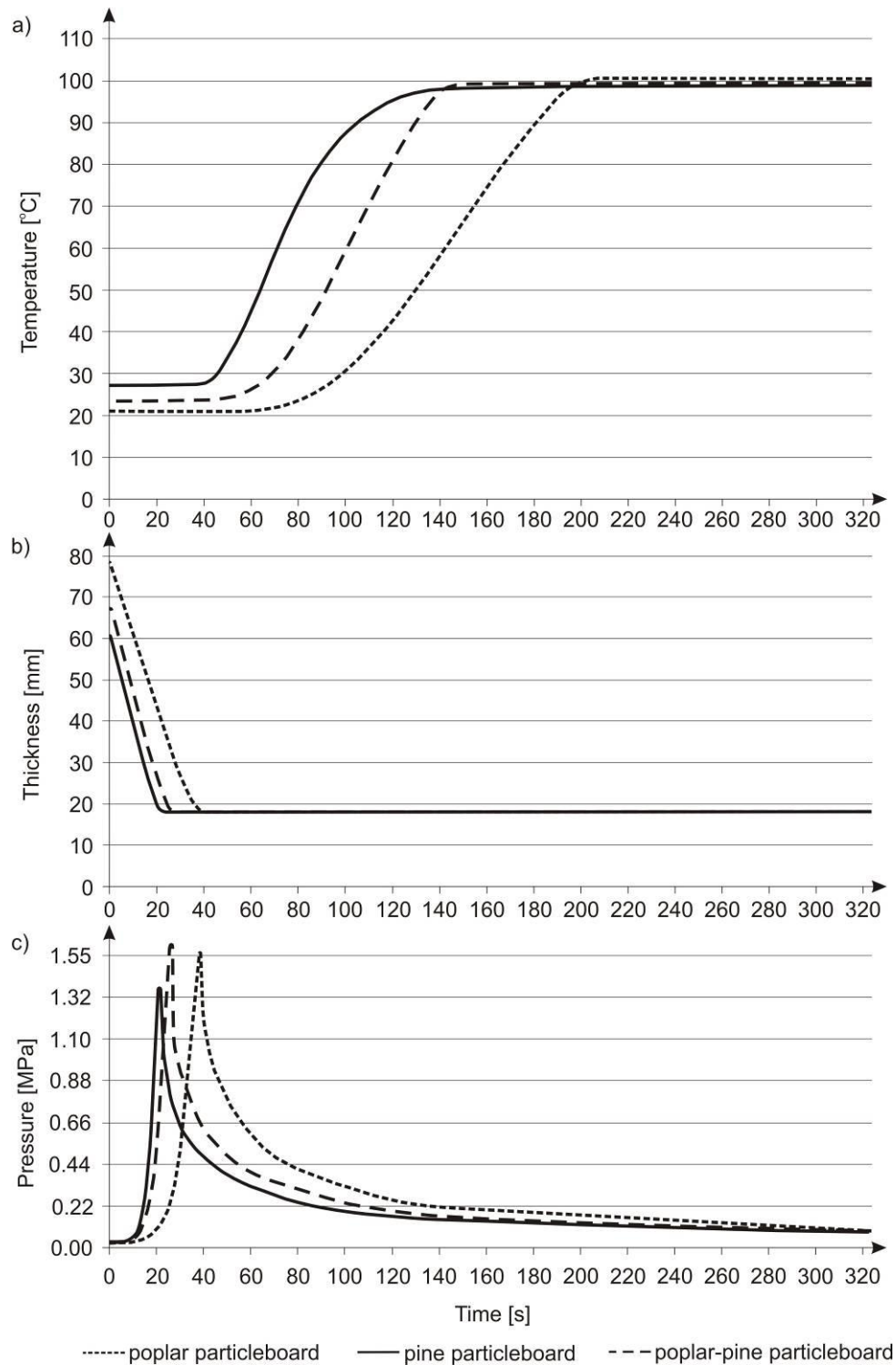


**Fig. 1.** Pressing parameters recorded during compression of particleboards (500 kg/m<sup>3</sup>) - (a) temperature, (b) thickness, (c) pressure

The highest heat transfer rate observed for pine mats was associated with a moisture content higher than that of the poplar material (5.0% face layer and 4.5% core layer vs. 3.5% face layer and 2.9% core layer), lower compression of the core layer (minimum density 402 kg/m<sup>3</sup>, Fig. 2), and subsequent easier steam penetration, which is the main heat carrier from face layer to core layer upon overheating (Sokolovs'kyi and Petriv 2007).

In addition, the heat transfer coefficient for pine wood was higher than that for poplar (pine, 0.14 W/mK; poplar, 0.10 W/mK (Niemz 1993)), which explains the higher heat transfer rates. Moreover, the lower heat transfer rates observed for poplar might come from higher compression of the mats (minimum density 431 kg/m<sup>3</sup>, Fig. 2), which is a hindrance to steam penetration. Because of the lower heat transfer rate, the plasticizing of the chips took more time. Slower heating resulted in more uniform compression of the boards (Fig. 2). In effect, a higher pressure was necessary to hold the target thickness of the mat for the poplar boards.

For the poplar-pine boards, middling heating times and moderate steam penetration were observed. This may have been a result of the mediocre compression of the core layer (minimum density 386 kg/m<sup>3</sup>) and its fairly porous structure.

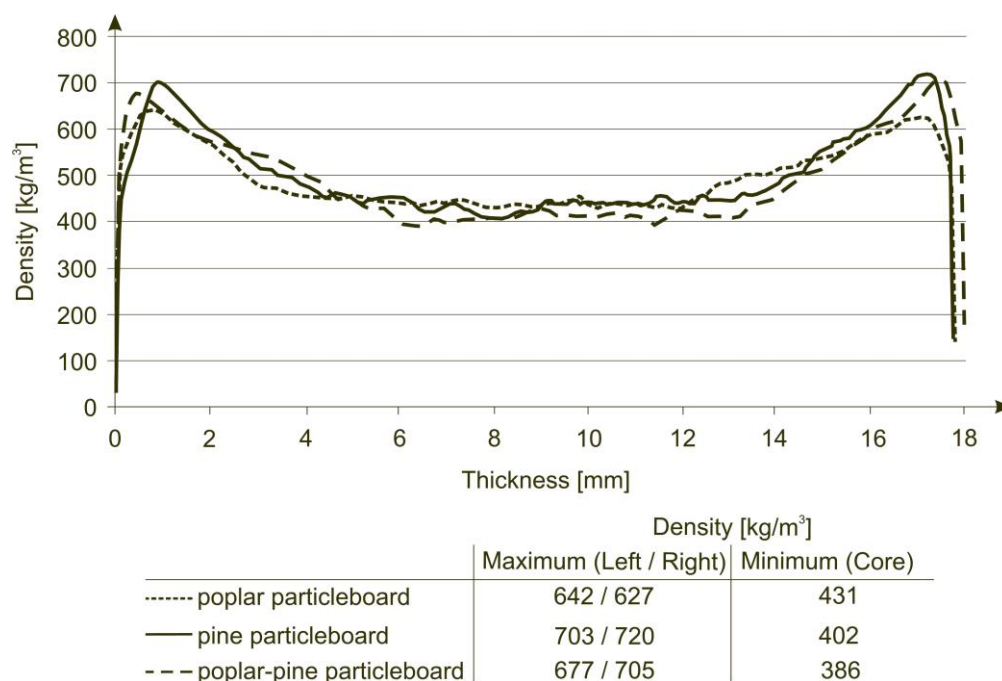


**Fig. 2.** Density profiles of the tested panels

Considering the mechanical properties of the manufactured panels (Fig. 3), it can be summarized by stating that the requirements for a P1 panel type (EN 312 (2010) - tab.1) were met to some extent by the respective panel series. Thus, the modulus of rupture (MOR) requirement was met by the poplar panels, pine panels, and mixed poplar-pine panels at 92%, 60%, and 71%, respectively, while the internal bond strength (IB) requirement was met respectively at 60%, 73%, and 100%.

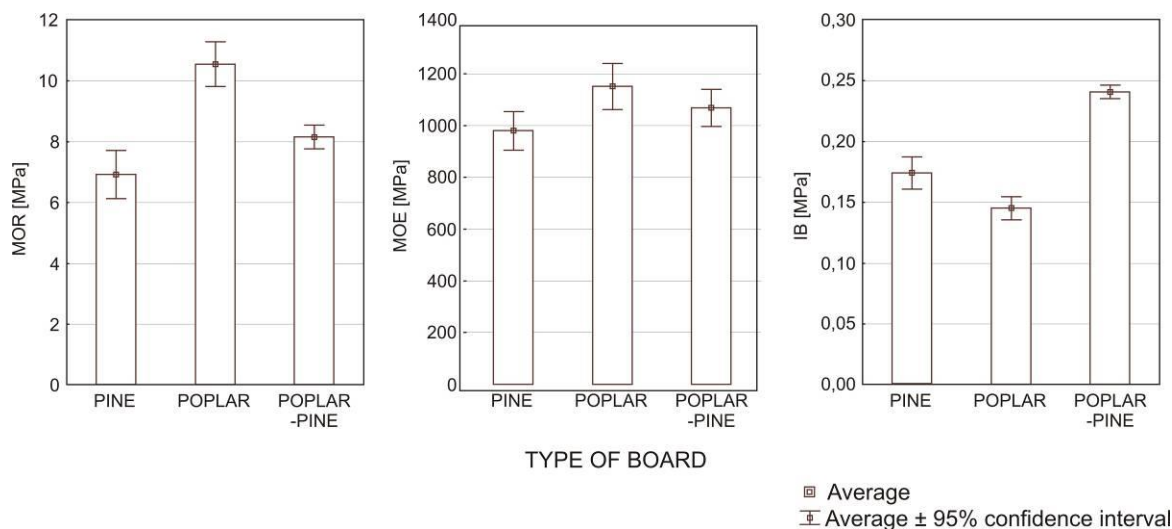


**Fig. 3.** Differences in mechanical properties (modulus of rupture (MOR), modulus of elasticity (MOE), and internal bond strength (IB)) of the tested panels

**Table 1.** General Purpose Boards for Use under Dry Conditions (Type P1) - Requirements for Specified Mechanical Properties (MOE for P1 boards is not defined by the standard)

| Property               | Test method | Unit              | Requirement                   |        |           |            |            |            |            |      |
|------------------------|-------------|-------------------|-------------------------------|--------|-----------|------------|------------|------------|------------|------|
|                        |             |                   | Thickness range (mm, nominal) |        |           |            |            |            |            |      |
|                        |             |                   | < 3                           | 3 to 6 | > 6 to 13 | > 13 to 20 | > 20 to 25 | > 25 to 32 | > 32 to 40 | > 40 |
| Bending strength (MOR) | EN 310      | N/mm <sup>2</sup> | 11.5                          | 11.5   | 10.5      | 10         | 10         | 8.5        | 7          | 5.5  |
| Internal bond (IB)     | EN 319      | N/mm <sup>2</sup> | 0.31                          | 0.31   | 0.28      | 0.24       | 0.20       | 0.17       | 0.14       | 0.14 |

NOTE: The values are characterised by moisture content in the material corresponding to a relative humidity of 65 % and a temperature of 20 °C.

It should be also noted that all the variants of panels in terms of MOR and MOE met the requirements for lightweight particleboard LP1 (CEN/TS 16368 (2014)), while the IB requirement was met by poplar-pine particleboard.

It is commonly agreed that the MOR of a panel is strongly correlated with the density of the face layers and mat compression, which are in turn determined by the chip geometry and their density. Lower density leads to a higher compression ratio of a mat and higher contact surface between chips is developed, so that the total bondline surface is larger (Grigoriu 1981; Xu *et al.* 2004). The data indicated that the highest MOR and MOE values were obtained for the panels containing poplar face layers, while the highest IB were observed for the mixed poplar-pine and neat pine panels. Higher MOR and MOE for poplar series resulted primarily from the higher chip compaction and lower porosity in a layer, while the densities of the face layers remained similar to each other (Fig. 2, Fig. 4). Figure 4 indicates that the structure of the poplar boards was more compact, which resulted from lower bulk density of poplar raw material and its easier compaction. Thus, internal empty spaces volume is minimized and no clear boundary between face and core layers can be observed. The porosity of core of the pine and mixed boards was

higher than that of the neat poplar boards, though the minimum densities are comparable (Fig. 2). The phenomenon results directly from the difference in wood density. The density of wood significantly affects the mat compaction ratio by the reduction of free volume between chips (Medved and Resnik 2006). The final properties of a panel can be even more influenced when different wood species are used in the face and core layers. Xu and Suchsland (1999) observed that MOR, MOE, and IB were higher for panels made of one species when compared with mixed ones. The results obtained in the present work for IB are not consistent with the abovementioned findings.

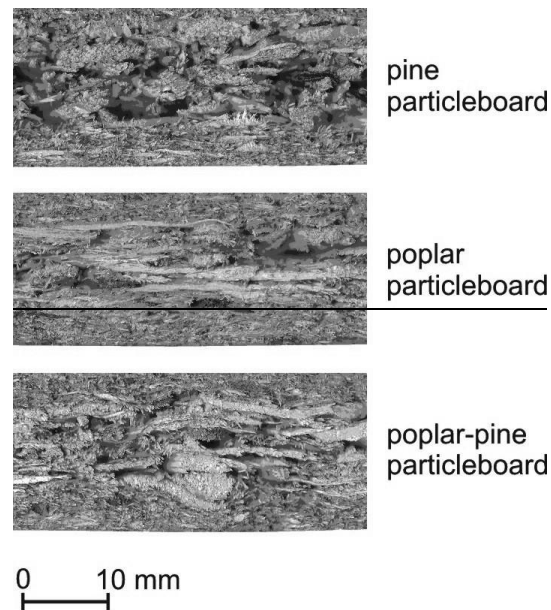


**Fig. 4.** Internal structure of the tested panels

It is likely that the increase in IB for the mixed poplar-pine boards, when compared with the other two series, comes from the fact that the bulk density of pine chips was higher than that of poplar. Thus, assuming a constant glue rate, the amount of the adhesive loaded on the core layer was higher for the mixed boards than that for the neat poplar ones. On the other hand, the poplar face layers of the mixed boards were compacted to a higher extent because of their lower bulk density, which resulted in a higher pressure transferred onto the pine core layer. A combination of these two factors may have led to the increase in IB observed for the mixed poplar-pine boards.

It is worth noting that the differences between mechanical parameters (MOR, MOE, and IB) found for the studied series were statistically significant at 95% confidence interval. The effect of density variation on the analyzed parameters is shown in Fig. 5.

The alternations in density affect the strength parameters of the boards (Xu and Suchsland 1998). The correlation was true for the investigated poplar and pine boards within the analyzed density range (450 to 550 kg/m<sup>3</sup>). The strongest correlations were found for the poplar panels, *i.e.*,  $r^2$  for MOR and MOE was, respectively, 0.4579 and 0.9362. The values achieved for the pine boards were 0.6412 and 0.2581, respectively, for MOR and MOE.

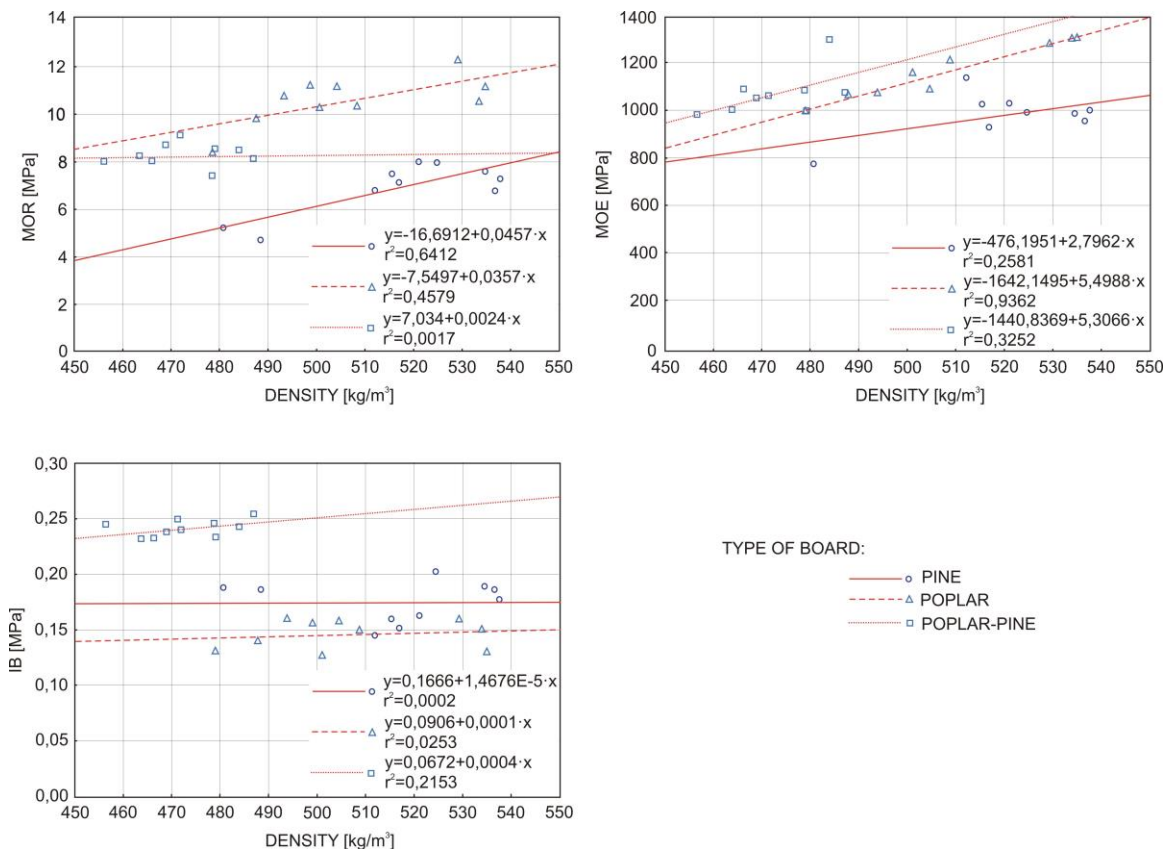


**Fig. 5.** The effect of density variation on the analyzed parameters (modulus of rupture (MOR), modulus of elasticity (MOE), and internal bond strength (IB)) of the tested panels ( $y$  - variable correlation equation,  $r^2$  – coefficient of determination)

No statistically significant correlations between density and MOR/MOE were found for the mixed poplar-pine boards (450 to 490 kg/m³). The  $r^2$  for IB ranged from 0.002 to 0.2153, which indicated no statistical significance. It was observed that both uneven density in the core layer and increased porosity resulted in a decrease in correlation between the density and mechanical performance of a board (MOR and MOE). Analysis of the data for the mixed poplar-pine boards showed lower correlation, which probably resulted from the variable rate of poplar and pine chips in the core layer. The compaction of the face layers that determine MOR and MOE was not altered.

## CONCLUSIONS

1. Compression processes during manufacturing of low-density particleboards depend on the species used, their heat transfer coefficients, and their moisture content.
2. These factors also affect heating times, so that pressing regimes must be carefully considered and empirically verified.
3. Raw material with lower density used for particleboard manufacturing requires either prolonged pressing times or higher heat transfer into the mat core.

4. In terms of mechanical properties, poplar-pine particleboards exhibited the best performance.

## ACKNOWLEDGMENTS

The authors are grateful for the support of the National Centre for Research and Development, Grant. No. LIDER/002/406/L-4/NCBR/2013.

## REFERENCES CITED

- Abdul Khalil, H. P. S., Nur Firdaus, M. Y., Jawaid, M., Anis, M., Ridzuan, R., and Mohamed, A. R. (2010). "Development and material properties of new hybrid medium density fibreboard from empty fruit bunch and rubberwood," *Materials and Design* 31(9), 4229-4236. DOI: 10.1016/j.matdes.2010.04.014
- Buschbeck, L., Kehr, E., and Jensen, U. (1961a). "Untersuchungen über die Eignung verschiedener Holzarten und sortimente zur Herstellung von Spanplatten - 1. Mitteilung: Rotbuche und Kiefer (Studies on the suitability of various wood species and assortments for particle-board manufacture. 1. Beech and Scots Pine)," *Holztechnologie* 2(2), 99-110.
- Buschbeck, L., Kehr, E., and Jensen, U. (1961b). "Untersuchungen über die Eignung verschiedener Holzarten und sortimente zur Herstellung von Spanplatten - 2. Mitteilung: Kiefernreiserholz (Studies on the suitability of various wood species and assortments for particle-board manufacture. 2. Pine small-wood)," *Holztechnologie* 2(3), 195-201.
- Cai, Z., Birkeland, M., Wescott, J. M., O'Dell, J., and Winandy, J. E. (2009). "Effects of press sizes on internal steam pressure during particleboard hot-pressing process," *Forest Products Journal* 59(4), 40-44.
- Carle, J. B., and Holmgren, L. P. B. (2009). "Wood from planted forests: Global outlook to 2030," *Planted Forests: Uses, Impacts and Sustainability*, J. Evans (ed.), CAB International and Food and Agriculture Organization of the United Nations, Rome, Italy. DOI: 10.1079/9781845935641.0047
- CEN/TS 16368 (2014). "Lightweight particleboards - Specifications," *European Committee for Standardization*, Brussels, Belgium.
- Clad, W. (1982). "Die Rohdichtesenkung bei Spanplatten, Eine Literaturübersicht," *Holz als Roh- und Werkstoff (European Journal of Wood and Wood Products)* 40(10), 387-393. DOI: 10.1007/BF02610724
- Dai, C., Wasylciw, W., and Jin, J. (2004). "Comparison of pressing behavior of wood particleboard and strawboard," *Wood Science and Technology* 38(7), 529-537. DOI: 10.1007/s00226-004-0256-2
- Dunky, M. (2001). "Wood based panels: An interdisciplinary approach," *Proceedings of the Fifth European Panel Products Symposium*, Llandudno, UK, 10-12 October, pp. 1-14.
- European Standard EN 310 (1993). "Wood-based panels - Determination of modulus of elasticity in bending," *European Committee for Standardization*, Brussels, Belgium.
- European Standard EN 312 (2010). "Particleboards - Specifications," *European Committee for Standardization*, Brussels, Belgium.

- European Standard EN 319 (1993). "Particleboards and fibreboards - Determination of tensile strength perpendicular to the plane of the board," *European Committee for Standardization*, Brussels, Belgium.
- Gatani, M. P., Fiorelli, J., Medina, J. C., Arguelo, R., Ruiz, A., Nascimento, M. F., and Savastano, H. Jr. (2013). "Technical production viability and properties of particleboard made with peanut husks," *Revista Materia* 18(2), 1286-1293. DOI: 10.1590/S1517-70762013000200004
- Grigoriu, A. (1981). "Der Einfluß verschiedener Holzarten auf die Eigenschaften dreischichtiger Spanplatten und deren Deckschichten," *Holz als Roh- und Werkstoff (European Journal of Wood and Wood Products)* 39(3), 97-105. DOI: 10.1007/BF02606283
- Haelvoet, W., and Medved, S. (2009). "Moisture resistance of wood- based panels," in: *Performance in Use and New Products of Wood Based Composites*, M. Fan (ed.), Brunel University Press, London, UK, pp. 23-46.
- Kelly, M. W. (1977). "Critical literature review of relationship between processing parameters and physical properties of particleboard," *Gen. Tech. Rep. FPL-10*, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI.
- Keylwerth, R. (1958). "Zur Mechanik der mehrschichtigen Spanplatte," *Holz als Roh- und Werkstoff (European Journal of Wood and Wood Products)* 16(11), 419-430. DOI: 10.1007/BF02617779
- McDonald, A. G., Gifford, J. S., Dare, P. H., and Steward, D. (1999a). "Characterisation of the condensate generated from vacuum-drying of radiata pine wood," *Holz als Roh- und Werkstoff (European Journal of Wood and Wood Products)* 57(4), 251-258. DOI: 10.1007/s001070050052
- McDonald, A. G., Steward, D., and Franich, R. A. (1999b). "Monoterpene composition of radiata pine (*Pinus radiata* D. Don) sapwood from a 13 year old progeny trial," *Holz als Roh- und Werkstoff (European Journal of Wood and Wood Products)* 57(4), 301-302. DOI: 10.1007/s001070050063
- Medved, S., and Resnik, J. (2006). "Impact of beech particle size on compaction ratio of the surface layer," *Wood Research* 52(3), 101-108.
- Meinlschmidt, P., Schirp, A., Dix, B., Thole, V., and Brinker, N. (2008). "Agricultural residues with light parenchyma cells and expandable filler materials for the production of lightweight particleboards," *Proceedings of the International Panel Products Symposium*, Espoo, Finland, 24-26 September, pp. 179-188.
- Miyamoto, K., Suzuki, S., Inagaki, T., and Iwata, R. (2002). "Effects of press closing time on mat consolidation behavior during hot pressing and linear expansion of particleboard," *Journal of Wood Science* 48(4), 309-314. DOI: 10.1007/BF00831352
- Moslemi, A. A. (1974). *Particleboard Vol. 2: Technology*, Southern Illinois University Press, Carbondale, IL.
- Nemli, G., Aydin, I., and Zekovic, E. (2007). "Evaluation on some of the properties of particleboard as function of manufacturing parameters," *Materials and Design* 28(4), 1169-1176. DOI: 10.1016/j.matdes.2006.01.015
- Nicewicz, D., Boruszewski, P., and Klimczewski, M. (2012). "Influence of addition of wood from containers and pallets and selected technological parameters on the properties of MDF," *Wood Research* 57(2), 309-315.
- Niemz, P. (1993). *Physik des Holzes und der Holzwerkstoffe*, DRW-Verlag Weinbrenner GmbH & Co., Leinfelden-Echterdingen, Germany.

- Papadopoulos, A. N., Traboulay, E. A., and Hill, C. A. S. (2002). "One layer experimental particleboard from coconut chips - (*Cocos nucifera* L.)," *Holz als Roh- und Werkstoff (European Journal of Wood and Wood Products)* 60(6), 394-396. DOI: 10.1007/s00107-002-0332-y
- Plath, E. (1971). "Beitrag zur Mechanik der Holzspanplatten," *Holz als Roh- und Werkstoff (European Journal of Wood and Wood Products)* 29(10), 377-382. DOI: 10.1007/BF02616673
- Sellers, T. Jr., Miller, G. D., and Fuller, M. J. (1993). "Kenaf core as a board raw material," *Forest Products Journal* 43(7-8), 69-71.
- Sokolovskiy, Y. I., and Petriv, O. M. (2007). "Investigation of the stress-strain state of particleboard in the process of hot pressing," *Materials Science* 43(1), 38-45. DOI: 10.1007/s11003-007-0003-6
- Steffen, A., Von Haas, G., Rapp, A., Humphrey, P., and Thömen, H. (1999). "Temperature and gas pressure in MDF-mats during industrial continuous hot pressing," *Holz als Roh- und Werkstoff (European Journal of Wood and Wood Products)* 57(2), 154-155. DOI: 10.1007/s001070050033
- Strauss, S. H., Brunner, A. M., Busov, V. B., Ma, C., and Meilan, R. (2004). "Ten lessons from 15 years of transgenic *Populus* research," *Forestry* 77(5), 455-465. DOI: 10.1093/forestry/77.5.455
- Varanda, L. D., Nascimento, M. F., Christoforo, A. L., Silva, D. A. L., and Lahr, F. A. R. (2013). "Oat hulls as addition to high density panels production," *Materials Research* 16(6), 1355-1361. DOI: 10.1590/S1516-14392013005000131
- Wang, D., and Sun, X. (2002). "Low density particleboard from wheat straw and corn pith," *Industrial Crops and Products* 15(1), 43-50. DOI: 10.1016/S0926-6690(01)00094-2
- West, P. W. (2006). *Growing Plantation Forests*, Springer Verlag, Berlin, Germany.
- Wong, E. D., Zhang, M., Wang, Q., and Kawai, S. (1999). "Formation of the density profile and its effects on the properties of particleboard," *Wood Science and Technology* 33(4), 327-340. DOI: 10.1007/s002260050119
- Xu, W., and Suchland, O. (1998). "Variability of particleboard properties from single- and mixed-species processes," *Forest Products Journal* 48(9), 68-74.
- Xu, W., and Suchland, O. (1999). "Within-panel variability and selected property relationships of particleboard from single- and mixed-species processes," *Forest Products Journal* 49(10), 36-40
- Xu, J., Sugawara, R., Widyorini, R., Han, G., and Kawai, S. (2004). "Manufacture and properties of low-density binderless particleboard from kenaf core," *Journal of Wood Science* 50(1), 62-67. DOI: 10.1007/s10086-003-0522-1

Article submitted: March 16, 2016; Peer review completed: May 9, 2016; Revised version received and accepted: June 17, 2016; Published: July 6, 2016.  
DOI: 10.15376/biores.11.3.6909-6919



## A review of carbon fibre rollers in the printing, papermaking and allied industries

Dr. Simon Hamblyn, Prof. Lutz Engisch

iP<sup>3</sup> Leipzig – Institute for Printing, Processing and Packaging

*The use of carbon fibre in industries such as aviation and automotive is already well documented. Carbon fibre combines strength with a low weight making it an ideal material for aircraft and motor racing parts where weight is a premium. Its use in the printing industry for rollers and cylinders is not well documented despite the fact that it is being used, albeit infrequently, and its use is normally not advertised. However, there is an increasing trend for using carbon fibre for components such as print cylinder sleeves for easier handling and idler rollers as they can reach higher rotational speeds than metal rollers for a given diameter. This is particularly important when wide web widths are used such as in papermaking and polymer film manufacturing. Their use is also likely to increase in the industry due to the manufacturing tolerances of emerging industries such as flexible electronics and solar.*

*This report aims to review the use of carbon fibre rollers in the printing industry as well as some of the other industries that are allied to it*

iP<sup>3</sup> Leipzig – Institute for Printing, Processing and Packaging.

Supplied by:

Jorn de Noord

Junior Sales Manager

Pronexos B.V. \ Planthofsweg 77 \ 7601 PJ Almelo \ The Netherlands

+31 546 54 5602

+31 6 28371179 (mobile)

[jorn.denoord@pronexos.com](mailto:jorn.denoord@pronexos.com)

[www.pronexos.com](http://www.pronexos.com)

pronexos

The Paper Industry Technical Association (PITA) is an independent organisation which operates for the general benefit of its members – both individual and corporate – dedicated to promoting and improving the technical and scientific knowledge of those working in the UK pulp and paper industry. Formed in 1960, it serves the Industry, both manufacturers and suppliers, by providing a forum for members to meet and network; it organises visits, conferences and training seminars that cover all aspects of papermaking science. It also publishes the prestigious journal *Paper Technology* and the *PITA Annual Review*, both sent free to members, and a range of other technical publications which include conference proceedings and the acclaimed *Essential Guide to Aqueous Coating*.

## **A review of carbon fibre rollers in the printing, papermaking and allied industries**

Dr. Simon Hamblyn, Prof. Lutz Engisch

iP<sup>3</sup> Leipzig – Institute for Printing, Processing and Packaging

### **Abstract**

*The use of carbon fibre in industries such as aviation and automotive is already well documented. Carbon fibre combines strength with a low weight making it an ideal material for aircraft and motor racing parts where weight is a premium. Its use in the printing industry for rollers and cylinders is not well documented despite the fact that it is being used, albeit infrequently, and its use is normally not advertised. However, there is an increasing trend for using carbon fibre for components such as print cylinder sleeves for easier handling and idler rollers as they can reach higher rotational speeds than metal rollers for a given diameter. This is particularly important when wide web widths are used such as in papermaking and polymer film manufacturing. Their use is also likely to increase in the industry due to the manufacturing tolerances of emerging industries such as flexible electronics and solar.*

*This report aims to review the use of carbon fibre rollers in the printing industry as well as some of the other industries that are allied to it*

**Stichwörter:** carbon fibre, idler roller, printing cylinder

**veröffentlicht:** 05.09.2018

---

### **Introduction**

The printing industry is one of the world's largest industries and encompasses not only the products typically associated with it such as publication and packaging but it is also used in the manufacturing of products such as designer handbags and laminate flooring, automotive parts, household appliances, and textiles. The global print market reached 785 billion USD in 2017 [1].

In many of the processes used for printing and coating, as well as the manufacturing of substrates such as paper and plastic films, a

long continuous belt of the substrate, known as a web is used. These processes rely on a series of rollers to guide and transport the substrate through the machines and control its tension as well as transfer inks and coatings onto the moving web. Traditionally these rollers were made of steel or aluminium, however, lighter weight composite materials such as carbon fibre are now being used to replace some of these rollers. The aim of this report is to review the current and potential future use of carbon fibre rollers in the printing, paper, and allied industries.

## The current use of Carbon Fibre Rollers

The first recorded use of carbon fibre was by Thomas Edison in 1880 during his development of the light bulb [2], where he carbonised a cellulose fibre to use as a filament. Further development in the 1950's led to the first patent for Polyacrylonitrile (PAN) based carbon fibres in 1959, which is the dominant precursor used for most carbon fibre applications today [3]. The first carbon fibres from pitch precursors were first manufactured in 1975; these result in a lower yield than PAN-based fibres but have higher elastic moduli. Carbon fibre rollers contain a high content of pitch fibres due to their higher stiffness [4].

Carbon fibre products are already being used in various capacities in the printing and coating industries, although the uptake is very much in its infancy. Currently one of the primary uses of carbon fibre is for components that need to be regularly removed from the printing press such as ink chambers and sleeves used for both anilox rollers and printing cylinders in flexographic printing. These both require a combination of low weight for easy handling with precise mounting on a mandrel, and high stiffness to ensure consistent ink transfer. Early sleeves were manufactured from glass fibre, but more manufacturers are now using carbon fibre because it offers a high stiffness for more accurate and consistent ink transfer making it an ideal choice for these components, particularly for wider web widths. One of the first systems for carbon fibre plate cylinders sleeves was developed by Rossini [5], other manufacturers including *Fischer and Krecke* [6] (now part of *König and Bauer*) have followed suit. Most manufacturers of wide web flexographic printing machines use sleeve technologies for the printing plates; for example, *König and*

*Bauer* are offering carbon fibre mandrels as an option on their *Evo* and *Neo* flexographic printing machines [7]. This is shown in Figure 1.

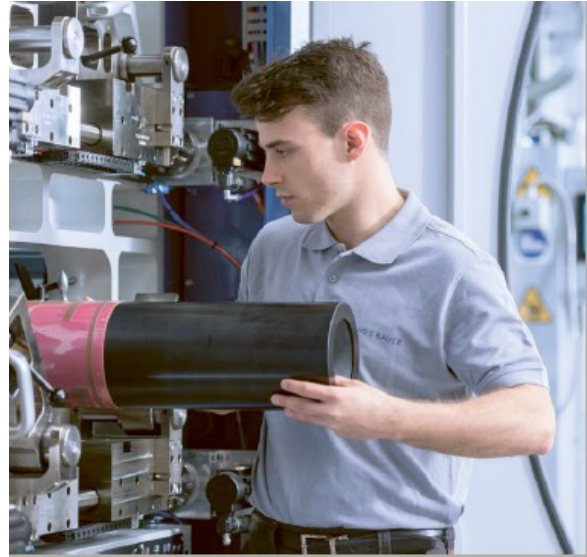


**Figure 1** – Flexographic plate sleeve system from König und Bauer [7]

Rossini have subsequently developed a carbon fibre bridge sleeve for adapting different sized printing sleeves so that different repeat lengths can be achieved [8].

In rotogravure printing, the printing cylinders have traditionally consisted of a steel cylinder that is plated with copper and chrome. Cylinder manufacturers have experimented with several combinations of materials [9] [10] in order to reduce the weight of these engraved cylinders to improve handling without compromising the print quality. One solution is available from *Janoschka* [11], which is based on a patent from *Sachsische Walzengravur* [12] uses the Coupling Effect of carbon fibre to secure the sleeve onto the mandrel, minimising distortion and alignment issues.

Carbon fibre rollers are used in some offset printing machines in the roller trains for inking and damping systems. A patent for carbon fibre inking rollers was filed by *Man Roland* in 1996 [13]. Other offset press manufacturers such as *König and Bauer* have subsequently patented carbon fibre inking rollers [14] [15]. *König and Bauer* incorporated carbon-fibre inking rollers for their C-series web offset machines [16] stating that these reduced vibration resulting in smoother running rollers and better process stability. These rollers are often coated with elastomeric materials to provide the ink transfer properties required [17] [18].

The area that sees the largest growth potential for carbon fibre rollers is for web handling. These include idler rollers and tension rollers. These are used extensively in printing machines and paper making machines as well as machines for metallizing, laminating and other converting operations. Printing machines for packaging, typically vary in web width from 0.3 m to 1.6 m and operate at speeds between 200 to 600 m/min. While for publication applications, printing presses can have web widths of over 4 m and operate at speeds of over 1000 m/min. It is the wider web widths that see the largest potential benefits of carbon fibre rollers.

The main printing processes using idler rollers are web offset, flexographic and rotogravure, these combine high printing speeds with wide webs for applications such as publication, packaging, decoration. The publication industry in Europe is dominated by web-offset and rotogravure and includes printing press manufacturers such as *Man Roland, König und Bauer*, and *Cerutti*. The flexible packaging industry is almost exclusively split between rotogravure and flexography with press

manufacturers such as *Bobst, Uteco, König and Bauer, Cerutti, Comexi* and *Windmüller and Hölscher*. Decoration printing is dominated by rotogravure and includes applications such as wood effect for furniture and laminate flooring and also decorative patterns for luxury goods such as designer handbags. Traditionally the web rollers are manufactured from either steel or aluminium and are often coated depending on the requirements. In 2003, *König und Bauer* announced that their TR12B Rotogravure press would utilise larger diameter carbon fibre idler rollers to provide a smoother acceleration and more uniform web tension [19].

Another application for carbon fibre rollers is in papermaking machines, these are typically between 1.5 m and 10 m wide and operate at speeds of over 1000 m/min. *Voith*, a leading manufacturer of machines for papermaking are using carbon fibre for their breast rollers to improve the distribution of fibers, reducing flocculations and therefore increasing the quality and strength of the paper. They have also replaced some of the rollers in the drying section from steel to carbon fibre to increase the production speed of the machines to over 1600 m/min [20].

Packaging uses an extensive amount of polymer films such as polyethylene and polypropylene. This also requires the use of rollers to transport a web of material. Here the polymer is usually melted and extruded through a circular die. Air is blown through the die forming a 'bubble' of the polymer which is stretched into a thin layer. This 'bubble' is then collapsed using rollers and then wound onto a reel. On modern machines, carbon fibre is used for the bubble collapsing rollers due to their low thermal conductivity, approximately 1000 times less than aluminium, and low inertia to minimise thickness variations and

wrinkles [21]. *Kampf* a manufacturer of slitting and winding machines used for polymer film production, use carbon fibre rollers for web handling on their machines that can be up to 10 m wide and operate at 1500 m/min.

The metal web transport rollers in other machines such as laminators and vacuum coating metallizers are also being replaced with carbon fibre rollers [4]. These machines also have production speeds of 1000 m/min with web widths up to 4 m.

### The benefits of Carbon Fibre Rollers

For idler rollers, steel and aluminium are the materials that are traditionally used. These can be precisely manufactured to high tolerances and provide the necessary stiffness needed by the rollers, especially over a wide web width. Steel rollers are traditionally used for machines that use paper-based substrates. But due to its high density, steel rollers have high inertia, requiring more energy to drive the press and can result in the rollers rubbing against the substrate as the press speed is increased or reduced. This can result in damage to the print and dust, which can lead to print defects such as hickeys and could also potentially pose a health risk to operators. When compared with steel rollers, aluminium rollers have a lower density and hence a lower inertia and are therefore often used for more delicate substrates such as polymer films, aluminium coated substrates and light paper stocks, which are more prone to scratching and stretching.

At higher press speeds and larger web widths, the critical speed of rollers is an important parameter. This is the speed at which the natural frequency of the roller is induced and is related to the stiffness, mass and the length

of the roller. Rollers must always be used below their critical speed or a vibration will be introduced into the web leading to problems with tension and registration among other issues. Metal rollers due to their mass, have relatively low critical speeds, therefore as the web width is increased, their critical speed is reduced therefore limiting the maximum line speed of the machine. This problem can be overcome by either utilising larger diameter rollers or materials with a lower mass while retaining the stiffness requirements.

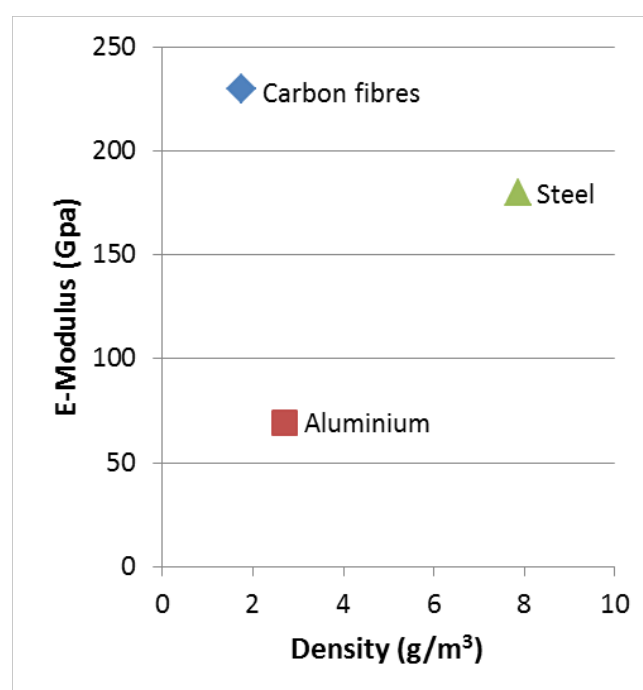


Figure 2 - Elastic modulus versus density [23]

A comparison between the Elastic moduli of carbon fibres, aluminium and steel is shown in Figure 2. Carbon fibre rollers have a significantly higher stiffness to mass ratio than metal rollers [22], which significantly increases their critical speed and therefore higher production speeds can be achieved with less vibration. This also allows for smaller roller diameters to be used.

Due to their lower rotational inertia compared to steel and aluminium rollers, carbon fibre

rollers respond quicker to changes in line speed, this reduces the rubbing between the roller and the substrate and therefore reducing damage to substrates and coatings, roller wear and also reduces dust, therefore leading to fewer print defects. The faster response should also bring other benefits such as improved tension control and less start-up waste. The lower mass of the rollers should also lead to less bearing wear and therefore increased bearing life, which is an important consideration when comparing the cost of rollers, as it should result in less downtime. Also smaller bearings can be used which have a lower rolling resistance and when combined with the lower mass of the rollers would result in a reduction in the overall energy requirements of the machine. The rollers can be coated [22] to improve their resilience to wear and chemical attack as well as to alter their thermal and electrical conductivities.

A low mass also means that rollers and cylinders can be more easily and safely handled. For components such as printing cylinders in flexography and rotogravure which need to be changed for each print job, this is a major consideration as lightweight cylinders can be more easily installed and removed from the machines. This can not only reduce the risk of injuries to personnel due to manual handling but also reduce the risk of damage to cylinders and machines stemming from handling difficulties. The other advantage of low mass cylinders is from a storage perspective, rotogravure cylinders are usually stored for use in repeat jobs. Traditional rotogravure cylinders require heavy duty racking and require more storage space than lighter weight cylinders.

Carbon fibre products are constructed from a composite material consisting of carbon fibres

in a polymer matrix. Because the fibres are orientated in one direction and due to the difference in properties between the fibres and the matrix material, its mechanical properties are anisotropic. By combining several layers of the composite material where fibres are orientated in different directions, a wide range of mechanical properties such as tensile strengths, torsional and bending resistances can be achieved.

This “coupling effect” can be used to provide certain properties in specific directions and therefore this can be exploited in ways that are not possible with more traditional materials. One such example is the *proRoto* sleeve system from *Janoschka*, Figure 3.

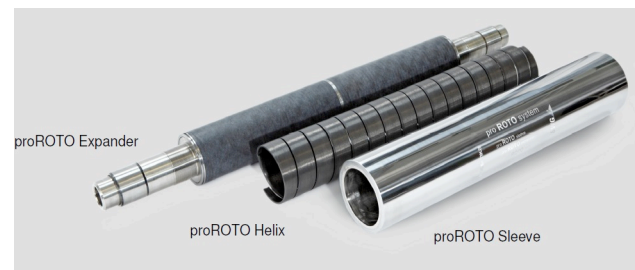


**Figure 3** – proROTO Rotogravure sleeve system [24]

This consists of a carbon fibre mandrel that has been designed based around the coupling effect. The addition of a mechanical force, results in a uniform increase in the diameter of the carbon fibre expander in order to grip a printing sleeve. Conversely, removal of this force reduces the diameter of the mandrel allowing the printing sleeve to be removed and replaced. This has some potential advantages over the more commonly used air mandrel systems, where the grip can vary along the length of the mandrel.

Vibration is an area that machine manufacturers strive to reduce. The vibration damping properties for carbon fibre is better than for metals [25], which could also be

particularly beneficial for printing cylinders and inking rollers, where any vibrations manifest themselves in variations in ink transfer and therefore have an adverse effect on the image quality.

### Current trends

The recent trend in the printing industry is shorter production runs [26] [27], Figure 4. As production lengths decrease the setup time and start-up waste are significant cost parameters and therefore need to be minimised. With this printers are relying on some of the lean manufacturing and Six-Sigma tools to reduce downtime and increase their productivity. One area of this is improving job changeover times with Single Minute Exchange of Dies (SMED) techniques. The use of low weight sleeves in Flexography and Rotogravure help to reduce the changeover times alongside the increased usage of machine automatization. Lower inertia idler rollers in web-based machines could also result in production quality being reached quicker and therefore reducing start-up waste as well as minimising damage to the print during the production run. Minimising how often idler rollers or bearings need to be changed is also a consideration in the reduction of downtime.

The overall maximum printing speed of machines has largely remained static over the last decade; however, web widths have increased to help improve the overall efficiency of the printing machines. Increasing the length of rollers pushes the rollers closer to their critical speed, which means that it is likely that some of the web-based machines for flexography, rotogravure and offset printing utilising steel or aluminium idler rollers are operating close to their critical speed. For

manufacturers to increase speeds or web widths in order to further increase efficiencies, carbon fibre rollers or larger diameter rollers will need to be considered.

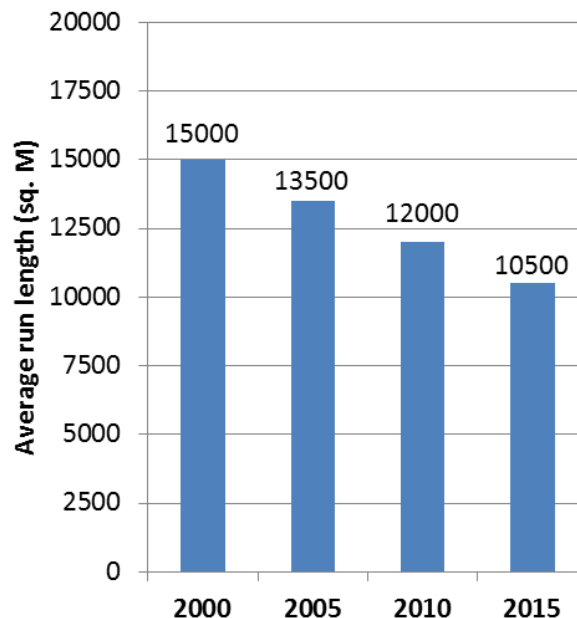


Figure 4 – Decline in average run length 2000 to 2015 [27]

The shift to shorter production runs has led to a rapid growth in digital printing [28] as these machines have little to no setup waste or make ready time. Currently, these digital printing machines, such as *Hewlett Packard's HP T400*, have maximum speeds of around 300 m/min and web widths up to 1 m and therefore the critical speeds of metal idler rollers are far from being reached. However, this is a rapidly developing market and web widths and speeds are likely to increase. But while digital printing machines do not require the higher critical speeds of carbon fibre rollers they can still benefit from the other advantages of lightweight rollers such as the lower energy requirements and improved control.

The overall demand for printed products is expected to increase between 2017 and 2020, but the current trend in the publication market

in Europe and North America is expected to continue to contract. The market for publication and commercial printing is continuing to grow slowly in some of the Asia-Pacific countries such as India [29], which could partly be due to books and other publications being exported to Europe [30]. This overall market contraction is likely to limit the sales of new printing presses for commercial and publication printing, which tend to be high speed and wide webs and therefore benefit the most from carbon fibre idler and inking rollers. The global demand for packaging is, however, increasing [31]. The largest growth is also expected in the Asia-Pacific countries with average growth of up to 6.9% [29] is likely to lead to more printing machines for packaging being built and also more demand for polymer films and hence substrate manufacturing equipment. A DRUPA report from 2018 [32] showed that printing companies were more likely to invest in new sheet-fed offset machines for the commercial, publishing and packaging markets and flexographic presses for packaging printing.

Currently, the largest market increase for carbon fibre rollers is replacement rollers in existing machines. Rollers need to be periodically replaced; however, this can result in significant capital expenditure. The price of metals have seen large increases in the 2 year period from July 2016 to July 2018 [33], with steel prices doubling, and aluminium prices increasing by approximately one third. This has narrowed the difference in the cost of replacing existing metal rollers with carbon fibre.

It should be possible to exchange metal idler rollers in most machines for carbon fibre equivalent rollers; however, it is advisable to first consult with the machine manufacturer.

New markets that utilise printing and coating processes are also growing, which include flexible solar panels. While these do not require the high critical speed capabilities that carbon fibre rollers provide, the manufacturing process demands a greater precision than required for graphics printing and therefore greater control over the web handling. Also, the printed devices are sensitive to damage that might come from dragging, therefore carbon fibre rollers could be beneficial due to their lower inertia.

## Future trends

As stated previously, if machine manufacturers intend to increase operating speeds, or increase web widths to further improve the economics, this would increase the likelihood of carbon fibre rollers being required unless manufacturers are willing to use larger diameter rollers. The trend of shorter runs and therefore the need to reduce start-up waste will continue as will the need to reduce energy usage and carbon footprints. This will likely lead to more printing machines having carbon fibre rollers fitted as standard.

The cost of carbon fibre rollers is likely to reduce as demand and competition increases and also as manufacturing efficiencies improve. When combined with the increasing price of metals this could make their inclusion more attractive to OEM's even for applications where the critical speeds are not a factor. The user could also see benefits in the longer term due to less downtime for maintenance, particularly when the rollers are coated to increase their life. The greater use of carbon fibre rollers would also lead to further developments and improvements in coatings. However, it is with the increasing number of Chinese and Indian built machines that could see the largest growth in carbon fibre rollers as they try to compete for machinery sales in western markets.

Currently, there is significant research and development of printed and flexible electronics as well as biomaterials. These technologies utilise printing and coating techniques as well as flexible substrates in the manufacture of devices including smart packaging, flexible displays, lighting, wearable technologies, medical sensors, batteries, and photovoltaics. While the manufacturing

industry for these is currently relatively small; it is an area that is forecasted to grow at an annual rate of 13.6% to over 26 billion USD [28] over the coming years and demand high levels of control and precision over web and sheet movements [34]. The value of these products is significantly higher than for graphics printing and any damage from scratches could result in a faulty device. These applications would benefit from low inertia rollers [35].

With the growing trend towards Industry 4.0 and therefore greater amounts of automatization, carbon fibre rollers and especially carbon fibre sleeves, have a significant advantage over their metal counterparts, as smart objects such as RFID tags can be more easily incorporated into them. Metals can cause problems for RFID tags as they reflect the energy emitted from an RFID reader and induce interference for RFID antennas, which means that the tags are difficult to read. Carbon fibre on the other hand, does not interfere with the signal and therefore the information from RFID tag can be more easily accessed. An example of where this could be used is part of an inventory system for printing cylinders, allowing the correct cylinders for a job to be automatically identified, removed from storage and inserted into the machine as part of an automated changeover system.

## Conclusions

Carbon fibre combines a high stiffness with a low mass, as such, it is being used for printing cylinders and other components that need to be changed regularly, therefore, minimising the risk of injuries due to handling.

A high stiffness to density ratio also significantly increases the critical speed of rollers. This has many benefits particularly for web transport rollers due to their potential to achieve higher rotational speeds and also wider web widths.

The low inertia of carbon fibre rollers can result in less rubbing of the substrate, therefore minimising damage to the print or to coating and also reducing print defects resulting from the dust. The increasing momentum for the manufacturing of functional products such as solar and flexible electronics could, therefore, see an increase in the use of carbon fibre rollers in order to increase yields.



Dr. Simon Hamblyn was born in Somerset, UK. He received a BEng degree in Mechanical Engineering in 1996 from Swansea University. This was followed by an MSc in Printing Technology and a

PhD focused on ink transfer in Flexographic Printing. He spent over 16 years at the Welsh Centre for Printing and Coating undertaking collaborative projects with Multi-National companies and SME's in the printing and coating industry. He is currently a researcher and lecturer at the University of Applied Sciences in Leipzig, specialising in printing and packaging.



Prof. Dr. Lutz Engisch was born in Chemnitz, Germany. After his diploma study for chemistry including promotion, he attended different research projects in the printing sector at

renowned institutes in Sweden and Australia. Before taking over the R&D department at SWG in 2008, Dr. Engisch was responsible for the digital printing department at the Institute for Printing and Media Technology (pmTUC) at the University of Technology Chemnitz.

In 2011, he was appointed professor for materials and materials testing in printing and packaging technics at the HTWK Leipzig.

## Bibliography

<http://www.janoschka.com/de/portfolio/d2/tiefdruck-sleeve/>.

- [1] Smithers Pira, „The Future of Global Printing to 2022,“ 2017.
- [2] S. C. Bushong, Radiologic Science for Technologists, Elsevier Health Sciences, 2013.
- [3] F. Pursche, T. DePalmenaer und G. Seide, „Future directions and trends of the carbon fibre market,“ in *ECCM17 - 17th European Conference on Composite Materials*, Munich, 2016.
- [4] D. Comand, „Low inertia carbon fibre rollers: a big step in the performance of coating, laminating and printing machines,“ in *AMICAL Conference*, Cascias, 2014.
- [5] F. Rossini, „Concentric double sleeve for a rotary printing cylinder“. Patent EP0732201A1, 1996.
- [6] A. Kückelmann, W. Brusdeilins, B. Steinmeier und W. Tappe, „Druckzylinder für Flexodruck“. Patent EP 1 808 293 A1, 2007.
- [7] KBA, „Neo XD LR,“ 27 August 2018. [Online]. Available: <https://www.koenig-bauer.com/produkte/flexo/ci-rotationen/neo-xd-lr/>.
- [8] F. Rossini, „Bridge sleeves with diametrically expandable stabilizers“. Patent PCT/EP2013/058971, 2016.
- [9] K. W. Saueressig, „Engraved cylinder composed of a core and a detachable sleeve“. Patent EP0295319A1, 1991.
- [10] R. M. Moss, J. W. Campion und S. R. Armfield, „Improved gravure printing rollers“. Patent WO2000059727A1, 2000.
- [11] „ProROTO,“ Janoschka, 28 August 2018. [Online]. Available: <http://www.janoschka.com/de/portfolio/d2/tiefdruck-sleeve/>.
- [12] V. Zschage, M. Mäser, L. Kroll, M. Klärner und J. Kaufmann, „Cylinder for a releasable connection with at least one working medium“. Patent DE102008018590B4, 2017.
- [13] W. Pilath, O. Dax und P. Dilling, „Ink transport roller for the inking unit of a web-fed rotary printing machine and process for producing the roll“. Patent DE19628647A1, 1996.
- [14] A. Jentzsch und U. Becker, „Farbheber für Druckmaschinen“. Patent DE4109438C2, 2001.
- [15] H. Kohtz, „Inking unit of a rotary printing press“. Patent DE102005010302B4, 2008.
- [16] KBA, „KBA C32 to C80: Productive high-performance web presses,“ 2012.
- [17] A. Jentzsch und U. Becker, „Ink applying roller for rotary printing machine - is made from carbon fibre reinforced plastics to minimise weight“. Patent DE102008018590B4, 2001.
- [18] J. Schölzig, „Coating device for printing or painting work in processing machine, comprises roller core formed from fiber composite material of carbon, where compressible layer formed from cellular foam material is adhered on roller core“. Patent DE102006037966A1, 2008.
- [19] KBA, „KBA TR12B for web width of 14ft: Exploring a New Dimension,“ October 2003. [Online]. Available: <http://whattheythink.com/news/5465-kba-tr12b-web-width-14ft-exploring-new-dimension/>.
- [20] H. Gruber, „Ultra-Leichtbau in der Papierindustrie,“ in *Automobil Industrie Leichtbaugipfel*, Würzburg, 2017.

- [21] B. H. Gregory, Polyethylene Film Extrusion: A Process Manual, Trafford , 2009.
- [22] A. Yoshiya, S. Shigemura, M. Nagai und M. Yamanaka, „Advances of thermal sprayed carbon roller in paper industry,“ in *Proceedings of the 2009 International Thermal Spray Conference*, Las Vegas, 2009.
- [23] H. P. Degischer, „Innovative light metals: metal matrix composites and foamed aluminium,“ in *Materials & Design*, Vol.18, Nos.46, 1997, pp. pp. 221-226.
- [24] „<http://www.janoschka.com>,“ 5 September 2018. [Online]. Available: [http://www.janoschka.com/uploads/media/prorOTO\\_download\\_DE.pdf](http://www.janoschka.com/uploads/media/prorOTO_download_DE.pdf). [Zugriff am 2012].
- [25] D. Montalvão, A. M. R. Ribeiro, N. M. M. Maia, J. Duarte Silva und R. A. Cláudio, „Damping measurements on a carbon fibre reinforced laminate,“ in *International Conference of Noise and Vibration Engineering (ISMA2006)*, Leuven, Belgium, 2006.
- [26] Smithers Pira, The Future of Global Print Equipment Markets to 2021, 2016.
- [27] R. Weis-Schiff, „Trends in innovations - flexible packaging,“ in *Image to Print*, Durban, 2018.
- [28] M. Sullivan, „Printed Electronics: Global Markets to 2022,“ BCC Research, 2018.
- [29] T. Long, „[printinnovationasia.net](http://printinnovationasia.net),“ 2018. [Online]. Available: <http://printinnovationasia.net/wp-content/uploads/2018/05/Thayer-Long-Trends-and-Opportunities-in-Global-Print.pdf>.
- [30] Statista, „Export value of books, publications and printing from India in FY 2015 and FY 2016,“ 2018.
- [31] Smithers Pira, „Global Packaging Trends,“ 2017.
- [32] DRUPA, „5th\_Global\_Trends\_Executive\_Summary\_EN.pdf,“ [www.drupa.com](http://www.drupa.com), 2018.
- [33] „DAX Index,“ 27 August 2018. [Online]. Available: [www.finanzen100.de](http://www.finanzen100.de).
- [34] D. Yoon, S.-H. Lee, J.-S. Kang und B.-O. Cho, „Cantilever Type Idler Roller in Roll-to-roll Process for Printed Electronics,“ 2011.
- [35] D. Lee, K. Choi und K. G. Bangjin, „Development of Composite Pressing Rollers for Thin Film Processing,“ in *Journal of Composite Materials* 34(9):, 2000.



## Examples of Cultural Differences in the Workplace

*Mariela Dabbah*

(A ward-winning, best-selling author, corporate consultant and international speaker on career success and women empowerment. Frequent media contributor on CNN, Univision, Telemundo and others. Her latest book "Find Your Inner Red Shoes" is the backbone of the Red Shoe Movement.)

It's useful to recognize examples of cultural differences in the workplace to avoid taking things personally & improve relationship with coworkers. Many of your daily misunderstandings at work are nothing more than clear examples of cultural differences in the workplace. Although this article focusses specifically upon attitudes to those of Hispanic background in an American context, the general principles apply to all work areas featuring people of mixed cultural backgrounds. Read on!

<https://redshoemovement.com>



No matter where you work, chances are you are surrounded by examples of cultural differences. These differences may be due to ethnic and racial background, age, geography, religion, and even the kind of school people attended.

What's fascinating is that classic examples of cultural differences are often misinterpreted as mere personality traits. People pick sides, "I'm right, they are wrong," and nothing constructive comes out of the argument. Knowing how to identify cultural differences in the workplace can give you a competitive edge while putting you in a position to enjoy your colleagues a whole lot more!



There are many subtle examples of cultural differences in the workplace that are not as obvious as how we introduce each other. Knowing about them can improve the work environment. Example: saluting each other.



There are many subtle cultural differences in the workplace that are not as obvious as how we introduce each other. Knowing about them can improve the work environment.

### **Examples of cultural differences in the workplace**

#### **Giving suggestions or keeping to yourself**

It wasn't the first time that Marta's manager asked her to copy-edit the store flyer. Their company served a large Latino population and Marta was happy that more Latino items were being offered at local supermarkets. As she worked on the flyer featuring the new products, Marta noticed that the items were not being promoted in a way that would appeal to Latinos. She thought of approaching her manager with her observations but she felt that the boss would take them as criticism of the advertising team who had created the copy. So she kept her mouth shut.

Later, when Marta mentioned her decision to Jim, an Anglo colleague, he said Marta's boss would probably welcome the suggestions. Jim is right. A good manager is usually happy to hear suggestions for improving products or services, something that, for many Latinos and people from other backgrounds, may come across as questioning authority. This is just one of many examples of cultural differences in the workplace. Think about it this way: you are being paid to think outside the box, to come up with unique ideas and points of view that can give your company a competitive advantage.



What utensils we use to eat, what we eat, whether we share our food or not, are all examples of cultural differences.

#### **To share or not to share**

Many of the examples of cultural differences have to do with how much people share about themselves and their families with their co-workers. How much is too much? It really depends on who you ask.

Latinos tend not only to share a lot about themselves but also to ask about other people's families. They can often surprise a colleague with a question like, "How's your aunt Margie doing?" when the colleague no longer remembers that her aunt had an operation a month ago. They ask because they care and they expect others to care about them as well. So when nobody asks Latinos about their sick child or their cousin who got married, they tend to feel isolated and disengaged. If you use these cultural differences at work as an opportunity to learn from each other, you can make it a much better (and humanized) workplace.



### **Waiting to be recognized**

Another one of the most common examples of cultural differences in the workplace is how well (and how much) someone promotes their contributions. Humility is a basic value for many cultures (Hispanic culture included), which means that self-promotion is not particularly appreciated, encouraged or even taught at home.



An example of cultural difference: Waiting to be recognized rather than boasting about your accomplishments.

Latinos, for instance, are usually taught to work hard and keep their heads down. They are taught that they will be recognized by their hard work. But the reality in workplaces across America is that people who fail to speak about their accomplishments are often passed over for promotion. The principle being that in order for someone to think of you when there's an opportunity, they need to know what you're good at and what you could do for the project they have in mind.

So the key in this case is to learn to balance your need to remain humble with cultural differences in the workplace that demand that you talk about your achievements if you want to move forward in your career.

These cultural differences in the workplace are the reason why managing a culturally diverse workforce is a challenge. But they are also the fibres that make the fabric of our workplaces stronger. Learn to identify them and value them, and you'll be several steps ahead of the pack.

What other examples of cultural difference in the workplace come to mind?



## 17 Tips To Survive Your Next Networking Event

Darrah Brustein

*(The founder of Network Under 40, a networking organization for young professionals.)*

No matter what profession you're in, networking is the fuel that accelerates success. Not only is it useful for learning directly from individuals you meet, but the benefits of association and growing your own authority are just as powerful. For some of us, the word networking can leave a bad taste in our mouths. Many of us aren't sure where to start, what to say when we connect with someone or how to maintain that relationship. What follows is a short guide to networking.

[www.forbes.com](http://www.forbes.com)

The Paper Industry Technical Association (PITA) is an independent organisation which operates for the general benefit of its members – both individual and corporate – dedicated to promoting and improving the technical and scientific knowledge of those working in the UK pulp and paper industry. Formed in 1960, it serves the Industry, both manufacturers and suppliers, by providing a forum for members to meet and network; it organises visits, conferences and training seminars that cover all aspects of papermaking science. It also publishes the prestigious journal *Paper Technology* and the *PITA Annual Review*, both sent free to members, and a range of other technical publications which include conference proceedings and the acclaimed *Essential Guide to Aqueous Coating*.



You arrive alone. Your heart is beating a little faster than normal and suddenly all of your charisma and charm go out the window. You try to lock eyes with someone so that you can find a temporary home in what can feel like a sea of strangers. But everyone looks happily engaged in conversation.

While this might sound like your experience at a middle school dance, it's also what many people feel when they enter a networking event. These are completely natural reactions, even for the biggest extroverts. The great news is that people go to these events to meet strangers, so you're in the same position as everyone else. Here are 17 helpful tips for navigating a networking event and making the most of your time there:

1. Find the bar! Whether or not you're drinking, it's always a great idea to position yourself at the edge of the bar. Many people run for the bar when they get to a networking event in order to get a short respite from an overwhelming entrance. If you position yourself a few steps from the bar, you can easily strike up a conversation as people turn with drink in hand.
2. Be yourself. Networking events are meant as jumping-off points for relationship building. If you can't be yourself, you'll be starting off these new relationships with a lie. Don't try to be the person you think others want to meet. Be genuine. The people you connect with when you are authentic are the ones you'll want to stay in touch with.
3. Set reasonable expectations. When attending an event, understand what you are there to do. Is your goal to feel out a new organization and get to know the vibe? Is it to meet five new people? Is it to meet one or two specific people? These are all reasonable expectations and it takes a little pre-planning to set these goals.
4. Don't spread yourself too thin. Start by spreading a large net to test out a handful of organizations and then commit yourself to only a few as time goes on. You want to become a staple at these events. When you bounce around to too many events where no one knows you, you're doing yourself a disservice by having to build your brand from scratch in each environment. You'll also find that networking is a lot more fun when you become a regular. People will sing your praises to new attendees (this is always better than you doing it yourself) and you'll see lots of familiar faces.
5. Take notes. When you ask for someone's card after having a great conversation, take notes on their business card after they walk away or immediately after the event. This will help you to be more specific in your follow-up.
6. Introduce yourself to the organizer. A great way to get to know more about an organization and who is involved is to seek out the event organizer and introduce yourself. He/she can then help point you in the right direction and can introduce you to other attendees to get you off on the right foot.
7. Treat people like friends. Would you go to a friend, interrupt his/her conversation, hand over a business card, talk about yourself and then walk away? Of course not. Treat new networking relationships as you'd treat your friendships. Build rapport and trust that business will happen.
8. Ask great questions. The only way to get to know someone else is to ask them genuine and thoughtful questions. It's always best to walk away from a conversation having allowed the other person to speak more than you did. Not only will they feel great about



the conversation, but you'll have gotten to know a lot about him/her, helping you plan and execute your follow-up more thoughtfully.

9. Sharing is caring. This is no less true now than it was in kindergarten. If you are willing to share your contacts and resources, others will be more likely to help you as well. Develop a sincerity in your giving nature without expectation of something in return.
10. Consider their network. When meeting people, it's important to remember that even if they can't help you directly, someone in their network probably can.
11. Treat connecting like a puzzle. If you're asking great questions and considering how you can help others, you'll naturally start to draw connections between who you are talking to and others in your network. Offer to make these connections! Perhaps they are two people who have the same target client industry, or maybe you know that a contact of yours is looking for the service the other provides. Encourage both parties to follow up with you after they meet so that you can hear what came of their interaction. It will not only pay dividends for you, it will also help you hone your matchmaking skills.
12. Don't be a card spammer. The closest thing to you throwing all of your business cards away is handing them out to anyone and everyone you meet without them asking. If you haven't built enough rapport with someone to encourage them to ask for your card, don't offer one.
13. Be specific. The more specific you can be about what you do and what others can do to help you (if they ask), the better. Tell them the names of a few specific companies you're looking to work with.
14. Ask yourself why they should care. Consider why the person you're speaking to should care about what you're saying. Craft your conversations accordingly. You only have a short time to make an impression, so try to make it favourable.
15. Be engaged. Keep eye contact with your conversation partner. Nod your head and tilt your body towards them when you're speaking. These small cues go a long way towards making them feel like you care, which helps you to build rapport and trust: the foundation on which you can later do business.
16. Do NOT "work the room." Don't try to meet as many people as possible in a room; focus on making just a few solid connections. People can sense when you're simply speaking with them to grab their card and go. These short interactions will not be memorable and therefore work against you. Aim to meet a few people and begin a meaningful dialogue.
17. Don't be afraid to join in. There is nothing wrong with joining a conversation and waiting for a natural break in the chatter to introduce yourself. In most cases, the people who are already speaking will enjoy the interruption because it gives them a chance to meet someone new. If you sense that you've entered into a serious discussion, it's okay to politely excuse yourself.

Now you're prepared to rock your next networking event and hopefully build some meaningful relationships in the process. And remember; do talk to strangers!



## Why (and How) to Confront Problem Employees

*Everybody's worked with a difficult colleague before, whether it's a passive-aggressive colleague, an explosive boss, or a lazy direct report. But despite their prevalence, many leaders seem to be unwilling or unable to deal with them effectively. And that hurts everyone.*

*Problem employees can have a negative impact on their team, but also on the career of their boss, our research shows. The good news — if you're willing to confront your problem employee about unacceptable behaviours, you can probably create a more positive outcome for everyone involved.*

*We've long known that confronting problem employees results in better outcomes for organizations and for leaders themselves. A classic study of managers shows the benefit of taking action; Leaders who consistently confronted problem employees tended to achieve better overall team performance. They're also more likely to get promoted.*

[www.ccl.org](http://www.ccl.org)

The Paper Industry Technical Association (PITA) is an independent organisation which operates for the general benefit of its members – both individual and corporate – dedicated to promoting and improving the technical and scientific knowledge of those working in the UK pulp and paper industry. Formed in 1960, it serves the Industry, both manufacturers and suppliers, by providing a forum for members to meet and network; it organises visits, conferences and training seminars that cover all aspects of papermaking science. It also publishes the prestigious journal *Paper Technology* and the *PITA Annual Review*, both sent free to members, and a range of other technical publications which include conference proceedings and the acclaimed *Essential Guide to Aqueous Coating*.



## Why You Should Deal with Problem Employees

There are several reasons why confronting problem employees improves results. In some instances, it can result in positive behavioural changes. It may also signal to others what effective behaviour looks like, and it indicates that managers are paying attention to the performance of the team. Plus, other group members may be more motivated if they know problem employees are being properly dealt with, rather than being ignored or left to diminish the work and morale of the team.

The effect of these problem employees and others like them is clear. Our research shows that they hurt their work groups in 5 primary ways:

- Eroding trust
- Reducing innovation
- Reducing output
- Disrupting decision-making
- Damaging the team's reputation

But that's not all. Problem employees also hurt their leaders by reducing your effectiveness, impairing your reputation, reducing your desire to stay in the department, decreasing your desire to stay with the organization, and diminishing your chances of a promotion, according to our research.

So, what can you do about it?

First, it's important to consider what kind of problem employee you're dealing with. To better understand what you're up against, we recently studied the scope of the issue by surveying more than 200 global leaders about problem employees they've dealt with. We found that these 5 behaviours are most common:

# 5 Problem Employee Behaviors

*As Described by Leaders Worldwide*

-  **1 Poor Job Performance**
-  **2 Can't Work Well with Others**
-  **3 Doesn't Respond to Coaching**
-  **4 Resistant to Change**
-  **5 Not Responsible for Own Actions**

 Center for Creative Leadership®



1. **Poor Job Performance.** An employee whose work falls below expectations, causing others to constantly have to pick up the slack, can be a tremendous drain on teams, especially when it's habitual.
2. **Can't Work Well with Others.** Employees who struggle to create positive relationships with their colleagues, clients, or customers can be a liability.
3. **Doesn't Respond to Coaching.** Employees who aren't responsive to coaching or feedback fail to make necessary changes despite repeated, explicit attempts to work with them.
4. **Resistant to Change.** Leaders report issues with employees who resist change, or who may even refuse a change altogether.
5. **Not Responsible for Own Actions.** An unwillingness to take responsibility for their actions — and instead blaming others — also ranked highly as a common negative attribute, regardless of the exact form the behaviour took.

### **How to Address Problem Employees**

Based on decades of research and experience, we recommend using the Situation-Behaviour-Impact (SBI) model. By relying on facts rather than judgment, you're more likely to change a problem employee's behaviour.

Ideally, giving consistent feedback — including praise — will result in better behaviours and performance from all employees. SBI can be used to reinforce positive behaviour, but we also recommend learning how to have better conversations every day. Difficult conversations are often necessary because better conversations didn't happen early on. You can get ahead of trouble instead of waiting for it to arrive.

When giving feedback, try to remember these 10 best practices:

1. Be timely and deal with issues as they arise.
2. Be open to the employee's perspective.
3. Keep it short, and let the employee respond.
4. Show empathy and genuine care.
5. Don't sandwich negative feedback between positive reinforcement.
6. Give positive feedback when it's deserved.
7. Aim for a 3:1 ratio of positive to negative feedback.
8. Practice what you're going to say, and how.
9. Aim for behavioural awareness, not "fixing" someone.
10. Create a favourable environment for feedback.

What if none of that works?

If you've repeatedly tried to provide feedback to your problem employee and it isn't working, it's time to consider other options. Sometimes you can help people the most by guiding them to pursue opportunities better suited to their capabilities, though it's important to approach this with care. Seek involvement and counsel from a supervisor, the HR department, or legal counsel.



Before you escalate a situation, be sure that you've made every effort to be fair, and that you've kept a written record of the problem behaviours, the impact of these behaviours, and the feedback that you delivered. This could reduce both pushback from your superiors or from the problem employee, and it may lower litigation risks or negative repercussions that might impact internal or public perceptions of your organization.

Hopefully, it won't rise to that level. But we understand that the daunting possibility is why some leaders choose to avoid potential conflict with a problem employee altogether. As noted, taking action is in the best interest of you, your team, and the employee in question.



## You Can Master the 3 Ways to Influence People

Influence is the power and the ability to personally affect others' actions, decisions, opinions, or thinking.

Ultimately, influence allows you to get things done and achieve desired outcomes.

At a basic level, influence is about compliance — getting someone to do what you want them to do (or at least not to undermine it). But genuine commitment from other people is often required for you to accomplish key goals and tasks.

Early in your career, or in individual contributor roles, influence is about working effectively with people over whom you have no authority. It requires the ability to present logical and compelling arguments and engaging in give-and-take. In senior-level or executive roles, influence is focused more on steering long-range objectives, inspiration, and motivation.

[www.ccl.org](http://www.ccl.org)

The Paper Industry Technical Association (PITA) is an independent organisation which operates for the general benefit of its members – both individual and corporate – dedicated to promoting and improving the technical and scientific knowledge of those working in the UK pulp and paper industry. Formed in 1960, it serves the Industry, both manufacturers and suppliers, by providing a forum for members to meet and network; it organises visits, conferences and training seminars that cover all aspects of papermaking science. It also publishes the prestigious journal *Paper Technology* and the *PITA Annual Review*, both sent free to members, and a range of other technical publications which include conference proceedings and the acclaimed *Essential Guide to Aqueous Coating*.



We've found that influencing tactics fall into 3 categories: logical, emotional, or cooperative. We call this influencing with head, heart, and hands.

1. Logical appeals tap into people's rational and intellectual positions. You present an argument for the best choice of action based on organizational benefits, personal benefits, or both.
2. Emotional appeals connect your message, goal, or project to individual goals and values. An idea that promotes a person's feelings of well-being, service, or sense of belonging has a good chance of gaining support.
3. Cooperative appeals involve collaboration (what will you do together?), consultation (what ideas do other people have?), and alliances (who already supports you or has the credibility you need?). Working together to accomplish a mutually important goal extends a hand to others in the organization and is an extremely effective way of influencing.

## 3 WAYS TO INFLUENCE:



### LOGICAL APPEALS

Tap into people's  
rational and intellectual  
positions



### EMOTIONAL APPEALS

Connect your message,  
goal, or project to  
individual goals & values



### COOPERATIVE APPEALS

Involve collaboration,  
consultation, and  
alliances



To maximize your personal influence, you'll want to become skilled in all 3 styles. Decide which tactics will reap the most support for a specific task or strategy and employ one or more approaches. To understand which tactics might work best, consider the following:

- **Assess the situation.** Why are you involved in this work? Why do you need this person's support? What outcomes are you trying to achieve by influencing this person? Be clear about whom you need to influence and what you want to accomplish.
- **Know your audience.** Identify and understand your stakeholders. Each will have special concerns and issues, as well as their own agenda, perspectives, and priorities. Various groups and individuals will require different approaches for influencing. Tailor your influencing strategy for the particular person — considering individual personalities, goals, and objectives — as well as organizational roles and responsibilities.
- **Review your ability.** What tactics do you use most often? Which seem to be most effective? What new tactics could you try in this situation? Draw on others for advice or coaching, too. For example, if you always focus on the logical appeals, have a co-worker who is a strong collaborator help you think through your collaboration tactics and arguments.
- **Brainstorm your approach.** What tactics would work best? Which logical appeals will be most effective? How could you make an emotional or cooperative appeal? What specifically could you say and do to use each type of tactic? Anticipate possible responses and prepare your reply. What counterarguments could you use? What additional influencing tactics would be helpful?

At first, you might want to try out new influencing tactics in low-risk situations, practicing these skills 1-on-1. As you become more versatile, you'll gain confidence in your ability to influence teams and larger groups, and to persuade others in higher-stakes situations.

But also consider changing tactics right away if you have a pressing issue that has stalled due to lack of buy-in or support. Would a more logical, emotional, or collaborative approach make a difference? If so, go ahead and try out a new angle — you might be more influential than you realized.

Influence is one of the key skills taught in our flagship Leadership Development Program and can help you dramatically improve your effectiveness at work.



## Bridging the Leadership Gap: Are We Any Closer?

*Do you know where your future leaders are?*

*Despite more than a decade's worth of widely disseminated leadership-gap research from CCL and others, a wide and growing gap remains between the future leadership needs of organizations around the world and their current leadership capabilities.*

*More than a decade ago, we started to document the gap between the readiness of future organizational leaders and their current leadership skills.*

*From 2006 to 2008, we surveyed 2,200 leaders from 15 organizations in 3 countries and found that crucial leadership skills necessary to meet future organizational demands were missing. Surveys of 2,339 managers from 24 organizations across 3 countries from 2009 to 2015 found that the leadership gap persisted, and suggested that little progress was being made in addressing it.*

*Other academics and leadership development organizations have documented similar shortcomings.*

*What's going on?*

[www.ccl.org](http://www.ccl.org)

The Paper Industry Technical Association (PITA) is an independent organisation which operates for the general benefit of its members – both individual and corporate – dedicated to promoting and improving the technical and scientific knowledge of those working in the UK pulp and paper industry. Formed in 1960, it serves the Industry, both manufacturers and suppliers, by providing a forum for members to meet and network; it organises visits, conferences and training seminars that cover all aspects of papermaking science. It also publishes the prestigious journal *Paper Technology* and the *PITA Annual Review*, both sent free to members, and a range of other technical publications which include conference proceedings and the acclaimed *Essential Guide to Aqueous Coating*.



## **Barriers to Bridging the Leadership Gap**

To be sure, companies, government agencies, and nonprofits want their future leaders to be prepared. But internal and external forces are blocking or slowing down leader development efforts. Those include:

1. **Outdated ideas about leadership.** For many leaders and employees, the term “leader” still suggests an individual whose role is to provide all the answers. However, we know the most effective leaders are those who are skilled at influencing, collaborating, and helping a team or organization discover the answers. Our research has also found that some individuals view leadership roles as requiring tradeoffs with other priorities, such as family. Those perceptions — whether true or not — are likely dissuading many high-potential employees from pursuing leadership development and leadership roles.
2. **Digital disruption.** The pace of technological innovation over the last generation has reshaped markets, created new industries, and transformed the way we work. But many organizations and their workers are struggling to keep up. Training and adoption of new technologies — such as those required for remote working and distributed teams — hasn’t kept up. One study a few years ago found that more than 60% of organizations surveyed provided no training for virtual teams or virtual team leaders on how to deal with the challenges of collaborating virtually. And opportunities such as analytics and the promise of Big Data have many organizations scrambling to understand what talent and skills they’ll need to succeed in the future.
3. **Flatter organizations and more dynamic environments.** In our faster-moving economy, rigid hierarchical organizational charts have given way to flatter, more agile structures. While this helps companies respond faster to customer needs and changing markets, it has also eliminated the traditional “move up the ladder” leadership development path. Now lateral movement — perhaps to a different geographic or functional area — is required for individuals who want to become leaders. Mapping out these lateral-and-upward career paths is tough for individuals and organizations.
4. **Intense competition for top talent and higher turnover.** The days of a 30- or 40-year career with a single organization are long gone. Organizations find themselves focused on competing with other organizations to attract and retain talent. In addition, as more workers reach retirement age, organizations may be challenged to identify new potential leaders and build a leadership pipeline.
5. **Misaligned systems for measuring and rewarding work performance.** Old ways of evaluating employees and rewarding them don’t make much sense when career growth requires lateral movement and employees may switch from one employer to another every few years. Furthermore, organizations may be investing in outdated practices that contribute to the leadership gap and also fail to align with organizational goals and strategies.



## **The Shape of Today's Leadership Gap**

So how has the leadership gap changed and grown over the last decade?

In our research, we identified 9 leadership competencies that were weak or missing. These represent both a gap between current leadership needs and skills as well as future leadership needs and current skills:

- Managing change
- Inspiring commitment
- Leading employees
- Taking initiative
- Building collaborative relationships
- Having a strategic perspective
- Knowing strategic planning
- Embracing participative management
- Being a quick learner

In the last couple of years, we've seen a 10th crucial leadership competency grow in importance — career management is now also critical. Current and future leaders can no longer rely on their employers to guide and manage their careers. But rather, they need to be able to do so on their own.

So where does all this leave us?

**Organizations that want to ensure they have the leaders they'll need (and won't have a leadership gap) must take leadership development into their own hands.** They need to be deliberative and strategic in defining their goals and strategies, and understand the challenges to achieving those goals.

Those challenges, in turn, should inform decisions about what leadership competencies the organization requires. With those established, employers can develop leadership development programs, talent management strategies, and leadership pipelines they need to nurture and grow future leaders.

These things are, unfortunately, harder than simply going out and hiring the next hotshot high-potential manager or implementing new collaboration software. Leadership development can be messy and challenging, just like the environments our organizations operate in.

But facing those messy challenges is the only way to bridge the leadership gap and ensure your organization survives and thrives.



## Improve Your Memory Developing Your Ability to Remember

*Are you often unable to remember an important fact or figure?*

*Do you forget people's names at the worst moments?*

*Are you ever asked a question, and you should know the answer, but you struggle to form an intelligent reply?*

*These are common instances where a good memory is important.*

**[www.mindtools.com](http://www.mindtools.com)**

The Paper Industry Technical Association (PITA) is an independent organisation which operates for the general benefit of its members – both individual and corporate – dedicated to promoting and improving the technical and scientific knowledge of those working in the UK pulp and paper industry. Formed in 1960, it serves the Industry, both manufacturers and suppliers, by providing a forum for members to meet and network; it organises visits, conferences and training seminars that cover all aspects of papermaking science. It also publishes the prestigious journal *Paper Technology* and the *PITA Annual Review*, both sent free to members, and a range of other technical publications which include conference proceedings and the acclaimed *Essential Guide to Aqueous Coating*.



Memory is more than recalling information for exams or trivia games. It's an important work skill that you can develop and improve. Whether it's remembering key statistics during a negotiation, or quoting a precedent-setting action when making a decision, or impressing clients with your knowledge of their product lines – your ability to remember is a major advantage.

People with good memories are often seen as knowledgeable, smart, competent, and dependable. And there are many techniques you can use to develop your own ability to remember information – and then recall it when and where you need it.

### **Take Care of Your Health**

The basis for a good memory is a healthy mind and body. You can't expect your brain to function at its best if you don't take care of the body that feeds it. Here are some key issues that you need to address:

- Eat well – Make sure key vitamins are in your diet, including folic acid, vitamin B12, and antioxidants. These improve the sharpness of the mind. If necessary, take vitamin supplements.
- Drink plenty of water – Most of us are dehydrated and don't even know it. When you don't drink enough water, your body and mind become weak and tired. Water makes red blood cells more active and gives you more energy.
- Get enough sleep – During sleep, your brain recharges itself. Studies have shown that your brain needs sleep to change new memories into long-term memories.
- Manage stress effectively – Ongoing stress has many harmful health effects. Learn to limit and control the stress in your life. Use physical relaxation techniques, thought awareness and rational positive thinking, and imagery to reduce your levels of stress.
- Don't smoke – Limit caffeine and alcohol use (excessive alcohol can seriously affect your short term memory). Get enough exercise.

These basic health tips allow you to maximize your brain's abilities.

### **Use Mnemonics**

Mnemonics are simple memory-improving tools that help you connect everyday, easy-to-remember items and ideas to information you want to remember. Later, by recalling these everyday items, you can also recall what you wanted to remember.

There are many mnemonic techniques:

- **The Number/Rhyme Technique** - This allows you to remember ordered lists. Start with a standard word that rhymes with the number (we recommend 1 – Bun, 2 – Shoe, 3 – Tree, 4 – Door, 5 – Hive, 6 – Bricks, 7 – Heaven, 8 – Gate, 9 – Line, 10 – Hen). Then create an image that associates each with the thing you're trying to remember. To remember a list of South American countries using number/rhyme, you might start with:



- One – Bun/Colombia: A BUN with the COLUMn of a Greek temple coming out of it.
  - Two – Shoe/Venezuela: VENus de Milo coming out of the sea on a SHOE.
  - Three – Tree/Guyana: Friends call GUY and ANnA sitting in a TREE.
  - Four – Door/Ecuador: A DOOR in the shape of a circle/globe with a golden EQUAtOR running around it.
- **The Number/Shape System** - Here, create images that relate to the shape of each number, and connect those images to the items in your list. Let's use the same example:
  - One – Spear/Columbia: The shaft of the SPEAR is a thin marble COLUMn.
  - Two – Swan/Venezuela: This time, VENus is standing on the back of a SWAN.
  - Three – Bifocal Glasses/Guyana: GUY has just trodden on ANnA's bifocals. She's quite cross!
  - Four – Sailboat/Ecuador: The boat is sailing across the golden line of the EQUAtOR on a globe.
- **The Alphabet Technique** – This works well for lists of more than 9 or 10 items (beyond 10, the previous techniques can get too difficult). With this system, instead of finding a word that rhymes with the number, you associate the things you want to remember with a particular letter of the alphabet, from A to Z. This is an efficient way to remember an ordered list of up to 26 items.
- **The Journey System** – In your mind, think about a familiar journey or trip: for example, you might go from your office to your home. Associate the things that you want to remember with each landmark on your journey. With a long enough, well-enough known journey, you can remember a lot of things!
- **The Roman Room System** (Loci Method) – This technique uses location to stimulate your memory. Connect your list with items you see in a familiar room or location. You might find associations with things in your kitchen, in your office, or at a familiar grocery store.

## **Mind Mapping**

**Mind Maps** (also called concept maps or memory maps) are an effective way to link ideas and concepts in your brain, and then "see" the connections firsthand. Mind Mapping is a note-taking technique that records information in a way that shows you how various pieces of information fit together. There's a lot of truth in the saying "A picture speaks a thousand words", and mind maps create an easily-remembered "picture" of the information you're trying to remember.

This technique is very useful to summarize and combine information from a variety of sources. It also allows you to think about complex problems in an organized manner, and then present your findings in a way that shows the details as well as the big picture.



The Mind Map itself is a useful end product. However, the process of creating the map is just as helpful for your memory. Fitting all the pieces together, and looking for the connections, forces you to really understand what you're studying – and it keeps you from trying to simply memorize.

### **Challenge Your Brain**

As with other parts of your body, your mind needs exercise. You can exercise your brain by using it in different ways, on a regular basis. Try the following:

- **Learn a new skill or start a hobby** – Find activities that build skills you don't normally use in your daily life. For example, if you work with numbers all day, develop your creative side with art classes or photography.
- **Use visualization on a regular basis** – Since much of memory involves associating and recalling images, it's important to build this skill. Get plenty of practice with this!
- **Keep active socially** – When you communicate and interact with people, you have to be alert. This helps keep your brain strong and alive.
- **Focus on the important things** – You can't possibly remember everything, so make sure you give your brain important things to do – and don't overload it with "waste." The "garbage in, garbage out" philosophy works well here.

**Tip: While it's important to develop a good memory, remembering unnecessary things (such as tasks you need to do, or things you need to buy) is hard work. What's more, because these consume short-term memory, they can diminish your ability to concentrate on other things. They can also leave you stressed, as you struggle to remember all of the things you have to do.**

**Write these things down on your to-do list! This way, you don't have to remember everything. And if your memory fails, you know where to look for the information you need.**

Keep your brain active with memory games and puzzles – Try Sudoku, chess, Scrabble, and Word Twist as well as trivia games, pair matching, and puzzles. These are popular ways to practice memorization while having fun. And explore brain-training sites like Lumosity as a way of pepping up your mind.

### **Key Points**

- Your memory is a valuable asset that you should protect and develop. Even if you no longer have to memorize information for exams, the ability to remember quickly and accurately is always important.
- Whether it's remembering the name of someone you met at a conference last month, or recalling the sales figure from last quarter, you must rely on your memory. Learn and practice the above techniques to keep your mind healthy.
- You have only one brain – so treat it well, give it lots of exercise, and don't take it for granted. You never know when you'll need its skills to be at their best!



## Products & Services

### PITA CORPORATE SUPPLIER MEMBERS

|         |                        |
|---------|------------------------|
| Page 2  | <b>ABB</b>             |
| Page 8  | <b>Archroma</b>        |
| Page 11 | <b>Buckman</b>         |
| Page 12 | <b>Jarshire</b>        |
| Page 15 | <b>SchaeferRolls</b>   |
| Page 18 | <b>Toscotec S.P.A.</b> |

### OTHER SUPPLIERS

|         |                                        |
|---------|----------------------------------------|
| Page 24 | <b>Cleaning / Maintenance / Safety</b> |
| Page 30 | <b>Materials Handling</b>              |
| Page 36 | <b>Pumps / Pumping</b>                 |
| Page 39 | <b>Miscellaneous</b>                   |



## **COMPLIMENTARY SERVICE PROTECTS DRIVE INVESTMENT FROM DAY ONE**

ABB drives customers now benefit from a complimentary support agreement during the warranty period.

A new service from ABB gives users of medium- and high- power variable speed drives complimentary access to a host of services throughout the warranty period. Drive users now receive access to on-site repair, rapid exchange of faulty parts with access to original spares, telephone support during office hours and technical query escalation.

Customers only need to register the drive at the point of commissioning to activate the service. The registration can be handled by ABB directly or through one of its authorised value providers. Alternatively, customers can download a registration app and enrol the drive themselves.

Both telephone and ABB Ability™ cloud-based remote support offers advice, guidance and issue resolution. This benefits those customers who are trying to get a drive up and running or seeking reassurance that the drive operates as intended. Reduced downtime and plant interruption is further enhanced by escalation to global experts who handle advanced user queries. For medium voltage drives, rare instances of drive failure or condition monitoring can benefit from ABB Ability remote support from specialist teams.

Throughout the warranty period customers will receive continuous support and engagement for backup. This includes advice on maintenance techniques, trends and practices. Customers will obtain priority notifications of upgrades and enhancements.

The service is available for larger ABB industrial drives that includes: ACS880, ACS1000, ACS2000, ACS5000, ACS6000, ACS6080, ACS580MV, Megadrive-LCI, DCS880.

“ABB Initial Care gets the best out of your investment without any extra costs, while maintaining seamless operation,” says Stuart Melling, ABB business unit manager, drives & controls, UK. “By simply registering your drive you get valuable access to ABB’s immense application know-how and product expertise. ABB Initial Care reduces the risk of downtime and offers peace of mind support throughout the warranty period; it also introduces the customer to the wider benefits of ABB Drive Care .”

Following the ABB Initial Care period, users have the option to transfer to a full ABB Drive Care service package with associated costs. This service includes preventive care, complete care and replacement care and features maintenance services, specialised support, ABB Ability digital activities such as remote assistance and remote condition monitoring and failure recovery.

[www.abb.com](http://www.abb.com)  
(May 2018)



## **ABB INTRODUCES NEW ABB ABILITY™ WEB MONITORING SYSTEM FOR PAPER INDUSTRY APPLICATIONS**

Innovative high resolution web monitoring system designed for the fastest paper, board or tissue machines.

ABB, the pioneer in Web Imaging Systems, introduces their new ABB Ability™ Web Monitoring System, for the paper industry. Part of ABB's suite of Quality Management Systems (QMS), the Web Monitoring system incorporates a new generation of imaging hardware and software to provide real-time web monitoring and analytics, for the quick identification of product deviations that can result in sheet breaks and lost production. With this technology, the paper production can run efficiently at its highest speed while maintaining the highest quality.

Accurate web defect detection, imaging and identification all play crucial roles in process improvement. Through the QMS Web Monitoring System's unique level of integration with the QMS Web Imaging System, critical insight is provided for the diagnosis and prevention of web breaks and improved sheet stability.

ABB Ability™ Web Monitoring System includes a new generation of high-speed cameras that deliver the required high resolution and sharp images. This is complimented by high speed video processing and synchronization, unique analytics, and operator interface features to reduce disruptive events and analyze process behavior.

[www.abb.com](http://www.abb.com)

(May 2018)



## **ABB EXPANDS UK NETWORK FOR LOW VOLTAGE DRIVES AND DODGE® PRODUCTS**

Companies in the North East and Cheshire now have new outlets to access low voltage variable speed drives, while a national single source for mechanical power transmission products is also established.

ABB has extended the reach of its UK variable speed drives (VSD) and mechanical power transmission products with an expansion of the ABB authorised value providers.

EDC (North East) is appointed as an ABB authorised value provider serving customers in Tyne & Wear and Cumbria with VSDs up to 500 kW and a range of life cycle services. The company operates from a dedicated facility on the Team Valley Trading Estate in Gateshead.

The services include reliability assessments and harmonic surveys, through to installation and start-up, operation and maintenance, upgrade and retrofit and replacement and recycling. The Gateshead site also houses a workshop for repair work.

Beta Power Engineering based in Stockport, Cheshire is expanding its current role as an ABB authorised value provider for low voltage motors, with the addition of VSDs up to 500 kW. The company has been an ABB authorised value provider since its inception and was previously a member of the ABB Motor Service Partner network for 15 years.

West Midlands-based Race Transmissions is appointed the first national ABB authorised value provider for mechanical power transmission products including Dodge bearings and shaft mounted gear reducers.

The company exclusively supplies and supports the full range of Dodge mounted bearings – including Type E tapered roller bearings, S-2000 series spherical roller bearings, along with Grip Tight and E-Z Kleen ball bearings. With some £500,000 worth of products stocked at its Brierley Hill premises, Race has the largest stockholding outside of the USA, where the products are manufactured.

The ABB authorised value provider programme provides UK customers with ABB motors, VSDs and mechanical power transmission products together with a wide range of services, technical advice, training and bespoke contracts. Although each ABB authorised value provider is an established and successful engineering company, all members of the network must undertake regular training to ensure their product, industry and technical knowledge is of the standard required to deliver accredited sales, support and service in close cooperation with ABB.

[www.abb.com](http://www.abb.com)  
(July 2018)



## **NEW ABB ABILITY™ CYBER SECURITY ASSET INVENTORY SOLUTION**

Today, at PowerGen Africa in Johannesburg, ABB unveils a new solution, ABB Ability™ Cyber Security Asset Inventory, designed to reduce the time, cost and vulnerability associated with managing assets connected to online services, the so called 'cyber inventory'. ABB Ability™ Cyber Security Asset Inventory will be available from September 2018 for customers in the power and water industry before later being rolled-out to all industries.

Cyber security standards require operators of critical infrastructure to assess their cyber security regularly. Typically, this is done every 12 to 24 months depending upon the corporate policy or national standard. To do this, an operator must first complete an inventory of the software, ports and services they have enabled within their control network. Until now there was no global automated tool available that could collect the information and create such an inventory for an operator's environment, so they had to either maintain their inventory manually or use consultants to deliver the work. Currently, most companies maintain their cyber security asset inventory in a manual way which is time consuming, expensive, and results in their inventory being incomplete.

The new ABB Ability™ solution significantly reduces the need for any manual collection and formatting of asset data. It automatically captures changes in the inventory and updates the industrial cyber asset inventory. Users benefit from an evergreen view to support vulnerability assessment efforts.

For the first time, operations and security teams always have up-to-date cyber asset inventory, helping them to make better decisions about cyber security, life-cycle and asset management.

ABB says that automating the cyber security asset inventory process could save companies significant man hours. Susan Peterson-Sturm, ABB's digital lead for Power and Water said, "Take an 880 MW coal fired plant with 8000 cyber assets. Manually maintaining its cyber asset inventory would require three employees working one to two days a week, the equivalent of around 48 hours weekly, 192 hours monthly, or 2304 hours annually. The automation through ABB Ability™ Cyber Security Asset Inventory significantly reduces labour costs as well as security risk."

The new solution reduces system vulnerabilities by comparing behaviours. Susan Peterson-Sturm adds, "In order to defend an environment you must first understand it. Knowing expected normal behaviour will help spot anything out of the ordinary so rogue devices or applications can be identified. Expected behaviour, through documentation and performance data, is crucial in detecting anomalies.

"ABB Ability™ Cyber Security Asset Inventory functions across most major control systems in the utilities space without impacting operations. The solution improves the strategic alignment of IT and operations, providing real-time visibility enabling both teams to work together effectively to defend the plant network."

ABB Ability™ is a unified, cross-industry digital capability that combines deep domain expertise from device to edge to cloud, with unmatched experience in connectivity.

[www.abb.com](http://www.abb.com)  
(July 2018)



## **ABB ABILITY™ COLLABORATIVE OPERATIONS**

Advanced digital services help increase overall mill productivity through expert insights and analysis of mill data that improve business decisions

ABB recently added ABB Ability™ Collaborative Operations to its service deliverables at a major paper mill in East Java, Indonesia. The site produces a variety of printing and writing paper, other paper-related products, and packaging products including cardboard boxes. With an annual capacity of 320,000 metric tons, the mill is one of the world's largest single-site producers of writing stationery.

Automating production requires processing large amounts of data. As complexity increases, so does the volume of data. Collaborative Operations helps paper producers to make productive use of this data to identify and address production, quality and cost issues that can inhibit peak performance. This improves return on capital. Collaborative Operations helps to maximize business value by turning data insights into direct action.

At the mill, Collaborative Operations is reducing cycle times on product grade changes, resulting in higher production. It is also stabilizing moisture and other additive levels using multivariable predictive controls. Specific improvements include increased production due to higher equipment availability, fewer sheet breaks, lower chemical costs and reduced paper quality variation. These improvements all lead to better product quality and consistency, fewer rejects and more sales.

This project builds upon ABB's 15-year history of delivering traditional and advanced services to the mill. Collaborative Operations enhances ABB's ability to positively impact daily mill operations to ensure that results achieved over the years will continue and improve.

ABB has three Collaborative Operations Centres dedicated to pulp and paper industry customers in Finland, the United States, and now Singapore, as well as many more that serve other industry segments. All three pulp and paper centres may be involved with delivering advanced services to this mill in order to leverage various skill sets in each region.

ABB Ability™ Collaborative Operations is a true Internet-of-Things application and is part of the company's portfolio of ABB Ability™ digital solutions. Collaborative Operations provides performance management, remote monitoring and preventive analysis technologies to improve security, efficiency and productivity in various industries. ABB Ability™ Collaborative Operations Centres connect people in enterprise-wide production facilities and headquarters to ABB's technology and expertise.

Learn more: <https://new.abb.com/pulp-paper/abb-in-pulp-and-paper/collaborative-operations>

[www.abb.com](http://www.abb.com)

(October 2018)



## **ABB DRIVES STANDARD FOR AUTOMATION AND FUTURE-PROOFED IIOT ARCHITECTURES**

Just as HTML spurred growth of the Web, the new Open Platform Communication Unified Architecture (OPC UA) interoperability standard will enable industrial players to unlock the full potential of Industry 4.0.

In an announcement published today by the OPC Foundation, the organization states its vision of becoming the worldwide industrial interoperability standard. This seamless IIoT communication standard, called Open Platform Communication Unified Architecture will apply for all levels of industrial automation. Combined with Time Sensitive Networking (OPC UA over TSN) it will be able to replace a myriad of different fieldbus systems. Forecasting the end of disparate protocols, it will enable devices from different vendors to talk to each other - from the field level to the controller level all the way to the cloud.

ABB is committed to support the industry-wide adoption of OPC UA over TSN. At the vanguard of driving interoperability in industrial automation, ABB and B&R - the acquired and integrated solutions provider for machine and factory automation - have played a pivotal role in bringing together industry stakeholders to establish an open standards based communication for Industrial IoT. Additionally, ABB will take up a designated seat on the board of the OPC Foundation in 2019 to further help accelerate development of the new technology.

As OPC UA over TSN is vendor neutral, customers will no longer see their efforts complicated by incompatible protocols or proprietary ecosystems. This will facilitate integration and spur innovation – an imperative as the Fourth Industrial Revolution accelerates digitalization via the interconnection of billions of smart devices worldwide.

"ABB has long been a pioneer within the automation industry developing leading-edge technologies to deliver solutions to some of industry's greatest challenges," said Peter Terwiesch, President, ABB Industrial Automation Division. "That we have taken a leading role in reaching this historic milestone for open standards and interoperability in industrial automation, which will see major dividends for both customers and suppliers alike, is further testament to our commitment, expertise and vision to unlock the full potential of Industry 4.0." Adoption of the OPC UA over TSN standard will allow companies to leverage the benefits of multi-vendor, peer-to-peer communications and control between sensors, control devices, programmable logic controllers and distributed control systems without the need for costly and time-consuming software development and cumbersome gateways and bridges.

"Customers across the industrial landscape will no longer be bound to suppliers based on the communications protocol used," said Bernhard Eschermann, CTO, ABB Industrial Automation Division and designated board member of OPC Foundation. "Adoption of the new standard will open up cross-industry collaboration and encourage partnerships driven by what creates the most value for customers."

[www.abb.com](http://www.abb.com)  
(November 2018)



## **ARCHROMA INTRODUCES LEUCOPHOR® MT, A NEW COST-EFFECTIVE OPTICAL BRIGHTENING AGENT FOR HIGH WHITENESS SURFACE APPLICATIONS**

Archroma, a global leader in colour and specialty chemicals, today announced the introduction of Leucophor® MT liq, a new tetrasulfonated optical brightening agent (OBA) modified to give high whiteness performance in surface applications.

The application of optical brighteners to the surface of paper is usually done by using either hexasulfonated OBAs, when high whiteness levels are required, or tetrasulfonated OBAs, when standard levels of whiteness are sufficient.

With the increasing costs of some of the key raw materials needed to manufacture hexasulfonated OBAs, Archroma asked its R&D experts to develop a tetrasulfonated agent for surface applications that would give comparable levels of whiteness to hexasulfonated grades.

The outcome is Leucophor® MT liq, a REACH-registered, urea-free, modified tetrasulfonated OBA that offers papermakers a new, cost-effective option to achieve high whiteness levels in a surface application, especially at the size press.

Leucophor® MT liq is produced in Archroma's OBA production facility near Barcelona, Spain, which was extended in 2017 to raise capacity to meet the demands of its European customers.

Andrew Jackson, Product Manager OBAs, Archroma Packaging & Paper Specialties, commented: "With Leucophor® MT liq, we are able to offer a new alternative to both standard tetrasulfonated and hexasulfonated optical brighteners for use in surface applications. This new portfolio option underlines once again Archroma's continuous commitment to delivering innovation and cost efficiency to our customers, and confirms our position as the leading supplier of OBAs to the paper industry."

Leucophor® is a trademark of Archroma registered in many countries.

[www.archroma.com](http://www.archroma.com)  
(February 2018)



## **ARCHROMA CELEBRATES OPENING OF GLOBAL COMPETENCE CENTER FOR WHITENESS**

Archroma, a global leader in color and specialty chemicals towards sustainable solutions, has officially inaugurated its new Global Competence Center for Whiteness in Prat, near Barcelona, Spain.

The Center, which opened on July 5, 2018, further establishes Archroma as a global whiteness leader and underlines Archroma's ambition to bring new, innovative whiteness and brightness solutions to the specialty paper and packaging markets.

Together with the Global Competence Centers for Colorants (Reinach, Switzerland) and for Surface & Coating Technology (Bradford, UK), the new Global Competence Center for Whiteness in Prat forms a unique network of experts fully dedicated to developing innovative product packages to support its customer production process with integrated system solutions.

Whiteness and brightness solutions for paper can be achieved with optical brightening agents complemented with shading dyes and pigments. The new Global Competence Center for Whiteness is therefore ideally located in Prat, where Archroma has major OBA (Optical Brightening Agent) and colorant manufacturing plants, recently extended with additional tetrasulfonated OBA production.

With this, Archroma confirms its unwavering commitment to OBA and the packaging and paper industries. The investment is the second step of a development plan started with the above mentioned OBA plant extension, with further investments to come.

The Global Competence Center for Whiteness team will work in close collaboration with Archroma's innovation organization and the sales teams around the globe, ensuring point-on market relevance of new solutions and innovations, both in terms of performance and sustainability.

During the last few years, Archroma has launched several eco-advanced innovations in the area of whiteness, such as Leucophor® MT liquid, a REACH-registered, urea-free, modified tetrasulfonated OBA that offers papermakers a new, cost-effective option to achieve high whiteness levels in a surface application, especially at the size press, and more recently on the North American market, Leucophor® ACK liquid, a patented ultra-concentrated, urea-free disulfonated OBA for brilliant whiteness in stock and coating applications.

At the opening ceremony held on July 5, 2018, Andrew Jackson, Product Manager OBAs, Archroma Packaging & Paper Specialties, commented: "At Archroma, we continuously challenge the status quo in the deep belief that we can make our industry sustainable. As the paper market has been re-morphing and transforming in the past years, we see a growing demand for chemical solutions that support sustainability. And as consumers are increasingly looking for safer and eco-friendlier options, Archroma is committed to help its customers answer the call, and that clearly includes making sure whiteness solutions are designed accordingly."

Leucophor® is a trademark of Archroma registered in many countries.

[www.archroma.com](http://www.archroma.com)  
(July 2018)



## **ARCHROMA ADDS STRENGTH BOOSTER CARTASTRENGTH® ABL TO ITS SOLUTION SYSTEM FOR PACKAGING AND TISSUE PAPER PRODUCTION**

Archroma, a global leader in colour and specialty chemicals towards sustainable solutions, today announced the introduction of its new innovation, Cartastrength® ABL, a dry strength booster for packaging and tissue papers.

Archroma is committed to introducing innovations especially aimed at making fast-growing sectors - such as packaging and tissue paper - more sustainable. Its innovation efforts focus on increasing performance and sustainability for its customers, both during the manufacturing process and in the end product.

Archroma is therefore working at helping create more durable board and paper, with products aimed at making board and paper stronger or by making the use of recycled fibre easier. The company recently reinforced its strength management portfolio with Cartastrength® ABL, a solution that combines increased filler retention whilst maintaining dry strength.

Archroma now adds a new innovation to its portfolio with Cartastrength® ABL, a product also aimed at boosting the performance of wet, dry and surface strength solutions, as well as improving the retention of fines and fillers.

As with the recently launched Cartastrength® DST.03, Cartastrength® ABL also helps with deposit control (stickies) and machine runnability.

John Cowman, Technical Manager at Archroma comments: "Cartastrength® ABL, and the recently Cartastrength® DST.03, are the latest illustrations of our commitment to continuously challenge the status quo in the deep belief that we can make our industry sustainable. The strength booster was inspired by our innovative focus on the needs of our customers and market. Once more the result is a new chemistry that benefits not only paper producers - who will enjoy a more efficient and cost effective production process, but also the environment, because the recyclability of paper and board is made easier."

[www.archroma.com](http://www.archroma.com)

(October 2018)



## **ADVANCED PROCESS CONTROL WITH SONAR-BASED TECHNOLOGY**

Get superior process control with ECHOWISE, the revolutionary non-invasive technology from Buckman.

Process variability costs money. It prevents your operation from running at optimum performance. ECHOWISE allows you to take control of your process, rather than falling victim to variability and suffering from the inefficiencies it causes.

By providing insight to the process, ECHOWISE assists our problem-solving associates in building a control method to boost the performance of your operation in a variety of ways. Some examples include:



- Paper: Increase machine efficiency, optimize raw materials and specialty chemical costs, improve final sheet quality.
- Pulp: Increase production rate, decrease bleaching costs, reduce steam usage in recovery, reduce soda make-up.
- Corn Processing & Ethanol: Increase production rate, increase yeast viability, capture CO<sub>2</sub>.

Gone are the days of not fully understanding the impact of entrained gasses on the process. With accurate, real-time measurement of entrained air, Buckman develops control algorithms to drive your process to new heights.

### **What makes it different?**

What sets ECHOWISE sonar technology apart from other monitoring options is its innovative, non-invasive design without moving parts or direct contact to process fluids. Installation is safe and easy with no required downtime. ECHOWISE is highly reliable and accurate providing real-time continuous measurement of your entrained air. Unlike conventional technologies, ECHOWISE is not maintenance intensive...no sample lines to plug and no calibration needed. ECHOWISE works in solids/consistency up to 20%.

### **How it Works**

Passive sonar flow processing employs two separate, but synergistic measurement techniques. The first technique measures volumetric flow rate by monitoring turbulent "eddies" within the process flow. The second technique measures the speed at which sound propagates through the fluid to provide compositional information.

[www.buckman.com/smart-technology/echowise/](http://www.buckman.com/smart-technology/echowise/)



## **JARSHIRE FORMS NEW CORRUGATING AND BOARD DIVISION**

With extensive industry experience going back to 1979, and an impressive portfolio of world-leading suppliers, Jarshire's new division has been established to focus solely on the needs of the corrugating and board industries.

The product range is extensive and includes fully and semi-automatic balers from American Baler; Agromech rubber belt conveyors; BACE vertical balers and compactors; Corfflexo knives, slotters and grinding wheels; Dasong corrugator rolls; Faro corrugator roller bearings; Jarshire reel savers; Mecoval mechanical chucks; Jarshire roll and reel movers, brakes and clutches; Taiwan Endurance floor conveyors and board handling systems; Kaituo complete corrugating lines, air extraction and conveying systems; and Svecom slitter scorer shafts.

Already the division has made an impressive start with Director Nick Jobson announcing a 3-year contract with a UK corrugating company for eight American Baler machines.

Already installed is a twin motor AB PAC 5029-T-30 baler with the customer engineering team delighted with the ordering process, installation, and performance of the machine. This horizontal, open-end, auto-tie, single ram baler will process corrugated sheets and trim, converting trim, shredded documents, printers' trim and shreds, folding carton trim, die cuts, and clothing.

Other horizontal balers on order include a PW3560 full-eject, closed door, single ram baler, and a 6042-T-30 open-end, auto-tie single ram shear baler. The PW3560 is suitable for baling OCC, ONP, MOW, tin and aluminium cans, vented PET and HDPE containers, shredded documents and paper, printers' waste, and non-ferrous metals. The 6042-T-30 is designed for small to medium sized MRF's, transfer stations, paper brokers, and printers/converters.

Nick has also reported strong interest in other products from the range, particularly Dasong corrugating rolls. 90% of Dasong's output is of tungsten carbide corrugated rolls - the 4000 sets manufactured in 2017 comprised all flute types including W flute.

Mecoval chucks are also attracting interest. With no internal components, the chucks are not prone to collapse or becoming adversely affected by dust. In operation, the chucks expand when the reel stand arms close guaranteeing that the lugs expand concentric and true, gripping the core perfectly.

Jarshire's Corrugating Division will operate alongside its well-established Converting, Paper, Plastic and Tissue Division headed by brother David. Although newly-formed, Jarshire's experience of the corrugating industry goes back a long way. The company, established by parents Myra and Peter Jobson in 1979, included corrugating-applied equipment in its range from the start and this has continued to the present day.

Although formation of the division is part of Jarshire's future planning, Nick and David have not lost sight of their parents' original philosophy: that is to represent the best, give attention to detail and provide 100% back-up and service to the customer.

[www.jarshire.co.uk](http://www.jarshire.co.uk)  
(January 2018)



## **JARSHIRE ANNOUNCES NEW AGENCY AGREEMENT WITH SCHÄFERROLLS**

Jarshire Limited continues its theme of expansion with the announcement that it has been appointed sole agent in the UK and Ireland for the German company SchäferRolls GmbH & Co. KG.

SchäferRolls has been producing polymer-based roll covers since 1946 and is a leading name in the industry. Renowned for its precision and technical expertise, the company operates within the highest levels of process engineering and process control which, together with state-of-the-art equipment, allows the company to exactly re-produce high quality roll covers with constant dimensional and shape stability.

Roll covers specifically manufactured for the converting, paper, tissue and web processing industries incorporate materials that have been designed to meet the chemical, thermal and mechanical requirements of modern paper manufacturing and converting processes, including tissue, adhesive labels and board. Rolls may be specified with an overall length of up to 15,000 mm, diameter of 2,000 mm and weight of 100 tons whilst production machinery can be adapted to the handling and processing characteristics of all types of rolls and sizes including embossing back rolls and size applicator rolls for converters, and rolls for the wire section, press section and reeling sections of paper mills.

SchäferRolls ( [www.schaeferrolls.com](http://www.schaeferrolls.com) ) operates in five locations worldwide including Nowack Gummiwalzen GmbH & Co KG, and Schäfer MWN GmbH with its brand :CCOR operating in Germany, as well as having subsidiaries in the USA and Slovenia.

Converting and Paper Mills Director, David Jobson says the new range adds a new dimension to the Division's portfolio of products for the converting and paper mills sectors.

[www.jarshire.co.uk](http://www.jarshire.co.uk)  
(April 2018)



## **JARSHIRE INTRODUCES JOHNSON SCREENS**

In a further development of its product range, Jarshire has announced an agency agreement with Johnson Screens for their Pulp and Paper Screens.

With its trade mark Vee-Wire®, Johnson Screens product lines for liquid, solid and gas/solid separation have been developed to satisfy the requirements for mill filtration and similar processes including water clarification and cleaning, dewatering, pulp screening and fractionation, fibre retention, drying and other liquid/solid separation processes.

Manufactured in stainless-steel, the Vee-Wire® filter elements are known for great strength, a long service life and a high level of adaptability. The screens are made by welding patented vee-shaped wire onto a variety of shapes including cylindrical, flat or curved panels, cones, or specific to an application. The process creates a slot that enlarges inwardly, creating a large open area and clog-resistant surface. The continuous welding method meets the most demanding standards for ruggedness, durability, resistance to abrasion, consistency and slot openings.

[www.jarshire.co.uk](http://www.jarshire.co.uk)

(August 2018)





## **SCHÄFERROLLS EXPANDS WITH SECOND PRODUCTION SITE IN THE USA**

SchaeferRolls Inc., manufacturer of high performance elastomeric and composite elastomeric roll covers based in Farmington, New Hampshire, U S A and subsidiary of SchäferRolls GmbH & Co. KG of Renningen, Germany, is expanding its operational footprint southward by constructing a new full-service roll shop to better serve their customers in the South/Southeast of the US. The new plant in Covington, Virginia will be equipped to manufacture the full roll cover product line as well as provide all mechanical repair, rebuild and grinding services needed to ensure a “one-stop shop” for all your roll maintenance needs.

“We have been looking for a location to site a second manufacturing facility to better serve our customers in the South,” said J.T. Fisher (picture), Vice President and General Manager of SchaeferRolls Inc. “Covington provides excellent transportation options and a skilled labour force, allowing us to provide products with enhanced economic value to our customers.”

With the decision for Covington, SchaeferRolls Inc. will also become the preferred supplier of the nearby located production site of the paper and packaging manufacturer WestRock Company.

The choice of location is also very welcomed by the Commonwealth of Virginia: “We are thrilled to welcome SchaeferRolls to the City of Covington and Virginia as a new corporate partner and the local supplier to WestRock’s major operation,” said Governor Northam. “The paper and packaging industries have a long history of success in the Commonwealth, and we are confident that the company will benefit from the competitive operating costs and dedicated regional workforce with strong industry skills. Gaining a new employer in the 21st century is an important step forward for the City, and we are confident in SchaeferRolls’ future success in Virginia.”

Through the systematic transfer of technology as well as targeted synergies between the international locations of the SchäferRolls-Group, the new production facility will be equipped with an optimal and future-oriented production process. “For SchäferRolls, this complete new building is a rare opportunity to use state-of-the-art technologies and processes to design production efficiently and to position ourselves optimally for the future,” says Carsten Sohl, technical managing director of the parent company in Renningen.

Construction is scheduled for the end of 2018. The beginning of operation is scheduled for mid-2019.

[www.schaeferrolls.com](http://www.schaeferrolls.com)  
(June 2018)

## INCREASED SERVICE LIFE DESPITE HIGH TEMPERATURE DIFFERENCE AT CALENDER APPLICATIONS

by Dipl.-Ing. (FH) Torsten Bellaire, Application Engineering SchäferRolls

Paper finishing or calendering is one of the most demanding processes in the paper machine from a roll cover point of view. Especially when high temperature differences  $\Delta T$  result in frequent cover damages and high impacts from deposits on the cover surface.



Since the first introduction of polymer based covers in the calender more than 20 years ago, the basic strength and durability of covers have improved significantly and an outstanding dynamic mechanic property is a basic requirement. Most state of the art covers can withstand the high line load and speed in a modern calender. Even an incidental impact can be accommodated by most modern cover materials. Today's challenge at a modern calender position (Fig. 1) is maximizing the service life in best balance with web quality. The service life of calender covers is normally limited to a certain level of barring, which is related to systematic wear or surface fatigue initiated by a system vibration. One major step towards extended service life is the increased strength and

stiffness of the basic polymer matrix employed in cover manufacturing. A novel nano and copolymer technology makes it furthermore possible to combine high stiffness with outstanding toughness and strength. The combination of the improved properties of these new cover materials require less reinforcing fibres, which leads to significantly improved cover homogeneity with controllable influence on the desired smoothness or gloss of the web.

However, difficult positions such as the 2 stack soft calender with 380 kN/m and temperatures up to 200°C challenge engineers.

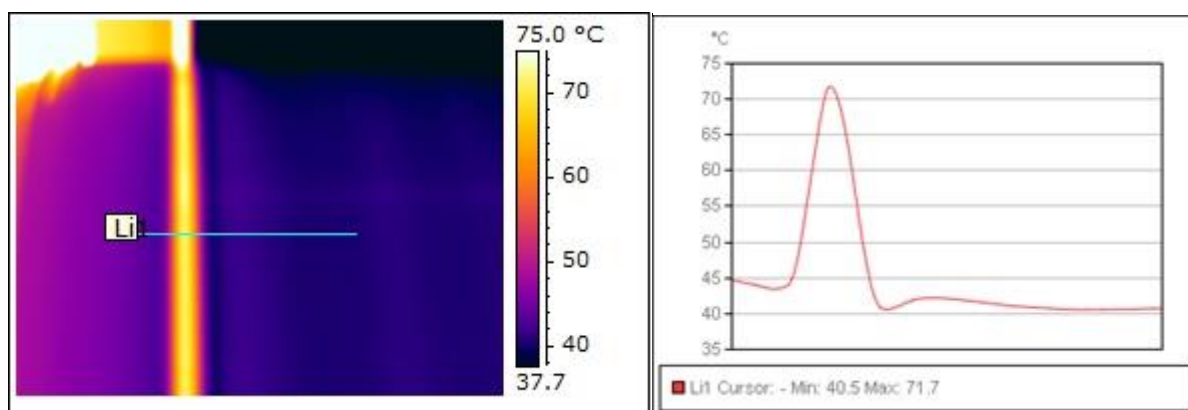


Fig. 2: conventional cover with high temperatures at the edges  $\Delta T$  32°C

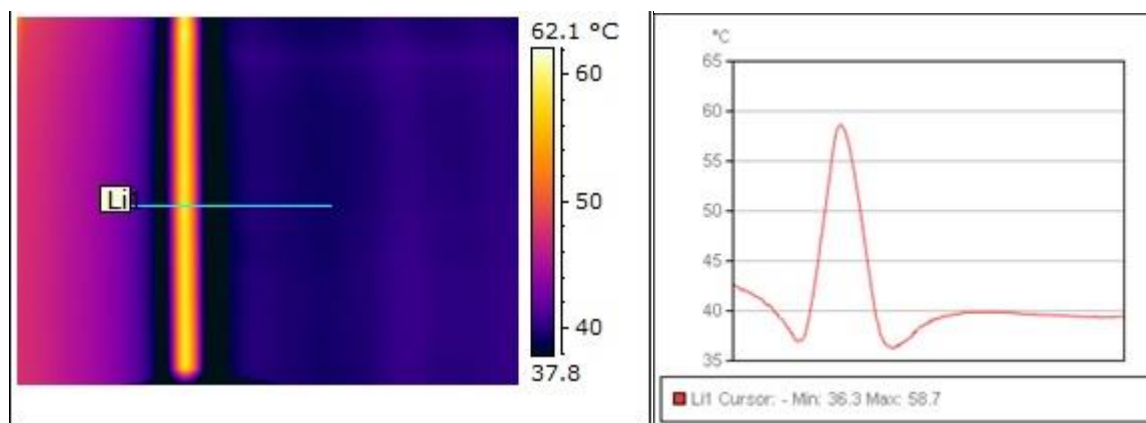


Fig.3: C2.yntec ht, same position  $\Delta T$  18°C

An application example shows a case, where the customer faced frequent and unpredictable damages of the cover due to high temperature differences  $\Delta T$  at the edges (Fig 2) and high impacts coming from deposits. In close cooperation with the customer, SchäferRolls developed a special material, aiming at reducing these difficulties. Regular on-site measurements and monitoring let to a solution in which a special structure of the cover reduces high differences in temperature  $\Delta T$  between areas that are touched resp. not touched by paper web: This C2.yntec ht cover – a further development of the current C2.yntec – cools down quickly and withstands high temperatures in the edge area (Fig. 3). Secondary, temperature peaks caused by e.g. Calcoil systems or TrioRolls (segment guide rolls) are compensated. As a result roll cover damages and in consequence unscheduled shut-down time are being avoided. Furthermore, the expected grinding interval of 30 weeks was exceeded by more than 20%.

### C2.yntec ht

#### Technical data

|                                          |                  |
|------------------------------------------|------------------|
| Hardness                                 | 88 +/- 2 Shore D |
| Colour                                   | pink             |
| E-Modulus                                | 4100 MPa         |
| Wear rate $w_s$                          | 290              |
| Fracture toughness $G_{Ic}$              | 300              |
| Surface roughness in operation $R_a$     | 0,20 $\mu m$     |
| Cover thickness                          | 14 mm            |
| Usable thickness of the functional layer | 6 mm             |
| Max. operating temperature               | 100 °C           |
| Max. $\Delta T$                          | 20 K             |
| Max. operation speed $V_{max}$           | 1500 m/min       |
| Max. line load                           | 450 kN/m         |

[www.schaeferrolls.com](http://www.schaeferrolls.com)

(October 2018)



## **SIXTEEN TT SYD ARE BEING MANUFACTURED AT TOSCOTEC'S MASSA TECHNOLOGY LAB.**

Toscotec, the world's leading supplier of Steel Yankee dryers, is currently manufacturing sixteen steel Yankee dryers at its TT SYD Technology Lab in Massa. Since its inauguration in 2016, this fully integrated plant has been operating at full capacity, implementing the entire production cycle of Toscotec's TT SYD, from metalworking, precision mechanical machining to thermal treatment and surface metallization, up to non-destructive tests and certifications.

The sixteen TT SYD that are presently under construction feature different sizes, with diameters ranging from 3,650 mm to 6,705 mm and width from 3,100 to 6,050 mm. Toscotec has been manufacturing the world's largest diameter steel Yankee dryers and their demand has been steadily going up to this day: 50% of the TT SYD currently under construction have diameters from 18 to 22 ft. In view of this, the strategic choice of the Technology Lab's location offers a clear logistical advantage, by ensuring that large diameter Yankees get easy access to the seaport for expedite shipping operations.

The market's demand for medium and large diameter TT SYD is far-reaching around the globe. The orders for these sixteen Yankee cylinders come from paper mills situated across four continents: Asia, North and South America, Europe and Africa, with Asia and the Americas together taking the lion's share.

Toscotec sustained operations in the manufacturing of TT SYD are testament to the success of Toscotec's design, including large diameter Yankees. Feedback from the first installations of 18 ft Yankees and of 22 ft Yankees have been of substantial improvements in drying efficiency, attracting paper mills to the opportunity of cost savings. Toscotec's global market share of steel Yankee dryers exceeds 60% and nearly all new steel Yankees currently installed in paper mills in Western Europe are Toscotec-supplied.

Parallel to the success of its manufacturing operations, Toscotec is relentlessly striving for new breakthroughs with its R&D division. Following the engineering of the second generation TT SYD in late 2013, with improved rib design and metallization, as well as increased thermal exchange, Toscotec's steel Yankee dryers are now looking into the future with their third generation's design, which will be presented later this year.

<http://www.toscotec.com/en/media/news/news-detail/article/sixteen-tt-syd-are-being-manufactured-at-toscotecs-massa-technology-lab/>  
(May 2018)



## **TOSCOTEC BOOSTS ITS GREEN PERFORMANCE THROUGH SUSTAINABLE OPERATIONS.**

Toscotec has successfully renewed its ISO 14001 certificate and EMAS (Eco-Management and Audit Scheme) registration for the twelfth consecutive year since 2006. It thereby confirms its long-standing commitment to eco-sustainability, starting from its own environmental performance.

In 2005, Toscotec began procedures to evaluate its internal processes according to the strictest international standards of environmental protection. This entailed undergoing an articulate and audited procedure, which led to the draw up of an environmental management system and a three-year plan. Specifically for EMAS, the Italian supplier also issues an annual report, examined by private and public bodies, including external auditors and EMAS national Competent Body ISPRA.

As a result, back in 2006, Toscotec became the first Italian supplier of tissue and paper machinery to obtain both the ISO 14001 and the EMAS registration and to this day, it remains the only one in Italy.

Toscotec strives to step up the eco-efficiency of its operations on an annual basis. In this view, EMAS is a guarantee vis-à-vis the community and the market at large, as it ensures a comprehensive set of corporate behaviours with environmental impact is kept under serious scrutiny.

Andrea Marzaro, Toscotec's Operations Director (COO), affirmed, "Toscotec is working towards a continued and tangible improvement of its environmental performance, on a voluntary basis. Full compliance with Italian laws and regulations is the minimum prerequisite for us. We are determined to go the extra mile, pursue the highest environment standards and achieve excellence. Eco-sustainability and environmental protection are our core values and as such inspire our operations. Energy reduction, in its widest sense, is a big part of it".

In recent years, Toscotec has partly redesigned its layout to become a fully integrated and compact production base, thereby optimizing its manufacturing efficiency. Inspired by lean production, it streamlined its logistic operations and achieved a concrete reduction of power consumption, due to the rationalization of handling and transportation processes.

Toscotec's headquarters currently include eight workshops, four of which dedicated to the pre-assembly of tissue and paper & board lines. Pre-assembly is one of the cornerstones of Toscotec's quality guarantee. It aims to reduce the time, the energy and the costs of the erection at the mill and therefore achieve the performance guarantees in a shorter period.

Andrea Marzaro also pointed out "With respect to renewable energy, since 2011 we have been generating electric power from solar energy. In 2011, we implemented the first installation of solar panels on the roofs, covering an area of approximately 1,250 m<sup>2</sup> and generating up to 190 kWh electricity, which we give back to the grid. Phase two was carried out in 2012, across 600 m<sup>2</sup>, with an output of 100 kWh. Phase three is currently underway".

Toscotec is committed to protecting the environment at local level through its operations, and globally through the design and manufacture of its cutting-edge technology. The Italian manufacturer manages both direct environmental aspects - pertaining to its own operations, like waste, emissions, use of raw materials, energy and water resources, etc. - and indirect aspects.

With respect to its indirect environmental aspects, Toscotec's Technical Director, Paolo Raffaelli pointed out, "through our advanced design and manufacturing process, we have achieved a significant reduction of the environmental impact generated by our machinery and process, confirmed by field data and positive customer feedback. Our engineering approach aims to enable paper mills to improve their overall performance, by reducing the need of fresh water, electricity and thermal energy, and minimizing their atmospheric emissions, including noise".

From TT SYD and TT SteelDryers, to Energy Saving tissue lines, to TT SAF (Short Approach Flow) and TT DOES (Drying Optimization for Energy Saving), Toscotec is the leading supplier of technology specifically designed for energy savings and with view to this, it is extensively investing in R&D and innovation.

[www.toscotec.com](http://www.toscotec.com)

(July 2018)





## **TOSCOTEC GROUP'S SERVICE PROVIDER S.TO.R.I.**

S.TO.R.I., owned by the Toscotec Group, specializes in maintenance services for all minor and major rolls used in papermaking and converting machinery of the tissue and paper industry. In 2017, S.TO.R.I. set a record for turnover in its forty-five year history. This positive performance derives from the strategic synergies achieved with Toscotec, who acquired 100% of S.TO.R.I.'s shares in December 2011. In the period from 2012 to 2017, S.TO.R.I. sustained a 30% growth rate and interim results in 2018 have been confirming this trend, leading to expectations that it will outperform last year's achievements.

Since 2012, S.TO.R.I. and Toscotec have deepened their long-standing cooperation. By merging S.TO.R.I.'s specialization in rolls maintenance with Toscotec's engineering capabilities, they accomplished full integration of expertise and higher efficiency in the design and services of roll refurbishing. S.TO.R.I.'s workshop and offices are located inside Toscotec's headquarters, in Marlia (Lucca).

S.TO.R.I.'s professional experience was built over forty-six years, starting from its foundation in 1972, when it started providing maintenance for papermaking and converting machines. S.TO.R.I. focuses on the inspection, repair and overhaul of not only press rolls but all other rolls, such as forming roll, wire and felt rolls, pope reel drum, and spools. Its mission is to deliver highly specialized services on a continuous basis. The timing becomes important insomuch as customers aim to increase their OEE and reduce maintenance costs.

S.TO.R.I.'s specialists make a precise assessment of the wear conditions of a roll and evaluate its expected performance and risk of failure, so that overhauling can be scheduled efficiently, maximising operation life and minimizing maintenance costs. The majority of S.TO.R.I.'s customers nowadays rely on predictive maintenance. Through regular vibration analyses, S.TO.R.I. estimates the performance trend of a given roll and the possibility of failure. Based on these results, it predicts the period before the next maintenance. This assessment is always a balance of different factors. Drawing on their vast experience, S.TO.R.I.'s specialists can provide the customer with a number of solutions, factoring in time, quality and cost. Based on the contingent needs of the mill, they apply the best-customized solution at a given moment in time. As a result, S.TO.R.I.'s skilled technicians know the components inside out, including their history, weak points and features, much like a doctor knows his patients.

S.TO.R.I.'s range of highly specialized services include predictive maintenance, preventive maintenance, press roll revision and complete overhauling, dynamic balancing, upgrades and non-destructive examinations (NDE). For press roll overhauling, for instance, the company provides complete service packages, including inspection, repairs and spare parts.

Production capacity exceeds 450 components per year, of which suction press rolls and blind drilled press rolls account for approximately 40%, while the rest is made up of various rolls of tissue, paper and converting machines.

S.TO.R.I.'s client base is twofold. Toscotec-associated business accounts for approximately 20% of turnover and covers Europe, Africa, the Middle East, South America and South-East Asia. Italy-based paper mills and converting companies generate approximately 80% of turnover. Essity, Smurfit Kappa, Lucart, Sofidel, Wepa, Cartiere Carrara, Industrie Cartarie Tronchetti, Industrie Cartarie Pieretti, DS Smith, Renova, The Navigator Company are among its main customers. To this second client base, Stori provides maintenance for equipment supplied by any manufacturer. As a result, S.TO.R.I.'s expertise and experience

encompasses a wide range of technical solutions designed throughout the years by all the main suppliers and it equips S.T.O.R.I.'s experts with the ability to devise tailor-made upgrades for its customers.

[www.toscotec.com](http://www.toscotec.com)  
(September 2018)





## **TOSCOTEC PARTNERS WITH CHEMITEX-EGYPT TO INCREASE SALES IN EGYPT.**

Toscotec signed an agency agreement for both its Tissue and Paper & Board divisions with Chemitex Egypt for Trading & Agencies, S.A.E. to increase its sales in the Egyptian market, where it recently landed a number of P&B rebuilding orders.

Toscotec entrusted Sameh Habib, founder and owner of Chemitex-Egypt, with the agency. Habib has fifteen years of sales experience in the tissue and paper industries in Egypt.

Following the deal with Toscotec, Habib said, “The Egyptian paper and tissue market has a high growth potential. Toscotec’s technology fits very well in this market for its strong focus on customization and flexibility, paired with energy reduction. Building on our customer portfolio and the relationships of mutual respect, trust, and cooperation we established, we expect to see promising results in the coming years”.

[www.toscotec.com](http://www.toscotec.com)  
(September 2018)



# PUMPS / PUMPING



## **HEAVY DUTY LEAK-FREE MAG-DRIVE PUMPS FOR EFFICIENT PUMPING**

Pumping specialists MICHAEL SMITH ENGINEERS are delighted to announce their appointment as official UK distributor for the full range of DICKOW magnet drive and mechanical seal centrifugal and side channel pumps. The range includes the SCM Series horizontal magnet drive side channel pumps which are ideal for handling low flows (up to 30m<sup>3</sup>/hr) at high differential heads (up to 400 metres) at temperatures up to 180°C.

This side channel pump has the advantage of operating more economically than centrifugal pumps on fluid handling applications involving low flows and high heads. Furthermore, the magnet drive design results in a range of important benefits. For example, there are no rotating seals to fail ensuring reduced downtime, optimised production and no cross contamination of the pumped fluid, resulting in increased operator safety and optimum process fluid containment.

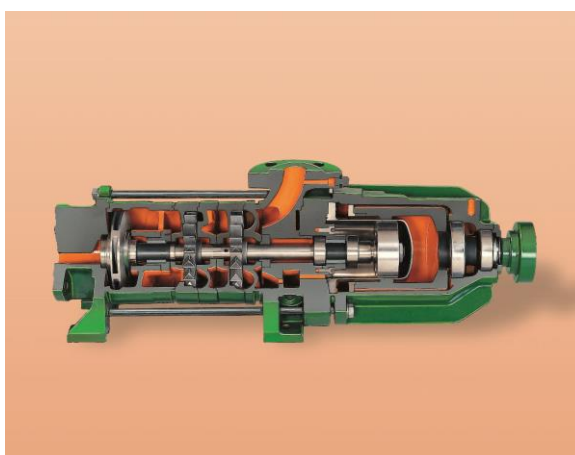
The tight clearances between the impeller and the discs enable them to generate high differential pressures and to self-prime – they are able to prime empty suction lines after initial filling with liquid. The SCM Series are also suited to handling liquid / gas mixture, allowing vessels to be fully emptied.

Another safety feature is the design of the containment shell where in the event of bearing failure the possibility of rub on the containment shell is prevented which eliminates the potential for leakage. There is also an option to specify silicon carbide insert rings in the pump's pressure discs which provides short term protection in the event of dry running.

Material options include ductile iron and stainless steel in close coupled and frame mount configurations. A modified design option with an inlet centrifugal impeller also enables the pumps to operate with NPSH (net positive suction head) of 1 metre or less.

Dickow SCM pumps are suitable for handling clean liquids without solids in the chemical and pharmaceutical industries. When coupled with Ex-drive motors they can also be used in hazardous areas.

<https://www.michael-smith-engineers.co.uk/products/dickow/side-channel/side-channel-pump-with-magnet-drive/scm-series>





## **METERING PUMPS COMBINE REPEATABLE ACCURACY WITH OUTSTANDING RELIABILITY AND ENERGY EFFICIENCY**

A new range of high pressure metering pumps which offer important features and benefits such as virtually pulse-free operation, consistent high accuracy and outstanding hydraulic efficiency, are now available from pumping specialists MICHAEL SMITH ENGINEERS.

HYDRA-CELL MT8 Series pumps will deliver positive displacement flows with highly repeatable accuracy so they are ideally suited to metering and dosing applications where precise volumes of liquid are required in a specified time period.

These pumps are designed to handle a variety of processing liquids at low flow rates and high pressures, exceeding API 675 performance standards for steady-state accuracy ( $\pm 1\%$ ), linearity ( $\pm 3\%$ ) and repeatability ( $\pm 3\%$ ). Electronic flow control increases accuracy and reliability and they are also available with a manual, variable speed gearbox for use in hazardous areas.

Their integral multiple hydraulically actuated diaphragms ensure pulse-free, linear flows across a wide pressure range, without the need for expensive pulsation dampeners. They are also easy to monitor ensuring simplified control systems.

MT8 pumps are also hermitically sealed which effectively separates the power end from the process fluid which helps to eliminate leaks and the associated risks and hazards along with the expense of seals and packing. They also have a replenishment valve system in every piston which ensures optimum actuating oil on every stroke resulting in the benefit of continuous accuracy whilst also protecting the pump from damage in the event of a blocked suction line.

The range covers capacities from 0.23 lit/hr up to 30.2 lit/hr at discharge pressures to 241 bar and is available in a choice of wetted materials including PVC, PVDF, 316 stainless steel and Hastelloy C. A duplexing option is also available which enables two MT8 pumps to run at the same flow rate with only one gearbox and one motor, effectively doubling capacity within a smaller footprint and also lower investment cost than conventional metering pumps. For example, two different chemicals can be metered in a precise 1:1 ratio. ENDS

<https://www.michael-smith-engineers.co.uk/products/hydra-cell/metering-pumps/mt8-triplex-metering-pumps>



## **NEW THERMODYNAMIC PUMP MONITORING SYSTEM**

Corroserve has just announced further major investment in its Thermodynamic Pump Monitoring (TPM) System. As a result, the Leeds based corrosion protection and engineering services specialist can now monitor the performance of any class C industrial pump over its working life and as a result highlight significant cost saving opportunities for the user.

Calibrated and certified by the Yamari Standard Laboratory in accordance with relevant Japanese standards, the updated TPM system calculates pump efficiency by the thermodynamic method based on the first law of thermodynamics. The effect is that energy losses in the pumping process are transferred to the pumped liquid in the form of heat energy, causing a rise in temperature. The TPM unit measures temperature and pressure at the pump suction and discharge and by inputting the motor power consumption, the system calculates the flow rate and actual pump performance and efficiency.

TPM identifies pump wear and measures changes in performance and efficiency, allowing the customer to make informed decisions about refurbishment and the optimum time for any work to be carried out. It also identifies the most efficient pumping conditions providing customers with a detailed & accurate report.

The financial investment in TPM testing will be quickly recouped in savings made by reduced energy costs from running a more efficient pump - savings that might be increased even more by using the company's Fluiglide coatings to further enhance pump efficiency.

[www.corroserve.com](http://www.corroserve.com)





## **INNOVATIVE GEAR PUMP IDEAL FOR SENSITIVE SOLIDS**

The simple design, reliability and ease-of-maintenance of internal gear pumps makes them a popular choice across a wide range of industry applications such as general processing, chemicals, oil & gas, food & beverage, refining, plastics and resins. The VIKING Universal Seal range available through MICHAEL SMITH ENGINEERS is one of the most established and widely used positive displacement internal gear pumps and is underpinned by Viking's extensive practical and technical experience in fluids handling.

A good example of Viking's innovative approach is a recent addition to their Universal Seal Range which features a modified ribbed / stepped idler gear design. This pump has been specifically developed for sugar processing but is also ideal for other applications where there are crystals in the pumped fluid. By removing 0.9mm (or 900 microns) of material from 80% of the flank of each idler gear tooth on both sides results in reduced gear-to-gear contact that could damage tiny sugar crystals or other solids in the pumped fluid.

Available in either hardened iron or hardened steel, the ribbed idler alternates position on each tooth to minimise wear on the rotor teeth in any given spot and since the idler turns at a different speed than the rotor, the contact point changes with each revolution of the rotor gear. The most significant impact of this is the creation of additional 'slip paths' that allow liquids to slip back from the high pressure (discharge) side of the pump to the low pressure (inlet side), the amount of which depends on the viscosity of the pumped liquid.

The pumps capacity on high viscosity liquids using ribbed idlers is virtually identical to the performance of pumps which have standard (non-ribbed) idler gears. For example, on liquids with a viscosity of 10,000 cSt operating at 50 RPM, the capacity is reduced by only about 1% compared to the standard pump performance at 3.5 Bar G, 7 Bar G and 10 Bar G.

By simply changing the idler gear from a standard to a ribbed idler and slowing it to appropriate speeds, users have the flexibility and convenience of using the same pump for liquids containing sensitive solids or for pumping other liquids such as syrups and molasses by switching back to a standard idler gear. This provides manufacturing plants with the potential to cover all of their positive displacement pumping needs with one or two sizes of the same pump which helps simplify plant operations and maintenance, while increasing reliability and uptime.

Viking Universal Seal Pumps also provide the benefit of being able to accommodate virtually all types of seal. These can be packing, component or cartridge mechanical seals which can be easily fitted, usually without bracket modifications. This means that operators have the flexibility to benefit from the latest sealing technology to both maximise performance and to meet the ever-changing fugitive emissions standards.

<https://www.michael-smith-engineers.co.uk/>



## **NEW TEFC MOTOR OPTIONS FOR FTI DRUM PUMPS**

Pumping specialists MICHAEL SMITH ENGINEERS have introduced new TEFC (Totally Closed Fan Cooled) IP55 motor options for their range of Finish Thompson drum and barrel emptying pumps. This type of pump is the most reliable and efficient method of transferring a wide range of fluids from container-to-container compared to hand pumps, and these new motor options extend their capability to an even wider range of applications.

The new motors include a powerful 1000 Watt continuous duty universal motor providing 0-12,000 rpm variable speed operation. The variable speed TEFC versions feature solid state control with chemical resistant touch pad for precise fluid dispensing and superior motor protection against overload and over temperature.

These motors provide 10 selectable speeds which can be easily controlled up or down by pushing appropriate key on the keypad. The motors also recall the last running speed when the power is switched on. LED lights provide useful feedback about the motors state – a blinking green light indicates the motor is in standby mode, a solid green light indicates the motor is on, a blinking red light indicates over-temperature and a solid red LED indicates over-current.

These motors also incorporate a zero voltage safety release feature which prevents the motor from turning back on after a power failure. The option of a lower cost, fixed speed version is also available.

Both the fixed speed and variable speed versions of these new motors are available for the best-selling PF series of drum pumps – available in polypropylene, PVDF or stainless steel in a choice of different lengths – as well as for the TB, TT and HVDP drum pumps and the TM drum mixer unit.

Connection of the motor to the drum pump is quick and simple without the need for tools, thanks to a unique collet design, while a threaded connection option is available for the HVDP Series.

<https://www.michael-smith-engineers.co.uk/products/finish-thompson/drum-pumps-and-barrel-pumps>





# **CLEANING / MAINTENANCE / SAFETY**

## **TANK CLEANING PRESSURE LOSS PROBLEMS**

Tank cleaning applications can be adversely affected by pressure loss problems which can have a direct impact on cleaning efficiency. A good example of this is where cleaning heads were installed and then subsequently found to be having very little impact on the tank walls. The tanks in question were large 10 metre diameter storage vessels that required periodic, as opposed to regular cleaning. In theory the 4 nozzle rotary jet heads should have had sufficient reach to provide adequate cleaning but, when observed, the jets were barely reaching the walls.

### **The Cause**

Following the investigation it was found that frictional pressure losses were causing a significant pressure drop between the pump and the cleaning head. The pipe run was quite long with an effective length of 50 metres and in addition, there was a 12 metre climb. Also, the tanks were larger than before so a natural conclusion would be that a larger tank cleaning system would be needed. However, what was not accounted for was the additional flow in the existing pipework, which then caused an increase in pressure losses. The result was that the cleaning heads only 'saw' a 4 bar pressure drop, as opposed to the 8 bar required.

### **The Solution**

As the cleaning required on this particular application was only periodic the time taken to clean was not critical. Therefore, swapping the cleaning heads from a 4 nozzle to a 2 nozzle configuration meant that the cleaning time was doubled, but crucially the flow rate was lowered. This reduced the frictional pressure losses incurred and allowed the new 2 nozzle configuration to 'see' the higher pressure drop and therefore, delivered a more powerful cleaning jet.

### **The Benefit**

This relatively simple reconfiguration meant that the time, expense and inconvenience of having to upgrade existing pipework was avoided and enabled the existing tank cleaning system to deliver the higher flows required for more effective cleaning.

<http://www.spray-nozzle.co.uk/spray-nozzles>



## **TSUBAKI CHAIN WEAR INDICATORS NOW AVAILABLE IN LARGE SIZES**

Tsubaki, the leading manufacturer of high quality industrial train and power transmission components, has expanded its line-up of chain wear indicators with the addition of larger sizes.

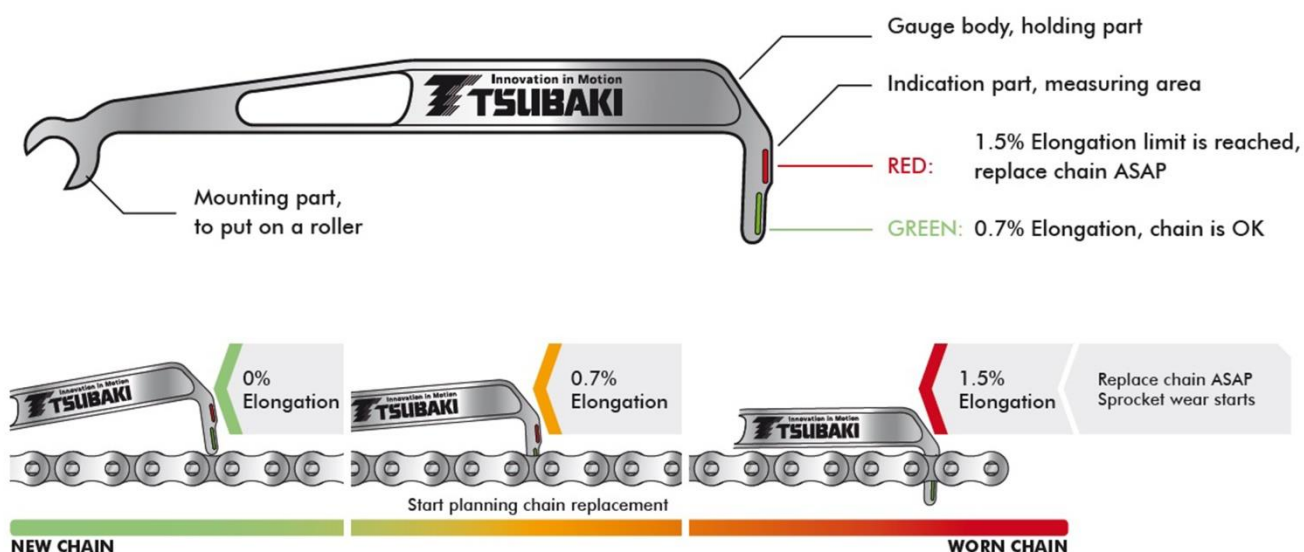
The new BS Large Size Indicator is available in sizes RS20B to RS48B and the ANSI Large Size Indicator – covers sizes from RS100 to RS240. These complement the existing BS Set which is used with sizes RF06B to RS16B and the ANSI Set for sizes RS35 to RS80. The new large size indicators are available to purchase as individual items, rather than as part of a set.

The Tsubaki Chain Wear Indicator enables plant and machinery engineers to measure roller chain condition and determine critical wear in one simple operation. In use one end is shaped to fit snugly over a roller and the tip of the other end indicates the degree of wear by highlighting the total elongation over a number of links. As such, they are a valuable tool for helping keep machinery in top condition and for minimising unexpected chain failures that could lead to costly production downtime.

All hard working roller chain will stretch over time, and equally it is inevitable that the sprockets with which it engages will wear. The stretch will cause a loss of tension, reducing the transmission efficiency. This wear is likely to cause loss of alignment accuracy for the overall drive system, leading to repercussions in positioning and locating duties, reduced efficiency and an increase in noise and vibration. If wear increases to a critical point the chain will begin riding and jumping on the sprockets which causes shock loads, which in turn will further accelerate wear.

These problems are avoided by regularly monitoring the chain for stretch and changing it before problems become manifest. Tsubaki's chain wear indicator gauges are made to high quality specifications and are resistant to corrosion. Their robust construction ensures accurate measuring every time over a long working life.

Visit the DMA Europa website for the full text in PDF format and the associated high resolution image and video files: Website: [www.dmaeuropa.com](http://www.dmaeuropa.com)





## **DUST SPECIALIST LAUNCHES POWERFUL GAS-POWERED EXTRACTOR**

Removing hazardous dust on an industrial scale has been made easier thanks to the UK's leading dust extracting specialist launching a high performance, gas-powered extractor on the market.

Dustcontrol UK's new and innovative propane-driven DC Storm LPG can last up to eight hours and doesn't require any cables, making it ideal for environments with a limited supply of electricity.

The robust machine's 15 kW/21hp motor has the capacity to manage dust extraction in conjunction with work involving large-scale concrete construction and brickwork projects.

In addition to operating without electricity, the DC Storm LPG is also High (H) class, meaning it offers a higher degree of filtration, with a filter leakage of less than 0.005%. Equipped with a HEPA H13 filter, it comfortably exceeds UK minimum standards for silica dust and other harmful properties.

James Miller, Managing Director of Dustcontrol UK, said: "The DC Storm LPG is our most powerful mobile dust extraction machine to date. It's perfect for large warehouse, civils and railway environments where electricity is not available or limited. What's more, being run on propane makes it an environmentally friendly option, as opposed to fossil-derived electric.

"It can be used to extract harmful dust created from floor grinders, hammer drills, scarifiers or cutting machines. It can also perform heavy-duty cleaning with a long suction hose."

The compact machine also comes equipped with USB-charging ports, LED lighting and forklift pockets, making it easy to transport.

James concluded: "The DC Storm LPG can also be used in conjunction with any kind of surface preparation, demolition and renovation work. It's effective dust extracting capabilities are very impressive."

[www.dustcontroluk.co.uk](http://www.dustcontroluk.co.uk)



## **SKF COOPER QUICK-CHANGE™ PEDESTAL REDUCES DOWNTIME**

For many pulp or paper mills, downtime is a serious threat to profitability – especially unplanned downtime. SKF Cooper Quick-Change™ pedestals offer the ultimate response time in replacing a failing bearing, as it often can be performed on-the-spot without having to remove the shaft or adjacent equipment or machinery.

- Reduces downtime.
- Ease of replacement.
- Lower maintenance costs with simple assembly.
- No small components to remove, replace or lose.
- Low cost of installation.
- Increases maintenance efficiency.
- Comprehensive Range of Mountings.
- Meets most application requirements from the standard range.
- Proven range of sealing options.
- Especially advantageous in inaccessible or trapped locations!

SKF acquired Cooper – the world leader in split-to-the-shaft bearings in 2013 and have been further developing the technology ever since.

Consult with SKF or your authorized SKF distributor to learn about Quick-Change™ pedestal options available for your pulp or paper applications!





## **YOKOGAWA RELEASES THE DTSXTM1 FIBRE OPTIC HEAT DETECTOR**

Yokogawa Electric Corporation has announced that it has developed the DTSXTM1 fibre optic heat detector, an OpreXTM Field Instruments heat sensing and fire detection solution. Housed in an enclosure and suitable for use with Yokogawa-specified fibre optic cables, the DTSX1 is a cost-effective all-in-one facility monitoring and fire detection solution that is easy to install. It is expected that this solution will aid in the timely identification of maintenance issues and thereby improve plant uptime and reduce maintenance costs.

### **Product Features**

1. Cost-effective and easy-to-install all-in-one solution.
2. Able to measure data from four cables up to 16 km in length.
3. Ready-to-use GA10 templates for monitoring facility status.

### **Major Target Markets**

The iron & steel, power, chemical, non-ferrous metal, pulp & paper, and oil & gas industries

### **Applications**

- Detecting fire at coal conveyors in thermal power plants and iron mills
- Monitoring abnormal heat build-up in power cable racks
- Detecting fire in service tunnels
- Maintenance monitoring for furnaces in iron & steel and chemical plants
- Detecting fire in transit tunnels and other infrastructure

<https://www.yokogawa.com/solutions/products-platforms/field-instruments/fiber-optic-sensor/>





# **MATERIALS HANDLING**



## **MIDLAND PALLET TRUCKS WARNS UNCERTAINTY OVER POST-BREXIT EMPLOYMENT RIGHTS COULD HAVE MAJOR SUPPLY CHAIN IMPACT**

Midlands-based supplier of logistics and materials handling equipment, Midland Pallet Trucks has warned that the continued uncertainty around post-Brexit working right could have a very real impact on the UK supply chain.

The company, which provides equipment such as hand pallet trucks and lift tables to firms across the logistics sector, has genuine concerns that the looming threat is not receiving enough attention from both those inside government and those that stand to feel the fallout the most acutely.

The Freight Transport Association – which represents some 17,000 UK logistics businesses – is calling on the government to immediately assess the potential employment shortfall that could result from new, restricted working rights for EU citizens in the UK. The most recent figures from the FTA highlight the scale of contribution EU workers make to the UK supply chain and how devastating their loss could be for an array of sectors and industries.

113,000 of the UK's warehouse workers are seasonal EU workers, with 30,000 van drivers and 43,000 HGV drivers occupying similar, seasonal roles. Midland Pallet Trucks is keen to draw focus to this area, with logistics and warehousing companies unlikely to be able to fill these numbers with short-term, seasonal workers with full UK residence. The firm points to the farming sector where a lack of seasonal workers has already had a significant impact, with employers struggling to attract UK workers to roles previously occupied by seasonal staff from across the EU. Without these workers, the UK supply chain could find itself understaffed at the most crucial points of the year, leading to spasmodic performance or, in a worst-case scenario, collapse.

Phil Chesworth, Managing Director of Midland Pallet Trucks, said, "With a no-deal Brexit looming and the UK so reliant on seasonal EU workers for the smooth performance of the supply chain, this issue is a very real worry for many in the sector. At the same time, it seems like the government either isn't fully aware of the potential impact of the loss of these workers, or they're simply ignoring the problem. Either way, the issue will remain urgent until there's some clear guidance from the government on how UK firms will be able to pick up the slack.

"Removing hundreds of thousands of workers from the supply chain will have a very real, detrimental impact on vast swathes of UK industry. If the workers aren't there to do the logistics and supply chain work, the system cannot function properly. One half-answer might be a big boost in the number of apprenticeships offered in the sector, but this still wouldn't cover the numbers we're talking about. We need to see some real government leadership on the issue."

<https://www.midlandpallettrucks.com/>

## **360 DEGREE HYSTER® SOLUTIONS OVERCOME INDUSTRY SPECIFIC CHALLENGES**

Whether it's a lack of space in a retail warehouse or the Just-In-Time demands of an automotive factory, Hyster® solutions are meeting the needs of specific applications.

### **Recycling**

Dusty environments are commonplace for lift trucks operating in the recycling, household waste or paper bale handling industry, meaning that the lift truck's radiators can easily get clogged up. This can cause unnecessary downtime that costs businesses money in lost production, as well as contributing to other truck problems.

To tackle this issue and help operations to increase productivity and maximise return on investment, the new Hyster® 'Cool Truck' package for 2-3.5 tonne capacity lift trucks has been designed to reduce the amount of debris entering the engine compartment and getting stuck on the transmission or in the radiator.

Developed following field trials in harsh paper applications, the truck features an innovative automatically reversing fan that significantly extends radiator cleaning intervals compared to a H2.0-3.5FT. Tilt and steer cylinder gaiters minimise the risk of damage to cylinders from debris, while tough rubber guards over the drive axle also minimise ingress of paper under the floorplates. Venting on side panels also helps to minimise the vacuuming effect of debris on the ground and a solid multi-piece belly pan under the engine compartment reduces the amount of loose debris entering the underside of the truck.

### **Supporting industry needs**

Regardless of the industry, the global network of local Hyster® distribution partners use extensive knowledge and experience to find the best ways to overcome specific application challenges. With local service and support, Hyster® dealers help to sustain even the most demanding operations.

[www.hyster.eu](http://www.hyster.eu)





# MISCELLANEOUS



## **MEKALL LAUNCHES NEW RANGE OF HD LIGHT BOXES**

Leading engineering firm Mekall has introduced a new range of high definition lightboxes which will offer superior performance and functionality.

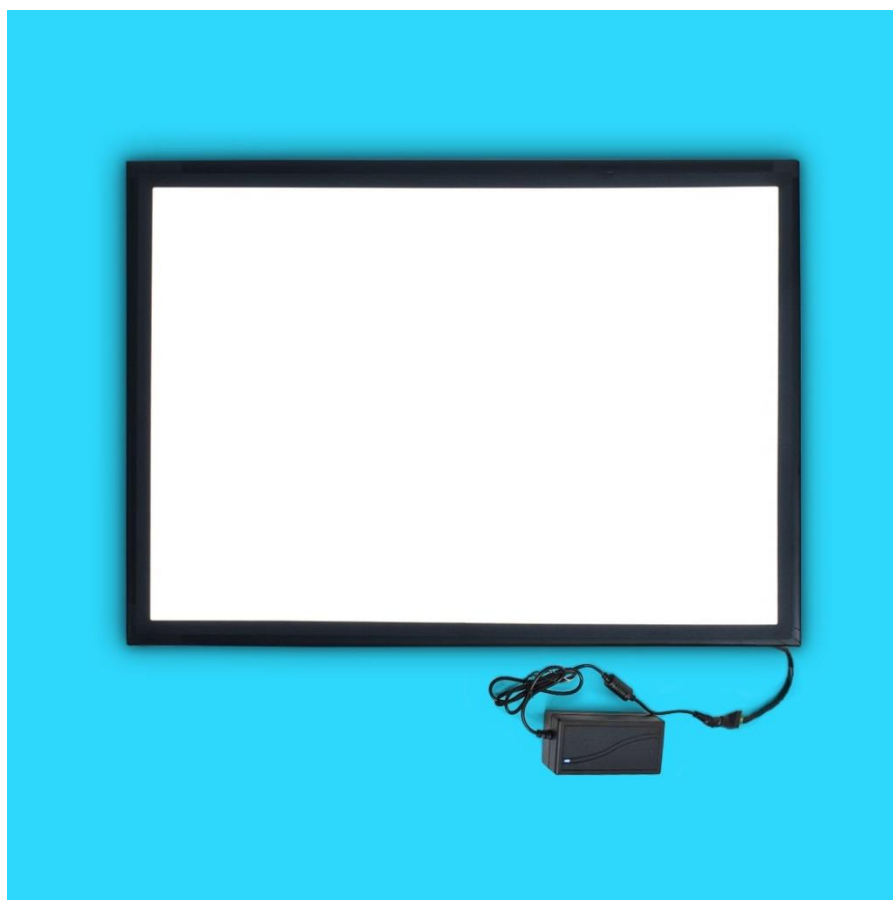
Harnessing its expertise in LED technology and industrial printing, the Mekall range of LED viewing panels offer consistency of light cross the whole surface of the panel. Traditional light boxes have a varied level of intensity and clarity.

The key benefit to the viewer is that the entire area of the object being viewed is illuminated at exactly the same level. As such the object only needs to be positioned once and viewed - no adjustment is required to seek a more effective point of light.

The light box can be used for a wide variety of applications including laboratory, industrial, scientific and photographic. A range of sizes are available up to A3 (297mm x 420mm).

David Westwood, sales and marketing manager, Mekall said: "The drawback with most light boxes is that the spread of light is not uniform across the surface meaning that the object has to be moved around to be viewed properly. Using our years of expertise in LED technology we have developed an HD light box which offers superior performance."

<https://www.rainbow-technology.com/products/mekall/led-viewing-panels/>





## Installations

*The following pages contain a summary of the various installations and orders from around the world of papermaking, wood panel and saw mills, and bio-power generation, received between May 2018 and November 2018. Also included are new announcements about plans to build new mills or install new machinery (in which case the supplier will be noted as 'TBA').*

The Paper Industry Technical Association (PITA) is an independent organisation which operates for the general benefit of its members – both individual and corporate – dedicated to promoting and improving the technical and scientific knowledge of those working in the UK pulp and paper industry. Formed in 1960, it serves the Industry, both manufacturers and suppliers, by providing a forum for members to meet and network; it organises visits, conferences and training seminars that cover all aspects of papermaking science. It also publishes the prestigious journal *Paper Technology* and the *PITA Annual Review*, both sent free to members, and a range of other technical publications which include conference proceedings and the acclaimed *Essential Guide to Aqueous Coating*.



| COMPANY, SITE                                                           | SUPPLIER | DESCRIPTION                                                                                                                                                                                                                                                                  | START-UP |
|-------------------------------------------------------------------------|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| AB Hilmer Andersson<br>Lässerud Saw Mill<br>Sweden                      | Andritz  | To supply a Universal Shredder FRP to process wood waste and offcuts from the saw mill to be used as biomass for heat generation                                                                                                                                             | Q4 2018  |
| Ahlstrom-Munksjö<br>Billingsfors Pulp Mill<br>Sweden                    | Valmet   | To upgrade the recovery boiler and surrounding systems                                                                                                                                                                                                                       | H2 2019  |
| Ahlstrom-Munksjö<br>Chirnside<br>UK                                     | TBA      | To install a second hand Voith paper machine                                                                                                                                                                                                                                 | Q4 2019  |
| Ahlstrom-Munksjö<br>Turin<br>Italy                                      | TBA      | To increase capacity for industrial filtration applications                                                                                                                                                                                                                  | H1 2020  |
| Air Water & Energia Power<br>Onahama Corporation<br>Iwaki City<br>Japan | Valmet   | To supply a multifuel power boiler and a flue gas cleaning system                                                                                                                                                                                                            | H1 2021  |
| Anon<br>Various<br>China                                                | Metso    | Has received two valve orders totalling 8,200 valves from major pulp and paper customers in China                                                                                                                                                                            |          |
| Anon<br>East Java<br>Indonesia                                          | ABB      | Added Ability™ Collaborative Operations to its service deliverables at a major paper mill. Collaborative Operations helps paper producers to make productive use of this data to identify and address production, quality and cost issues that can inhibit peak performance. |          |
| APRIL Group<br>Various sites                                            | Greycon  | To provide new planning software                                                                                                                                                                                                                                             |          |
| ARAUCO<br>Arauco Mill<br>Bio Bío Region<br>Chile                        | Andritz  | To supply of major technologies and equipment for the modernization and extension of the pulp mill                                                                                                                                                                           |          |
| ARAUCO<br>Arauco Mill<br>Bio Bío Region<br>Chile                        | Valmet   | To supply key pulp mill technology including pulp drying and baling, a recovery boiler and a biomass boiler.                                                                                                                                                                 | 2021     |
| Arctic Paper Kostrzyn S.A.<br>Poland                                    | PMPoland | To supply a press section rebuild for PM1, that includes a Shoe Press.                                                                                                                                                                                                       | 2019     |
| Arkhbum Tissue Group LLC<br>Vorsino (Kaluga region)<br>Russia           | Andritz  | To supply a tissue machine                                                                                                                                                                                                                                                   | Q3 2019  |
| Asia Symbol Paper Company<br>Guangdong<br>China                         | Pasaban  | To supply two new paper sheeting machines                                                                                                                                                                                                                                    |          |



| COMPANY, SITE                                                                         | SUPPLIER      | DESCRIPTION                                                                                                                                                        | START-UP                       |
|---------------------------------------------------------------------------------------|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|
| Asia Symbol (Shandong) Pulp and Paper Co., Ltd<br>China                               | Valmet        | To provide long-term mill maintenance services                                                                                                                     |                                |
| Berli Jucker Cellox Ltd.<br>Prachinburi Mill<br>Thailand                              | Andritz       | To supply a tissue machine with shoe press, including stock preparation and automation systems                                                                     |                                |
| Ahlstrom-Munksjö<br>Billingsfors Mill<br>Sweden                                       | Valmet        | To upgrade the recovery boiler and surrounding systems of the Pulp Mill                                                                                            | H2 2019                        |
| BillerudKorsnäs<br>Skärblacka Mill<br>Sweden                                          | Valmet        | To supply a process and quality vision system for PM7                                                                                                              |                                |
| Blue Tissue Sapi de C.V.<br>Mustertextzuaktivieren                                    | A.Celli Paper | To supply a turnkey tissue plant                                                                                                                                   | Q1 2019                        |
| Burgo Ardennes Pulp Mill<br>Belgium                                                   | Valmet        | To supply batch cooking plant                                                                                                                                      | Q1 2020                        |
| Burgo Group S.p.A.<br>Lugo di Vicenza<br>Italy                                        | A.Celli Paper | To supply a high-tech Pope Winder                                                                                                                                  |                                |
| Burgo Group S.p.A.<br>Verzuolo Mill<br>Italy                                          | Valmet        | To convert PM9 from coated mechanical papers to container board production                                                                                         | Q4 2019                        |
| C.A.S. Paper Mill<br>Sing Buri<br>Thailand                                            | Toscotec      | To supply a turnkey tissue line                                                                                                                                    | Q1 2020                        |
| C&S Paper<br>China                                                                    | PMPoland S.A. | To supply a Tissue Machine                                                                                                                                         |                                |
| Cascades Packaging<br>Kingsey Falls<br>Cabano Mill<br>Canada                          | Toscotec      | To rebuild the dryer section of PM1                                                                                                                                | Q3 2018                        |
| Cascades Tissue Group<br>Wigram<br>USA                                                | TBA           | To install five new state-of-the-art tissue converting lines and the modernise four existing lines                                                                 | Q2 2019 to Q1 2020             |
| Celupaper S.A.<br>Argentina                                                           | Toscotec      | To supply a new tissue line (PM5)                                                                                                                                  | Q3 2019                        |
| Clariant<br>Romania                                                                   | Valmet        | To supply a BioTrac biomass pretreatment system with a capacity of over 800 tonnes of dry biomass a day for this sunliquid® cellulosic 50,000 tonnes ethanol plant | 2020                           |
| CMPC Cellulose Riograndense<br>city of Guaíba<br>state of Rio Grande do Sul<br>Brazil | Konecranes    | To deliver two industrial cranes                                                                                                                                   | One Q4 2018, the other Q2 2019 |
| CMPC<br>Zarate Mill<br>Argentina                                                      | Valmet        | To supply a tissue production line (50ktpy)                                                                                                                        | Q4 2019                        |



| COMPANY, SITE                                                             | SUPPLIER                 | DESCRIPTION                                                                                                                                                                                                                                             | START-UP              |
|---------------------------------------------------------------------------|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Copamex<br>Anáhuac<br>Monterrey<br>México                                 | Voith Paper              | To install a stock preparation system to process a variety of raw material including Old Corrugated Containers (OCC) and mixed waste.                                                                                                                   | H1 2019               |
| Dalian HuaYang Bicoweb Technology Co., Ltd.<br>Liaoning province<br>China | Valmet                   | To deliver a Spunbond Nonwoven Honeycomb Thru-Air Bonding system                                                                                                                                                                                        | Q2 2019               |
| Dalkia<br>Seven power plant sites<br>France                               | Valmet                   | To supply Valmet DNA automation services                                                                                                                                                                                                                | Over the next 5 years |
| Drewsen Spezialpapiere GmbH & Co. KG<br>Germany                           | TBA                      | To modernise the press section on PM5 with the installation of a shoe press. The company will therefore be able to expand its market position for Thermal base papers, Thin printing and Label papers, and moreover, Barrier papers for food packaging. |                       |
| Elenia Lämpö Oy's Vanaja power plant<br>Hämeenlinna<br>Finland            | Valmet                   | To supply a biomass-fired boiler plant                                                                                                                                                                                                                  | 2020                  |
| Estonian Cell<br>Estonia                                                  | Valmet                   | To supply a BCTMP plant conversion, slab press and conveyor systems                                                                                                                                                                                     | Q2 2019               |
| Fapajal – Fábrica De Papel Do Tojal, S.A.<br>Portugal                     | A.Celli Paper            | To supply a latest-generation E-WIND® T80S rewinder for the production of tissue                                                                                                                                                                        |                       |
| Fibria<br>Aracruz Pulp Mill<br>Espírito Santo state<br>Brazil             | FITNIR<br>Analyzers Inc. | To supply FITNIR Online liquor analyzer and FITNIR MC chip moisture analyzer                                                                                                                                                                            | Q1 2019               |
| FICAP<br>Region of Champagne-Ardenne<br>France                            | Valmet                   | To deliver the world's first BioTrac™ Steam Explosion System for black pellet production (to be used by district heating network operators)                                                                                                             | 2020                  |
| Finnpulp<br>Sorsasalo<br>Kuopio                                           | Pöyry Oyj                | Signed a basic engineering partnership agreement for the bioproduction mill                                                                                                                                                                             |                       |
| Green Bay Packaging<br>Green Bay<br>Wisconsin<br>USA                      | Voith Paper              | To supply a full packaging line (PM4)                                                                                                                                                                                                                   | Q1 2021               |
| Greenalia<br>Curtis-Teixeiro biomass power plant<br>Teixeiro<br>Spain     | Valmet                   | To supply a biomass boiler (Electrical 50MW, Thermal 130MW)                                                                                                                                                                                             | Q1 2020               |



| COMPANY, SITE                                                                              | SUPPLIER          | DESCRIPTION                                                                                                                                                                                                                                                                                                                               | START-UP |
|--------------------------------------------------------------------------------------------|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| Grupo Gondi<br>Monterrey<br>Mexico                                                         | TBA               | To build a new 400,000 ton containerboard mill                                                                                                                                                                                                                                                                                            |          |
| Hua-Chuan Group<br>China                                                                   | A.Celli Paper     | To supply two E-WIND® P-100 rewinders to process high-strength medium board paper                                                                                                                                                                                                                                                         | H2 2019  |
| Heleneholmsverket (HVK)<br>combined heat and power plant<br>Malmö<br>Sweden                | Valmet            | To deliver a turnkey automation solution                                                                                                                                                                                                                                                                                                  | H2 2019  |
| Iggesund Paperboard<br>Sweden                                                              | PulpEye AB        | To supply two complete PulpEye sets, one for the unbleached and one for the bleached pulps. Both PulpEye cabinets are equipped with modules for online analysis of kappa number, brightness, fibre, shives and fibre wall thickness as well as the dot analyser DotEye. The order also comprises two ScreenEye, two LabEye and one RMEye. |          |
| Holmen Paper<br>Hallsta<br>Roslagen<br>Sweden                                              | SPM Instrument AB | To upgrade the condition monitoring system on PM12                                                                                                                                                                                                                                                                                        |          |
| JSC Mayak<br>Penza<br>Russia                                                               | PMPoland S.A.     | To deliver a headbox and size press for PM2 (which is being rebuilt to make fluting and testliner)                                                                                                                                                                                                                                        | Q1 2019  |
| Jyväskylän Energy Group<br>CHP production plants,<br>Keljonlahti and Rauhalampi<br>Finland | Valmet            | To supply a district heat network optimization solution. The scope of the delivery scope also includes a Valmet DNA Information Management system upgrade.                                                                                                                                                                                | Q2 2019  |
| Kabel Premium Pulp & Paper GmbH<br>Hagen site<br>Germany                                   | Pöyry             | Awarded detailed engineering services assignment for a new ATMP (Advanced Thermo Mechanical Pulp) plant                                                                                                                                                                                                                                   |          |
| Kimberly Clark Products<br>Kluang Johor Mill<br>Malaysia                                   | A.Celli Paper     | To upgrade TM1 tissue line with a new off-line shaft puller and new set of expandable spools.                                                                                                                                                                                                                                             |          |
| Kotkan Energia<br>waste-to-energy plant<br>Korkeakoski<br>Finland                          | Valmet            | To supply a flue gas cleaning and heat recovery plant                                                                                                                                                                                                                                                                                     | Q3 2019  |
| KP Tissue and Kruger Products<br>Brompton area of Sherbrooke<br>Quebec                     | TBA               | To supply a through-air-dry (TAD) machine                                                                                                                                                                                                                                                                                                 | H1 2021  |
| Kruger<br>Trois-Rivières Mill<br>Québec<br>Canada                                          | Andritz           | To reconfigure the TMP peroxide bleach plant                                                                                                                                                                                                                                                                                              | Q4 2018  |



| COMPANY, SITE                                                                 | SUPPLIER       | DESCRIPTION                                                                                                                                                                                                                                                                                                   | START-UP |
|-------------------------------------------------------------------------------|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| Kyiv Cardboard and Paper Mill<br>JSC<br>Ukraine                               | EBRD           | To provide a €10 million loan to the mill for purchase of new equipment to expand production, implementation of EU standards and CO2 emissions reduction. To include installation of shoe press for cardboard drying, addition of tissue converting lines, and upgrading of waste paper processing equipment. |          |
| Lahti Energy<br>Lahti<br>Finland                                              | Valmet         | To supply automation                                                                                                                                                                                                                                                                                          | 2020     |
| Lila Group<br>Corlu<br>Turkey                                                 | Valmet         | To supply a tissue production line (TM3)                                                                                                                                                                                                                                                                      | 2020     |
| Lucart<br>Porcari<br>Italy                                                    | Voith Paper    | To supply a BlueLine stock preparation system                                                                                                                                                                                                                                                                 |          |
| Marutomi Paper Co., Ltd<br>Japan                                              | Toscotec       | To provide two tissue machines                                                                                                                                                                                                                                                                                |          |
| Metsä Board<br>Äänekoski Mill<br>Finland                                      | TBA            | To construct a new sheeting line                                                                                                                                                                                                                                                                              | Q3 2019  |
| Metsä Board<br>Kaskinen mill<br>Finland                                       | Andritz        | To upgrade two screw presses so that they can be utilized as bleach presses                                                                                                                                                                                                                                   | Q1 2019  |
| Mondi<br>Ruzomberok<br>Slovakia                                               | Valmet         | To investment in new 300,000 tonne kraft top white machine                                                                                                                                                                                                                                                    | H2 2020  |
| Mohawk<br>Envelope/substrate converting<br>various locations                  | Greycon        | To roll out opt-Studio software to improve customer service                                                                                                                                                                                                                                                   |          |
| Nordic Paper Bäckhammar<br>Sweden                                             | SPM Instrument | To expand online vibration monitoring on PM4                                                                                                                                                                                                                                                                  |          |
| Oulun Energia<br>Biopower Plant<br>Laanila Industrial Park<br>Oulu<br>Finland | Valmet         | To supply advanced automation                                                                                                                                                                                                                                                                                 | Q4 2020  |
| Papelera San Andrés de Giles<br>Argentina                                     | Valmet         | To supply a tissue production line                                                                                                                                                                                                                                                                            | H2 2018  |
| Papertech<br>Tudela Mill<br>Spain                                             | Toscotec       | To rebuild the dryer section of PM1                                                                                                                                                                                                                                                                           | Q1 2019  |
| Papier- u. Kartonfabrik Varel<br>GmbH & Co. KG<br>Germany                     | Valmet         | To supply new winding technology and surrounding equipment for PM4.                                                                                                                                                                                                                                           | Q1 2020  |
| Polímeros y Derivados city of<br>Leon<br>Guanajuato                           | Greycon        | Supplied the opt-Studio software to improve customer service                                                                                                                                                                                                                                                  |          |



| COMPANY, SITE                                                                               | SUPPLIER                 | DESCRIPTION                                                                                                                      | START-UP                                       |
|---------------------------------------------------------------------------------------------|--------------------------|----------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|
| Pro-Gest<br>Cartitalia and Cartiera di<br>Carbonera paper mills<br>Italy                    | Procemex Oy              | Web monitoring system to increase<br>quality monitoring and decrease web<br>break times                                          | Q4 2018                                        |
| Progroup AG<br>Sandersdorf-Brehna<br>near Bitterfeld (Saxony-Anhalt)<br>Germany             | Voith                    | To supply a packaging production<br>line (PM3) (capacity 750ktpy)                                                                | H2 2020                                        |
| Sappi Austria Produktions-<br>GmbH & Co. KG<br>Gratkorn paper mill<br>Austria               | Honeywell                | To implement a range of upgrades<br>that include server virtualisation,<br>process visualisation and<br>cybersecurity solutions. |                                                |
| Shandong Chenming Paper<br>Holdings Ltd.<br>Shouguang<br>Shandong Province<br>China         | Minerals<br>Technologies | To build a 150,000 metric ton per<br>year satellite precipitated calcium<br>carbonate plant                                      | H2 2019                                        |
| Shanying International Holdings<br>Co., Ltd.<br>City of Jingzhou<br>Hubei province<br>China | Valmet                   | To supply a containerboard making<br>line (PM23) capacity 1200tpd. Also to<br>supply web monitoring systems.                     | Q4 2019                                        |
| Siam Kraft Industry Co., Ltd.<br>(SKIC) in its three mills in<br>Thailand                   | Greycon                  | Supplied the latest version of X-Trim<br>and opt-Studio to update scheduling<br>and slitting optimisation                        |                                                |
| Smurfit Kappa Nettingsdorfer<br>Papierfabrik AG & Co KG<br>Nettingsdorf Mill<br>Austria     | Andritz                  | To supply a HERB recovery boiler<br>and a pre-evaporation plant                                                                  | mid-2019<br>(evap) and<br>mid-2020<br>(boiler) |
| Smurfit Kappa Nettingsdorfer<br>Papierfabrik AG & Co KG<br>Nettingsdorf Mill<br>Austria     | Toscotec                 | To rebuild the dryer section of PM6                                                                                              | Q2 2019                                        |
| Södra Cell<br>Mörum Pulp Mill<br>Sweden                                                     | Cellwood<br>Machinery AB | To supply a Pulper installation                                                                                                  | Q3 2018                                        |
| Sofidel<br>Inola<br>Oklahoma<br>USA                                                         | Toscotec                 | To supply two tissue lines                                                                                                       | Mid-2020                                       |
| Stora Enso Maxau<br>Germany                                                                 | TBA                      | To install a new steam turbine with a<br>closed-loop cooling system and<br>additional biomass storage                            | 2020                                           |
| Taison Pulp<br>Suzhou<br>Anhui Province<br>China                                            | Andritz                  | To supply two tissue machines                                                                                                    | 2019                                           |



| COMPANY, SITE                                                            | SUPPLIER      | DESCRIPTION                                                                                      | START-UP                             |
|--------------------------------------------------------------------------|---------------|--------------------------------------------------------------------------------------------------|--------------------------------------|
| UAB Vilniaus Kogeneracine<br>Jegain<br>CHP plant<br>Vilnius<br>Lithuania | Valmet        | To supply automation technology to two new power plants                                          | Q3 2019                              |
| UPM Changshu<br>China                                                    | Valmet        | To supply a Valmet Pulp Analyzer (Valmet MAP) for PM2                                            | Q3 2018                              |
| UPM Nordland Papier<br>Germany                                           | Andritz       | To rebuild PM2 to produce release/glassine papers, including an off-line multinip calender       | Q4 2019                              |
| Verso<br>Androscoggin Mill<br>Jay<br>Maine<br>USA                        | TBA           | To increase release liner paper capacity on PM4                                                  | Phase 1 Q3 2018; phase 2 during 2019 |
| Xinxiang Xinya Paper Group Co. Ltd<br>Henan Province<br>China            | A.Celli Paper | To supply a P100 Rewinder                                                                        | Q1 2019                              |
| Yibin Paper Industry Co., Ltd<br>China                                   | A.Celli Paper | To supply two sets of 18 ft. steel Yankees                                                       | Q4 2018                              |
| Yiwu Yinan Paper Co., Ltd<br>China                                       | A.Celli Paper | To supply two rewinders to be used in the production process of high-strength medium board paper | H2 2019                              |
| Luzhou Yongfeng Pulp and Paper Co., Ltd<br>China                         | Valmet        | To supply a Valmet IQ steam profiler                                                             | Q4 2018                              |
| Zanders GmbH<br>Bergisch<br>Gladbach<br>Germany                          | TBA           | To convert power plant from hard coal to natural gas                                             |                                      |



## Research Articles

*Most journals and magazines devoted to the paper industry contain a mixture of news, features and some technical articles. However, very few contain research items, and even fewer of these are peer-reviewed.*

*This listing contains the most recent articles from the five main journals that publish original research:*

- APPITA JOURNAL
- IPPTA JOURNAL
- J-FOR
- NORDIC PULP & PAPER RESEARCH JOURNAL
- TAPPI JOURNAL

The Paper Industry Technical Association (PITA) is an independent organisation which operates for the general benefit of its members – both individual and corporate – dedicated to promoting and improving the technical and scientific knowledge of those working in the UK pulp and paper industry. Formed in 1960, it serves the Industry, both manufacturers and suppliers, by providing a forum for members to meet and network; it organises visits, conferences and training seminars that cover all aspects of papermaking science. It also publishes the prestigious journal *Paper Technology* and the *PITA Annual Review*, both sent free to members, and a range of other technical publications which include conference proceedings and the acclaimed *Essential Guide to Aqueous Coating*.



**APPITA JOURNAL, Vol.71, No.2, Apr-Jun 2018**

1. The strength properties of paper made from bamboo fibres under the treatment of ZnCl<sub>2</sub> aqueous solution
2. Understanding and managing the liquor cycle bottleneck
3. New method for estimating chemical pulp washer efficiency using online data reconciliation
4. DNA sequencing of pulp and paper wastewater treatment systems to inform process analysis
5. Omyaboard: Fresh GCC filler for corrugated board production

**APPITA JOURNAL, Vol.71, No.3, Jul-Sept 2018**

1. Highly efficient utilization of dissolved and colloidal substances in surface sizing for low-cost and sustainable water consumption
2. Isolation of microcrystalline cellulose using phosphotungstic acid and microwave synergistic treatment to improve the hydrolysis selectability of cellulose
3. Steam exploded pellets made from bark and residues – a new possible value stream for the pulp and paper industry
4. Bleaching efficiency of softwood thermomechanical pulps treated with ozone

**IPPTA JOURNAL, Vol.30, No.1, Jan-Mar 2018**

1. An approach towards sustainability by adopting new innovative concepts at M/S Bindals Paper Mills Ltd, UP
2. A break through BIOPAQ anaerobic reactor proves itself in the pulp and paper industry
3. Automation in pulp and paper industry
4. Advanced digital mill operations
5. Bleaching enzymes – back from the drawing board
6. Continuous growth and innovative measures at JK Paper for sustainability
7. Creating sustainable source of raw material through agro forestry models
8. Fennobind new generation of functional coating binder allows new coating properties design and higher cost efficiency
9. Fiberlean<sup>TM</sup>: an innovative composite material
10. Innovative approach on reduction of carbon foot print, environment impact and enhancement in productivity – a case study of Emami Paper Mills
11. Innovative approach towards energy efficiency
12. Innovation for growth and sustainability – efforts at Yash Paper Limited
13. Optimal design of the bleach plant and global trends
14. Over all improvement in chemical recovery and lime kiln by innovation and out of box thinking
15. Smart factory

**IPPTA JOURNAL, Vol.30, No.2, Apr-Jun 2018**

1. A Novel Approach to Utilize Straw Black Liquor from Mills Producing Unbleached Packaging Grade Paper
2. A novel fly ash based calcium silicate paper filler: its retention, drainage and particle size effects



3. Case Study of Consistent Pulp Quality with Optimization utilizing advance algorithms
4. COD Optimization for Zero Discharge Mills- UASB approach & its Pre-treatment
5. Converting opportunities into Economic Benefits Data Mining Applications in Pulp & Paper Industry
6. Efficient and Environment Friendly Paper Making – Value addition by forming Fabric and Case Studies
7. High Efficiency Agro Based Integrated Chemical Recovery Plant at Bindals Papers Mills Ltd.
8. Technological advancement and Trends for Sustainability of Coated Duplex Board making industries in India
9. Validation of Feasibility of Zero Liquid Discharge in a RCF based Kraft Paper Mill – A Case Study
10. Variation in Process Measurement of variation in terms of Cp & Cpk with methodology of implementation

#### **J-FOR, Vol.7, No.1, 2018**

1. Fibre Pad Density Profiles of a High-Consistency TMP Refiner
2. CFD Modelling of Reduced-Lignin Black Liquor Combustion
3. SoftSensor for Compression and Burst Strength: Identification and Uncertainty Analysis

#### **J-FOR, Vol.7, No.2, 2018**

1. The Next-Generation Lignoboost – Tailor-Made Lignin Production for Different Lignin Bioproduct Markets Modelling deposit Breakup Under Sootblower Jet Impingement
2. Operating Experience of the World's Largest Lime Kiln
3. Paper CFD Modeling of Black Liquor Spray Nozzles Strategies for Controlling Sodium Salt Scaling in Black Liquor Evaporator: The Influence of the Bulk Crystal Population
4. The Effect of Smelt Composition on Smelt Droplet-water Interaction in the Kraft Recovery Boiler Dissolving Tank
5. A Fundamental Study on the Change in Composition of Fireside Deposits with Time in Kraft Recovery Boilers
6. Operating Parameters Affecting Black Liquor Combustibility

#### **J-FOR, Vol.7, No.3, 2018**

1. Mixing of High-momentum-flux Jets with a Confined Crossflow: Computational Analysis and Applications to Recovery Boiler Air Systems
2. Thermal Pre-treatment of Black Liquor: A Conceptual Design
3. Variation of Recovery Boiler NOx Emissions Based on Wood Species, Boiler Age, and Other Operating Parameters
4. Reduction of Alkali Loss in Ash Leaching System
5. A Field Study on the Use of Sootblower Acoustics to Monitor Recovery Boiler Fouling
6. Avoiding Short-term Overheat Failures of Recovery Boiler Superheater Tubes
7. Recovery Boiler SCR: A Challenge and an Opportunity in Retrofit Cases



8. The Role of Potassium in the Melting Behaviour of Recovery Boiler Smelt: An Experimental Study and Thermodynamic Analysis

#### **NORDIC PULP & PAPER RESEARCH JOURNAL, Vol.33 No.1, May 2018**

1. Now at De Gruyter: Nordic Pulp & Paper Research Journal
2. News from Nordic Pulp & Paper Research Journal
3. Chemical pulping: Optimum strategies for pulp fractions refining
4. Deinking: Deinkability of different secondary fibers by enzymes
5. Mechanical pulping: Investigation of low consistency reject refining of mechanical pulp for energy savings
6. Mechanical pulping: Control strategies for refiners Part I: Soft sensors for CD-refiner control
7. Mechanical pulping: Control strategies for refiners Part II: Consistency control in twin-disc refining zones using temperature profile information
8. Mechanical pulping: Indications of the onset of fiber cutting in low consistency refining using a refiner force sensor: The effect of pulp furnish
9. Mechanical pulping: TMP properties and refining conditions in a CD82 chip refiner. Part I: Step changes of process variables, description of the tests
10. Mechanical pulping: TMP properties and refiner conditions in a CD82 chip refiner at different operation points. Part II: Comparison of the five tests
11. Paper chemistry: Parameters influencing hydrophobization of paper by surface sizing
12. Paper chemistry: Effect of pigment sizing on printability and coating structure of decorative base paper
13. Paper chemistry: Strengthening effect of polyelectrolyte multilayers on highly filled paper
14. Paper physics: The effect of the through-thickness moisture content gradient on the moisture accelerated creep of paperboard: Hygro-viscoelastic modeling approach
15. Paper technology: Online quality evaluation of tissue paper structure on new generation tissue machines
16. Paper technology: Strong paper from spruce CTMP – Part II: Effect of pressing at nip press temperatures above the lignin softening temperature
17. Printing: Impact of non-uniform water absorption on water-interference print mottle in offset printing

#### **NORDIC PULP & PAPER RESEARCH JOURNAL, Vol.33 No.2, Jul 2018**

1. Biorefinery: Improving the efficiency of enzymatic hydrolysis of Eucalyptus residues with a modified aqueous ammonia soaking method
2. Chemical pulping: Enhancement of eucalypt pulp yield through extended impregnation cooking
3. Chemical pulping: Xyloglucan adsorption for measuring the specific surface area on various never-dried cellulose nanofibers
4. Chemical pulping: Xyloglucan for estimating the surface area of cellulose fibers
5. Mechanical pulping: Validation of crill measurements in a high-yield pulp refining process for improved fines material control
6. Mechanical pulping: Bar force measurement in low consistency refining: the effect of plate pattern
7. Paper technology: The influence of bar width on bar forces and fibre shortening in low consistency pulp refining



8. Paper technology: Density development in foam forming: wet pressing dynamics
9. Paper physics: Effect of softwood kraft fiber coarseness on formation and strength efficiency in twin-wire roll forming
10. Paper physics: Phosphorescence and fluorescence of fibrillar cellulose films
11. Paper physics: A three-dimensional numerical model for large strain compression of nanofibrillar cellulose foams
12. Paper physics: Effect of machine speed on formation and strength efficiency in twin-wire roll forming of never-dried unbleached softwood kraft pulp
13. Paper physics: The versatility of the Bristow absorption tester – a review
14. Paper chemistry: Optimizing the preparation conditions of amphoteric polyacrylamide as a strength additive for recycled paper
15. Paper chemistry: Preparation of nanocomposite polypyrrole/cellulose nanocrystals for conductive paper
16. Paper chemistry: Preparation and characterization of AKD sizing agent by “one-pot cooking”
17. Paper chemistry: Thermal and natural aging of bagasse paper sheets coated with gelatin
18. Coating: Crack analysis of barrier coatings based on starch and starch-PVOH with and without plasticizer
19. Packaging: Effect of blank pre-conditioning humidity on the dimensional accuracy and rigidity of paperboard trays
20. Environmental impact: Biological treatment and ultrafiltration of woodchip pre-hydrolysis liquor from dissolving pulp mills
21. Recycling: Circular action treatment (CAT): a new strategy for mechanical treatment of old corrugated container I – effects of control parameters on paper strength

#### **NORDIC PULP & PAPER RESEARCH JOURNAL, Vol.33 No.3, Sept 2018**

1. Editorials: Farewell and good luck to Nordic Pulp & Paper Research Journal
2. Editorials: Change of Editor-in-Chief
3. Biorefinery: Kinetic study on the decomposition of cellulose into 5-hydroxymethylfurfural in an ionic liquid/organic biphasic system
4. Biorefinery: Antibacterial evaluation of CNF/PVAm multilayer modified cellulose fiber and cellulose model surface
5. Chemical pulping: Dewatering properties of low grammage handsheets of softwood kraft pulps modified to minimize the need for refining
6. Chemical pulping: NSSC pulping of fast growing trees
7. Chemical pulping: Addition of corn fiber xylan to eucalyptus and pinus pulp and its effect on pulp bleachability and strength
8. Recovery: Removal of hazardous trace elements from green liquor dregs by mechanical separation methods
9. Bleaching: Additives to decrease cellulose chain scission during ozone bleaching of wheat straw pulp
10. Mechanical pulping: Comparative properties of nanofibers produced using unbleached and bleached wheat straw pulps
11. Mechanical pulping: Effects of chip pretreatment and feeding segments on specific energy and pulp quality in TMP production
12. Mechanical pulping: An experimental study of the chipping process with focus on energy consumption and chipping angles
13. Mechanical pulping: Average fibre length as a measure of the amount of long fibres in mechanical pulps – ranking of pulps may shift



14. Paper technology: The effect of in-line foam generation on foam quality and sheet formation in foam forming
15. Paper technology: The wet strength of water- and foam-laid cellulose sheets prepared with polyamideamine-epichlorohydrin (PAE) resin
16. Paper technology: Manufacture of high bulk paper using alkali swollen kraft pulp
17. Paper physics: The impact of zeolite filler on ageing and mechanical failure of paper
18. Paper physics: The relationship between shrinkage and elongation of bleached softwood kraft pulp sheets
19. Paper chemistry: Engineered porous calcium silicate as paper filler: effect of filler morphology on paper properties
20. Printing: Edge spread function for the paper-ink system
21. Packaging: Lignin-containing coatings for packaging materials
22. Environmental impact: Application of Fenton's reagent degrades dissolved and colloidal substances in old corrugated container white water
23. Environmental impact: Quick estimation for pollution load contributions of aromatic organics in wastewater from pulp and paper industry
24. Recycling: Circular action treatment (CAT): a new strategy for mechanical treatment of old corrugated containers II – comparison of CAT with low-consistency beating
25. Corrigendum: Corrigendum to: The influence of bar width on bar forces and fibre shortening in low consistency pulp refining

#### **TAPPI JOURNAL, May 2018**

1. Editorial: 2017 PEERS Conference: Maximizing success through innovation
2. A hundred years of corrosion in the pulp and paper industry
3. Use of vent stack temperature as a feedforward variable for dissolver total titratable alkali control
4. Factors affecting particulate removal efficiency of kraft recovery boiler electrostatic precipitators: a technical review
5. Effect of ring formation on burner flame stability in lime kilns

#### **TAPPI JOURNAL, June 2018**

1. Editorial: TAPPI Journal 2017 Best Research Paper Award recognizes recycling technology
2. Factors affecting the free shrinkage of handsheets: apparent density, fines content, water retention value, and grammage
3. Evaluation of the out-of-plane response of fiber networks with a representative volume element model
4. Using online bubble size and total dissolved solids measurements to investigate the performance of oxygen delignification
5. Decreased water usage in a softwood ECF bleaching sequence – full mill simulations

#### **TAPPI JOURNAL, July 2018**

1. Editorial: Remembering Phil Clark: A Coating “Master Man”
2. Effects of lignin chemistry on oxygen delignification performance
3. Influence of tensile straining and fibril angle on the stiffness and strength of previously dried kraft pulp fibers



4. Wet-end addition of nanofibrillated cellulose pretreated with cationic starch to achieve paper strength with less refining and higher bulk
5. Effect of pH and enzymes on strength of recycled fibers during refining

#### **TAPPI JOURNAL, August 2018**

1. Editorial: Douglas Coffin: Paper Physics Guru
2. Prediction of box failure from paper data for asymmetric corrugated board
3. Impact of fiber structure on edge-wicking of highly-sized paperboard
4. Enzymatic treated viscose fibers functionalized by chitosan
5. Effect of pulper consistency on stickies size distribution

#### **TAPPI JOURNAL, September 2018**

1. Editorial: PaperCon: A ten-year journey of papermaking excellence
2. Rewet in wet pressing of paper
3. Boosting the elongation potential of paper by mechanical refining and additives
4. Dielectric spectroscopic studies of biological material evolution and application to paper
5. Mineral/microfibrillated cellulose composite materials: High performance products, applications, and product forms

#### **TAPPI JOURNAL, October 2018**

1. Editorial: Looking back and looking forward: Paper physics and the paper industry
2. Laboratory method for determining the source of brightness loss at a southern United States bleached paperboard mill
3. Production of polyhydroxyalkanoates (PHA)-based renewable packaging materials using photonic energy: A bench and pilot-scale study
4. A review of green liquor scale formation
5. A Theory for the Tensile Strength of Paper



## Technical Abstracts

*The general peer-reviewed scientific and engineering press consists of several thousand journals, conference proceedings and books published annually. In among the multitude of articles, presentations and chapters is a small but select number of items that relate to papermaking, environmental and waste processing, packaging, moulded pulp and wood panel manufacture. The edited abstracts contained in this report show the most recently published items likely to prove of interest to our readership, arranged as follows:*

|         |                                         |
|---------|-----------------------------------------|
| Page 2  | 3-D Printing                            |
| Page 3  | Coating<br>Moulded Pulp<br>Nano-Science |
| Page 5  | Novel Products                          |
| Page 7  | Packaging Technology                    |
| Page 8  | Papermaking                             |
| Page 9  | Pulping<br>Testing<br>Waste Treatment   |
| Page 11 | Wood Panel                              |

The Paper Industry Technical Association (PITA) is an independent organisation which operates for the general benefit of its members – both individual and corporate – dedicated to promoting and improving the technical and scientific knowledge of those working in the UK pulp and paper industry. Formed in 1960, it serves the Industry, both manufacturers and suppliers, by providing a forum for members to meet and network; it organises visits, conferences and training seminars that cover all aspects of papermaking science. It also publishes the prestigious journal *Paper Technology* and the *PITA Annual Review*, both sent free to members, and a range of other technical publications which include conference proceedings and the acclaimed *Essential Guide to Aqueous Coating*.



### **3-D PRINTING**

**3D printing using plant-derived cellulose and its derivatives: A review, Lei Dai *et al*, Carbohydrate Polymers, Vol.203.** Three-dimensional (3D) printing is classified as a revolutionary, disruptive manufacturing technology. Cellulose (the most abundant natural polymer) and its many derivatives have been widely studied for many applications. The combination of 3D printing with cellulose-based feedstocks is therefore of critical interest. This review highlights many studies on 3D printing applications of plant-derived cellulose and its derivatives. Potential materials include cellulose ethers/esters, microcrystalline cellulose, nanocellulosic materials, and other products. It focuses on their roles and functions in 3D printing processes and the performance of the resultant printed objects. The outlook for future work is also provided, to underscore critical issues and opportunities.

**Selective Recrystallization of Cellulose Composite Powders and Microstructure Creation through 3D Binder Jetting, Sonia Holland *et al*, Carbohydrate Polymers, online.** Binder jetting is an additive manufacturing technique in which powdered material is sequentially laid down and printed on by an ink binder, in a selective manner, to form a 3D object. Unfortunately work in this area relevant to food materials is largely unpublished, however a typical application of this technique is sugar powder bound by a water and alcohol based ink with optional colour or flavour demonstrated by commercial ventures. In this work we demonstrate the use of a small scale powder layering device under an ink jet printer to test prototype powders prior to producing quantities typically used in commercially available binder jetting machines. Powders comprising predominantly of ball milled, amorphous cellulose were successfully used to create 3D structures when interacting polysaccharides were present in the ink (xanthan gum) and as a proportion of the powder component (glucomannan) by inducing selective recrystallization. These ingredients are categorized as dietary fibre, thus such formulations can be used to create low-calorie 3D printed food designs to be used within food products.

**Current advances and future perspectives of 3D printing natural-derived biopolymers, Jun Liu *et al*, Carbohydrate Polymers, online.** 3D printing enables the complex or customized structures production in high speed and resolution. However, the lack of bio-based materials with user-defined biochemical and mechanical property is a significant barrier that limits the widespread adoption of 3D printing for products fabrication. This paper reviews the state-of-the-art in terms of 3D printing technology using natural-derived feedstocks, including lignocellulose, starch, algae, and chitosan-based biopolymers. Special consideration is given to the development of lignocellulosic materials, i.e. cellulose, hemicellulose, lignin, and their derivatives as 3D printing feedstocks. It serves as guideline aiming to explore natural-derived biopolymers as novel feedstocks for different 3D printing technologies that will be potentially applied in various areas.

**3D printing with cellulose materials, Qianqian Wang *et al*, Cellulose, Vol.25 (8).** This critical review focuses specifically on the development and assessment of cellulose materials for 3D printing. A special focus was paid on extrusion based 3D printing. Detailed examinations of cellulose hydrogel rheology, fibre entanglement, fibre alignment, gelation, printability, shape fidelity, cell viability and processing parameters in extrusion based 3D printing are explored. The properties and performances of 3D printed cellulose constructs as well as their potential applications in the fields of medical, electronics, and smart textile are discussed. Finally, perspective and current important limitations of 3D printing with cellulose materials for advanced application are provided.



## COATING

**Photoluminescent spray-coated paper sheet: Write-in-the-dark, Tawfik A. Khattab et al, *Carbohydrate Polymers*, Vol.200.** A simple formulation of an organic-inorganic composite for spray-coating was adopted toward photoluminescent paper sheets. The coating composite layer was composed of a synthetic organic adhesive binder mixed with an inorganic lanthanide-doped strontium aluminate pigment. Such pigment-binder formula was applied effectively onto paper sheets via spray-coating followed by thermal fixation. The spray-coated paper sheets demonstrated good fastness to light and reversible phosphorescence without fatigue.

**Continuous roll-to-roll coating of cellulose nanocrystals onto paperboard, Rajesh Koppolu et al, *Cellulose*, Vol.25 (10).** There is an increased interest in the use of cellulose nanocrystal (CNC) films and coatings for a range of functional applications in the fields of material science, biomedical engineering, and pharmaceutical sciences. Most of these applications have been demonstrated on films and coatings produced using laboratory-scale batch processes, such as solvent casting, dip coating, or spin coating. For successful coating application of CNC suspensions using a high throughput process, several challenges need to be addressed: relatively high viscosity at low solids content, coating brittleness, and potentially poor adhesion to the substrate. This work aims to address these problems. Compared to other film casting techniques, the process employed in this work deposits a relatively thick coating in significantly less time, and may therefore pave the way toward various functional applications based on CNCs.

## MOULDED PULP

**Moulded pulp products manufacturing with thermoforming, Mattia Didone & Guido Tosello, *Packaging Technology and Science*, Vol.0 (0).** Over the past years, eco-friendly packaging solutions such as moulded pulp have resonated with a growing number of consumers. Among all of them, the thermoformed products make use of the most recent manufacturing approach that produces high-quality, thin-walled items. However, it remains an under-researched area, and the development of an efficient and precise manufacturing process is fundamental in order to increase the implementation of sustainable packaging.

## NANO-SCIENCE

**Preparation and characterization of antimicrobial films based on nanocrystalline cellulose, Yan Zhang et al, *Journal of Applied Polymer Science*, Vol.0, (0).** Nanocrystalline cellulose (NCC) has great potential in applications in medical and food packaging due to its abundance, high specific surface area, biodegradability, biocompatibility, and reproducibility. N-Halamine is one of the most effective antibacterial agents, with broad-spectrum efficacy against microorganisms, good stability, and reproducibility. Due to the nanosize effect and high specific surface area of NCC, N-halamine-modified NCC is potentially an excellent biocidal compound. In this paper, an N-halamine precursor 1-hydroxymethyl-5,5-dimethylhydantoin (HDH) was used to modify NCC with cyanuric chloride (cych) as the bonding agent.

**Green synthesis of cellulose nanofibers using immobilized cellulose, Mohamed A. Yassin et al, *Carbohydrate Polymers*, Vol.205.** Isolation of cellulose nanofibers (CNF) using cellulase immobilized on cheap and easily formed polymeric gel disks is discussed. Such gel disks based on carrageenan gel coated with hyperbranched polyamidoamine that can covalently bind to cellulase through glutaraldehyde spacer. Thermal and mechanical stability of the coated gel disks were significantly improved. Free and immobilized cellulase exhibited maximum activities at 50 °C and pH 5. However,



immobilized cellulase exhibited broader temperature stability than in the free form. Additionally, immobilized cellulase gel disks can be easily separated and reused with great reusability capacity of about 85% of the initial activity after six cycles. Immobilized cellulase was capable to disintegrate cellulose fibres providing nanofibres with diameter of 15–35 nm and several micrometres long. Overall, enhanced thermal stability and reusability of immobilized cellulase pave the way for its use in industrial production of CNF that can be applicable for biomedical and food packaging applications.

**Preparation and properties of microfibrillated cellulose with different carboxyethyl content, Jing-Huan Chen et al, Carbohydrate Polymers, Vol.206.** Carboxyethyl reaction was used as a pretreatment method before grinding and homogenization to prepare microfibrillated cellulose (MFC). The effect of carboxyethylation on the properties of cellulose materials and prepared MFC samples were investigated. Results showed that cellulose materials with different carboxyethyl content were obtained by controlling the chemical dosage. This reaction increased the water retention value, decreased the degree of polymerization and crystallinity, and changed the crystalline structure of cellulose. This study provides a comprehensive understanding of carboxyethyl pretreatment for the preparation of MFC, which may help to enrich and promote the preparation and application of MFC.

**Nanoparticles capture on cellulose nanofiber depth filters, Houssine Sehaqui et al, Carbohydrate Polymers, online.** A self-standing filter with a porosity of 80% is prepared from naturally abundant cellulose biopolymer in its native state by water-based cationization and freeze-drying processes. The positive surface charge of the filter in a wide pH range favours its interaction with various nanoparticles (NPs), while its tortuous sheet structure builds a contact between cellulose nanofibres (CNF) and the NPs, and hinders them to pass through the filter. Unlike membranes used for the retention of NPs and viruses, the separation in the CNF filter is not only limited to its surface but occurs also in its interior even when the NPs are orders of magnitude smaller than the filter pores. The present filter concept may not only address shortcomings of the current membrane systems, but could offer a disruptive technology for the sustainable and universal water purification.

**Eco-friendly Modification of a Regenerated Cellulose Based Film by Silicon, Carbon and N-doped Carbon Quantum Dots, Cuevas, B.B. et al, Carbohydrate Polymers, online.** Modification of a regenerated cellulose thin film by inclusion of different non-toxic nanodots (silicon-dots (SiDs), carbon-dots (CDs) or nitrogen-doped carbon dots (N-CDs)) by aqueous nanodots solution immersion was performed. Our results reveal that the inclusion of the different nanodots in the cellulosic support increases, in different percentages, the mechanical resistance and electrical conductivity, but they hardly affect the transmittance of the original film. In fact, the non-toxic character of both support film and nanodots, endorses the use of these new nano-engineering films in biomedical applications.

**Recyclable deep eutectic solvent for the production of cationic nanocelluloses, Panpan Li et al, Carbohydrate Polymers, online.** Deep eutectic solvents (DESSs) are potential green systems that can be used as reagents, extraction agents and reaction media. DESSs are often biodegradable, easy to prepare and have low toxicity. In this work, a recyclable DES formed from aminoguanidine hydrochloride and glycerol (AhG) was used as a reaction medium and reagent (aminoguanidine hydrochloride) for the production of cationic nanocelluloses.



**Bacterial cellulose for increasing barrier properties of paper products, Amanda Fillat *et al*, *Cellulose*, Vol.25 (10).** Bacterial cellulose was combined with wood cellulose papers in order to obtain biomaterials with increased barrier properties. Results obtained show the contribution of bacterial cellulose to improve the properties of paper and its potential for the design of new added value paper products from biomass.

**Enhancement of hydrophobicity of nanofibrillated cellulose through grafting of alkyl ketene dimer, Zhaoyang Yuan *et al*, *Cellulose*, Vol.25 (12).** To expand the application of nanofibrillated cellulose (NFC), the increase of its hydrophobicity is considered to be critical. In the present work, hydrophobic NFC powder was prepared through chemical modification with alkyl ketene dimer (AKD). The hydrophobicity of AKD-modified NFC increased with increasing AKD graft yield.

### **NOVEL PRODUCTS**

**Paper in Electronic and Optoelectronic Devices, Dongheon Ha *et al*, *Advanced Electronic Materials*, Vol.4 (5).** Paper, one of the oldest materials for storage and exchange of human's information, has been reinvented as a building component of electronic and optoelectronic devices over the past decades with successful demonstration of paper-based or paper-using devices. This article provides a review of electronic and optoelectronic devices relying on or making use of the unique properties achievable with paper-based materials. Basic scientific/technical principles, quantitative comparisons of material, electronic and/or optical properties, and benefits for each paper-based application are given. Application-specific research challenges, future design considerations, and development directions are also discussed.

**Thermoplastic starch foamed composites reinforced with cellulose nanofibers: Thermal and mechanical properties, Abbas Ghanbari *et al*, *Carbohydrate Polymers*, Vol.197.** The present work reports the effect of cellulose nanofibers (CNFs) on the thermal, dynamic mechanical analysis (DMA), density and water uptake of thermoplastic starch (TPS) foamed composites.

**Cellulose and nanocellulose-based flexible-hybrid printed electronics and conductive composites – A review, Sachin Agate *et al*, *Carbohydrate Polymers*, Vol.198.** Flexible-hybrid printed electronics (FHPE) is a rapidly growing discipline that may be described as the precise imprinting of electrically functional traces and components onto a substrate such as paper to create functional electronic devices. The mass production of low-cost devices and components such as environmental sensors, bio-sensors, actuators, lab on chip, radio frequency identification smart tags, light emitting diodes, smart fabrics and labels, wallpaper, solar cells, fuel cells, and batteries are major driving factors for the industry. The aim of these developments is to enable the creation of FHPE devices and components made almost entirely of cellulose materials.

**Production of Self-Supported Conductive Films based on Cellulose, Polyaniline and Silver Nanoparticles, Roselaine da S. Oliveira *et al*, *Carbohydrate Polymers*, Vol.199.** Synthetic efforts are being made to produce electrical conductive films based on a combination of cellulose matrix with conducting polymers. Improved mechanical properties and processability of the conducting polymers can be attained by promoting this combination. The high conductivity was promoted by the presence of polyaniline in its most conductive state with the silver nanoparticles affording the electrical contact among these chains creating a conductive network spread throughout the insulating cellulose matrix.



**Characterization of pulp derived nanocellulose hydrogels using AVAP® technology, Stuart Kyle et al, Carbohydrate Polymers, Vol.198.** Bioinspiration from hierarchical structures found in natural environments has heralded a new age of advanced functional materials. Nanocellulose has received significant attention due to the demand for high-performance materials with tailored mechanical, physical and biological properties. In this study, nanocellulose fibrils, nanocrystals and a novel mixture of fibrils and nanocrystals (blend) were prepared from softwood biomass using the AVAP® biorefinery technology. It is thought that these materials show great potential in (bio)nanomaterial applications where careful control of microarchitecture, surface topography and porosity are required.

**Photochromic properties of stimuli-responsive cellulosic papers modified by spiropyran-acrylic copolymer in reusable pH-sensors, Amin Abdollahi et al, Carbohydrate Polymers, Vol.200.** Photochromic chemosensors based on spiropyran have attracted great attentions in recent years. Here, stimuli-responsive papers were prepared by chemical attachment of epoxy functionalized latex particles containing spiropyran moieties on the cellulose fibres by a new strategy for design and preparation of an acrylic copolymer pH-sensor.

**Enhanced antibacterial profile of nanoparticle impregnated cellulose foam filter paper for drinking water filtration, Shikha Jain et al, Carbohydrate Polymers, online.** Filtration is a promising water treatment method to purify drinking water. To develop highly efficient drinking water filter paper, water-resistant cellulose foam paper with a high wet strength property was fabricated using diverse metal oxide (e.g., copper oxide (CuO), zinc oxide (ZnO), and silver oxide (Ag<sub>2</sub>O)) nanoparticles. The antibacterial profile of the cellulose foam filter impregnated with Ag<sub>2</sub>O nanoparticles, when tested against different types of bacteria, exhibited higher antibacterial activity than the cellulose foam filter impregnated with ZnO and CuO nanoparticles.

**One-step nanocellulose coating converts tissue paper into an efficient separation membrane, Sunanda Roy et al, Cellulose, Vol.25 (9).** This article reports robust technology for converting tissue paper (TP) into an efficient separation membrane by coating with a novel superhydrophobic material that was synthesized by a rapid, one step approach without using any hazardous chemicals viz fluorinated materials or organic/inorganic nanoparticles. The coating was prepared using modified cellulose nanofibers which can readily transform a TP into an excellent oil/water separation membrane as well as a highly efficient dye absorbent upon spray coating. We believe that our ecofriendly versatile superhydrophobic coating material can be a new promising choice for many advanced applications to create more sustainable earth.

**Conversion of paper to film by ionic liquids: manufacturing process and properties, Atsushi Tanaka et al, Cellulose, Vol.25 (10).** In this study, we investigate the “chemical welding” of paper with the ionic liquid (IL) 1-ethyl-3-methylimidazolium acetate ([EMIM]OAc) using a two-step process. The “chemically welded” paper structure has both elevated dry and wet strength. The treatment conditions can be adjusted to produce both paper-like materials and films. The most severe treatment conditions produce films that are fully transparent and their oxygen and grease barrier properties are excellent. As an all-cellulose material, the “chemically welded” paper is fully biodegradable and is a potential alternative to fossil fuel-based plastics.



**Preparation of lignocellulose/graphene composite conductive paper, Ruibin Wang *et al*, *Cellulose*, Vol.25 (10).** Practical production of conductive paper requires the balancing of high electrical conductance, thermal stability and tensile modulus, with cost effectiveness. By utilizing lignocellulose and graphite as starting materials, a lignocellulose/reduced graphene oxide (LRGO) composite conductive paper is successfully fabricated. Moreover, LRGO paper was used to make active electrodes for a supercapacitor that achieved a specific capacitance of 77.0 F/g. There has been minimal reporting of applying lignocellulose in conductive paper production, so this new method is anticipated to pave the way for developing advanced materials derived from low cost biomass.

**High-Performance Virus Removal Filter Paper for Drinking Water Purification, Olof Gustafsson *et al*, *Global Challenges*, Vol.2 (7).** Access to drinking water is one of the greatest global challenges today. In this study, the virus removal properties of mille-feuille nanocellulose-based filter papers of varying thicknesses from simulated waste water (SWW) matrix are evaluated for drinking water purification applications. The filter paper presented in this work shows great promise for the development of robust, affordable, and sustainable water purification systems.

**Novel applications of nonwood cellulose for blood typing assays, Jasmina Casals-Terré *et al*, *Journal of Biomedical Materials Research Part B: Applied Biomaterials*, Vol.0 (0).** Paper-based microfluidics devices can create a new healthcare model. Previous studies focused on either commercial papers or lab papers from wood-cellulose fibres, with different basis-weight. This work introduces the effect of refining process and lab paper from nonwood-cellulose fibres, focusing on sisal fibres.

### **PACKAGING TECHNOLOGY**

**An approach for reinforcement of paper with high strength and barrier properties via coating regenerated cellulose, Ruonan Zhu *et al*, *Carbohydrate Polymers*, Vol.200.** The applications of cellulose are increasing rapidly attributing to their biodegradability and renewability. In this study, a facile method was applied to fabricate composite paper with excellent mechanical and barrier properties via simple coating dissolved cellulose in ionic liquid. Though the composite papers showed enhanced hydrophilicity, it exhibited strong water-resistant and shape-retaining properties in water. Therefore, the resultant composite papers showed great potential in packaging application with higher humidity.

**Highly stretchable and transparent films based on cellulose, David Boon *et al*, *Carbohydrate Polymers*, Vol.201.** Developing natural products to replace synthetic plastics is necessary due to the serious environmental problem of non-biodegradable plastic waste. This paper reports our success in achieving the most stretchable and transparent cellulose-based films through a very green process. The mechanisms in achieving high transparency, flexibility and stretchability of the cellulose-based films are discussed.

**MWCNT-coated cellulose nanopapers: Droplet-coating, process factors, and electrical conductivity performance, Mahdi Mashkour *et al*, *Carbohydrate Polymers*, Vol.202.** Electrically conductive cellulose nanopapers (EC-CNPaps) were fabricated by the droplet-coating of multiwall carbon nanotubes (MWCNTs) on cellulose nanopapers (CNPaps), and the effects of the process factors on the electrical conductivity of EC-CNPaps were investigated.



**Nanocellulose-based Multilayer Barrier Coatings for Gas, Oil, and Grease Resistance, Preeti Tyagi *et al*, *Carbohydrate Polymers*, online.** Cellulose nanofibers (CNF) have been studied for their excellent oxygen and gas barrier properties; however, their performance rapidly decreases in the presence of moisture and higher humidity. Cellulose nanocrystals (CNC) are less sensitive to moisture due to their highly crystalline nature; however, coatings and films made of CNCs are more prone to fractures due to their high brittleness. Our work demonstrates a unique composite barrier coating system of CNF and CNC that synergistically enables oil and grease resistance (a kit rating of 11) comparable to fluorochemicals. The improvements in oil and gas barrier properties were evaluated with respect to the molecular, chemical, and structural properties of the developed coatings.

**Multifunctional nano-cellulose composite films with grape seed extracts and immobilized silver nanoparticles, Zhengguo Wu *et al*, *Carbohydrate Polymers*, online.** Nowadays, traditional packaging films with weak activity or single function cannot satisfy the active packaging requirements. In this paper, novel multifunctional films (TNC/GSE/AgNPs) based on TEMPO-oxidized nano-cellulose (TNC), grape seed extract (GSE) and TNC immobilized silver nanoparticles (TNC@AgNPs) are reported. The results showed that transparent TNC/GSE/AgNPs films exhibited better mechanical properties, lower water vapour permeability and oxygen permeability compared to pure TNC films. The prepared films will exhibit multifunction as food packaging to extend storage period.

**Evaluation of the functionality of bio-based food packaging films, D. Briassoulis & A. Giannoulis, *Polymer Testing*, Vol.69.** The importance of bio-based food packaging films is increasing rapidly. The functionality of selected representative bio-based compostable food packaging films was investigated against that of conventional films. The evaluation of the functionality of food packaging films was based on testing their performance with respect to critical mechanical and other functional properties. The mechanical and other functional characteristics of the bio-based food packaging films offer new design possibilities for targeted food packaging applications.

## **PAPERMAKING**

**Exploring structural variations of hydrogen-bonding patterns in cellulose during mechanical pulp refining of tobacco stems, Deqing Zhao *et al*, *Carbohydrate Polymers*, online.** Hydrogen bonding and mechanical refining are closely correlated. In this work, structural variations of hydrogen bonding patterns in cellulose during mechanical pulp refining, including the hydrogen bonding energy and distance as well as the content of hydrogen bonds, have been explored by using the second derivative FTIR spectra and deconvolving spectra in the OH stretching vibrational region.

**Development and utilization of lime-mud waste as filler for production of green paper, Abd El-Aziz A. Said *et al*, *Environmental Progress & Sustainable Energy*, Vol.0 (0).** In this article, the lime-mud (LM) as a waste generated in the Kraft pulping process was treated to improve its quality to be utilized again as filler. The final treated LM was characterized by different techniques and compared with the currently used calcium carbonate filler.



## **PULPING**

**A new approach to improve dissolving pulp properties: spraying cellulase on rewetted pulp at a high fiber consistency, Jianguo Li *et al*, *Cellulose*, Vol.25 (12).** Cellulase treatment is a promising technology that will increase the reactivity of a prehydrolysis kraft (PHK) dissolving pulp. In this study, a cellulase solution was sprayed onto rewetted pulp at a very high consistency (about 60%) to increase its Fock reactivity with high efficiency and low cost. This novel and facile approach is based on favourable cellulose adsorption onto pulp fibres and high cellulose concentration at the reaction sites. Consequently, the enzymatic reactions towards cellulose fibres are more effective, thus a higher enzymatic performance in comparison with the conventional process. Herein, the proposed cellulase spraying technology is flexible and readily implementable in practice.

## **TESTING**

**Improved method for measuring moisture content of mineral-oil-impregnated cellulose pressboard based on dielectric response, M. Zhang *et al*, *Cellulose*, Vol.25 (10).** The moisture content in transformer insulation pressboards is an important index to evaluate the insulation aging in the transformer. The dielectric-response technique based on frequency domain spectroscopy is used to accurately measure the moisture content in transformer insulation pressboard. In this study, according to the distribution of water molecules in oil-impregnated cellulose pressboard and the polarization behaviour of water molecules at different frequencies, a theoretical calculation method for moisture content in a composite model of cellulose pressboard, mineral oil, and moisture based on a typical transformer structure is proposed.

**Experimental investigation on bending fatigue failure of corrugated paperboard, Zhi-Wei Wang & Yu-Cheng Sun, *Packaging Technology and Science*, Vol.31 (9).** A series of 3-point bending fatigue tests were conducted to investigate the bending fatigue behaviour of flute type B and C corrugated paperboard samples under cyclic loading. The results obtained in this paper may be applied to the dynamic design and accelerated vibration test of stacked corrugated boxes.

**Study on the method for testing the water vapor diffusion resistance of membranes, Wei Li & Ye Yao, *Polymer Testing*, Vol.69.** Water vapour diffusion resistance is an important property of porous membranes. In the paper, a new apparatus for specially measuring the water vapour diffusion resistance of porous membranes was developed. In the new apparatus, the humidity of circulating carrier air streams flowing over both sides of test membrane are controlled by different saturated salt solutions, which makes a variety of humidity conditions and improves the humidity stability. In order to decrease the error caused by the air boundary layer, the structure of the test chamber was optimized with the help of computational fluid dynamics technology. The new apparatus is a simple, low-cost and time-saving alternative for measuring the water vapour diffusion resistance of porous membranes.

## **WASTE TREATMENT**

**Effective lactic acid production from waste paper using *Streptococcus thermophilus* at low enzyme loading assisted by Gleditsia saponin, Shujuan Yang *et al*, *Carbohydrate Polymers*, Vol.200.** Waste paper has considerable potential as a raw material for lactic acid (LA) production due to high cellulose content, abundance and low cost. In this study, four kinds of waste papers were used for LA production through simultaneous saccharification and fermentation (SSF) by *Streptococcus thermophilus*.



**Review on recent progress in chitosan-based hydrogels for wastewater treatment application, Parisa Mohammadzadeh Pakdel & Seyed Jamaledin Peighambaroust, *Carbohydrate Polymers*, Vol.201.** Recently, chitosan has been used as a raw material for synthesis of hydrogels in a wide range of potential and practical applications like wastewater treatment, drug delivery, and tissue engineering. This review represents an overview of the application of chitosan-based hydrogels for wastewater treatment.

**Utilisation of natural cellulose fibres in wastewater treatment, Nur Syazwani Abd Rahman *et al*, *Cellulose*, Vol.25 (9).** This review has explored the role of natural fibres as adsorbents for wastewater treatment while at the same time, for the removal of adsorbates such as oil, dyes, heavy metals, ionic compounds, and others as reported in the literature. Also investigated in this study, were the different modification types used to enhance the fibres and the mechanism of contaminant removal by the absorbents. Lastly, the physical forms of adsorbates and common types of effluents treated using natural fibres were examined and discussed.

**Effect of thermal sludge processing on selected components of air quality in the vicinity of a wastewater treatment plant, Robert Cichowicz *et al*, *Chemical Papers*, online.** Wastewater treatment plants (WWTPs) generate considerable amounts of sewage sludge. The thermal sludge treatment system (TSTS) is therefore one of the most important technological units of a WWTP. However, due to technological processes involved in thermal sludge treatment, specific chemical, physical and biological conditions may arise that can affect air quality both within the WWTP area and in its vicinity. This study uses data from experimental measurements taken in and around a WWTP to assess the impact of thermal sludge treatment on air quality.

**Constructed Wetland Technology for Pulp and Paper Mill Wastewater Treatment, Satish Kumar & Ashutosh Kumar Choudhary, book chapter in *Constructed Wetlands for Industrial Wastewater Treatment*, Wiley.** This chapter describes the characteristics of pulp and paper mill wastewater and the suitability of constructed wetlands (CWs) for wastewater treatment from such facilities.

**Paper sludge functionalization for achieving fiber-reinforced and low thermal conductivity calcium silicate insulating materials, Mingxu Chen *et al*, *Journal of Thermal Analysis and Calorimetry*, online.** Paper sludge generated from the paper industry is classified as solid waste, comprising primarily wood fibre and calcium carbonate with low thermal conductivity. This paper is concentrated on the comparison of wood fibre and paper sludge from the structural strength and insulation property of calcium silicate insulating materials (CSIM). It can be concluded that the utilization of paper sludge presents a great potential to develop fibre-reinforced and low thermal conductivity CSIM and benefits to the development of waste management in producing sustainable CSIM.

**Fabrication of polypyrrole composite on perlite zeolite surface and its application for removal of copper from wood and paper factories wastewater, Ali Naghizadeh *et al*, *Korean Journal of Chemical Engineering*, Vol.35 (3).** The large volumes of water used in wood and paper industries produce substantial amounts of wastewater. We studied copper removal from the effluents of a wood and paper factory by using a polypyrrole composite consisting of natural Zeolite coated on Perlite (PPy/Perlite). Evaluation of experimental information for studying the kinetics of copper adsorption by PPy/Perlite revealed that copper adsorption followed the pseudo-second-order kinetic model.



## **WOOD PANEL**

**Reuse and Valorisation of Hemp Fibres and Rice Husk Particles for Fire Resistant Fibreboards and Particleboards, Daniele Battezzore et al, *Journal of Polymers and the Environment*, Vol.26 (9).** The present manuscript deals with the reuse and valorisation of agricultural wastes and by-products (namely, hemp fibres and rice husk particles) to produce fire retardant fibreboards and particleboards for applications in biobuilding. Since fire retardancy is one of the most important challenges, a detailed study on the thermal and flame retardant properties of the above materials assembled using starch as the binder and different ammonium dihydrogen phosphate contents as fire retardant agents, is proposed.

**Investigation of Using Cork- and MDF-Layered Panel Material in Interior Furnishing, Mustafa Adil Kasapseckin, *Journal of Interior Design*, Vol.0 (0).** In the furniture industry, wood-based panel products are widely used for the constitution of any fixed or moveable furniture in interior space. These panel products are commonly described as plywoods, particleboards, and fibreboards. This paper presents a material science study that investigates an alternative to these products in the usage of cork, which is a lightweight, flexible, and renewable material. Cork was combined with medium-density fibreboard (MDF) in the form of a layered panel.

**Lightweight Wood Composites: Challenges, Production and Performance, Sandra Monteiro et al, *Lignocellulosic Composite Materials*, online.** Wood composites are materials made by bonding together wood and adhesives into a large material that can be used for different purposes. Nowadays, lightweight materials play an important role in several industries: aerospace, building and furniture. The reduction of weight is desirable for economic reasons (materials and transportation costs) and environmental reasons (resources, eco-efficiency). Once wood composites are employed in these industries, low density is a desired property. There are several options in the market to reduce the weight of composites, such as the use of low-density wood species, lower compaction of the wooden mat, incorporation of light fillers in the core layer of the panel, or use of sandwich panels with honeycomb core. All these strategies have challenges with respect to manufacturing, machinability (connections and lamination of the edges) and performance (physico-mechanical properties).



## Forthcoming Events

**PAPER ONE SHOW (Beirut) – PITA Members get 20% discount on Stand**

28-30 January 2019

<https://paperoneshow.net/>

**INGEDE SYMPOSIUM (Munich) – Papers contained in this PDF**

13 February 2019

<http://pub.ingede.com/en-GB/symp2019/>

**PITA ENERGY OPTIMISATION COURSE (Bury)**

26-27 February 2018

[info@pita.co.uk](mailto:info@pita.co.uk)

**PITA 'AN INTRODUCTION TO TISSUE MANUFACTURE' (Bury)**

12-14 March 2019

[info@pita.co.uk](mailto:info@pita.co.uk)

**TISSUE WORLD EUROPE (Milan) – PITA Members get 20% discount on Conference**

25-27 March 2019

[www.tissueworld.com](http://www.tissueworld.com)

**PITA PUMP EFFICIENCY COURSE (Bury)**

30 April 2019

[info@pita.co.uk](mailto:info@pita.co.uk)

**PITA PAPER APPRECIATION COURSE (Bury)**

14-15 May 2019

[info@pita.co.uk](mailto:info@pita.co.uk)

**PAPER & BIOREFINERY (Graz) – Papers contained in this PDF**

5-6 June 2019

<https://paper-biorefinery.com/>

The full PITA Calendar of World Events can be found at:

<https://www.pita.org.uk/what-we-do/events-activities/calendar-of-world-events>



# INGEDE

# ***Hotels in Munich***

Hotel Anna\*\*\*\*  
Schützenstraße 1  
80335 München

**0.8 km to HBW**  
Fon+49 89 599940  
[www.annahotel.de](http://www.annahotel.de)

135.00 EUR Single Room  
22.00 EUR Breakfast

Excelsior\*\*\*\*  
Schützenstr. 11  
80335 Munich

**1.0 km to HBW**  
Fon+49 89 551370  
[www.excelsior-hotel.de](http://www.excelsior-hotel.de)

111.00 EUR Single Room  
Excl. Breakfast

Maritim Hotel München\*\*\*\*  
Goethestraße 7  
80336 Munich

**1.4 km to HBW**  
Fon: +49 89 552350  
[www.maritim.de](http://www.maritim.de)

119.70 EUR Single Room  
24.00 EUR Breakfast

Hotel Amba \*\*\*  
Arnulfstrasse 20  
80335 Munich

**1.6 km to HBW**  
Fon:+49 89 545140  
[www.hotel-amba.de](http://www.hotel-amba.de)

44.00 EURO Single Room  
11.50 EUR Breakfast

Hotel Torbräu \*\*\*\*  
Tal 41  
80331 Munich

**2.5 km to HBW**  
Fon +49 89 24234234  
[www.torbraeu.de](http://www.torbraeu.de)

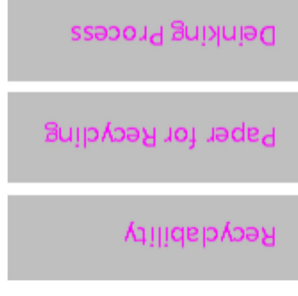
160.00 EUR Single Room  
incl. Breakfast

Hotel Prinz \*\*\*\*  
Hochstr. 45  
81541 Munich

**4.5 km to HBW**  
Fon+49 89 4414080  
[www.hotel-prinz.de](http://www.hotel-prinz.de)

115.20 EUR Single Room  
17.00 EUR Breakfast

HBW = Haus der Bayerischen Wirtschaft, Max-Joseph-Straße 5, 80333 Munich



**INGEDE** invites you to the **28<sup>th</sup> INGEDE Symposium** on  
**13 February 2019** at Haus der Bayerischen Wirtschaft  
in Munich, Germany

The **INGEDE** Symposium is the only international conference covering all  
aspects from **recyclability** and **paper recovery** to the treatment  
of **paper for recycling**

**A more intense focus on the topics by enlarging the technical sessions**

**Reaching a higher level in paper recycling – Together chances and  
challenges can be met!**

You will find the detailed programme on the next pages

Conference languages: English and German with simultaneous translation

**New at the INGEDE Symposium 2019**  
Two sessions, focusing on paper for  
recycling and recyclability

At the upcoming symposium, INGEDE is even more  
focusing on the needs and interests of all members of  
the paper chain – with a plenary meeting in the morn-  
ing and two parallel sessions in the afternoon. These  
offer more insight into current issues in the collection,  
sorting, and inspection of paper for recycling; as well  
as in the recyclability of different printing products  
and how to deal with them in the deinking process,  
the challenges of newer printing processes and diffe-  
rent kinds of certification of printed products.

The **participation fee** of 650 EUR (early bird: 580 EUR)  
includes lunch, get together, and conference docu-  
mentation. For more **details** such as the final pro-  
gramme or hotel recommendations and about the  
venue see

**[www.ingede.org](http://www.ingede.org) or contact [office@ingede.org](mailto:office@ingede.org)**

# INGEDE Symposium Programme

## Common Session 1 (9:30 h until 12:30 h)



|       |                                                                                                                                                                            |                                                                                                                                                                   |
|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 9:00  | Registration & coffee                                                                                                                                                      |                                                                                                                                                                   |
|       | <b>Welcome and Opening of Session 1</b><br><i>Thomas Krauthauf, Chairman of INGEDE</i>                                                                                     |                                                                                                                                                                   |
|       | <b>Welcome address by Bernhard Steinbeis, the founding chairman of INGEDE</b><br><i>Bernhard Steinbeis</i>                                                                 |                                                                                                                                                                   |
|       | <b>Annual report, achievements of INGEDE</b><br><i>Thomas Krauthauf, Chairman of INGEDE</i>                                                                                |                                                                                                                                                                   |
|       | <b>Session: The paper value chain</b><br>Books are made for readers – challenges from e-books to environmental certifications<br><i>Barbara Scheuer-Arlt, Random House</i> | <b>Breakthroughs in recyclability:</b><br>UV/LED deinking – ready for a greener printing<br><i>Thomas Glaser, Siegwerk</i><br><i>Peter Hengesbach, Stora Enso</i> |
|       |                                                                                                                                                                            | <b>New PSA labels</b><br><i>Weronika Kot and Marta Zajac, UPM Raflatac</i>                                                                                        |
|       |                                                                                                                                                                            | <b>Implementation of the Circular Economy Package</b><br><i>Ulrich Leberle, CEPI</i>                                                                              |
|       |                                                                                                                                                                            | <b>From graphic to packaging – Conversion of a paper mill</b><br><i>Christian Schürmann, LEIPA</i>                                                                |
|       |                                                                                                                                                                            | <b>Closure of common session</b><br><i>Thomas Krauthauf, INGEDE</i>                                                                                               |
| 12:30 | Lunch break                                                                                                                                                                |                                                                                                                                                                   |

# INGEDE Symposium Programme

## Session 2.1 and Session 2.2 (14:00 h until 17:30 h)



### Paper for Recycling – Introduction Session 2.1

*Manfred Geistbeck, UPM*

### Optimised sorting plant Kinsau

*Christian Ascherl, ROWE*

### Hyperspectral camera (INGEDE Project 156 18)

*René Michels, Cubert*

### Foreign particles

*Dennis Voß, Perlen Papier*

### How can the paper industry benefit from the new packaging legislation?

*Robin Huesmann, LEIPA*

*Andreas Faul, INGEDE*

### Audit of Entry Inspection (INGEDE Project 157 18)

*Andreas Faul, INGEDE*

### Closure of session

*Manfred Geistbeck, UPM*

### Deinking process – Introduction Session 2.2

*Anne-Katrin Klar, Essity*

### HP Indigo – Still a serious challenge for the deinking process

*Axel Fischer, INGEDE*

### Healthy printing

*Katja Hansen, EPEA*

### CITEO's approach on fee's modulation depending on recyclability

*Jean-François Robert, CITEO*

### Influence of anionic trash on ink removal efficiency

*Bernhard Nellessen, Solenis*

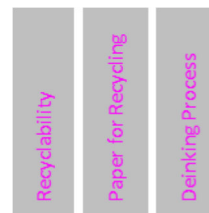
### Challenges in the development of deinking processes

*Johann Oberndorfer, UPM*

### Closure of session

*Anne-Katrin Klar, Essity*

# INGEDE Events 2019



## Registration Form INGEDE Guests

**13 FEBRUARY 2019**

Haus der Bayerischen Wirtschaft (HBW), Max-Joseph-Straße 5, 80333 Munich

**INGEDE SYMPOSIUM** (Europasaal and Münchner Saal)

### GET-TOGETHER

Restaurant "Augustiner Klosterwirt", Augustinerstraße 1, 80331 Munich

**13 February 2019**

*... please complete and return by 1 February 2019*

|                                                     |                                                                                                                            |                                                                                         |                                                         |
|-----------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|---------------------------------------------------------|
| INGEDE Symposium<br>Session 1<br><br>9:30 h–12:30 h | INGEDE Symposium<br>Session 2.1<br>"Paper for Recycling"<br>14:00 h–17:30 h                                                | INGEDE Symposium<br>Session 2.2 "Deinking Process,<br>Recyclability"<br>14:00 h–17:30 h | Get-together<br>"Augustiner Klosterwirt"<br><br>19:00 h |
| <input type="checkbox"/>                            | For logistical purposes we ask you to tick<br>session <input type="checkbox"/> 2.1 or session <input type="checkbox"/> 2.2 |                                                                                         | <input type="checkbox"/>                                |

For lunch I prefer: ☐ Fish ☐ Meat ☐ Vegetarian ☐ No preference

Name: .....

Company: .....

Country: .....

VAT number: .....

PO number: .....

Date/Signature: .....

Please note that we offer a discounted fee of 290 € for your participation.



# PAPER & BIOREFINERY

# PAPER&BIOREFINERY

CONFERENCE

5 - 6 June 2019, Graz

TRADE SHOW\*

PARTNERKONZEPTE

## FACHAUSSTELLUNG



PARTNER CONCEPTS

## TRADE SHOW



\* **AUSSTELLER ERHALTEN 15 % BONUS**

auf alle für Angebote aus  
„Sponsoring & Werbung“

\* **EXHIBITORS RECEIVE A 15 % BONUS**

on all offers for  
“Sponsoring & Advertising”

A JOINT INITIATIVE BY / EINE GEMEINSAME INITIATIVE VON

**APV**  
Academic Paperengineering-Association  
at the University of Technology Graz

**austropapier**  
Association of the Austrian  
Paper Industry

**ÖZEPÄ**  
Austrian Association of Pulp and  
Paper Chemists and Technicians

# EINLADUNG ZUR FACHAUSSTELLUNG FÜR DEN SEKTOR ZELLSTOFF/PAPIER/BIORAFFINERIE

Sehr geehrte Damen und Herren,

Herr Univ.-Prof. Wolfgang Bauer, Obmann des APV Graz, lädt Sie herzlich zur Beteiligung an der **PAPER & BIOREFINERY CONFERENCE** (vormals: „Österreichische Papierfachtagung“) ein, die am 5./6. Juni 2019 im Messecongress Graz stattfindet.

Wichtige Ergänzung des wissenschaftlichen Programms wird wieder eine repräsentative FACHAUSSTELLUNG sein. Diese beliebte Kommunikationsmöglichkeit im Rahmen der Tagung bietet eine besonders ansprechende Gelegenheit zur Präsentation Ihres Unternehmens und Leistungsangebotes.

## DIE FACHAUSSTELLUNG 2019:

**Der Preis für die Ausstellungsfläche beträgt € 250,- / m<sup>2</sup> (netto)**

\* Frühbucherbonus: Bei Buchung bis 28. Februar 2019 erhalten Sie einen Rabatt von EUR 20,- / m<sup>2</sup>. Mindestnennung: 6 m<sup>2</sup>. Die gebuchte Fläche versteht sich exklusive aller zusätzlich bestellten Extras wie Mobiliar, Reinigung, Strom etc.

Bitte entnehmen Sie den nachfolgenden Unterlagen die näheren Details zu unseren Ausstellungsangeboten.

Wir hoffen, Ihr Interesse geweckt zu haben und bitten um Rücksendung der beiliegenden Anmeldung zur Fachausstellung mit der gewünschten Standgröße. **Anmeldeschluss ist der 5. Mai 2019.** Die Platzeinteilung erfolgt unter Berücksichtigung der Sponsortätigkeit sowie nach Standgröße und Anmeldedatum.

Bestätigte Aussteller erhalten selbstverständlich zeitgerecht detaillierte AusstellereinFORMATION. Für Ihre Fragen stehen wir sehr gerne jederzeit zur Verfügung.

*Mit freundlichen Grüßen*

*Die Ausstellungsleitung*

**Kontakt:** Carmen Zavarsky und Verena Schachenhofer  
c/o Media-Plan Ausstellungsorganisation und Werbung  
Tel.: +43 (0)1-536 63 -23 oder -26 Fax: +43 (0)1-535 60 16 Email: [papierfachtagung@media.co.at](mailto:papierfachtagung@media.co.at)

# WICHTIGE INFORMATIONEN

RUND UM DIE PAPER & BIOREFINERY CONFERENCE 2019

## FREIE KONTINGENTE

Abhängig von der bezahlten Standfläche stehen Ihnen folgende kostenfreien Kontingente zur Verfügung:

| Standfläche          | Zutritt zur<br>Konferenz/Ausstellung<br>(Standpersonal) | Freikarten für das<br>Conference Dinner | Freie <b>Parkplätze</b><br>am Gelände |
|----------------------|---------------------------------------------------------|-----------------------------------------|---------------------------------------|
| ab 6 m <sup>2</sup>  | 2 Personen                                              | 2 Tickets                               | 2 Fahrzeuge                           |
| ab 12 m <sup>2</sup> | 3 Personen                                              | 3 Tickets                               | 3 Fahrzeuge                           |
| ab 18 m <sup>2</sup> | 4 Personen                                              | 4 Tickets                               | 4 Fahrzeuge                           |
| ab 24 m <sup>2</sup> | 5 Personen                                              | 5 Tickets                               | 5 Fahrzeuge                           |

## VERANSTALTUNGSORT

**Messecongress Graz**

(Messegelände, bei Stadthalle Graz)

Messeplatz 1, A-8010 Graz Web: [www.mcg.at](http://www.mcg.at)

## HOMEPAGE

[www.paper-biorefinery.com](http://www.paper-biorefinery.com)

## VERANSTALTER

**APV** Akademischer Papieringenieur-Verein  
an der Technischen Universität Graz  
Institut für Papier-, Zellstoff- und Fasertechnik  
Inffeldgasse 23/EG, A-8010 Graz

## TAGUNGSLEITUNG

**Univ.-Prof. Dr. Wolfgang Bauer**

Technische Universität Graz  
Institut für Papier-, Zellstoff- und Fasertechnik  
Inffeldgasse 23/EG, A-8010 Graz

## TAGUNGSSEKRETARIAT

**Kerstin Schefzik**

Tel.: +43 (0)316-873 30 799  
Fax: +43 (0)316-873 10 30 751  
Mail: [office@paper-biorefinery.com](mailto:office@paper-biorefinery.com)

## AUSSTELLUNGSLEITUNG

**Carmen Zavarsky & Verena Schachenhofer**

c/o Media-Plan Ausstellungsorganisation und Werbung  
Helferstorferstrasse 2, A-1010 Wien  
Tel.: +43 (0)1-536 63 -23 oder -26  
VOR ORT: +43 (0)664 515 3114

Fax: +43 (0)1-535 60 16  
Mail: [papierfachtagung@media.co.at](mailto:papierfachtagung@media.co.at)

## TAGUNGSORGANISATION

### INKL. SPONSORING/WERBUNG

**Birgit Hasler**

Tel.: +43 (0)664-84 44 950  
Mail: [birgit.hasler@paper-biorefinery.com](mailto:birgit.hasler@paper-biorefinery.com)

Bitte retournieren Sie das ausgefüllte Formular an MEDIA-PLAN: Mail: [papierfachtagung@media.co.at](mailto:papierfachtagung@media.co.at), Fax: (+43/1) 535 60 16

## AUSSTELLER

Rechnungsempfänger: \_\_\_\_\_

(Firmenname und Anschrift) \_\_\_\_\_

Sachbearbeiter: \_\_\_\_\_ Fax: \_\_\_\_\_

Telefon: \_\_\_\_\_ UID Nr.: \_\_\_\_\_  
(verpflichtend für EU Länder)

E-Mail: \_\_\_\_\_ Bestellnr.: \_\_\_\_\_  
(falls erforderlich)

## ANMELDUNG ZUR FACHAUSSTELLUNG

Wir bestellen: **Anmeldeschluss: 5. Mai 2019**

**Bodenfläche:** ..... m<sup>2</sup> (nur Bodenfläche, keine Trennwände, Stromanschluss, etc.)

**Mindestmeldung: 6 m<sup>2</sup>**

**zum Frühbucherpreis von**  
**ab 1. März 2019**

**€ 230,-- / m<sup>2</sup>**

**Gewünschte Maße: ..... m lang x ..... m tief**

**€ 250,-- / m<sup>2</sup>**

Sonstiges: \_\_\_\_\_  
(Nicht für Bestellungen etwaiger Zusatzausstattung)

Bestätigte Aussteller erhalten rechtzeitig Auf- und Abbauezeiten und detaillierte AusstellereinFORMATION und Bestellformulare für Zusatzausstattung. **Bestellungen etwaiger Zusatzausstattung werden nur mittels offizieller Bestellformulare akzeptiert.**

Angegebene Maße gelten als Außenmaße; Anmeldung nur auf volle und halbe Meter. Anteilige Grundreinigungskosten sind obligatorisch und werden gesondert verrechnet.

Zur Information – bitte ankreuzen:

- ☐ Wir werden einen Eigenstand bauen (Genehmigung des Standplans durch Media-Plan erforderlich).
- ☐ Wir werden einen Faltstand mitbringen.
- ☐ Wir werden eine Standardkoje gegen Extrakosten bestellen (mittels Bestellformulare für Zusatzausstattung).

**Zahlungs- und Stornobedingungen:** Preise sind Nettopreise. Für Firmen mit Österr. UID-Nr.: +20% MwSt. + 1% Vertragsgebühr. Für alle anderen Länder: Preise netto - die Steuerschuld liegt beim Leistungsempfänger. Nach Einsendung der „Anmeldung zur Fachausstellung“ erhält der Aussteller die Bestätigung der Anmeldung und die Zahlungsrechnung über 50%. Diese ist unmittelbar nach Erhalt fällig. Die Rechnungslegung für den Restbetrag erfolgt 2-3 Monate vor Kongressbeginn – die Endrechnung ist unmittelbar nach Erhalt zur Zahlung fällig. Bei Anmeldung ab 3 Monaten vor Kongressbeginn erhält der Aussteller mit der Bestätigung die Rechnung über den vollen Betrag (100%) – diese ist unmittelbar nach Erhalt zur Zahlung fällig. Überweisungen auf das Konto der „MEDIA-PLAN“ bei der UniCredit Bank Austria AG, Schottengasse 6-8, 1010 Wien, BLZ: 12000, Konto-Nr. 02250170400, IBAN: AT181100002250170400, BIC: BKAUATWW spesenfrei für den Empfänger. Stornogebühr: 50% des gesamten Mietentgeltes für die Fläche und die volle Anmeldegebühr bei Storno oder Reduzierung bis spätestens drei Monate vor Kongressbeginn, 100% bei Storno oder Reduzierung danach. Erfüllungsort und Gerichtsstand: Wien.

Die Platzvergabe erfolgt unter Berücksichtigung von Sponsoringaktivitäten, Standgröße, Datum der Anmeldung und Eingang der Anzahlung. **Mit unserer Unterschrift anerkennen wir die beiliegenden Teilnahmebedingungen.**

Ort / Datum

Stempel/Firmenmäßige Zeichnung des Ausstellers

**MEDIA-PLAN**

Gesellschaft für Ausstellungsorganisation und Werbung Karl Kreiner & Co KG  
Engerthstrasse 128, 1200 Vienna/Austria  
City office: Helfferstorferstrasse 2, 1010 Vienna/Austria  
Tel.: (+43/1) 536 63-0, Fax: (+43/1) 535 60 16  
e-mail: [mp@media.co.at](mailto:mp@media.co.at), [www.mediaplan.co.at](http://www.mediaplan.co.at)  
VAT-Reg.-No: ATU 10902102, commercial court Vienna: FN 9129a

Bitte retournieren Sie das ausgefüllte Formular an MEDIA-PLAN: Mail: [papierfachtagung@media.co.at](mailto:papierfachtagung@media.co.at), Fax: (+43/1) 535 60 16

## AUSSTELLER

Rechnungsempfänger: \_\_\_\_\_

(Firmenname und Anschrift) \_\_\_\_\_

Sachbearbeiter: \_\_\_\_\_ Fax: \_\_\_\_\_

Telefon: \_\_\_\_\_ UID Nr.: \_\_\_\_\_  
(verpflichtend für EU Länder)

E-Mail: \_\_\_\_\_ Bestellnr.: \_\_\_\_\_  
(falls erforderlich)

## BESTELLUNG EINES STANDARD STANDS

Bestellmenge

.....m<sup>2</sup>

### Standard Stand Basis Paket

- **Auf- und Abbau**
- **Rück- und Seitenwände** inkl. Abstützungen, 250 x 100 cm
- **Bodenteppich** – bitte wählen Sie die Farbe: ☐ blau ☐ grau
- 2,5 KW (230 Volt) **Stromanschluss** inkl. 3-fach Steckdose
- 1 **Strahler** pro 3m<sup>2</sup>
- **Blende** an allen offenen Standseiten inkl. Blendenbeschriftung (max. 20 Buchstaben). Bitte führen Sie hier die gewünschte Blendenbeschriftung an:  
\_\_\_\_\_

pro m<sup>2</sup> € 95,--



.....m<sup>2</sup>

### Standard Stand möbliert

- **Standard Stand Basis Paket**  
Bitte geben Sie Blendenbeschriftung und Teppichfarbe oben an.
- 1 **Corpus Pult** (100 x 50 x 90 cm) mit Schiebetür, versperbar
- 1 **Prospektständer**
- **Wahlweise:** ☐ 1 Sitzgarnitur (1 Bistro-Tisch Ø ca. 70 cm inkl. Tischtuch und 3 Stühle)  
oder ☐ 1 Stehtisch und 3 Barhocker

pro m<sup>2</sup> € 125,--



### Logo Druck auf Blende

(Preis pro Blende, bei Eckstand 2x, bei Kopfstand 3x Blenden benötigt)

pro Graphik € 78,--

**Zahlungs- und Stornobedingungen:** Preise sind Nettopreise. Für Firmen mit Österr. UID-Nr.: +20% MwSt. + 1% Vertragsgebühr. Für alle anderen Länder: Preise netto – die Steuerschuld liegt beim Leistungsempfänger. Nach Einsendung der „Anmeldung zur Fachaussstellung“ erhält der Aussteller die Bestätigung der Anmeldung und die Anzahlungsrechnung über 50%. Diese ist unmittelbar nach Erhalt fällig. Die Rechnungslegung für den Restbetrag erfolgt 2-3 Monate vor Kongressbeginn – die Endrechnung ist unmittelbar nach Erhalt zur Zahlung fällig. Bei Anmeldung ab 3 Monaten vor Kongressbeginn erhält der Aussteller mit der Bestätigung die Rechnung über den vollen Betrag (100%) – diese ist unmittelbar nach Erhalt zur Zahlung fällig. Überweisungen auf das Konto der „MEDIA-PLAN“ bei der UniCredit Bank Austria AG, Schottengasse 6-8, 1010 Wien, BLZ: 12000, Konto-Nr. 02250170400, IBAN: AT181100002250170400, BIC: BKAUATWW spesenfrei für den Empfänger. Stornogeühr: 50% des gesamten Mietentgeltes für die Fläche und die volle Anmeldegebühr bei Storno oder Reduzierung bis spätestens drei Monate vor Kongressbeginn, 100% bei Storno oder Reduzierung danach. Erfüllungsort und Gerichtsstand: Wien.

Ort / Datum

Stempel/Firmenmäßige Zeichnung des Ausstellers

# MEDIA-PLAN

Gesellschaft für Ausstellungsorganisation und Werbung Karl Kreiner & Co KG  
Engerthstrasse 128, 1200 Vienna/Austria  
City office: Helfferstorferstrasse 2, 1010 Vienna/Austria  
Tel.: (+43/1) 536 63-0, Fax: (+43/1) 535 60 16  
e-mail: [mp@media.co.at](mailto:mp@media.co.at), [www.mediaplan.co.at](http://www.mediaplan.co.at)  
VAT-Reg.-No: ATU 10902102, commercial court Vienna: FN 9129a

Bitte retournieren Sie das ausgefüllte Formular an MEDIA-PLAN: Mail: [papierfachtagung@media.co.at](mailto:papierfachtagung@media.co.at), Fax: (+43/1) 535 60 16

## AUSSTELLER

Rechnungsempfänger: \_\_\_\_\_

(Firmenname und Anschrift) \_\_\_\_\_

Sachbearbeiter: \_\_\_\_\_ Fax: \_\_\_\_\_

Telefon: \_\_\_\_\_ UID Nr.: \_\_\_\_\_  
(verpflichtend für EU Länder)

E-Mail: \_\_\_\_\_ Bestellnr.: \_\_\_\_\_  
(falls erforderlich)

## BESTELLFORMULAR FÜR ZUSATZAUSSTATTUNG

### Bestellmenge

|                                                                                                                              |                    |   |        |
|------------------------------------------------------------------------------------------------------------------------------|--------------------|---|--------|
| _____ <b>T Teppich</b> , bitte wählen Sie die Farbe: <input type="checkbox"/> blau <input type="checkbox"/> grau             | pro m <sup>2</sup> | € | 16,--  |
| _____ <b>Wandpanel, weiß</b> , 100 cm b x 250 cm h, nutzbare Fläche 97cm b x 229cm h                                         | pro Stück          | € | 36,--  |
| _____ <b>Tür</b> , versperbar, weiß, 100 cm b x 250 cm h                                                                     | pro Stück          | € | 138,-- |
| _____ <b>Regalfach</b> , auf Wandpanel montiert, 30 cm t <input type="checkbox"/> horizontal <input type="checkbox"/> schräg | pro Stück          | € | 27,--  |
| _____ <b>Tisch</b> (140 cm b x 70 cm t x 72 cm h), inkl. Stoffbespannung und Tischtuch                                       | pro Stück          | € | 47,--  |
| _____ <b>Stehtisch</b> (Ø 60 cm x 110 cm h inkl. Tischtuch)                                                                  | pro Stück          | € | 41,--  |
| _____ <b>Stuhl</b>                                                                                                           | pro Stück          | € | 24,--  |
| _____ <b>Barhocker</b>                                                                                                       | pro Stück          | € | 37,--  |
| _____ <b>Sitzgarnitur</b> (1 Bistro Tisch Ø 60 cm x 70 cm h inkl. Tischtuch und 3 Stühle)                                    | pro Garnitur       | € | 105,-- |
| _____ <b>Prospektständer</b>                                                                                                 | pro Stück          | € | 63,--  |
| _____ <b>Corpus Pult</b> (100 cm b x 50 cm t x 90 cm h, mit versperbarer Schiebetür)                                         | pro Stück          | € | 119,-- |
| _____ <b>Corpus Vitrine</b> (100 cm b x 50 cm t x 90 cm h), versperbares Pult, Glasteil: 20 cm h                             | pro Stück          | € | 144,-- |
| _____ <b>Kühlschrank</b> (Dauerstromanschluss muss zusätzlich bestellt werden)                                               | pro Stück          | € | 95,--  |
| _____ <b>Papierkorb</b> , grau                                                                                               | pro Stück          | € | 8,--   |
| _____ <b>Stromanschluss</b> , 230 Volt inkl. 3er Verteiler                                                                   | pro Anschluss      | € | 110,-- |
| <input checked="" type="checkbox"/> Anteilige <b>Grundreinigungskosten</b> , obligatorisch (einmalig nach Aufbau)            | pro m <sup>2</sup> | € | 3,50   |

### Zahlungs- und Stornobedingungen:

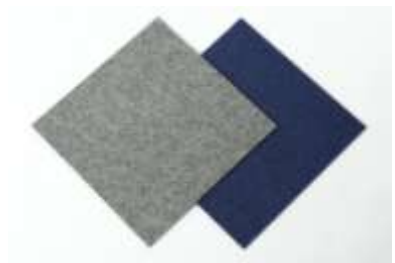
Preise sind Nettopreise. Für Firmen mit Österr. UID-Nr.: +20% MwSt. Für alle anderen Länder: Preise netto - die Steuerschuld liegt beim Leistungsempfänger. Preise gelten für die Dauer der Veranstaltung, inkl. Hin- und Rücktransport. Bezahlung sofort bei Erhalt der Faktura. Bei Abbestellung bis 10 Werktagen vor Aufbaubeginn wird eine Manipulationsgebühr von 50% einbehalten, danach werden 100% Stornokosten verrechnet. Umtausch ist nur bis 10 Werktagen vor Aufbaubeginn möglich. Verlorene oder beschädigte Mietgegenstände werden dem Mieter weiterverrechnet. Preisbasis 2015. Erfüllungsort und Gerichtsstand: Wien.

Ort / Datum

Stempel/Firmenmäßige Zeichnung des Ausstellers

**MEDIA-PLAN**

Gesellschaft für Ausstellungsorganisation und Werbung Karl Kreiner & Co KG  
Engerthstrasse 128, 1200 Vienna/Austria  
City office: Helfferstorferstrasse 2, 1010 Vienna/Austria  
Tel.: (+43/1) 536 63-0, Fax: (+43/1) 535 60 16  
e-mail: [mp@media.co.at](mailto:mp@media.co.at), [www.mediaplan.co.at](http://www.mediaplan.co.at)  
VAT-Reg.-No: ATU 10902102, commercial court Vienna: FN 9129a

|                                                                                     |                                                                                     |                                                                                       |
|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
|    |    |    |
| Standardstand (Beispiel)                                                            | Wandpanel, weiß                                                                     | Tür                                                                                   |
|    |    |    |
| Vorhang                                                                             | Regalfach (horizontal)                                                              | Regalfach (schräg)                                                                    |
|   |   |   |
| Strahler/Spot                                                                       | Deckenraster                                                                        | Bodenteppich                                                                          |
|  |  |  |
| Tisch                                                                               | Stehtisch                                                                           | Barhocker                                                                             |
|  |  |  |
| Sitzgarnitur                                                                        | Prospektständer                                                                     | Corpus Pult                                                                           |
|   |  |  |
| Corpus Vitrine                                                                      | Kühlschrank                                                                         | Papierkorb                                                                            |

## TEILNAHMEBEDINGUNGEN

- Vertragsabschluss – Ausstellungstermin:** Die Zusendung oder Aushändigung der Anmeldeformulare durch Media-Plan (künftig Ausstellungsleitung) begründet noch keinen Anspruch auf die Zulassung zur Ausstellung. Anmeldungen können ohne Angabe von Gründen abgelehnt werden. Die Anmeldung muss auf dem Vordruck ordnungsgemäß ausgefüllt, rechtsgültig unterschrieben und termingerecht eingereicht werden. Besondere Platzwünsche werden nach Möglichkeit berücksichtigt, können jedoch nicht als Bedingung einer Beteiligung anerkannt werden; weiters kann die beantragte Ausstellungsfläche durch die Ausstellungsleitung beschränkt werden. Die Ausstellungsleitung ist berechtigt, die Ausstellung zu verlegen, zu verkürzen oder abzusagen. Änderungen der Dauer oder des Termines der Ausstellung berechtigen den Aussteller nicht zum Vertragsrücktritt, zur Minderung des Entgeltes oder zur Geltendmachung von Schadenersatzansprüchen. Bei Ausstellungsabsage erstattet die Ausstellungsleitung die erhaltene Anzahlung unter Abzug der Anmeldegebühr und des Betrages, der den ihr entstandenen Kosten entspricht.
- Verwendungszweck – Werbung:** Die Stände dürfen nur zur Ausstellung eigener Waren und deren Werbung, nicht jedoch für den Warenverkauf verwendet werden. Bei Entgegennahme von Bestellungen sind die gesetzlichen Bestimmungen einzuhalten. Werbematerial darf nur innerhalb des Standes ausgegeben werden. Die Stände sind während der Öffnungszeiten dauernd besetzt zu halten. Die Benützung der Ausstellungsräume ist nur während der üblichen Öffnungszeiten der Ausstellung gestattet. Für die Veranstaltung von Werbevorträgen, Werbefilmen, Diavorführungen, für die Abgabe von Warenproben, Getränken, Nahrungsmitteln oder Kostproben ist die schriftliche Genehmigung der Ausstellungsleitung einzuholen. Firmen, die nicht ausstellen, ist jede Art von Werbung im Kongress-Saal oder in den Ausstellungsräumen sowie am Ein- und Ausgang des Gebäudes verboten. Jegliche Werbung außerhalb des Standes ist verboten (Walking Acts, Flyers etc.).
- Aufbau der Stände – Instandhaltung:** Vor Errichtung des Standes hat sich der Aussteller über Standort und besondere Einrichtungsanordnungen bei der Ausstellungsleitung zu erkundigen. Die Aufbauhöhe beträgt 2,5 m; Unter- und Überschreitungen müssen von der Ausstellungsleitung genehmigt werden. Veränderungen an der vermieteten Fläche oder den vermieteten Einrichtungen dürfen nur mit schriftlicher Zustimmung der Ausstellungsleitung vorgenommen werden. Der ausstellungsfertige Aufbau der Stände ist während der bekanntgegebenen Zeiten abzuschließen. Stände, die bis dahin nicht fertig sind, können von der Ausstellungsleitung unter Ausschluss jeglicher Schadenersatzansprüche anderwärtig vergeben werden, wobei der Aussteller für den Ausfallschaden haftet. Vor Aufstellung von eigenen Ständen hat der Aussteller bzw. dessen beauftragter Werbestalter der Ausstellungsleitung Skizzen und Farbangaben zur Genehmigung vorzulegen, diese behält sich das Recht vor, auf Grund der Sicherheitsvorschriften und der technischen Notwendigkeit bzw. zur Herbeiführung eines möglichst einheitlichen Gesamtbildes Änderungen zu verlangen. Kojenwände sind grundsätzlich an der Innen- und Außenseite zu verkleiden. Anordnungen der Ausstellungsleitung, insbesondere über Verwendung und Ausgestaltung der Kojen, Eigenstände und Ausstellungseinrichtungen müssen im Interesse einer reibungslosen Abwicklung der Ausstellung befolgt werden. Kommt der Aussteller einer diesbezüglichen Aufforderung nicht rechtzeitig nach, so können die erforderlichen Maßnahmen auf Kosten des Ausstellers ergriffen werden. Die Ausstellungsleitung ist berechtigt, falls erforderlich auch abweichend von einer schon erfolgten Bestätigung, dem Mieter einen anderen Platz in anderer Lage anzuweisen, Ein- und Ausgänge der Ausstellungsräume zu verlegen oder zu schließen. Fußböden und Wände der Räumlichkeiten, Stiegenaufgänge und Lagerplätze, die gemieteten Stände und Ausstellungseinrichtungen sind schonend zu gebrauchen, und letztere nach Beendigung der Ausstellung in ordnungsgemäßem Zustand zurückzustellen. In Räumen mit Parketten oder einwandfreien Boden belägen dürfen schwere Kisten nicht ausgedrückt werden. Zur Vermeidung von Kratzern oder Rillen durch Verschieben der Kisten sind empfindliche Bodenbeläge vor Aufstellung des eigenen Ausstellungsmaterials mit Schutzbelägen zu schützen. Kisten oder sonstiges Schwermaterial sind mit besonderer Vorsicht zu transportieren, bei Speditionsaufträgen ist dies den zustellenden Firmen mitzuteilen. Die Aufstellung von besonders schweren Ausstellungsstücken, die Fundamente oder besondere Vorrichtungen benötigen, ist mit der Ausstellungsleitung rechtzeitig zu klären. Das Einschlagen von Nägeln oder Haken in die Wände, das Verlegen von eigenen Leitungen, das Anbohren oder Einschneiden gemieteter Kojenwände ist nicht gestattet. Leergut und Verpackungsmaterial sind vor Ausstellungsbeginn auf eigene Kosten zu entfernen, für die Reinigung der Kojen hat der Aussteller zu sorgen. Es ist nicht gestattet, von den Decken der Ausstellungsraumlichkeiten Ständekonstruktionen abzuhängen. Vorbauten oder Überbauten über die zugewiesene Ausstellungsfläche sind untersagt, Firmenschilder dürfen nicht über die Kojengrenze hinausragen, jede Beeinträchtigung der Sicht auf die Nachbarstände ist zu vermeiden. Standbeleuchtung und Anstrahlung dürfen weder Besucher noch Nachbarstände belästigen. Vom Aussteller beigestellte Dekorationsstoffe sind feuerhemmend zu imprägnieren, Bescheinigung hierüber ist auf Verlangen der Ausstellungsleitung vorzulegen. Es ist jederzeit, auch während des Auf- und Abbaus, auf strengste Einhaltung aller polizeilichen oder sonstigen behördlichen Vorschriften zu achten.
- Elektroinstallationen – Stromverbrauch:** Die Ausstellungsleitung stellt eine Ringleitung mit 230 Volt Wechselstrom auf Kosten der Aussteller zu den einzelnen Ständen her. Die Aussteller verpflichten sich, ihren Stromverbrauch aus dieser Ringleitung zu decken. Die Ausstellungsleitung haftet jedoch nicht für Verluste und Schäden, die durch Störungen der Zuführung von Elektrizität und dergleichen entstehen. Die Kosten der Ringleitung und des festgestellten Stromverbrauches sämtlicher Aussteller werden auf die einzelnen Aussteller entsprechend der Anschlusswerte der installierten Elektroeinrichtungen aufgeteilt. Für Elektroinstallationen innerhalb seines Standes hat der Aussteller auf seine Kosten aufzukommen. Diese Installationen dürfen nur durch die von der Ausstellungsleitung zugelassenen Installationsfirmen durchgeführt werden.
- Untervermietung – Zutrittsrecht:** Jede gänzliche oder teilweise Untervermietung oder sonstige Überlassung des Standes oder eines Teiles desselben an Dritte sowie das Vertauschen von Ständen ist untersagt. Die Ausstellungsleitung kann jederzeit den Stand des Ausstellers betreten.
- Abbau der Stände:** Der Aussteller hat die Stände bis zum angegebenen Termin abzubauen, die mit vermieteten Einrichtungsgegenstände zurückzustellen und die Bodenfläche geräumt von sämtlichen Fähnissen gereinigt zu übergeben. Gelagerte Waren, Leergut und Verpackungsmaterial sind zu entfernen. Zurückgelassene Investitionen, soweit sie nicht schon auf Kosten des Ausstellers entfernt und eingelagert wurden, gehen entschädigungslos in das Eigentum der Ausstellungsleitung über. Diese kann vom Aussteller die sofortige Herstellung des früheren Zustandes verlangen. Die mangels schriftlicher Reklamation in ordnungsgemäßem Zustand übernommenen Ausstellungseinrichtungen sind in demselben Zustand zurückzustellen. Schadhafte Stellen und Einrichtungen können auf Kosten des Ausstellers gereinigt und repariert werden. Bei nicht rechtzeitiger Räumung erfolgt diese durch die Ausstellungsleitung auf Kosten des Ausstellers; dieser haftet für den der Ausstellungsleitung tatsächlich entstandenen Schaden, mindestens aber für € 100,- pro angefangenen Tag der verspäteten Räumung.
- Haftung:** Der Aussteller haftet für sämtliche Schäden, die durch ihn, seine Bediensteten, seine Beauftragten oder seine Besucher verursacht werden und hält die Ausstellungsleitung diesbezüglich klag- und schadlos. Es wird dem Aussteller empfohlen, für die von ihm eingebrachten Ausstellungsstücke seiner Stände und für seine Ausstellungseinrichtung eine angemessene Versicherung abzuschließen, weil die Ausstellungsleitung für sämtliche Personen- und Sachschäden sowie für Diebstahl oder Verlust während der Aufbau-, Kongress- und Abbauphase nicht haftet.
- Ausstellungsentgelt – Vertragsrücktritt:** Die angegebenen Ausmaße der Bodenfläche, Kojen und Ausstellungseinrichtungen sind annähernd. Die Ausstellungsleitung ist berechtigt, die Ausmaße entsprechend abzuändern, um die vorhandene Ausstellungsfläche ökonomisch zu nutzen und die Stände den vorliegenden Plänen anzupassen. Die Preise bemessen sich nach den tatsächlichen Ausmaßen; wird nachträglich mehr Fläche als angemeldet beansprucht und zugeteilt, so ist der Mehrbetrag unverzüglich nachzuzahlen. Der Aussteller trägt die 1%ige Vertragsgebühr vom Mietentgelt sowie alle sonstigen auf das Mietentgelt entfallenden Steuern, Gebühren und öffentlichen Abgaben. Bei Zahlungsverzug werden 10% Verzugszinsen p. a. angerechnet. Verzichtet eine Firma nach Abschluss des Vertrages auf die Beschickung der Ausstellung, so tritt folgende Stornogebühr in Kraft: 50% des gesamten Mietentgeltes für die Bodenfläche und die volle Entfallengebühr bei Storno oder Flächenreduzierung bis spätestens drei Monate vor Kongressbeginn, 100% bei Storno danach.
- Schlussbestimmungen:** Firmen, die den Vorschriften der Ausstellungsleitung zuwiderhandeln, können durch die Ausstellungsleitung mit sofortiger Wirkung ausgeschlossen werden. Sie haften für den vollen Betrag der Miete, für die Anmeldegebühr und alle Nebenkosten zusätzlich der gesetzlichen Mehrwertsteuer. Der Aussteller kann Forderungen gegen die Ausstellungsleitung gegen seine Verpflichtungen aus diesem Vertrag nur mit schriftlicher Zustimmung der Ausstellungsleitung aufrechnen. Auf jede Aufhebung des Vertrages, insbesondere wegen Irrtums und Verletzung über oder unter die Hälfte des wahren Wertes wird verzichtet. Alle mündlichen Vereinbarungen, Einzelgenehmigungen und Sonderregelungen gelten nur nach schriftlicher Bestätigung. Für alle Streitigkeiten aus diesem Vertrag wird der ausschließliche Gerichtsstand bei dem sachlich zuständigen Gericht in Wien vereinbart. Wahlweise kann die Ausstellungsleitung auch das zuständige Gericht am Sitz des Ausstellers anrufen. Es ist österreichisches Recht anzuwenden.

## INVITATION TO THE TRADE SHOW FOR PULP- PAPER- AND BIOREFINERY INDUSTRIES

Dear Sirs,

Univ.-Prof. Wolfgang Bauer, Chairman of the APV Graz, would like to invite you to participate at the **PAPER & BIOREFINERY CONFERENCE** (before: „Austrian Paper Conference“), which will take place on the 5<sup>th</sup> and 6<sup>th</sup> June 2019 in Graz.

An important addition to the scientific program will be a representative TRADE SHOW. This popular communication platform within the conference offers an especially appealing opportunity to present your company and your service offer.

### THE EXHIBITION 2019:

**The rate for exhibition space is € 250.00 / m<sup>2</sup>\* (net)**

\*Early booking bonus: For reservations until 28<sup>th</sup> February 2019 you receive a discount of EUR 20.00 / m<sup>2</sup>.

Minimum booking size: 6 m<sup>2</sup>. The booked space is excluding all additionally ordered extras as furniture, cleaning fee, electricity, etc.

Please find all further details regarding our exhibition offers in the enclosed documents.

We hope we have drawn your interest and kindly ask to return the enclosed registration form for the exhibition with your desired exhibition space size. **End of registration is the 5<sup>th</sup> May 2019.**

The space allocation will be done according to sponsor activities as well as exhibition space size and date of registration.

Confirmed exhibitors of course receive detailed exhibition information on time. Do not hesitate to contact us if you have any further questions.

*With kind regards,*

*The Exhibition Management*

**Contact:** Carmen Zavorsky and Verena Schachenhofer

c/o Media-Plan International Exhibitions & Advertising

Phone: +43 (0)1-536 63 -23 or -26 fax: +43 (0)1-535 60 16 Email: [papierfachtagung@media.co.at](mailto:papierfachtagung@media.co.at)

## IMPORTANT INFORMATION

FOR THE PAPER & BIOREFINERY CONFERENCE 2019

### FREE CONTINGENTS

Depending on the size of your booth, the following free quotas are available:

| Paid booth size        | Free access to the conference and trade show (exhibitor staff) | Free tickets for the Conference Dinner | Free parking space at the event site |
|------------------------|----------------------------------------------------------------|----------------------------------------|--------------------------------------|
| from 6 m <sup>2</sup>  | 2 persons                                                      | 2 tickets                              | 2 vehicles                           |
| from 12 m <sup>2</sup> | 3 persons                                                      | 3 tickets                              | 3 vehicles                           |
| from 18 m <sup>2</sup> | 4 persons                                                      | 4 tickets                              | 4 vehicles                           |
| from 24 m <sup>2</sup> | 5 persons                                                      | 5 tickets                              | 5 vehicles                           |

### VENUE

**Messecongress Graz**

(fairgrounds at Stadthalle Graz)

Messeplatz 1, A-8010 Graz Web: [www.mcg.at](http://www.mcg.at)

### HOMEPAGE

[www.paper-biorefinery.com](http://www.paper-biorefinery.com)

### ORGANISER

**APV Akademischer Papieringenieur-Verein**  
 at Graz University of Technology  
 Institute for Paper and Fiber Technology  
 Inffeldgasse 23/EG, A-8010 Graz

### EXHIBITION MANAGEMENT

**Carmen Zavarsky & Verena Schachenhofer**

c/o Media-Plan  
 International Exhibitions & Advertising  
 Helferstorferstrasse 2, A-1010 Wien  
 Phone: +43 (0)1-536 63 -23 or -26  
 ON SITE: +43 (0)664 515 3114

### CONFERENCE MANAGEMENT

**Univ.-Prof. Dr. Wolfgang Bauer**

University of Technology Graz  
 Institute for Paper and Fiber Technology  
 Inffeldgasse 23/EG, A-8010 Graz

Fax: +43 (0)1-535 60 16  
 Email: [papierfachtagung@media.co.at](mailto:papierfachtagung@media.co.at)

### CONFERENCE OFFICE

**Kerstin Schefzik**

Phone: +43 (0)316-873 30 799  
 Fax: +43 (0)316-873 10 30 751  
 Email: [office@paper-biorefinery.com](mailto:office@paper-biorefinery.com)

### CONFERENCE ORGANISATION & SPONSORING/ADVERTISING

**Birgit Hasler**

Phone: +43 (0)664-84 44 950  
 Email: [birgit.hasler@paper-biorefinery.com](mailto:birgit.hasler@paper-biorefinery.com)

Please return the filled in form to MEDIA-PLAN: mail: [papierfachtagung@media.co.at](mailto:papierfachtagung@media.co.at), fax: (+43/1) 535 60 16

### EXHIBITOR

Invoice Recipient: \_\_\_\_\_

(company name and address) \_\_\_\_\_

Contact Person: \_\_\_\_\_ Fax: \_\_\_\_\_

Tel: \_\_\_\_\_ VAT Reg. No.: \_\_\_\_\_

(obligatory for EU countries)

E-Mail: \_\_\_\_\_ PO No.: \_\_\_\_\_

(if required)

## BOOKING FORM FOR EXHIBITION SPACE

We hereby order:

Deadline: 5<sup>th</sup> May 2019

**Floor Space..... sqm** (floor space only, without partitions, electricity, etc.)

**Minimum Registration: 6 sqm**

**Early Fee: € 230.00 / sqm**

**Desired space: \_\_\_\_\_ m long x \_\_\_\_\_ m deep**

**From 1<sup>st</sup> March 2019: € 250.00 / sqm**

Notes: \_\_\_\_\_

(do not use for ordering additional services)

Confirmed exhibitors will receive the time schedule, further detailed information and order forms for additional services in due time. **Orders for additional services will only be accepted by submitting the respective order forms.**

Measurements are outside measurements; space booking only in full and half meters.

Proportionate basic cleaning costs are obligatory and at extra cost.

For information – please check:

- ☐ We will set up our own pre-constructed stand (approval of stand design by MEDIA-PLAN required)
- ☐ We will bring a folding/umbrella stand
- ☐ We will order a standard rental booth at extra cost (by submitting the respective order form)

#### Conditions of payment and cancellation:

Prices are net. For companies with Austrian VAT Reg. No.: + 20% VAT + 1% contract fee. For all other countries: net prices – the tax liability lies with the benefit recipient. After submitting the "Booking form for Exhibition Space" the exhibitor will receive a confirmation of the booking as well as the 50% part-payment invoice which is payable on receipt. The final invoice will be issued 2-3 months prior to the start of the congress and is again payable on receipt. For all bookings which are submitted less than 3 months before the start of the congress, the exhibitor will receive a confirmation of the booking as well as the invoice for the whole rental fee (100%) which is again payable on receipt. Bank transfer to the "MEDIA-PLAN" account at UniCredit Bank Austria AG, Schottengasse 6-8, 1010 Vienna, Austria, account no. 02250170400, bank code 12000, BIC: BKAUATWW, IBAN: AT18 1100 0022 5017 0400. All charges shall be covered by the sender. Cancellation fee: 50% of total space plus application fee if rental is cancelled or reduced up to 3 months prior to the congress, 100% thereafter. Place of jurisdiction: Vienna, Austria.

Booth allocation will consider the overall contribution, the booth size, the date of application and the payment date of the part-payment invoice. **By signing this contract we accept the enclosed conditions for participants in the exhibition.**

Place / Date

Stamp of company / Signature of Official Representative

# MEDIA-PLAN

Gesellschaft für Ausstellungsorganisation und Werbung Karl Kreiner & Co KG  
Engerthstrasse 128, 1200 Vienna/Austria  
City office: Helfferstorferstrasse 2, 1010 Vienna/Austria  
Tel.: (+43/1) 536 63-0, Fax: (+43/1) 535 60 16  
e-mail: [mp@media.co.at](mailto:mp@media.co.at), [www.media-plan.co.at](http://www.media-plan.co.at)  
VAT-Reg.-No: ATU 10902102, commercial court Vienna: FN 9129a

Please return the filled in form to MEDIA-PLAN: mail: [papierfachtagung@media.co.at](mailto:papierfachtagung@media.co.at), fax: (+43/1) 535 60 16

### EXHIBITOR

Invoice Recipient: \_\_\_\_\_

(company name and address) \_\_\_\_\_

Contact Person: \_\_\_\_\_ Fax: \_\_\_\_\_

Tel: \_\_\_\_\_ VAT Reg. No.: \_\_\_\_\_

(obligatory for EU countries)

E-Mail: \_\_\_\_\_ PO No.: \_\_\_\_\_

(if required)

## ORDER FORM RENTAL BOOTH



### Standard Rental Booth Standard Package

- **Set up and dismantling**
- **Back and sidewalls** incl. Supports, 250 x 100 cm
- **Carpet**—please choose your colour: ☐ blue ☐ grey
- 2,5 KW (230 Volt) **electricity connection** with electrical triple socket outlet
- 1 **spotlight** for each 3 sqm
- **Fascia sign** with exhibitor name in standard lettering on every open side (max. 20 letters). Please indicate company name for fascia board:

per sqm € 95.00



### Furnished Rental Booth

- **Standard Booth Standard Package** (please indicate fascia sign and carpet colour above)
- **1 Counter** (100 x 50 x 90 cm) with sliding doors, lockable
- **1 Brochure Rack**
- **Choose between:**
  - ☐ 1 Seating Set (1 Bistro-Table Ø ca. 70 cm incl. Tablecloth and 3 Chairs)
  - or ☐ 1 High Table and 3 Bar Stools

per sqm € 125.00



### Company logo on fascia board

(price per fascia, for corner booths 2x, for peninsula booths 3x fascia needed)

€ 78.00

#### Conditions of payment and cancellation:

Prices are net. For companies with Austrian VAT No.: + 20% VAT. For all other countries: net prices - the VAT tax liability lies with the benefit recipient. After submitting the booking form the customer will receive a confirmation of the booking. The invoice will be issued after the assignment of the slots, not later than 6 months prior to the congress and is payable on receipt. Bank transfer to the "MEDIA-PLAN" account at UniCredit Bank Austria AG, Schottengasse 6-8, 1010 Vienna, Austria, account no. 02250170400, bank code 12000, BIC: BKAUATWW, IBAN: AT18 1100 0022 5017 0400. All charges shall be covered by the sender. Cancellation fee: 50% of total amount if cancelled up to 6 months prior to the congress, 100% thereafter. Place of jurisdiction: Vienna, Austria.

Place / Date

Stamp of company / Signature of Official Representative

# MEDIA-PLAN

Gesellschaft für Ausstellungsorganisation und Werbung Karl Kreiner & Co KG  
Eingerthstrasse 128, 1200 Vienna/Austria  
City office: Helfferstorferstrasse 2, 1010 Vienna/Austria  
Tel.: (+43/1) 536 63-0, Fax: (+43/1) 535 60 16  
e-mail: [mp@media.co.at](mailto:mp@media.co.at), [www.media-plan.co.at](http://www.media-plan.co.at)  
VAT-Reg.-No: ATU 10902102, commercial court Vienna: FN 9129a

Please return the filled in form to MEDIA-PLAN: mail: [papierfachtagung@media.co.at](mailto:papierfachtagung@media.co.at), fax: (+43/1) 535 60 16

### EXHIBITOR

Invoice Recipient: \_\_\_\_\_

(company name and address) \_\_\_\_\_

Contact Person: \_\_\_\_\_ Fax: \_\_\_\_\_

Tel: \_\_\_\_\_ VAT Reg. No.: \_\_\_\_\_

(obligatory for EU countries)

E-Mail: \_\_\_\_\_ PO No.: \_\_\_\_\_

(if required)

## ORDER FORM FOR RENTAL FURNITURE

Quantity required

|                                     |                                                                                                                     |            |   |        |
|-------------------------------------|---------------------------------------------------------------------------------------------------------------------|------------|---|--------|
| _____                               | <b>Carpet</b> – please choose your colour: <input type="checkbox"/> blue <input type="checkbox"/> grey              | Per sqm    | € | 16.00  |
| _____                               | <b>Wall Panel, white</b> , 100 cm w x 250 cm h, useable area: 97 cm w x 229 cm h                                    | per piece  | € | 36.00  |
| _____                               | <b>Door</b> , lockable, white, 100 cm w x 250 cm h                                                                  | per piece  | € | 138.00 |
| _____                               | <b>Shelf</b> , mounted on wall panel, 30 cm d <input type="checkbox"/> horizontal <input type="checkbox"/> slanting | per piece  | € | 27.00  |
| _____                               | <b>Table</b> (140 cm x 70 cm x 72cm height), incl. Tablecloth                                                       | Unit Price | € | 47.00  |
| _____                               | <b>High Table</b> (Ø 60cm x 110cm height incl. Tablecloth)                                                          | Unit Price | € | 41.00  |
| _____                               | <b>Chair</b>                                                                                                        | Unit Price | € | 24.00  |
| _____                               | <b>Bar Stool</b>                                                                                                    | Unit Price | € | 37.00  |
| _____                               | <b>Seating Set</b> (1 Bistro Table Ø 60cm x 70 cm height incl. Tablecloth and 3 Chairs)                             | Unit Price | € | 105.00 |
| _____                               | <b>Brochure Rack</b>                                                                                                | Unit Price | € | 63.00  |
| _____                               | <b>Counter</b> (100 cm x 50 cm x 90 cm height, with lockable sliding doors)                                         | Unit Price | € | 119.00 |
| _____                               | <b>Vitrine</b> (100 cm x 50 cm x 90 cm height), lockable, glass component: 20 cm height                             | Unit Price | € | 144.00 |
| _____                               | <b>Refrigerator</b> (24 hrs electricity supply not included)                                                        | Unit Price | € | 95.00  |
| _____                               | <b>Waste Basket</b> , grey                                                                                          | Unit Price | € | 8.00   |
| _____                               | <b>Electricity</b> , 230 Volt incl. Triple socket outlet                                                            | Unit Price |   | 110.00 |
| <input checked="" type="checkbox"/> | <b>Obligatory one-time basic cleaning</b> (after set up)                                                            | per sqm    | € | 3.50   |

#### Conditions of payment and cancellation:

Prices are net. For companies with Austrian VAT No.: + 20% VAT. For all other countries: net prices - the VAT tax liability lies with the benefit recipient. After submitting the booking form the customer will receive a confirmation of the booking. The invoice will be issued after the assignment of the slots, not later than 6 months prior to the congress and is payable on receipt. Bank transfer to the "MEDIA-PLAN" account at UniCredit Bank Austria AG, Schottengasse 6-8, 1010 Vienna, Austria, account no. 02250170400, bank code 12000, BIC: BKAUATWW, IBAN: AT18 1100 0022 5017 0400. All charges shall be covered by the sender. Cancellation fee: 50% of total amount if cancelled up to 6 months prior to the congress, 100% thereafter. Place of jurisdiction: Vienna, Austria.

Place / Date

Stamp of company / Signature of Official Representative

# MEDIA-PLAN

Gesellschaft für Ausstellungsorganisation und Werbung Karl Kreiner & Co KG  
Engerthstrasse 128, 1200 Vienna/Austria  
City office: Helfferstorferstrasse 2, 1010 Vienna/Austria  
Tel.: (+43/1) 536 63-0, Fax: (+43/1) 535 60 16  
e-mail: [mp@media.co.at](mailto:mp@media.co.at), [www.mediaplan.co.at](http://www.mediaplan.co.at)  
VAT-Reg.-No: ATU 10902102, commercial court Vienna: FN 9129a



Standard Booth (Example)



Panel, white



Door



Curtain



Shelf (flat)



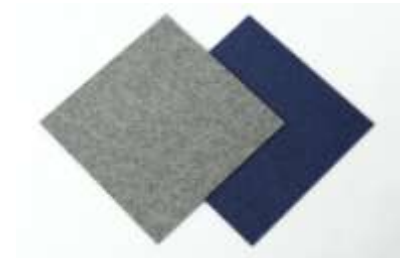
Shelf (sloping)



Spotlight



Ceiling Grid



Carpet



Table



High Table



Bar Stool



Seating Set



Brochure Rack



Counter



Vitrine



Refrigerator



Wastebasket

## Conditions for Participation in the Exhibition

**1. Contract – Exhibition Dates:** Mailing or delivering this Registration Form does not constitute a formal agreement that the exhibitor is admitted to the exhibition. Contractual conditions are constituted first when Media-Plan (subsequently the Exhibition Management) sends written acceptance of the exhibitor to the exhibition. Any registration to an exhibition can be refused by the Exhibition Management without giving cause. The registration form must be filled in, signed with a legally competent signature and delivered to us on time. Special wishes regarding placement of the stands will be given all possible consideration, but placement demands as a condition of registration on the part of the exhibitor cannot be recognised; furthermore the requested floor space may be reduced by the Exhibition Management. The Exhibition Management has the right to revise the location and time of the exhibition, to shorten the time of the exhibition and to cancel the exhibition. Any change in the length or time of the exhibition does not entitle the exhibitor to cancel the contract nor to request lowering of fees nor to put forward a claim to damages incurred thereby. In case of cancellation of the exhibition, the Exhibition Management will return the part payments received less the sum equivalent to the costs which have arisen for the Exhibition Management up to the time of cancellation; the registration fee will not be returned.

**2. Purpose of the Exhibition – Advertising:** The stands may be used only for exhibiting and advertising the exhibitor's own products, not however for the sale of any products. Any orders for products which are taken must be in accordance with laws covering such orders. Advertising materials may be distributed only within the stand. During exhibition hours all stands must be continually staffed. The exhibition rooms are to be used only during the usual opening hours. For the presentation of advertising lectures, advertising films, slide projection, for the distribution of samples, drinks or foodstuffs it is necessary to obtain written permission from the Exhibition Management. Companies which are not exhibitors are forbidden to advertise in any way in the exhibition hall or in the entrances to the exhibition hall. Any kind of promotion outside of your exhibition space is forbidden (such as Working Acts, Flyers etc.).

**3. Setting up stands – Maintenance of stands:** Before setting up their stands, exhibitors must contact the Exhibition Management and reconfirm the placement of the stand as well as inform themselves of any special regulations relating to their stand. Side and back walls of stands are to be 2.50 m (two and a half) high; for any variation from this norm (2.50 m) specific permission must be obtained from the Exhibition Management. For any changes in the size or structure of the floor space or for any changes to the rented objects specific written permission must be obtained. Stands must be set up and completely fitted during the announced time; stands which are not finished can be rented to another applicant; in such case the exhibitor is responsible for costs arising from cancellation and all attempts to put forward a claim to damages are invalid. An exhibitor or advertising company contracted by the exhibitor who wishes to set up a stand or exhibit of their own design and construction must submit sketches and plans with a statement of colour schemes of such a stand or exhibit to the Exhibition Management. The Exhibition Management reserves the right to demand changes in such stands or exhibits if safety regulations, technical requirements or the responsibility of preserving or obtaining the best possible overall image for the exhibition, as judged by the Exhibition Management, should so require. The side and back walls of all stands should be finished on the outside as well as the inside. All directives and instructions of the Exhibition Management with regard to the use of stands, the decoration of them, the use of self-designed and self-constructed stands, and fitting and furnishings of the stands, must be obeyed so that the exhibition may take place with as few complications as possible. If an exhibitor does not follow the directives of the management or does not carry out such directives punctually, the Exhibition Management reserves the right to take the necessary steps at the cost of the exhibitor. The Exhibition Management reserves the right to close or obstruct unused entrances or exits to the exhibition rooms and the right to direct the exhibitor to another place in the exhibition hall if necessary even if this directive conflicts with previous written agreements. The exhibitors are responsible for the proper care of the floors, walls, staircases and storage rooms as well as the hired stands and hired furnishings. Hired stands and furnishings must be returned in an orderly condition and in an orderly way. In rooms with parquet flooring or unmarred flooring special care must be taken. Heavy packing cases may not be unpacked in such rooms. To avoid scratches and grooves in such floors as could be damaged by sliding packing cases, the exhibitors are required to place a protective covering under heavy packing placed on such floors. The exhibitors and their shipping agents, on specific orders from the exhibitor, must take special care in transporting heavy packing cases and heavy loads. Exhibitors who wish to display extra heavy exhibits demanding special supports or foundations must get specific permission for this from the Exhibition Management. It is not permitted to drive nails or hooks in the walls of the exhibition hall nor to install electric wiring nor to cut or drill holes in the walls of the rented stands. Empty containers and packing materials must be disposed of at any cost of the exhibitor before the exhibition begins; cleaning the stand is in the responsibility of the exhibitor. No part of an exhibition stand may be hung from the ceiling. No structure of an exhibit or stand may project on any side beyond the limits of

the stand location. No signs may project beyond the delimiting walls of the stand and each exhibitor must avoid hindering the view or entrance way of neighbouring stands. Special care must be taken to avoid lights or spot lights which are annoying to visitors or neighbouring stands. Decorating materials which are used by the exhibitor must be fire-proof and written credible proof of this must be presented to the Exhibition Management upon request. Police regulations, fire regulations and other official regulations are to be observed at all times even during the construction and dismantling of the exhibits.

**4. Electrical Installations – Power consumption:** The Exhibition Management arranges for the installation of a 230 Volt ring main supply at the cost of the exhibitors. The exhibitors agree to use this installation for all electric power requirements. The Exhibition Management however is not responsible for any losses or damage which may occur from interruptions or defects in the electric power supply. The costs incurred for the installation of the ring main supply are carried equally by all the exhibitors; the cost of the electricity for each exhibitor is calculated according to the wattage of the electric equipment in his stand; this cost will be invoiced to each exhibitor according to a separate price not included in the rental prices. The exhibitor is responsible for the cost of electrical installations within the stand, however these installations may be carried out only by an electrician appointed by the Exhibition Management.

**5. Subleasing – Access permission:** Partially or wholly subleasing or otherwise relinquishing a stand to a third party as well as private agreements for exchange of stands or floor space between two exhibitors is prohibited. The Exhibition Management reserves the right to enter any stand at any time.

**6. Dismantling of stands:** The exhibitor must dismantle the stand within the allotted time and return the hired furnishings on time. The exhibitor must leave the stand area cleared and the floor cleaned. Stored materials, empty containers and packing materials must be disposed of. Items for which no arrangements have been made for removal and storage at the cost of the exhibitor and which are left behind become the property of the Exhibition Management and no reimbursement will be made for such items. The Exhibition Management can demand that exhibitors restore the exhibition area to the original condition at the exhibitor's expense. The rented items which were accepted as satisfactory for rental by the exhibitor are to be returned in satisfactory and undamaged condition. All rented items are considered to be in a satisfactory condition unless a written notation signed by the Exhibition Management is made at the time of rental. Exhibitors must bear the costs of repairs to damaged exhibition areas and of repairs or of necessary cleaning of rented items. If the exhibitor does not dismantle and clear away his exhibit punctually, this will be removed by the Exhibition Management at the cost of the exhibitor. The exhibitor is liable for the actual cost incurred by the Exhibition Management in such removals of abandoned exhibits.

**7. Liability:** The exhibitor is liable for all damages caused by himself, by his staff, by his visitors and clients and by any agent acting for him; the exhibitor indemnifies the Exhibition Management in all such cases. The Exhibition Management recommends that the exhibitors take out an insurance policy to cover damage, loss or theft of their furnishings and fittings during entire time of the exhibition, including the time allotted for setting up and dismantling, as well as during the exhibition days themselves, as the Exhibition Management is not liable for personal or property damage nor loss or theft.

**8. Payments – Breach of contract:** The given dimensions of floor space, stands and rented items are approximate. The Exhibition Management reserves the right to change the dimensions in order to use the available exhibition area most efficiently and in order to adjust the stands to the blueprints of the exhibition hall. Prices charged are however based on the actual dimensions; if more floor space than was ordered is later allotted and actually used, the fee for it is to be paid immediately. The exhibitor bears the costs of the Contract Fee which is one per cent (1%) of the rental costs, as well as all other taxes, fees or official charges on the rental sum. In case of delayed payment ten per cent (10%) interest per annum is charged. If a company wishes to give up all claim to taking part in an exhibition after having contracted to do so, the following cancellation fees apply: 50% of total space costs if rental is cancelled or reduced up to three months prior to the congress, 100% thereafter.

**9. Final Stipulations:** Any company which disobeys the directives of the Exhibition Management can be excluded immediately from the exhibition by the Exhibition Management. Such companies are liable for the whole rental sum, for the registration fee and for all incidental expenses including the legal value added tax. In cases in which the Exhibition Management is indebted to the exhibitor, the exhibitor may demand compensation instead of cash payment only with permission of the Exhibition Management. The exhibitor gives up all claim to contestation of the contract especially in cases of mistakes and in cases in which the value of the contract exceeds or falls short of half the true value. All oral agreements, special permissions and special arrangements are valid only upon receipt of written confirmation. In all cases of litigation it is agreed to by the exhibitor that the competency of the duly authorised court in Vienna, Austria is recognised. Electively the Exhibition Management may choose to appeal to the competent court in whose jurisdiction the exhibitor falls. Austrian law is to be used.



## Latest Recruitment Opportunities

The most recent Job Opportunities advertised with PITA are:

**DS Smith** – Kemsley – Technical Operations Manager (November 2018)

**Palm Paper** – King's Lynn – Shift Manager (October 2018)

**Palm Paper** – King's Lynn – Senior Production Manager (October 2018)

**Poole Projects** – UK – Senior Electrical, Control and Instrumentation Design Engineer (October 2018)

**Voith Paper** – UK – Sales Manager Tissue UK (October 2018)

Details of each vacancy can be found in the following pages, and on the PITA website.



## Vacancy

### Technical Operations Manager - Kemsley



We are a leading European manufacturer of high-quality recycled papers. Our papers are used by our packaging division for conversion into board for making corrugated boxes. Kemsley Paper Mill is the biggest paper mill in the UK, and it forms part of the DS Smith Paper division within Supply Engine. Here's what you need to know:

- Kemsley produce over 800,000 tonnes of paper a year from our 3 paper machines, and we employ over 400 staff;
- We are the flag ship of Paper Mills within the DS Smith group;
- Some of our customers are household names such as Mondelez and Amazon;
- We are at the helm of innovation in our sector and challenge ourselves to always do things better, smarter and faster;
- In 2018, announced we have the capacity to recycle the 2.5 billion coffee cups that are used in the UK annually;
- Sustainability is at the heart of our business, and our energy efficiency projects (including a new combined heat and power plant) will reduce Kemsley's carbon footprint by 30%;
- We are wholly committed to employee progression and career development, and will actively support employees on their career journey;
- We internally developed our OPOM (Our Paper Operating Model) programme; a world-class lean management programme that is now delivered across DS Smith sites globally.

We have an excellent opportunity for a results driven Technical and Operations professional to join our Kemsley Senior Management Team as Technical Operations Manager. This role will see you as a core member of the Senior Management Team, providing expert knowledge and support to the wider mill operations function. You will be able to prioritise a busy workload and lead by example to deliver an excellent level of customer service, acting as the link between the mill and our customers, whilst also having key involvement across our Quality, Technical, Production and Engineering teams.

### **What being a Technical Operations Manager at DS Smith will involve...**

Reporting to the Mill Manager you lead Technical Operations within the Mill. The Technical Operations Department is responsible for Product Quality and associated Quality Management Systems, Product Development and Raw Material supply. This role has a wide scope and will also include the following:

- Ensure a safe working environment at all times.
- Support and drive operational excellence at all levels.
- Display clear leadership skills, ensure performance and manage a multi skilled team.
- Support both the Production & Engineering Manager in daily and site management.
- Represent Kemsley Mill for External Affairs such as Industry and our Customers.
- Be an ambassador of continuous improvement ensuring a consistently developing workplace and represent Kemsley within the BAT Group.
- Build a team to capture and develop talent.
- Ensure compliance of products.
- Work closely with the project management team to support business plans and whilst remaining cost efficient.
- Be a key member of business development plans within the mill.

### **What we would like our candidate to have...**

- Good communication, with the ability to communicate at all levels, including senior management, both within internal and external customers.
- Ideally degree qualified in a Technical / Scientific subject.
- Ability to lead a team and drive performance.
- Experience in controlling spend and costs.
- Experience in a paper manufacturing environment would be desirable.
- Knowledge of LEAN manufacturing is highly desirable.
- Demonstration of a high level of Industry & legislation knowledge including across paper and plastics grades and treatment technologies.
- An ability to work to and meet set deadlines, both customers defined and internal.
- Commercial negotiation skills.

**We are always looking for new self-motivated highly-skilled talents to join us on our journey. If you have a strong Operational, Technical (Production or Engineering) background and are looking to join an exciting place of work, please get in touch.**

**Location:** Sittingbourne, Kent, UK.

To apply, please forward a copy of your most recent CV to: [rob.williams@dssmith.com](mailto:rob.williams@dssmith.com)



## Palm Paper Vacancies:

- **SHIFT MANAGER**
- **SENIOR PRODUCTION OPERATOR**

Palm Paper is the UK subsidiary of the German Based, privately owned Papierfabrik-Palm.

Since 2009, Palm Paper has continued to develop and improve its efficiency and portfolio of products with its latest development this year being the commissioning and start-up a new

Combined Heat and Power Plant.



At the heart of any organisation sits the staff and Palm prides itself on the personal and technical development offered to all their staff allowing them all the opportunity to achieve the highest professional standards.

To enhance their current team, Palm Paper are now looking to offer the rare opportunity for external experienced paper making specialists to apply to join the team in King's Lynn.

Recruiting for a **Shift Manager** and **Senior Production Operator**. Both roles working a mixed 8 and 12 hour continuous shift pattern.

The overall reward and benefits package will be discussed at interview, but they are extremely competitive and amongst the best in the industry.

Applicants for both positions must be:

- A qualified, or experienced hands on paper technologist/process engineer or similar
- Educated to A or AS level in Maths, English and or Science
- A logical thinker with the ability to control multiple operations
- Self-motivated, flexible and committed work ethic
- An excellent planner, with strong decision making skills

Application is by CV, which should be sent in Word or pdf format to [mick.beckett@palmpaper.co.uk](mailto:mick.beckett@palmpaper.co.uk)



Poole Projects is an independent engineering company specialising in the design, manufacture and installation of pulp and paper machinery and process systems. We are looking to strengthen our engineering team with the following position

**Senior Electrical, Control and Instrumentation Design Engineer**

The successful candidate will be educated to at least HND level and have a Minimum 10 years' experience in the paper industry or similar industrial environment. They must be familiar with all aspects of electrical, control and instrumentation design and have the ability to communicate at all levels both in house and with our client's engineers and managers.

We offer a competitive salary and the opportunity for career progression in a strong and sustainable business.

Please send applications including CV to Miss M Barber at:  
**[mbarber@pooleprojects.co.uk](mailto:mbarber@pooleprojects.co.uk)**

**Voith Paper Limited** are recruiting within their UK Tissue Sales team for a  
**Sales Manager Tissue UK**

## Key Responsibilities

- Visit and service current and potential customers in the assigned area;
- Maintain and improve customer relationships;
- Promote new products and services in the assigned area across the FRS portfolio;
- Carry out 'hands-on' machine surveys and provide technical reports and recommendations;
- Technical trouble shooting at customer premises;
- Liaising with other key departments to provide effective applications and solutions to customers;
- Main customer contact for all commercial aspects: offers, negotiations, order and delivery process, overdues and ageing stock;
- Conduct product presentations for customers or at relevant trade events;
- Investigate and facilitate customer queries on behalf of the Company;
- Create and update the business plan for the area.

## Who we are looking for

- Highly self-motivated, driven individual willing to travel extensively within the UK;
- Proactive work ethic and an interest in social networking;
- Ability to work independently, take responsibility for own work load and business area whilst also work as part of a team;
- Completed technical studies and working experience in an engineering field and/or paper technology is highly valued;
- Experience in papermaking is valued;
- Experience in paper machine clothing and/or rolls in particularly desirable;
- Valid driving licence is essential for this role;
- Good knowledge of Office and adaptable when it comes to new systems;
- Location is flexible; home office provided.

To apply please visit [voith.com/career](http://voith.com/career) or contact:  
Charlotte Jackson, HR Business Partner on [charlotte.jackson@voith.com](mailto:charlotte.jackson@voith.com)