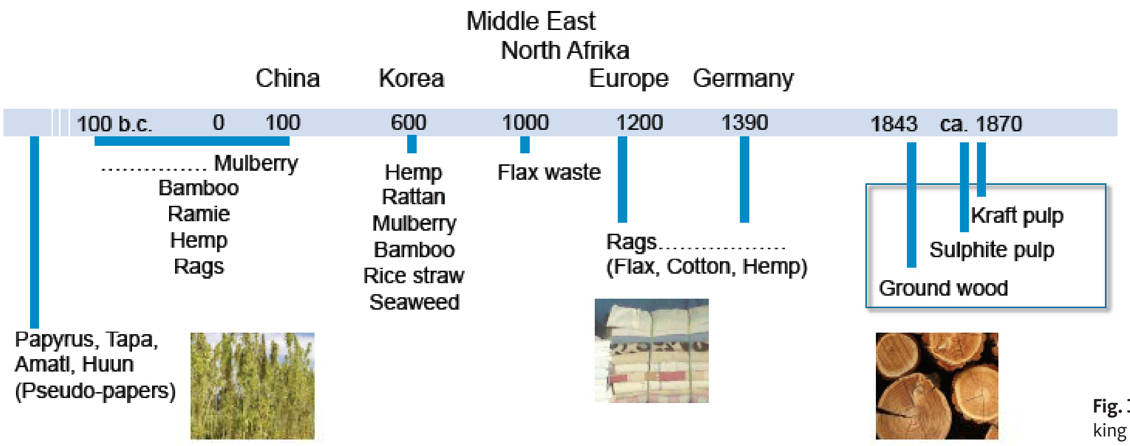

Fig. 1: The history of papermaking raw materials

[GOING GREEN AS A TREND]

PAPERMAKING WITH AGRIFOOD BY-PRODUCTS – BENEFITS, TRENDS AND OPTIONS

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Introduction

The prices of fibre raw materials for papermaking have risen sharply over the last years. Market interest in 'green' products has shown constant growth at the same time. These trends suggest taking alternative biogenic feedstock into consideration. The partial replacement of (in particular) recycled pulp by prepared agrifood by-products makes it possible to save costs, broaden the raw materials procurement base, enhance product properties, reduce environmental loads and offer unique selling points. This article highlights motivations, experiences, boundary conditions and trends in this field.

History

Wood as a raw material is a recent phenomenon when compared to the entire history of paper (**Fig. 1**). Until about 170 years ago, paper was made from linen, hemp, cotton and other plant fibres. Today, wood plays a dominant role as the feedstock for paper production. Only some fibre-plant pulps that proved to be useful for specialty papers, e.g. cotton for artist paper or flax for cigarette paper, have an established role there. Furthermore, non-wood pulps still exist in regions where wood is scantily available, as in large parts of Asia. Even there, the use of cereal straw, bamboo and bagasse for chemical pulps is on the decline.

Motivations

So why address non-wood biogenic resources for papermaking today? The major aspects driving the current interest in non-wood plant material are as follows: High prices of standard feedstock; price volatility and dependence on suppliers; in the case of paper for recycling, also the fluctuating quality that is dwindling in the long term, considerable and continually growing consumer interest in 'green' products.

Furthermore, alternative fibre materials can introduce or enhance the desired technological properties and mitigate the environmental footprint of the product. (**Fig. 2**) summarises these motivations.

In terms of market presentation, a concept termed the 'integral approach' is especially appealing: leftovers from the manufacture of a food (or other biological) product are processed and introduced into the product packaging. This concept is visualised in @BU: Fig. 3. The EcoPaper project tackled this concept (s. the chapter on 'Hazelnut shells'). A few implementations are already on the market.

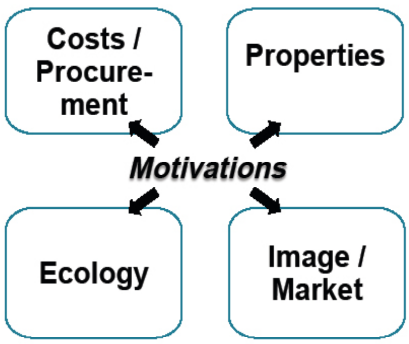

Fig. 2: Motivations for non-wood fibre feedstocks

Concept

In view of the cost aspect, a good starting point is a simple material preparation procedure. In the last few years, PTS has studied numerous materials after simple mechanical comminution. Agrifood by-products were given priority in order to avoid the „food or fuel" debate. In most cases, the prepared by-products were studied regarding their suitability to replace recycled fibre feedstock in shares of up to 50 %.

Examples

Miscanthus for fibre mouldings

Moulded pulp products are very similar to paper and board in terms of raw materials, stock preparation and influences on product quality. Packaging applications require formability, shock absorption, abrasion resistance, form fit, cost-effectiveness as well as recyclability and compostability. These requirements can be promoted by specifically treating alternative raw materials. A PTS study conducted for Fasergusswerk Polenz (FGW) on Miscanthus addition to the fibre stock (illustrated in **Fig. 4**) constituted the beginning of a project that subsequently succeeded in accomplishing market introduction. Miscanthus pulp reduces internal bonds whilst enhancing bulk **(Fig. 5)**. The partial replacement of standard feedstock on an industrial scale then showed that advantages such as reduced suction time and reduced drying energy actually facilitated the production process. The products have improved technological properties as well, including better dampening properties and reduced mould growth. Increased wire pollution and intricate Miscanthus logistics, however, were minor drawbacks.

Additional alternative feedstocks for moulded pulp products have been suggested lately, such as grass, sugar beet pulp or coconut fibre. The last two examples seem to involve major changes in product characteristics.

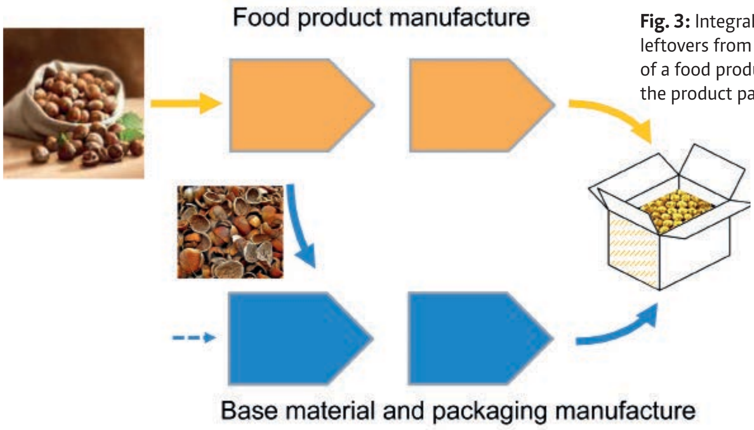

Fig. 3: Integral approach: leftovers from the manufacture of a food product are re-used in the product packaging

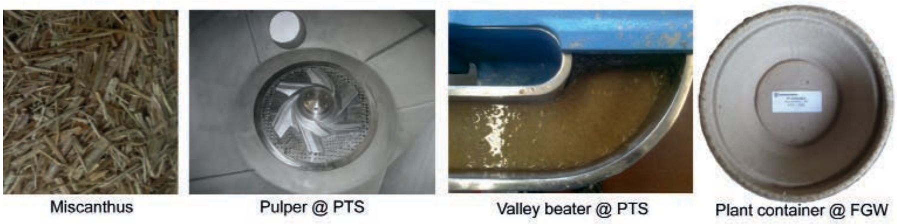

Fig. 4: Impressions from the development work for Miscanthus in moulded fibre products

Hazelnut shells

Hazelnut shells are a by-product of confectionary manufacture, amounting to approx. 450k tpa in Europe. Up to now, they have been regarded as waste and disposed of by incineration, although in most cases the energetic efficiencies were poor. A confectionary manufacturer decided to invest in the development of a recyclable solution. He teamed up with PTS who proved the feasibility of the solution both on laboratory and pilot scales, and then with a board mill for industrial trials. The raw material was dry-milled, further prepared and introduced to the middle ply of a multi-ply folding box board machine. The middle layer made with nutshells exhibited greater volume compared to the conventional pulp blend. The bending stiffness of the paperboard was increased in this way. The volume-enhancing effect exceeds that of conventional virgin or secondary fibre pulps, and equals that of energy-intensive mechanical pulps. The resulting packaging material involves cost savings or better product characteristics.

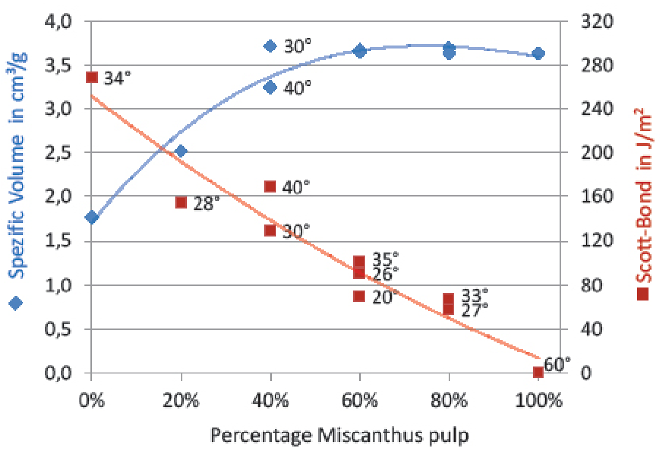

Fig. 5: Reduced internal bond and enhanced bulk as a result of the addition of Miscanthus pulp to standard recovered fibre pulp, tested with lab sheets

Hop extraction residues

By-products from the beer manufacturing chain were studied regarding their potential as a fibre material in paper products [i]. Hop extraction residues amount to approx. 7000 tpa in Bavaria alone. They were milled and incorporated into the middle ply of a three-ply board. Tensile strength and most static strength properties decreased when as much as 55 % hop pulp was added to the virgin pulp – although the bending stiffness could be maintained or even enhanced. These findings made the material especially suitable for board products. Downstream processability was investigated as well. Dye cutting and creasing did not reveal any problems. It goes without saying that the product is recyclable and compostable. It satisfies the requirements for food contact although there are some limitations when it comes to organoleptic properties. The downstream processability was confirmed by the manufacture of paper cores from pilot plant hop papers **(Fig. 6)**.

Fig. 6: Demonstration scale conversion of papers with 25 % share of hop residue pulp into paper cores

Beyond mechanical treatment

The examples depicted have one issue in common: when compared with recycled fibre pulp, the materials enhance bulk – often to the extent of stone-ground wood **(Fig. 7)** – but simultaneously weaken tensile and other static strength parameters. This is typical for the vast majority of biogenic fibre substitutes. As the materials often lack fibrous consistence and as they are not subjected to chemical pulping, it is not surprising that the fibre morphology and bonding characteristics necessary for paper strength are not developed.

Experimental tests within the framework of the SUBWEX project indicated that dry-milled barley straw can achieve tensile values comparable to recycled fibre pulp by simple hydrothermal treatment at temperatures above 160 °C. This opens up opportunities for chemical-free pulping/extraction processes aimed at coupled production: additives e.g. for the food and cosmetics sector, and papermaking pulp. The approach still demands dedicated research. Another promising pathway – equally subject to research demand – is a simplified chemical pulping process involving regional small-scale implementations.

Developing a paper product with agrifood residues

Depending on the initiating party, either a specified agrifood material is provided and potential paper applications are then investigated, or a specified paper application is pre-defined and suitable agrifood materials are subsequently determined. In any case, technological product specification is only one facet of the whole project. At the same time, reliable sources for the biogenic materials and supply paths have to be clarified, legal aspects investigated, and preparation processes specified. Paper mill processability has to be addressed as well, with regard to particle size, drainability, detrimental substances, microbiological impact, abrasion tendency or effluent loads – just to name a few of the major factors.

Defining the targeted market segment and integrating customers at an early stage will foster straightforward development work. The project set-up should have a tiered approach, thereby allowing essential criteria to be identified and addressed first. Technical and economic feasibility should then be proven. Successive tiers refine the process design, add more evaluation criteria and involve scale-up. **Fig. 8** highlights a four-tier approach. Its particular design will depend on the objectives and boundary conditions. When targeting food-contact papers, for example, it might be sensible to investigate later legal conformity even at an early stage.

Conclusions and outlook

The replacement of wood-based standard fibre raw materials can bring about cost savings, expansion of the raw-materials procurement base, enhancement of product properties, reduction of environmental footprint and unique selling points. At best, these benefits will be

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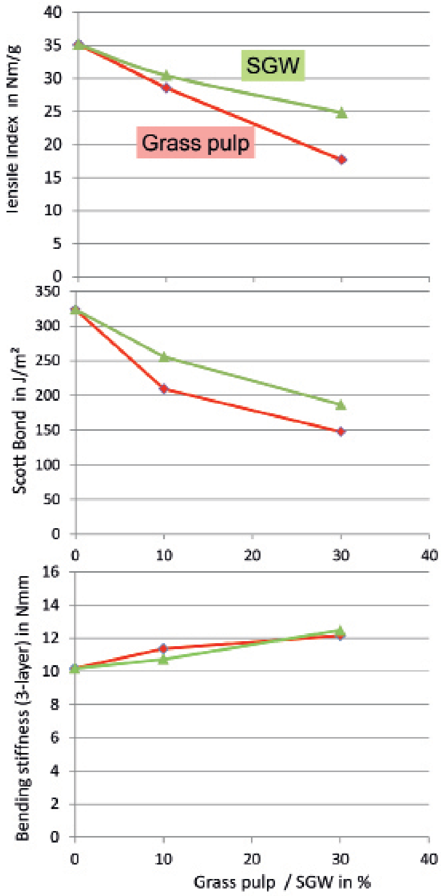

Fig. 7: Comparison of the effect of mechanically prepared grass pulp and stone-ground wood (SGW) market pulp on major board properties when substituted for recycled fibre pulp. Bending stiffness for a three-layer board was calculated based on al laminate-theory modul

combined. Sometimes advantages on one side, e.g. market attractiveness, outweigh the losses of other requirements, e.g. mechanical properties. Development work is multi-faceted and – in our experience – has non-obvious implications at times.

What is the future potential of agrifood by-products in paper? Up to now, developments have focussed on packaging papers/boards and moulded pulp products. Moreover, adding plant materials ("spice ingredients") for fancy stationery products is an established approach with an explicit but limited market. There is a huge and as yet unexploited potential for using volume-enhancing by-products in board grades. Driving factors that will further promote the long-term use of biogenic by-products in commodity (packaging) papers are:

- Cost-effective pre-treatments to achieve tensile strength (and related parameters such as SCT, burst strength, etc.)
- The on-going upward trend in prices and the downward trend in the strength potential of paper for recycling
- Substantiated environmental benefits

With a view to a future bio-economy, research and development in this field have laid down good knowledge foundations so far and have yielded some viable applications. There is still plenty of room for identifying and developing future-oriented applications of agrifood by-products in paper and board products. | SHA

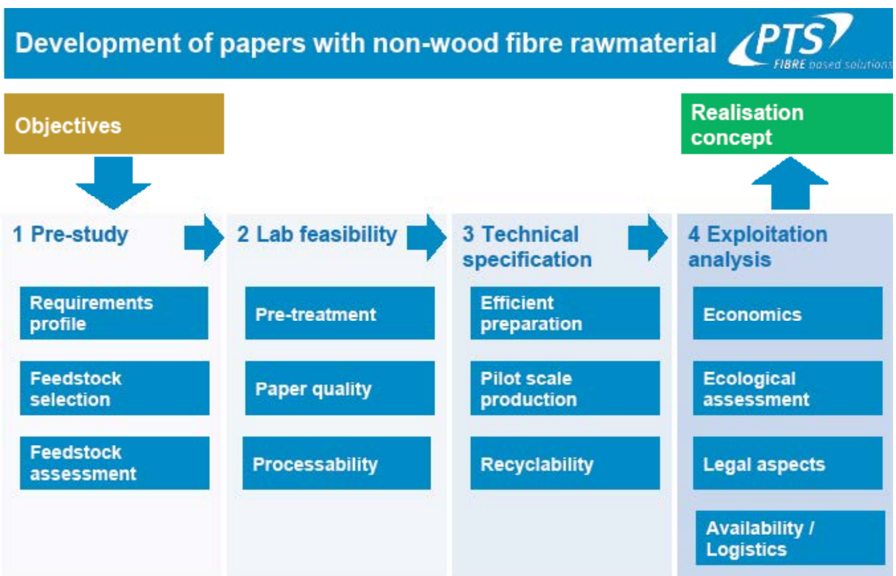

Fig. 8: Tiered approach to developing a paper product with novel non-wood components