Alternative raw materials and their effect on pulp dewatering and paper properties

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Introduction

The paper and board industry is facing a serious problem due to raw material shortages. While wood is the main papermaking resource, there are plenty of non-wood materials such as bagasse, bamboo, cereal straw, esparto, grass, kenaf or reed, which are also applicable to paper manufacture. However, problems encountered by non-wood-based pulp and paper mills are related to the supply, collection, transportation, storage and preparation of the fibre raw material[1,2].

Fortunately, non-wood resources can be efficiently used in small portions as a substitute for more expensive wood fibres or as an additive in order to obtain particular paper properties. Additionally, unconventional alternative raw materials are also being developed for the same purpose. There is a wide range of reject materials from different industrial processes that have some potential for papermaking purposes. The most interesting are those which are of natural origin, biodegradable (organic) and (may) contain cellulose and/or hemicelluloses. For example, various agricultural or agro-industrial lignocellulosic resources, which are globally available at reasonable cost, may be considered as suitable alternative papermaking raw materials.

Proper (re)use of these substances may bring significant advantages in reduction of wood raw material consumption and overall have a positive impact on the environment. Moreover, new substances may enable modification of pulp and paper properties; as a result, new paper products can be developed.

The aim of this study was to assess the application of different hydrophobic and hydrophilic, fibrous and/or non-fibrous materials and rejects originating from production of cooperating bio-based industries, in papermaking pulp. Effects of applying different materials on pulp dewatering and paper properties of recovered and virgin pulp were studied. Apple pulp, beer fines, beetroot pieces, citrus pulp, Betacal, deinking sludge, onion skins and sawdust were used in experiments as unconventional alternative additives.

Materials and experimental

The first part of the project relied on identifying relevant and available, alternative raw materials. A matrix with non-technological data: price, availability, seasonality, solids content, and composition of alternative raw materials, was created. The information about activities performed elsewhere to valorise the raw materials and trials performed in papermaking related to alternative raw materials was also gathered. After that, the most promising additives were chosen according; the initial properties of selected materials are listed in *Table 1*.

Additive	Celluose [g/kg]	Hemicelluloses [g/kg]	Ash [g/kg]	Solid content [%]	Seasonality	Availability [ton/year]	Price [€/dry ton]
Apple pulp	285	Not defined	25	21	Continuously	10,000	75
Beer fines (wet and dried)	220	480	Not defined	22-27	Continuously	100,000 dry	120
Beetroot pieces	270	290	40	20-30	Sep-Feb (fresh), Continuously(siled)	150,000-180,000 dry	30
Betacal	-	-	43	64	Produced by 4 months, available all year	100,000 dry	20
Citrus pulp	130	Not defined	40	16	Continuously	10,000	75
Deinking sludge	356	94	250	45-55	Continuously	100,000	0
Onion skins	245	Not defined	90	84	Continuously	25,000	40-60
Sawdust C100	450-550	100-200	5	92	Continuously	Not defined	200
Sawdust C320	474	214	2	92	Continuously	Not defined	200
Long-fibre northern bleached softwood kraft pulp.							798
Short-fibre hardwood kraft pulp							716

Table 1: Non-conventional alternative additives used in experiments.

These materials *(Figure 1)* were supplied by several Dutch companies. Most were used as supplied, although some were pre-treated by mechanical means using a coffee grinder or kitchen blender to decrease their particle size. Neither chemical pre-treatment nor mechanical refining was applied to the raw materials.

The alternative materials were added in proportions of 5%, 10% and 15% to two reference pulps:

- Recovered pulp used for fluting in a Dutch paper mill (60% OCC and 40% MOW), supplied in the form of dry sheets.
- Virgin wood-pulp (a mixture of bleached hardwood and softwood) from another Dutch paper mill, supplied in the form of dry fibre pads.

Experiments were accomplished in two series. The first set investigated the influence of additives on pulp dewatering; the second looked at their effect on paper properties.

In order to determine what effect the addition of bio-based additives in different ratios had on pulp dewatering, a wide range of dewatering apparatus was used. No universal, standard technique for assessment of pulp drainage exists, so the following methods and tests (standardized and non-standardized) were applied to fully investigate and describe dewatering of pulp stock mixed with the alternative materials:

1. Schopper-Riegler (SR) according to ISO 5267-1.

2. Hydrodynamic Specific Surface Area (HSSA) assessment, based on the permeability of compressed water-swollen fibre pads. The HSSA is defined as the surface area of fibres in a compressed water-swollen fibre pad of known dry-matter mass that is accessible for streaming water molecules. During the measurement pulp compressibility can also be estimated[3,4].

3. Rapid-Köthen (RK) number, measures the drainage time of prepared suspensions under atmospheric pressure. The RK number is described as the time taken for a volume of 6L of aqueous fibre slurry with initial consistency of 0.3g/L to drain in an RK former from 8L to 2L under atmospheric pressure[5-7].

4. Water Retention Value (WRV), was determined by centrifugation of a fibre pad with centrifugal force of 3000g in 15 minutes[8].

5. FiberXPress test unit which was developed by Voith Paper Automation. The FiberXPress dryness value can be interpreted as the dryness of a paper web going through an ideal press section[9-11].

In order to estimate what effect the addition of alternative materials had on paper properties, laboratory sheets of 110g/m^2 were formed in an RK sheet former according to EN ISO 5259-2:2001. All handsheet properties were tested in accordance with appropriate EN ISO standards.

Figure 1: Raw materials used as additives for paper manufacture.

Effects on pulp drainage

Results of dewatering tests are divided into few categories. Separate figures present the results for swollen and non-swollen pulps, and for those additives added to recovered pulp and to virgin pulp. As not all additives were tested with every test mentioned above, only the most interesting graphs are shown.

The correlation between SR value and additive percentage is shown in *Figure 2*; a lower SR value is better in terms of paper web dewatering on a paper machine. According to this method, almost all additives decrease the SR value in comparison with the reference pulp; the one exception was beetroot pieces, which caused an increase of the SR value, so is expected to reduce pulp drainage rate.

When HSSA is considered it was seen that Betacal, sawdust C100, sawdust C320 and citrus pulp decrease this pulp property. The greatest changes were caused by sawdust C320 and Betacal - their application allowed HSSA to reach below 1.5m^2/g. According to theory, these substances added to reference pulp decrease the flow resistance of water through the water-swollen fibre pad and therefore a decreased surface of fibres was determined that is accessible for streaming water. It can be assumed that the application of sawdust C320 and Betacal in practice should result in an improvement of dewatering ability.

Assessment of compressibility during HSSA testing used only the recovered pulp as a reference. Pulps exhibited higher

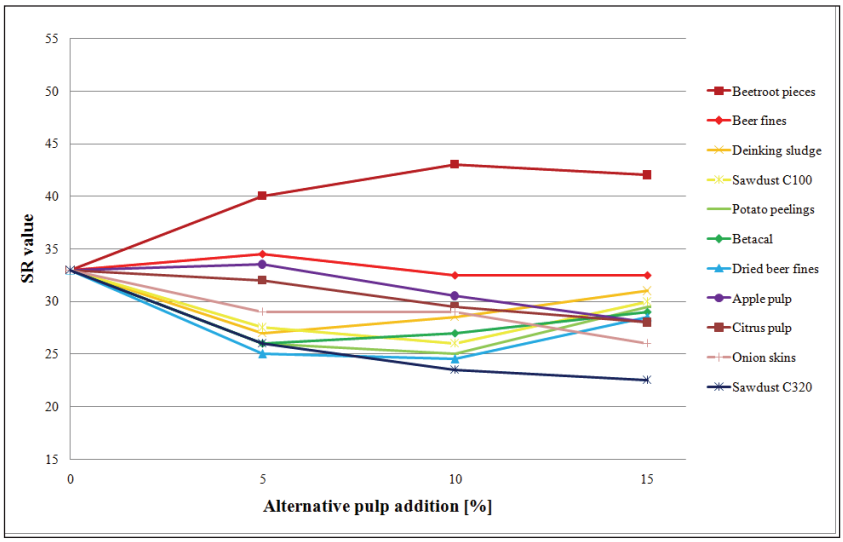

Figure 2: Dewatering of non-swollen recovered pulps with addition of alternative materials determined by drainability measurement in the Schopper-Riegler apparatus.

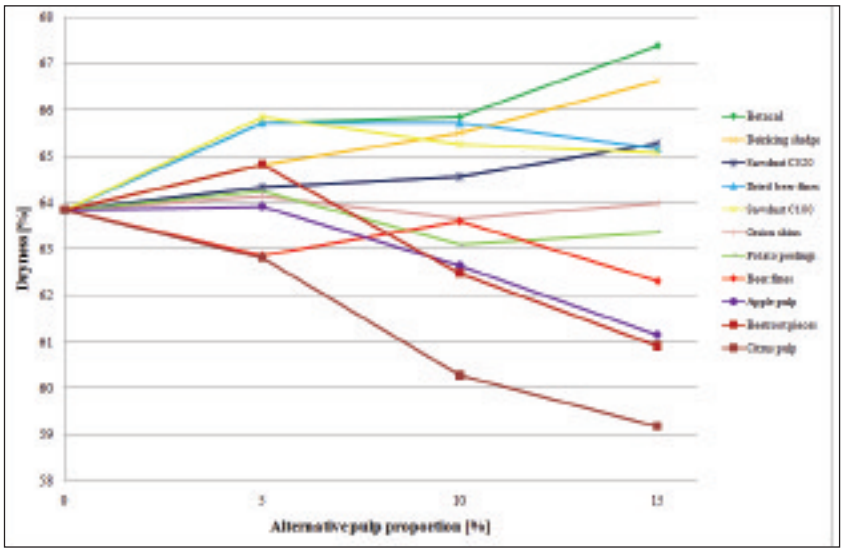

Figure 3: Dewatering of swollen recovered pulps with addition of alternative materials determined by FiberXPress.

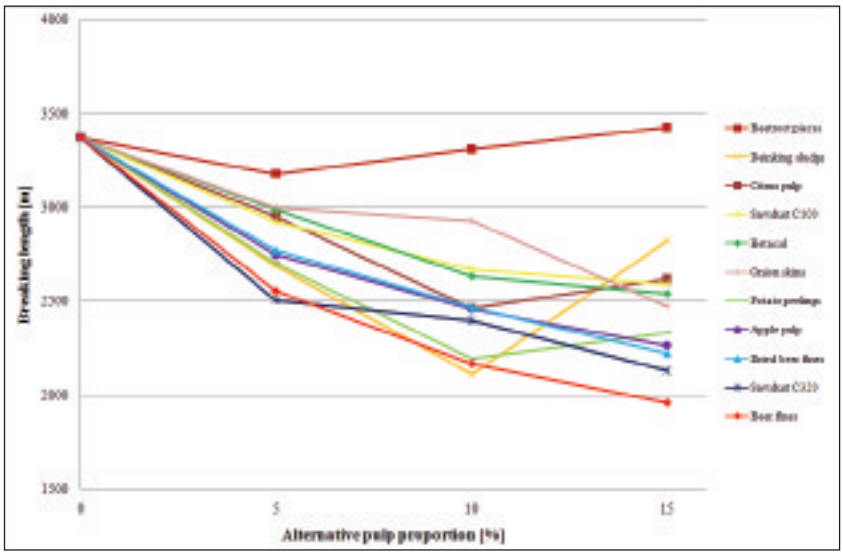

Figure 4: Comparison of breaking length as an indicator of strength properties of Rapid-Köthen handsheets made of recovered pulp with addition of alternative materials.

compressibility than the reference pulp when Betacal, apple pulp, deinking sludge and sawdust C100 were applied. However, it was also observed that sawdust C100 and deinking sludge can only be used sparingly without deterioration of drainability / compressibility behaviour.

The results of WRV tests show that all of the five tested alternative materials (sawdust C320, sawdust C100, Betacal, beer fines and apple pulp) improve the dewatering of pulp after the press section. The best results were achieved with the application of both types of sawdust; for this material, high nominal dryness may be caused by the high dryness and low swelling ability of sawdust itself. The application of beer fines may be limited due to the fact that a decrease of the nominal dryness was observed for this additive.

The results of drainage tests performed with the press section simulator FiberXpress are shown in *Figure 3*; they revealed that an improvement of dewatering can be achieved by applying (in the given sequence): Betacal, deinking sludge, sawdust C320, dried beer fines and sawdust C100. The highest dryness was obtained when Betacal was used. Other results suggest that additives such as citrus pulp, beetroot pieces, apple pulp and beer fines should decrease the dryness of recovered pulp. The experiments indicate that in general, all substances with high ash content or with high initial dryness improve pulp dewatering.

The influence of the addition of alternative materials on pulp dewatering varies significantly depending on the initial properties of the reference pulp. Differences in pulp dewatering depend also on the shape and size of the added particles. Because of that, the measurement results seem to be spread and do not always show an obvious trend. It may be noted that further investigations need to be performed with improved or modified pre-treatment methods for suitable alternative materials.

Overall it should also be noted that the SR test was the most reliable dewatering method used to estimate the dewatering ability of pulps. The other tests brought questionable or contradictory results; therefore they may be considered as providing additional information about dewatering, with the SR method being the primary evaluation method.

Paper properties

When analysing the influence of alternative additives on paper properties *(Figure 4)* it was noticed that all of the applied materials reduced paper strength

properties. The lowest strength decrease was obtained with beetroot pieces; using beetroot pulp achieved a similar strength to the reference pulps. The worst results (i.e. the highest decrease of strength properties) were obtained by the application of beer fines.

The strength properties were also considered in relationship to sheet formation. Unfortunately, some of the applied alternative pulps were not well bonded to the reference pulp, i.e. their particles were only partly retained in the fibre mat - as a result they were visible on the paper surface. The best aesthetic impression of handsheets (without specks, discoloration, stains, etc.) was received with Betacal, sawdust C100, beer fines dried and beetroot pieces.

The general reduction of paper properties was an expected result, because none of the raw materials has been pre-treated with a chemical or mechanical pulping method to make the materials more available for bonding. The technical potential of the unconventional alternatives is expected to be significantly improved when they undergo pre-treatment.

Conclusions

It can be shown that there is a certain papermaking potential in all the unconventional raw materials used in these experiments.

It was found these alternative materials changed dewatering ability in different ways. Some showed promise for the improvement of pulp dewatering and thus the improvement of quality in paper or board production. According to all tests, pulp dewatering could be improved by the application of sawdust C320, Betacal and dried beer fines, but it may be deteriorated by beetroot pieces. Results for the other substances such as sawdust C100, onion skins, deinking sludge, citrus pulp, apple pulp and beer fines suggest they may improve the pulp dewatering ability; however, this was not clearly shown by all test methods.

Results show that the lowest negative impact on paper strength properties was obtained with beetroot pieces. This alternative additive was also not visible in the paper structure. Acceptable paper sheets (without specks, discolorations, stains, etc.) were also obtained with Betacal, sawdust C100 and dried beer fines.

From these experiments we conclude that in order to make these alternative materials more suitable for papermaking, correct pre-treatment to alter their size, shape and surface character is required. Therefore, further investigations need to be performed to make different organic bio-streams suitable for papermaking.

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(All information from websites verified on 15/12/2010)