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# INFLUENCE OF SUGAR BEET PULP ON BOND STRENGTH AND STRUCTURE OF PAPER

Mária Fišerová, Juraj Gigac, Rudolf Butaš
Pulp and Paper Research Institute, Bratislava, Slovak Republic

## ABSTRACT

Influence of sugar beet pulp on properties of fibre suspension and paper from recovered fibres and soda-AQ semichemical pulp was investigated in laboratory scale. Sugar beet pulp was beaten in a Valley laboratory hollander to 50°SR and added to recovered fibres and soda-AQ semichemical pulp. With gradually increasing sugar beet pulp content of 5 to 40% internal bond strength, $CMT_{30}$, SCT, burst index, tensile index and tensile energy absorption index increased proportionally. Sugar beet pulp has an influence mainly on internal bond strength and SCT value. With increased input of sugar beet pulp to recovered fibres and soda-AQ semichemical pulp bending resistance and porosity is decreasing. Macro photographs of paper surface are showing that with increasing sugar beet pulp content in furnish the variability of paper surface geometry increases. It is recommended to apply up to 15% sugar beet pulp content in furnish in production of fluting and test liner. With increased addition dewatering is impaired, water retention increases and initial wet web strength of recovered fibres and soda-AQ semichemical pulp decreases. At 15% sugar beet pulp content in furnish with recovered fibres and soda-AQ semichemical pulp an increase of $CMT_{30}$ by 3-11%, SCT by 20-23 % and burst index by 7-9 % is achieved. Beaten sugar beet pulp significantly increases specific bond strength especially of recovered fibres. Increase of recovered fibres mechanical properties makes possible to replace a part of soda-AQ semichemical pulp by recovered fibres in production of fluting and test liner without decrease of mechanical properties.

KEY WORDS: sugar beet pulp, beating, recovered fibres, soda-AQ semichemical pulp, suspension properties, physical and mechanical properties of paper

## INTRODUCTION

Sugar beet pulp is mainly utilized as animal feed but the very large volume produced annually calls for research to alternative uses. Sugar beet pulp can be utilized after hydrolysis by biotechnology for production of ethanol and biogas, for enzymes and for solid-state protein-rich feed production. By submerged fermentation arabans or other hemicelluloses can be separated, pectin and derivatives as well as the cellulose component and lignin can be utilised. Moreover, the possibility of sugar beet pulp exploitation at production of bio-composites, fertilizers, fuel, dietary fibres and other non-food applications can also be considered. Sugar beet pulp is also a rich source of fibres which can be exploited in the paper industry (Slugeň, Rosenberg et al. 2005).

The composition of dried sugar beet pulp as frequently referred in literature is following: 65-80% of polysaccharides which contain approximately 40% of cellulose, 30% of hemicelluloses and 30% of pectines. Sun and Hughes (1998) specified the following minor fractions: 1.44% fats, 10.29% protein, 3.68% ash and 5.85% lignin. The difference – 78.47% are polysaccharides. The polysaccharides fraction includes saponines and lignin components too. The polysaccharides fraction contains abundantly glucose (in the metabolically unusable form of cellulose and hemicelluloses), galacturonic acid and arabinose in the quantity from 25 to 20%. Important is also the rhamnose and xylose content. Sugar beet pulp is attractive due the highest L-arabinose content among all easy available natural waste materials, which is at least twice higher in comparison with other alternative sources

Structure of purified sugar beet pulp was described by Dinand et al. (1999). Sugar beet pulp is more or less, according of the mode of processing, composed of cellulose fibres. Fibres from sugar beet pulp can be used as a substrate for production of carboxymethyl cellulose (Togrul and Arslan 2003). Due to presence of residual side chains after partial hydrolysis of other polymers, sugar beet pulp fibres have unique properties. Sugar beet pulp fibres practically do not contain lignin but have a small amount of xylan side chains, which ensure stability of emulsions. Sugar beet pulp fibres freed from lipids and pectic substances can be applied in paper special processing. Intensive chemical treatment by concentrated NaOH solution makes its properties close to microcrystalline cellulose. It differs from standard cellulose fibres prepared from wood raw materials by significantly lower aggregation of cellulose fibres and is more hydrophilic.

Papers for corrugated layer and liner (fluting, test liner, liner) are construction materials of corrugated board which should fulfil two main functions: to protect the goods packed in boxes during handling, storing and transport of boxes and moreover it should render a printing surface for marking the manufacturing or trade company etc. In manufacturing construction materials virgin and recovered fibres are used. The furnish composition depends on the standard of manufacturing technology and requirements of converters on qualitative properties on the final product.

The simplest alternative to increase strength properties of paper is application of wet end additives into the fibres furnish in stock preparation. This does not require change of equipment or technology. Modified (cationic) maize and potato starches, pectin preparations, carboxymethyl cellulose, urea-formaldehyde resins and lignin preparations are used to increase strength properties of paper. Improvement of properties is not always adequate to costs and to problems arising with presence of another compound in the paper furnish.

Increase of paper and board production forces researchers to search for new raw materials which could reduce input of fibrous raw materials as well as to search for ecologically acceptable natural materials for dry strength increase. Sugar beet pulp is a rich source of fibres which can be exploited in the paper industry.

The objective of this work was to investigate influence of beaten sugar beet pulp on fibre suspension properties and physical and mechanical properties of paper from recovered fibres and soda-AQ semichemical pulp and the possibility of exploitation of sugar beet pulp in fluting and test liner production.

## MATERIALS AND METHODS

***Soda-AQ (SAQ) semichemical pulp*** prepared from mixed hardwoods (40% poplar, 35% birch, 25% hornbeam). The SAQ semichemical pulp was beaten in a Valley laboratory hollander to 28°SR according to ISO 5264-1 standard.

***Recovered fibres*** (34°SR) prepared from following waste paper classes according to EN 643: 3% of mixed papers and boards, 16% of corrugated paper and board from department stores, 65% of old corrugated board boxes and 16% of new cuttings from corrugated board.

***Sugar beet pulp*** extruded and dried particles (1-6 mm) after soaking 2 hours in water were beaten in a Valley laboratory hollander to 50°SR according to ISO 5264-1. Beaten sugar beet pulp contained particles of 0.01-1.5 mm dimensions.

***Three different basic furnish composition*** were used in this investigation:

- Two components furnish of recovered fibres (RF) with gradually increasing sugar beet pulp content of 0, 5, 10, 20, and 40%.
- Two components furnish of soda-AQ semichemical pulp fibres (SAQSCP) with gradually increasing sugar beet pulp content of 0, 5, 10, 20 and 40%.
- Three components furnish consisting of equal proportion of soda-AQ semichemical pulp and recovered fibres (RF+SAQSCP 1:1) with gradually increasing sugar beet pulp content of 0, 5, 10, 20 and 40%.

Beating degree and drainability was determined according to ISO 5267-1 standard and water retention value according to TAPPI UM 256. Test sheets from recovered fibres and SAQ semichemical pulps were prepared according to ISO 5269-2 standard and mechanical properties determined according to ISO 5270 method. Fibre length distribution was determined on an ADV-3 instrument developed by the Pulp and Paper Research Institute Bratislava measuring fibre length in a capillary with a conductivity detector. Internal bond strength was measured as Scott Bond Energy according to TAPPI method 506 wd-83 and tensile energy absorption according to ISO 1924-2 standard. Stiffness was determined as bending resistance by a two point method at 15° bending angle 25 mm distance of clamp and blade distance according to T 556 pm-95 method. Porosity was measured as resistance to air penetration according to Gurley (ISO 5636-5) and flat crush resistance according to ISO 3035 standard. Values corresponding to SCT (Short Span Compression Test) were calculated from an equation using internal bond strength, bending resistance and relative pore volume calculated from apparent density (Vullierme and Serra-Tosio 2000). Variability of paper surface geometry was evaluated by macro photography of surface and subsequently by computer processing of the surface image. The method is similar to photoclinometry.

## RESULTS AND DISCUSSION

### Influence of sugar beet pulp on fibre suspension properties

For manufacture of fluting and test liner virgin and recovered fibres are used. The proportion of these components depends on the standard of technology and requirements of converters on properties of the final product. In order to increase qualitative parameters of fluting and test liner commercial agents for improvement of dry strength are applied. In this work possibility of sugar beet pulp application in manufacture of wrapping materials from SAQ semichemical pulp and recovered fibres was explored based on the assumption that sugar beet pulp contains pectin, which is used to improve strength properties of paper.

Sugar beet pulp is suitable for papermaking application after a physical treatment by beating or micronisation. Laboratory scale experiments showed that sugar beet pulp beaten in a Valley hollander has a positive influence on specific bond strength only if are beaten to a higher beating degree (50°SR). At a lower beating degree sugar beet pulp reduces mechanical properties of paper.

Addition of sugar beet pulp beaten to 50°SR in an amount up to 40% to a mixture with recovered fibres increased beating degree by 4°SR (from 34 to 38°SR) while in case of SAQ semichemical pulp up to 6°SR (from 28 to 34°SR). The increase of the beating degree of the fibre suspension with increasing of sugar beet pulp content in furnish is the higher the lower is the beating degree of the original fibre suspension.

Fig. 1 shows the influence of sugar beet pulp content in furnish on change of drainage time of recovered fibres, SAQ semichemical pulp and a mixture of these fibres in a proportion 1:1. Drainage time of 700 ml on a wire increases with increasing sugar beet pulp content in furnish with all fibre types. The longest drainage time is in case of recovered fibres which have also a highest beating degree. Highest increase of drainage time was observed with SAQ semichemical pulp. At 40% content of sugar beet pulp in furnish the drainage time increased by 46%. Increase of drainage time has a negative influence on paper machine output therefore in mill conditions it will be possible to apply only lower of sugar beet pulp content in furnish in the range 10 to 20%.

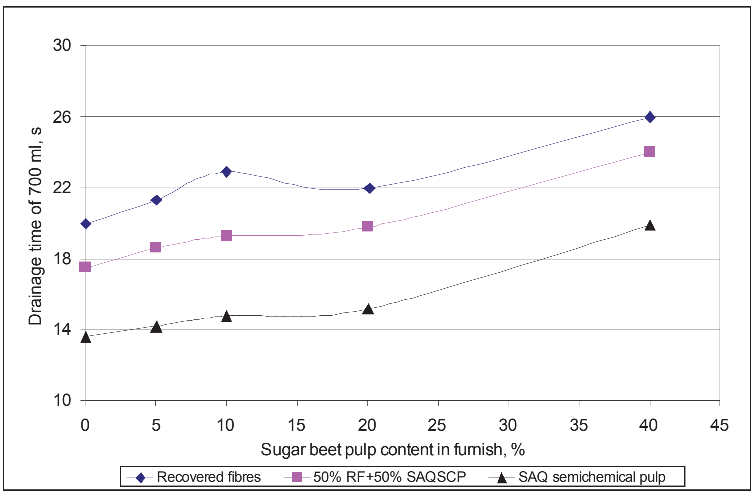


*Fig. 1: Drainage time change of various fibre suspensions with increasing content of sugar beet pulp beaten to 50°SR*

On Fig. 2 change of water retention value of the three furnishes with increasing sugar beet pulp content is presented. It is known, that the lower is the water retention value the higher dryness of the paper web can be achieved in the press part of a paper machine. Recovered fibres have the lowest water retention value while SAQ semichemical pulp the highest. With increasing sugar beet pulp content in furnish the water retention value increases proportionally but more significantly in case of recovered fibres. At 40% content of sugar beet pulp the water retention value of recovered fibres increased by 71%, of a mixture of recovered fibres and SAQ semichemical pulp by 42% and of SAQ semichemical pulp by 27%. Recovered fibres have in the whole range lowest water retention values. At 30% content of sugar beet pulp the water retention value of recovered fibres – sugar beet pulp furnish is the same as of the SAQ semichemical pulp at 28°SR.

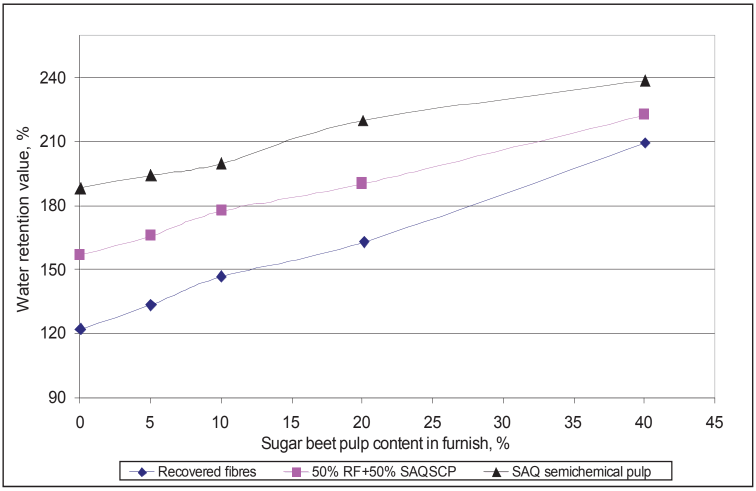


*Fig. 2: Change of water retention value of various fibre suspensions with increasing content of sugar beet pulp beaten to 50°SR*

Influence of beaten sugar beet pulp content in furnishes with recovered fibres, SAQ semichemical pulp and a mixture of SAQ semichemical pulp and recovered fibres in a proportion 1:1 on weighted average fibre length is shown on Fig. 3. The weighted average fibre length is proportionally decreasing with increasing of sugar beet pulp. At 40% sugar beet pulp content the weighted average fibre length reduction of the recovered fibre furnish represents 18%, of the mixed recovered fibres and SAQ semichemical pulp furnish 10% and in case of the SAQ semichemical pulp the fibre length reduction was 7%.

Fig. 4 shows the change of initial wet web strength index of the three furnishes with increasing sugar beet pulp content at a water retention value corresponding to sugar beet pulp addition (see Fig. 2). Initial wet web strength is the strength of the fibre mat created from papermaking fibres after dewatering and pressing without drying. The dryness of the mat depends on the drainage resistance of the sample. The initial wet web strength is influenced by fibre length, roughness of surface, water volume and dimension of the water meniscus between fibres. The wet web strength index of recovered fibres, SAQ semichemical pulp and of a mixture 1:1 of these fibres decreases proportionally with increasing content of sugar beet pulp in furnish. The decrease of initial wet web strength is caused by increased water retention and reduction of weighted average fibre length. This increases the probability of paper web breaks on the paper machine resulting in reduced output. Due to this it is suitable to apply only lower addition of sugar beet pulp.

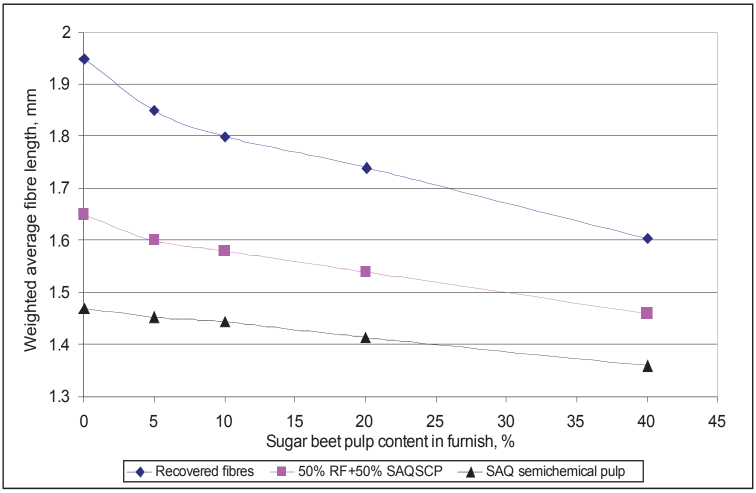


*Fig. 3: Change of weighted average fibre length with increasing content of sugar beet pulp beaten to 50°SR*

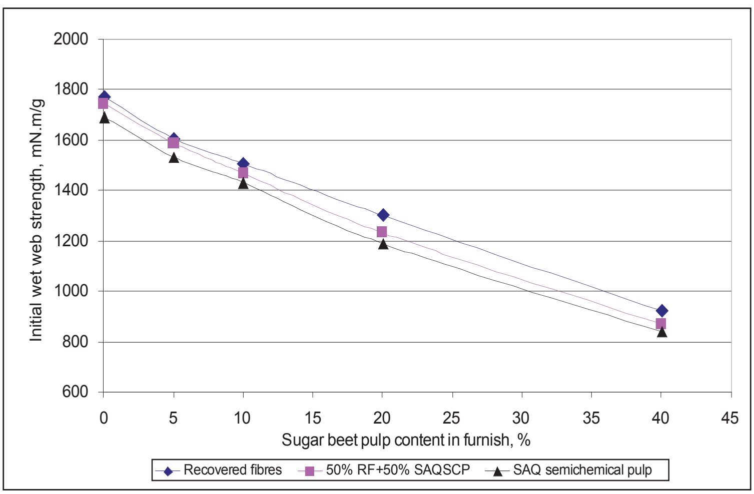


*Fig. 4: Change of initial wet web strength of various fibre webs with increasing content of sugar beet pulp beaten to 50°SR at a water retention value corresponding to sugar beet pulp content (see Fig.2)*

## Influence of sugar beet pulp on physical and mechanical properties of paper

Internal bond strength, stiffness and porosity are the most important parameters for fluting and test liner evaluation. These parameters participate with different measure on mechanical properties of construction materials such as flat crush resistance CMT (Concora Medium Test) and SCT (Vullierme and Serra-Tosio 2000). Internal bond strength is determined as energy required for quick disrupting fibre to fibre bonds in the paper sheet in thickness direction (Z-direction). Fibre to fibre bonds are disrupted when shear forces are larger than the specific bond strength which is a product of relative bonded area and cohesion (Cowan 1986).

Fig. 5 shows the change of internal bond strength of the three furnishes with increasing sugar beet pulp content. At zero content of sugar beet pulp in the furnish SAQ semichemical pulp has highest and recovered fibres lowest internal bond strength. Internal bond strength of individual fibre types is increasing proportionally with increasing sugar beet pulp content. At 40% content of sugar beet pulp in furnish the internal bond strength of recovered fibres increased by 174%, of a 1:1 mixture of recovered fibres and SAQ semichemical pulp by 138% and of SAQ semichemical pulp by 119%. It can be concluded from evaluation of internal bond strength that sugar beet pulp is the more actively involved in the internal bond system of recovered fibres and SAQ semichemical pulp the lower is the internal bond strength of the respective fibres.

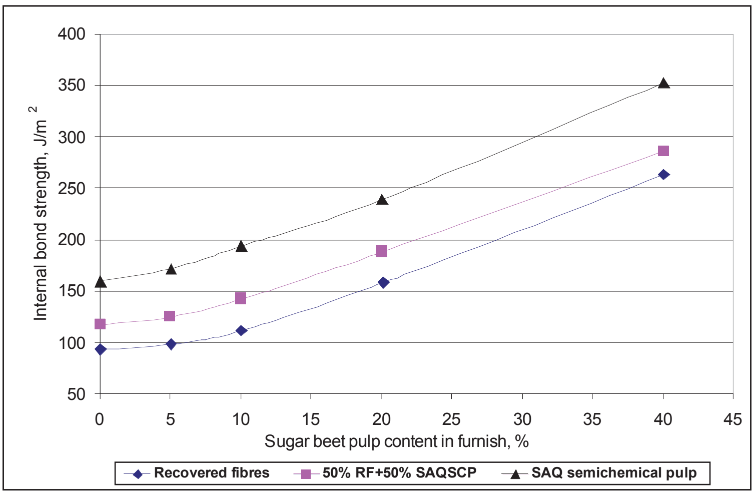


*Fig. 5: Change of internal bond strength of papers from various fibre furnishes with increasing content of sugar beet pulp beaten to 50°SR*

Stiffness is one of the important parameters expressing how paper will be deformed by an external force. Stiffness increases with modulus of elasticity. Fig. 6 shows the change of bending resistance of test sheets prepared from recovered fibres, SAQ semichemical pulp and of a mixture 1:1 of these fibres as a result of increasing sugar beet pulp content. Stiffness determined as bending resistance decreases proportionally with increasing sugar beet pulp content in furnish. At 40% content of sugar beet pulp bending resistance of recovered fibres decreased by 32%, of a 1:1 mixture of SAQ semichemical pulp and recovered fibres by 40% and bending resistance of SAQ semichemical pulp by 37%. Beaten sugar beet pulp reduces bending resistance what is unfavourable in case of fluting and test liner manufacture. Stiffness has an influence on $CMT_{30}$ and SCT. The influence is higher on CMT which is the most important parameter for fluting evaluation.

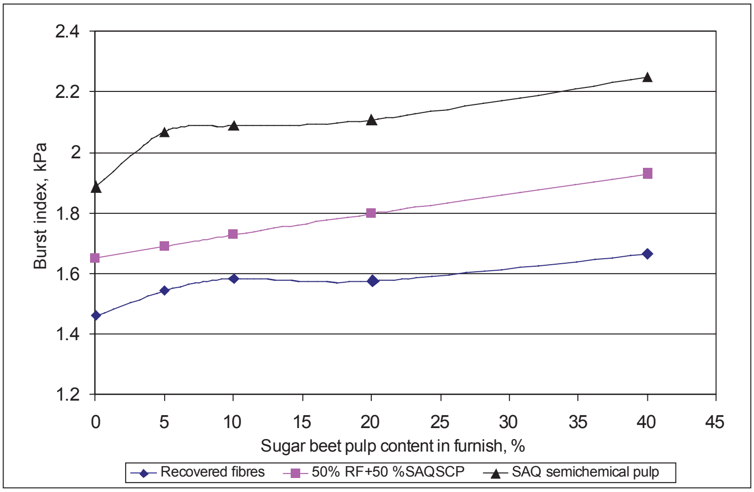


*Fig. 6: Change of bending resistance of papers from various fibre furnishes with increasing content of sugar beet pulp beaten to 50°SR*

Porosity was determined as resistance to air penetration according Gurley. Paper porosity is the higher the lower is the resistance to air penetration. Passage of air through paper is determined by passage pores connecting both sides of paper making possible air flow in direction of descending pressure. Fig. 7 shows the change of air penetration resistance of test sheets prepared from recovered fibres, SAQ semichemical pulp and of a mixture 1:1 of these fibres with increasing sugar beet pulp content in furnish. Resistance to air penetration slightly increases to about 15% content of sugar beet pulp in furnish and increases dramatically at higher contents. At 40% content of sugar beet pulp resistance to air penetration of paper test sheets prepared form SAQ semichemical pulp increased by 1500%, of test sheets from a 1:1 mixture of SAQ semichemical pulp and recovered fibres by 1200% and of test sheets from recovered fibres by 950%. Porosity of paper decreases with increasing sugar beet pulp content in furnish. This is unfavourable for corrugated board manufacture as absorption of adhesives required for gluing together fluting and test liner is suppressed. Measurement of air penetration resistance is in good relation with increase of bulk density of paper prepared from recovered fibres and SAQ semichemical pulp with increasing content of sugar beet pulp.

Flat crush resistance is defined as ability of corrugated board to resist a force acting perpendicularly to the surface up to the moment of crush. The test renders information about quality of paper used for the corrugated layer and its ability to keep the liners separated in a required distance. Fig. 8 shows the change of flat crush resistance (measured as $CMT_{30}$) of paper test sheets from various fibre furnishes with increasing sugar beet pulp content. SAQ semichemical pulp has the highest $CMT_{30}$ and recovered fibres the lowest. With increasing content of sugar beet pulp $CMT_{30}$ proportionally increases. At 40% sugar beet pulp content $CMT_{30}$ of SAQ semichemical pulp increased by 8%, of the SAQ semichemical pulp and recovered fibres mixture by 21% and of recovered fibres even by 27%.

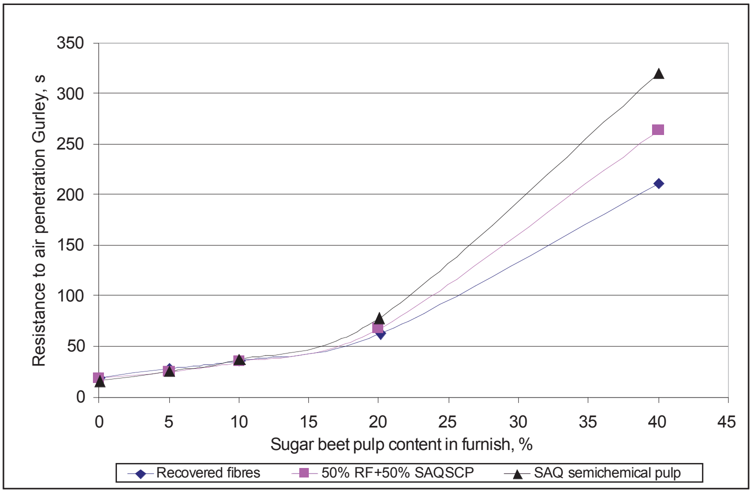


*Fig. 7: Change of air penetration resistance according Gurley of papers from various fibre furnishes with increasing content of sugar beet pulp beaten to 50°SR*

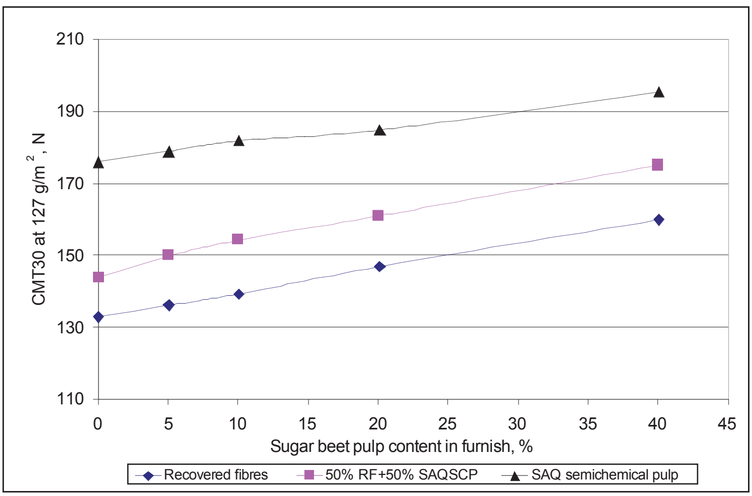


*Fig. 8: Change of flat crush resistance ($CMT_{30}$) of papers from various fibre furnishes with increasing content of sugar beet pulp beaten to 50°SR*

The Short Span Compression Test (SCT) is defined by the maximal force pressing on the cross section of a test strip at 0.7 mm distance of clamps. It is the most important mechanical property of test liner. Fig. 9 shows the change of SCT of test sheets prepared from recovered fibres, SAQ semichemical pulp and of a mixture 1:1 of these fibres with increasing sugar beet pulp content. With increasing sugar beet pulp content in furnish SCT of all fibre types increases proportionally. At 40% sugar beet pulp content SCT of SAQ semichemical pulp increased by 70%, of the SAQ semichemical pulp and recovered fibres mixture by 77% and of recovered fibres even by 105%. Short Span Compression Test depends mainly on internal bond strength. This is significantly increased by beaten sugar beet pulp as this enters into the bond system between wood fibres. The more significant increase of SCT when compared with $CMT_{30}$ is due to the fact that SCT depends mainly on internal bond strength and $CMT_{30}$ is more influenced by bending resistance.

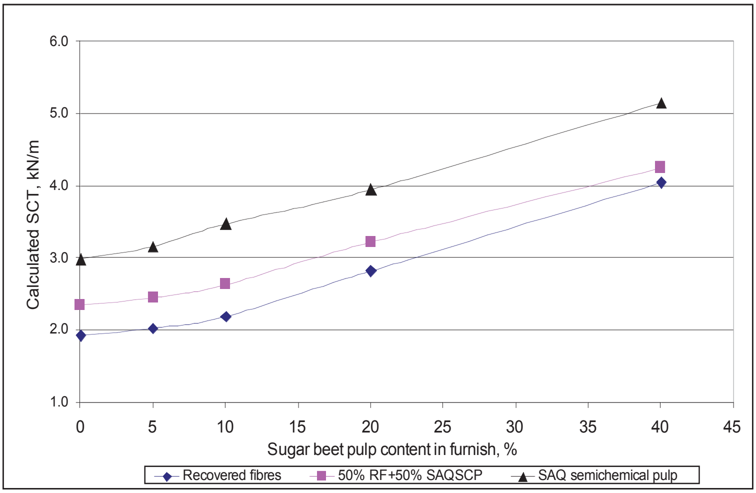


*Fig. 9: Change of Short Span Compression Test (SCT) of papers from various fibre furnishes with increasing content of sugar beet pulp beaten to 50°SR*

Burst strength expresses the resistance of paper against an even pressure acting perpendicularly to the surface in the moment of rupture. Fig. 10 shows the change of burst index of test sheets prepared from various fibre furnishes with increasing sugar beet pulp content. SAQ semichemical pulp has the highest and recovered fibres the lowest burst index. With increasing beaten sugar beet pulp content the burst index increases proportionally. At 40% content of sugar beet pulp burst index of all fibre types increased by 18%.

Tensile strength depends on specific bond strength (Cowan 1986) and strength and length of fibres. Fig. 11 shows the change of tensile index of test sheets prepared from recovered fibres, SAQ semichemical pulp and of a mixture 1:1 of these fibres with increasing sugar beet pulp content in furnish. The tensile index is proportionally increasing with increasing sugar beet pulp content. SAQ semichemical pulp has the highest and recovered fibres the lowest tensile index. At 40% sugar beet pulp content tensile index of recovered fibres increased by 25%, of the SAQ semichemical pulp and recovered fibres mixture by 20% and of SAQ semichemical pulp by 14%. Sugar beet pulp has a positive influence on tensile index. Increase of tensile index is the higher the lower is the tensile index of the original pulp. The results are in accordance with internal bond determination which increased most significantly in case of recovered fibres.

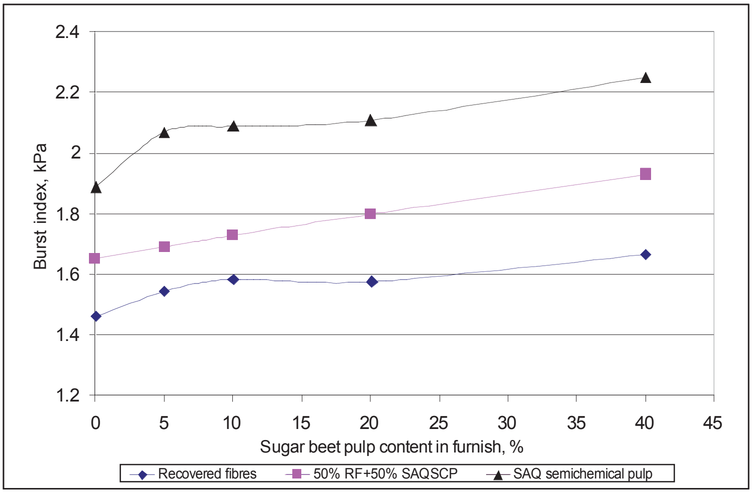


*Fig. 10: Change of burst index of papers from various fibre furnishes with increasing content of sugar beet pulp beaten to 50°SR*

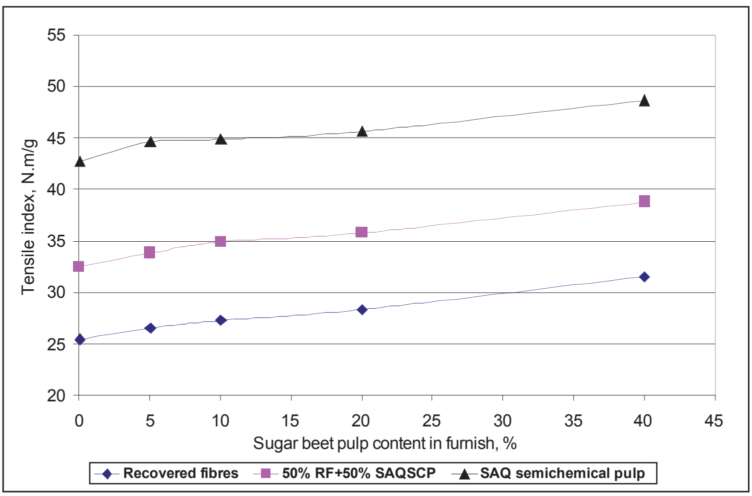


*Fig. 11: Change of tensile index of papers from various fibre furnishes with increasing content of sugar beet pulp beaten to 50°SR*

Tensile energy absorption informs about energy absorbed by paper or board during elongation up to rupture and indicates durability of paper when submitted to repeated or dynamic tension or loading. It is an acknowledged parameter characterising runnability of fluting on the corrugating machine. Fig. 12 shows the change of tensile energy absorption index of test sheets prepared from various fibre furnishes with increasing content of sugar beet pulp. SAQ semichemical pulp has the highest and recovered fibres the lowest tensile energy absorption index. The tensile energy absorption index proportionally increases with increasing beaten sugar beet pulp content in furnish. At 40% sugar beet pulp content tensile energy absorption index of recovered fibres increased by 31%, of SAQ semichemical pulp and recovered fibres mixture by 30% and of SAQ semichemical pulp by 25%.

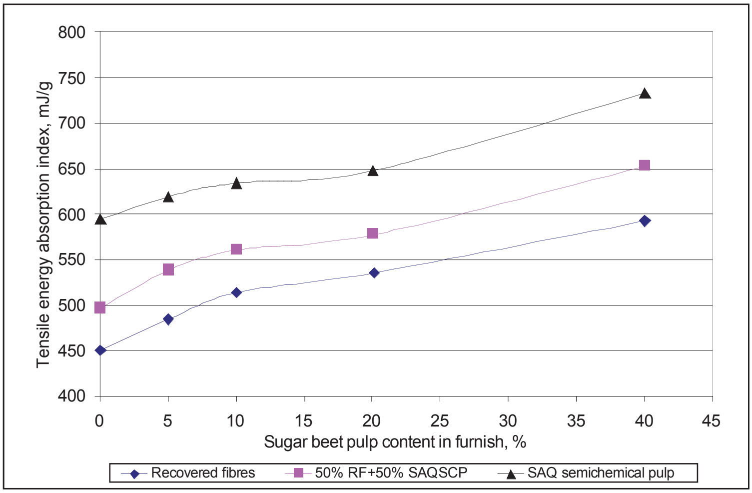


*Fig. 12: Change of tensile energy absorption index of papers from various fibre furnishes with increasing content of sugar beet pulp beaten to 50°SR*

## Influence of sugar beet pulp on surface structure of paper

Variability of paper surface geometry can be evaluated by macro photography and computer image analysis. A paper sample isolated from surrounding light is illuminated with a light source from one direction under a small angle. Under these conditions the image of surface irregularities is accentuated by spots which are illuminated and spots in shade. This method is similar to photoclinometry.

The macro photographic image of paper surface after transformation from RGB mode to grey values mode represents a group of image pixels with different intensity in a range of 256 degrees of grey value corresponding with the geometrical shape of paper surface for the given way and direction of illumination. An image with optically low zoning represents a narrow histogram (in limit a line) with a standard deviation of grey of near to zero value. A broad histogram with high standard deviation of grey value indicates a larger optical variability representing in a final evaluation a larger unevenness of paper surface.

Fig. 13 is a macro photographic image of sugar beet particles beaten in a Valley hollander to 50°SR. On Fig. 14 is a macro photographic image of a particle of sugar beet pulp beaten in a Valley hollander to 50 °SR on the surface of paper from SAQ semichemical pulp. A particle placed in this way causes a maximal change of paper surface structure.

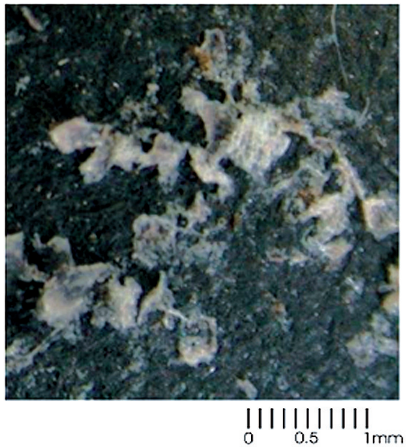


*Fig. 13: Macro photographic image of sugar beet pulp beaten to 50°SR*

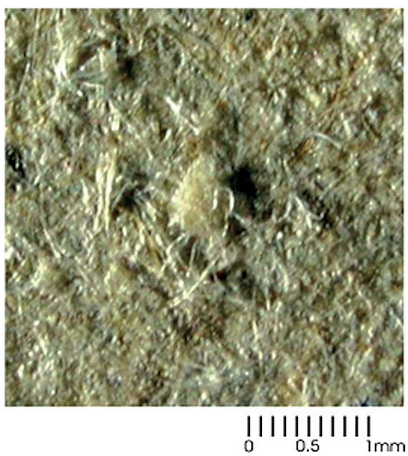


*Fig.14: Macro photographic image of a particle of sugar beet pulp beaten to 50°SR on the surface of paper from SAQ semichemical pulp*

Sugar beet particles are larger than thickness of paper fibres. For evaluation of sugar beet pulp addition on paper surface it is therefore necessary to filter off the image of the fibrous structure of paper as the histogram of paper is comparable with the histogram of original image containing sugar beet particles. The masking effect of the fibrous structure over covers the structural changes caused by the presence of sugar beet particles in a mixture with SAQ semichemical pulp or recovered fibres. The suitable filtration method must be determined experimentally with regard to concrete elements of the image, separation efficiency and overall effectiveness and sensibility of the method.

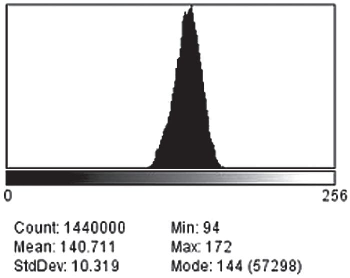


*Fig. 15: Histogram of filtered image of paper surface structure (Paper sheet prepared from recovered fibres with a content of 5% sugar beet pulp beaten to 50°SR)*

Surface structure of paper is expressed by the respective parameters of the grey value image points histogram such as shape, position and width of histogram. The most important parameter is the width of histogram expressed by standard deviation (Fig. 15) or variability. Fig. 15 shows the influence of sugar beet pulp addition on the surface structure of a paper sheet prepared form a furnish of recovered fibres and 15% sugar beet pulp beaten to 50°SR.

Correlation between sugar beet pulp content in furnish and variability of paper surface geometry expressed by standard deviation of the filtered image of paper surface structure histogram is presented on Fig. 16. With increasing content of beaten sugar beet pulp in papers prepared from recovered fibres and SAQ semichemical pulp the standard deviation of grey value is increasing and can be a suitable parameter for evaluation of paper surface quality.

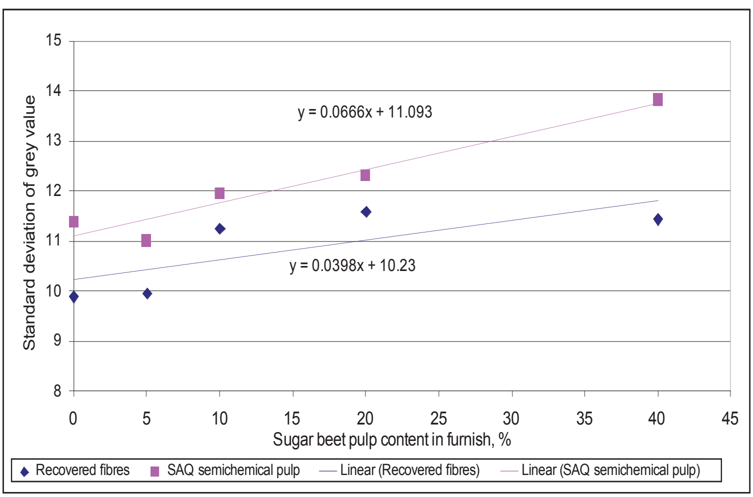


*Fig. 16: Change of standard deviation of paper surface grey value from recovered fibres and SAQ semichemical pulp with increasing content of sugar beet pulp beaten to 50°SR*

## CONCLUSIONS

Sugar beet pulp is an ecologically acceptable additional raw material for paper manufacture. Sugar beet pulp with beating degree approximately 50°SR is suitable as an agent for increase of specific bond strength and a partial replacement of recovered fibres and SAQ semichemical pulp in manufacture of fluting and test liner.

Addition of sugar beet pulp beaten in a Valley hollander to 50°SR to recovered fibres, SAQ semichemical pulp and a 1:1 mixture of these fibres has a favourable influence on internal bond strength, $CMT_{30}$, SCT, burst and tensile index as well as on tensile energy absorption index. Sugar beet pulp increase manly internal bond strength and SCT which depends mainly on specific bond strength of recovered fibres and SAQ semichemical pulp. Beaten sugar beet pulp increases internal bond strength mainly of recovered fibres. This makes possible a partial replacement of SAQ semichemical pulp by recovered fibres while strength properties of fluting and test liner remain on same level.

With increasing content of beaten sugar beet pulp in furnish with recovered fibres and SAQ semichemical pulp bending resistance and porosity decreases which is undesirable from fluting and test liner quality point of view.

Beaten sugar beet pulp increases drainage time and water retention value, reduces initial wet web strength of recovered fibre and SAQ semichemical pulp which impairs productivity of the paper machine.

Macro photographic images of paper surfaces showed with increased sugar beet content in furnish increased variability of paper surface.

Content of beaten sugar beet pulp in fluting and test liner furnishes is limited due to worsening of drainage, increase of water retention and decreasing of porosity. It is therefore recommended to continue research up to a 15% content of beaten sugar beet pulp in furnish.

At a 15% content of sugar beet pulp beaten in a Valley hollander to 50°SR increased $CMT_{30}$ by 3-11%, SCT by 20-23% and burst index by 7-9% of paper from recovered fibres and SAQ semichemical pulp.

## ACKNOWLEDGEMENT

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Ing. Mária Fišerová, PhD.
Pulp and Paper Research Institute
Lamačská cesta 3
841 04 Bratislava
Slovak Republic
E-mail: fiserova@vupc.sk

Ing. Juraj Gigac, PhD.
Pulp and Paper Research Institute
Lamačská cesta 3
841 04 Bratislava
Slovak Republic
E-mail: gigac@vupc.sk

Ing. Rudolf Butaš
Pulp and Paper Research Institute
Lamačská cesta 3
841 04 Bratislava
Slovak Republic
E-mail: butas@vupc.sk