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IMPORTANCE OF THE HARDWOOD CHIPS QUALITY FOR PULP PRODUCTION

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ABSTRACT

The aim of this work was to underline the importance of hardwood chips quality for pulp production under the conditions of modern displacement sulphate cooking.

The speed at which the cooking chemicals come into contact with particular wooden fibres is decisive for the optimal delignification process. This speed is given by chips quality – their dimensional, chemical and moisture uniformity.

Quality of the hardwood chips was evaluated by gravimetric method (amount of impregnated liquor, yeld and content of undercook) and by chemical methods (residual effective alkali content and Kappa number).

The recommendations are summarized and based on obtained knowledge of optimal delignification process of non-uniform hardwood chips:

- recommended thickness of well-impregnating and cooking sapwood chips is 3–4mm,
- recommended thickness of hardly impregnated and cooked heartwood is 2–3mm,
- constant ratio of sapwood and heartwood mixture (the recommended ratio is 4:1),
- the maintenance of constant and high moisture of the chips entering into cooking replacement.

The suitable combination of parameters stated above allows the production of high quality pulp from non-uniform chips.

Key words: hardwood, chips quality, displacement cooking, uniformity of chips, moisture.

INTRODUCTION

Wood is the most widespread raw material in the pulp and paper industry. It has anisotropic character and due to this fact it causes specific problems during its processing.

Technical and technological progress in the pulp and paper industry mainly in the last 30 years brought a demand of new understanding of wood chips quality for sulphate pulping.

Wood chips delignification always presents a reaction in the heterogeneous system and its course is not only determined by the speed of the reaction itself but first of all by the speed of the contact of cooking chemicals with single wood fibres. To reach optimal yield and pulp quality it is necessary for each wood fibre to be in the contact with cooking liquor of the same concentration for equally long time (HNĚTKOVSKÝ 1983).

Penetration and propagation of cooking liquors into the structure of a fibre wall are affected by morphology of a fibre. The following factors are important determinants of liquid penetration:

- chip dimensions
- entrained air
- chip moisture.

HARTLER and ONISKO (1962) evaluated the importance of chip dimensions for pulping uniformity and reject content. They recommended using chips as thin as 2 mm, since the reject content was lowest for thin chips and the viscosity of the holocellulose was stable in the 2−7mm chip thickness interval.

During the impregnation stage, increased liquor-to-wood ratio at high sulphidity increases the amount of available hydrogen sulphide ions and ensures the effective diffusion of hydrogen sulphide into the chips. It has been demonstrated that hydrogen sulphide ions diffuse into the saturated wood faster than do hydroxide ions, possibly because the hydrogen sulphide ions are prevented from entering some of the pores in the wood chip (JACOBSON *et al*. 2006) due to charge exclusion. This is claimed to be the reason why some parts of the wood chip are exposed to higher concentrations of alkali than the others are. This could explain the importance of a high HS^-/OH^- ratio early in the cook (JACOBSON *et al*. 2006). It has been suggested that high concentration of hydrogen sulfide early in the cook is important for increasing the selectivity towards lignin degradation (HARTLER 1978, VIKSTROM *et al*. 1988, SIXTA 2006).

The uniform delignification of wood chips can also be described as homogenous delignification. This means delignifying all the wood chips to the same residual lignin level and all the fibres to a similar lignin content. Low cooking temperatures and thin chips should be used to achieve homogenous delignification (HARTLER and ONISKO 1962). Their investigation provided strong support of the diffusion theory, as opposed to the moving interface theory (KULKARNI and NOLAN 1955), of the liquid impregnation of wood chips. They concluded and recommended that as low cooking temperature as possible should be used, since the wood substance is already completely penetrated at 130−140°C. The cooking temperatures investigated in 1962 were 170°C, 180°C, and 190°C (HARTLER and ONISKO 1962). GULLICHSEN *et al*. (1992) also demonstrated that pulping uniformity could only be achieved by using sufficiently thin chips (1.5–2 mm) under normal pulping conditions, which at that time was a cooking temperature of 175°C.

Unlike other cooking processes, the substantial delignification occurs only after the temperature reaches 140°C, while in the early stage of cooking under this temperature, hemicelluloses are almost exclusively hydrolysed. In the early stages of the cooking process, on condition that cooking is properly controlled and the dimensions of chips are optimal, the process of preimpregnating of chips by cooking liquor practically in all substance occurs even before delignification itself begins. In order to reach the best possible impregnation, the most important dimension of the chip is its thickness. From this point of view, its length and width are not significant. The optimal thickness of chips is about 3–4mm (BUČKO 2001).

To maintain a high enough alkali concentration to neutralize accessible carbohydrates and promote the diffusion of cooking chemicals into the chip, it is very important to reduce the temperature. The driving force for the transport process is favoured by the concentration difference between the outside and inside of the chip.

To achieve good liquor penetration, air must be removed from within the wood chips. This is done by pre-steaming, which also increases the temperature to 100−120°C. The entrained air is removed by the temperature increase in the chip followed by the expansion of the air (GULLICHSEN and FOGELHOLM 2000).

The ideas mentioned above study chemical properties in particular, while anatomical and morphological properties of wood are only taken into account marginally. However, these properties are also very important in the process of impregnation. Displacement cooking of pulp, which is considerably widespread at present, is characteristic by so-called "continualisation of discontinuous process". The impregnating phase here is maximally shortened therefore all the greater demands shall be put on uniform and high quality of chips.

Anatomical and morphological properties of wood elements as well as their share in wood also have very important influence on the impregnation process.

In 1985 Chovanec carried out typification of morphology of hardwood fibrous elements, according to which fibres of all surveyed wood species were classified in Ist to Vth type according to different thickness of wall - from thick-walled (I) to thin-walled (V). On the basis of the relationship between wood density and morphology of wood fibres we might distinguish four characteristic group (POŽGAJ *et al*. 1997).

CBC displacement cooking system

Bleached sulphate hardwood pulp is produced by CBC (Continuous Batch Cooking) process at the biggest sulphate pulp mill Mondi SCP Ruzomberok at present. It is already the third sulphate cooking process in this mill since its putting in operation in 1981. The basic difference between individual cooking processes in this mill could be seen in Fig.1. Demand of assurance of high chips quality results from it.

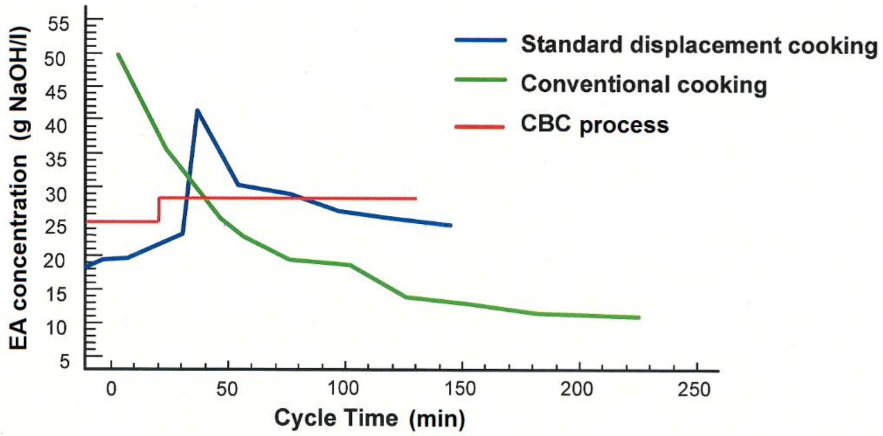

Fig. 1 Comparison of the profile of cooking chemicals for various cooking systems (SIXTA 2006).

The great problem of pulp production by CBC cooking system at Mondi SCP Ruzomberok is treatment of very heterogeneous wood mixture from cca 15 hardwood species, which have different chemical and morphological composition. Wood with good permeability is cooked along with wood with minimum permeability (heartwood) from the start at high temperatures and short times and at this cooking it isn´t possible to achieve uniform impregnation and optimum overcooking of wood.

METHODS

For needs of experiment wood chips of needed thickness (thin 2–3mm and thick 4–5mm) from sound beech and oak wood were prepared by hand. Warm fill liquor (WFL) from Mondi SCP Ruzomberok with concentration of effecitve alkali (EA) 17.2g NaOH/l was used as impregnating liquor in the first step.

Impregnation

Impregnating conditions:	hydromodule (H)	1 : 4
	temperature	120°C
	time	from 0 (-5) till 60 minutes.

Impregnation process was evaluated by amount of impregnated WFL and determined by gravimetric method (g WFL) and by decreasing of REA (residual effective alkali) content (g NaOH/l) and determined by acidimetric titration with hydrochloric acid on phenolphtalein indicator.

Conventional Laboratory Sulphate Cooking

hydromodule (H)	1 : 4
charge of active alkali (AA)	16.5% (c=99.51g Na_2O/l; 128,4g NaOH/l; S=21,8%)
heating (from 80 to 170°C)	2 hours
holding time (at 170°C)	45 minutes.

CBC laboratory cooking

By module 2 of CBC laboratory digester house at Mondi SCP Ruzomberok. Cooking process was evaluated by yields and contents of undercook (both parameters determined by gravimetric method), Kappa number (by STN ISO 302(50 0258)) and REA (according to the method above).

RESULTS AND DISCUSSION

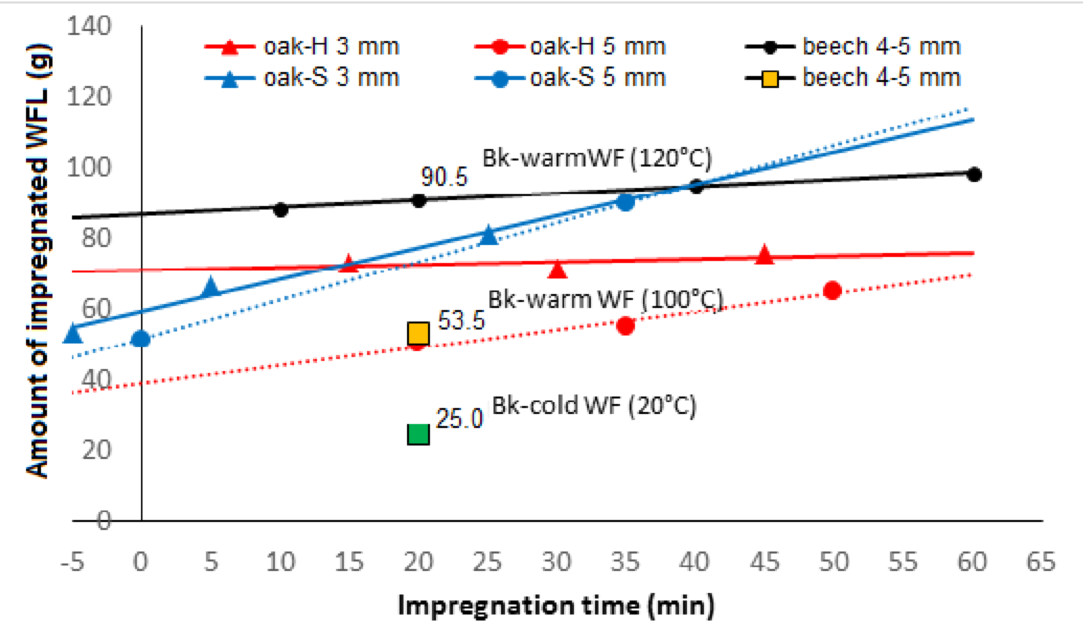

Fig. 2 Process of WFL impregnation - amount of impregnated WFL.

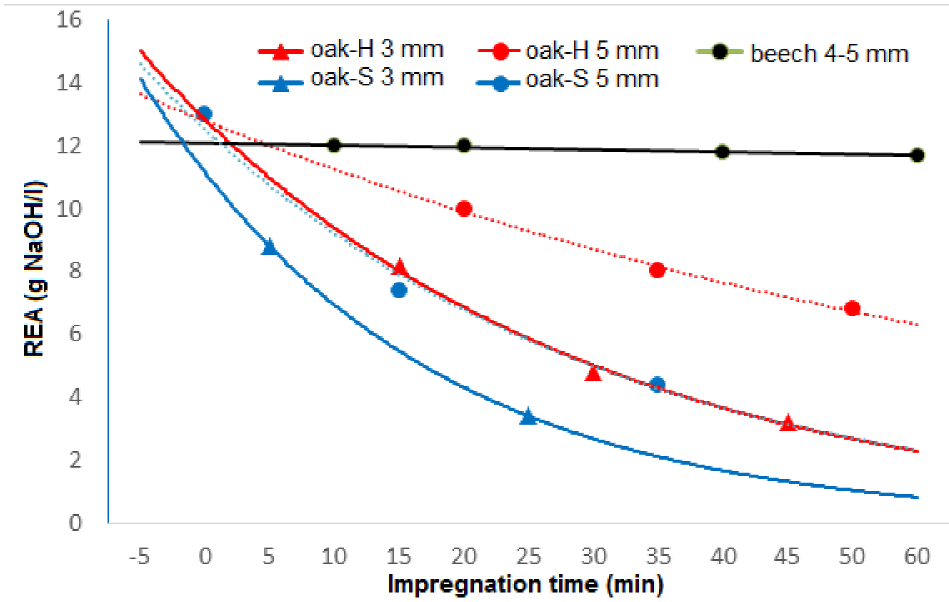

Fig. 3 Process of WFL impregnation – decreasing of REA content.

The above figures of impregnation process show that:

- oak heartwood (oak-H) is impregnated markedly more slowly and harder than sapwood (oak-S). Oak wood in rotation period contains about 70% heartwood,
- thin oak chips (3mm) are impregnated more easily than thick chips (5mm), which could be explained by much greater surface of thin chips. The surface is limiting diffusion processes in impregnation,
- beech chips (4–5mm) have been impregnated more quickly and more thoroughly under equal experimental terms (t = 120°C). It could be explained by different morphology and chemical compound of beech wood. Process of impregnation is markedly dependent on impregnating temperature,
- in impregnation process there occur development of chemical reactions in oak wood (mainly in heartwood) and it increases consumption of cooking alkali.

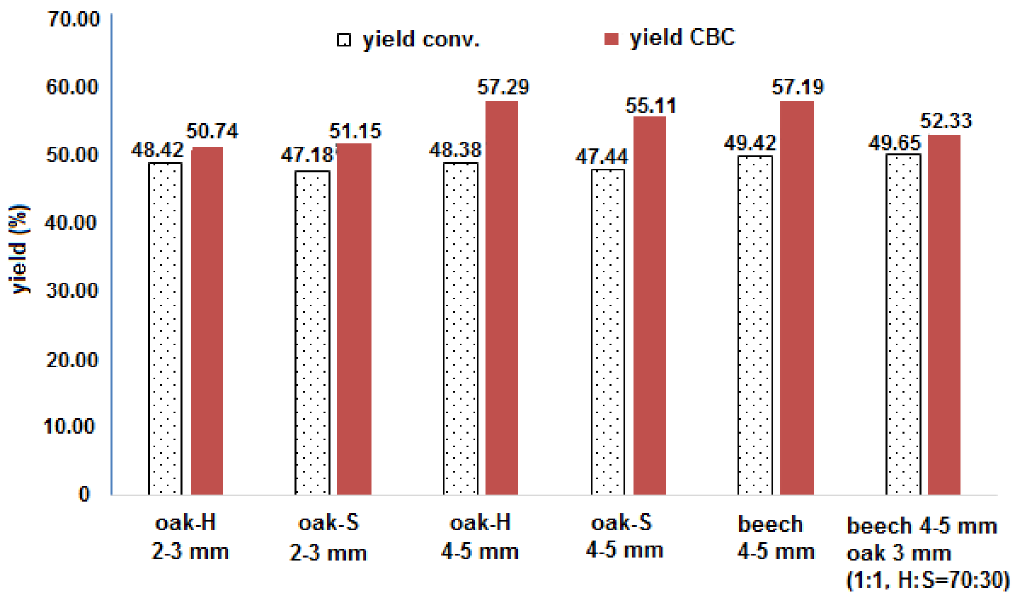

Fig. 4 Dependence of yield on wood species and thickness of chips.

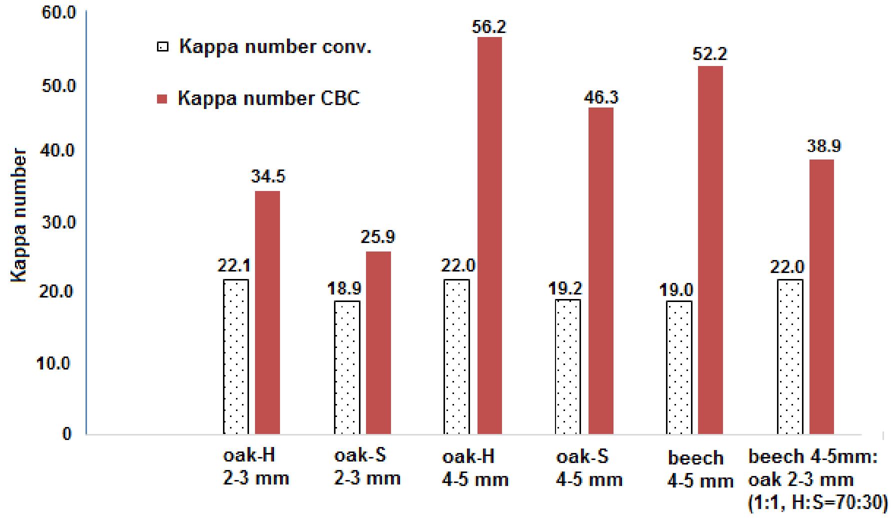

Fig. 5 Dependence of Kappa number on wood species and thickness of chips.

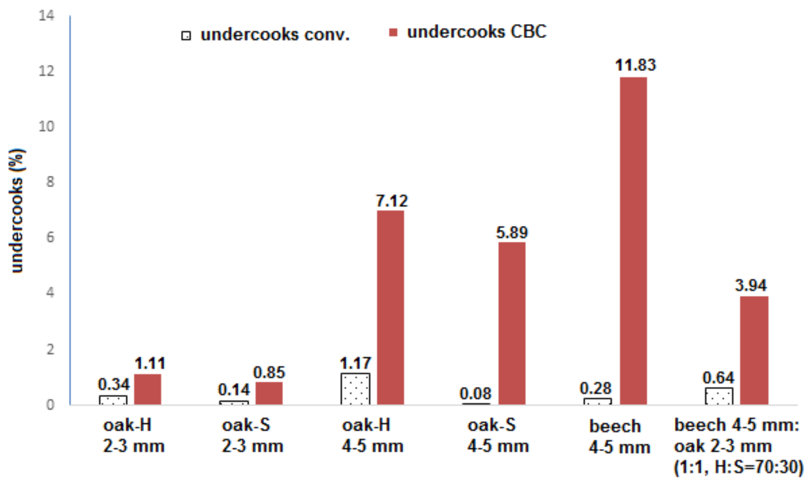

Fig. 6 Dependence of undercook content on wood species and thickness of chips.

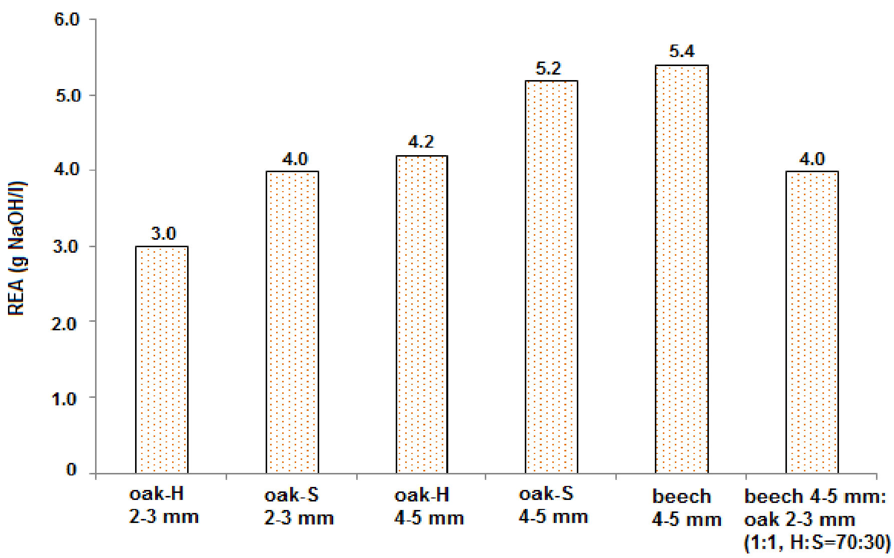

Fig.7 Dependence of REA on wood species and thickness of chips.

From measured data which are shown in the figures 4‒7 it is possible to point out that:
- in conventional laboratory sulphate cooking there was not observed the marked difference of the monitored parameters between cooking of thin and thick chips from oak and of the done mixed cooking (from beech and oak chips in different proportion) either. It was caused by regime of this cooking. In this case we may talk about gradual impregnation of chips by cooking liquor (time about 60 minutes at temperatures under 120°C) and about adequate holding time when there is adequate scope for uniform level of delignification reactions at decreasing of lignin and cooking chemical concentrations,
- the marked different results were obtained by CBC laboratory cooking. These results showed the undone process of delignification reaction, which confirmed high values of monitored parameters - yield, content of undercook, Kappa number,
- since the samples of beech and oak chips were the same in both cases, we may infer that it could be caused by high total solids of used chips (between 86.8 to 89.3%) and this is also mentioned in the works of cited authors.

CONCLUSION

Recommended thickness of well-impregnable and cooking sapwood chips is 3‒4mm and recommended thickness for chips prepared from hard impregnable and cooked heartwood is 2‒3mm.

Significantly slower and incomplete impregnation progress of oak-heartwood chips could be explained by different chemical composition. Oak-heartwood contains so called "heart substances" impregnating heart zone and which causes the closure of conductive elements in wood. Minimal permeability of oak-heartwood caused that the penetration of impregnation solution into chips was possible only by diffusion, accompanied by simultaneous chemical reactions. It is expected that at temperature 120°C mainly more unstable hemicelluloses and acidic extractives from wood were reacting with impregnation solution (WFL with REA concentration 18g/l NaOH).

Regular impregnation and delignification of chips from hardwood mixture necessitate preparing chips with thickness of app. 3mm from species with heartwood ratio greater than 50% (oak, black locust). The recommended ratio of sapwood and heartwood mixture is 4:1.

Different progress of impregnation of chips with thickness of 2‒3 and 4‒5mm was caused primarily by different impregnation surface - the surface of fine chips was larger by 34.6%.

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