INNOVATION IN WOODWORKING INDUSTRY AND ENGINEERING DESIGN, 1/2017 (11): 5–13

CBC KRAFT COOKING OF HARDWOODS WITH VARIOUS QUALITY OF CHIPS

Anton Geffert, Jarmila Geffertova, Blazej Seman
Technical University, Zvolen, Slovakia
e-mail: geffert@tuzvo.sk, geffertová@tuzvo.sk, xsemanb@is.tuzvo.sk

ABSTRACT

The aim of this work was to highlight the importance of chip thickness and type of wood for pulp production under the conditions of modern displacement sulphate cooking CBC (Continuous Batch Cooking).

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

The optimal thickness of well-impregnable sapwood chips 3–4 mm and recommended thickness for chips prepared from hard impregnable heartwood 2–3 mm are very important for impregnation phase of CBC cooking.

Different progress of impregnation of chips with thickness of 2–3 and 4–5 mm can be explained by different impregnation surface - the surface of fine chips was larger by 34.6%.

There are no significant differences between a conventional cooking of chips with different size of the monitored wood species. Influence of the chip thickness and the type of wood on monitored parameters (yield, kappa number, amount of undercooks and REA) in CBC cooking was more evident, because of very high dry matter value of used chips.

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

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

Key words: wood chips quality, displacement cooking, uniformity of chips, impregnation, delignification, yield.

INTRODUCTION

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 primarily 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).

In the early stages of the cooking process, on condition that cooking is properly controlled and the dimensions of chips are optimal, impregnating of chips by cooking liquor practically in all substance occurs even before delignification itself begins. Simultaneous course of the delignification reaction in the chips substance is necessary for well and uniformly overcooked pulp. Shortening of the impregnation phase below necessary time means the imperfect impregnation of chips, creation of unovercooked knots and also non-uniform delignification for each individual kind of wood. On the contrary, extention of impregnating time means improvement of pulp quality. This is true provided chips are uniform and have optimal dimensions. The optimal thickness of chips is about 3–4 mm, optimal length and width are about 18–20 mm (Bučko 2001).

The ideas mentioned above study chemical properties in particular, while anatomical, morphological and physical properties of wood are taken into account only 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.

Impregnation of wood by cooking liquor is together deeply wedded with its porosity and also with liquid permeability, because cooking liquor gets into chips only through the poruses in wood (Požgaj et al. 1997). The defunctioning poruses in wood, e.g. due to deposited substances in heartwood, cause its low permeability and such wood should be cooked in different treatment from the one needed for wood with standard permeability.

The important determinants of liquid penetration are chip dimensions, entrained air and 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 interval of 2–7 mm of chip thickness.

To achieve good liquor penetration, air must be removed from the wood chips. If the original water is heated to sufficiently high temperature and pressures to cause boiling inside the capillaries, the boiling water will displace the entrained air (Gullichsen and Fogelholm 2000).

The uniform delignification of wood chips can also be characterised 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. 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.

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

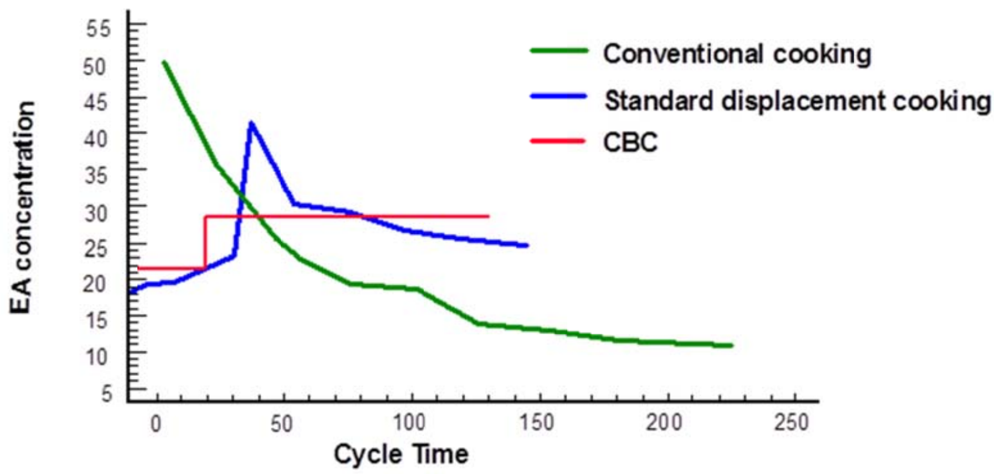

Figure 1: Comparison of the profile of effective alkali (EA) for various cooking systems (Operating manual 2003)

The great problem of pulp production by the CBC system at Mondi SCP Ružomberok 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. At this cooking it is not possible to achieve uniform impregnation and optimum overcooking of wood.

EXPERIMENTAL PART

The wood chips of thickness (thin 2–3 mm and thick 4–5 mm) made from sound beech and oak wood were prepared by hand for needs of experiment. Since, under realistic practice, pulp is produced from blend of chips from different types of wood, conventional and CBC cooking under laboratory conditions of beech chips (4–5 mm of thickness) and oak chips (2–3 mm of thickness) were made in a 1:1 ratio. (Notice: The ratio of the heartwood and the sapwood in oak chips was cca 70:30.)

The liquor of warm fill (WF) from Mondi SCP Ružomberok was used as impregnating liquor in the first step.

Impregnation

residual effective alkali content (REA) in impregnation liquor		17.2 g/dm^3 NaOH
Impregnating conditions:	mass of wood	cca 100 g air-dry chips
	hydromodule	4 : 1
	temperature	120°C
	time	from 0 to 70 minutes.

Impregnation process was evaluated by amount of the used impregnated liquor (m_{WF}) and by decreasing of residual effective alkali content – REA (in g/dm^3 NaOH).

Conventional laboratory sulphate cooking

mass of wood	cca 100 g air-dry chips
liquor-to-wood ratio	4 : 1
charge of active alkali (AA) on oven-dry wood	16,5%
concentration white liquor	128.4 g/dm^3 NaOH
sulphidity	21.8%
heating time (from 80 to 170 °C)	2 hours
holding time (at 170 °C)	45 minutes.

CBC laboratory cooking

The CBC laboratory digester house at Mondi SCP consists of a laboratory digester with a cooking space divided into three chambers (up to 500 grams of air-dry wood chips can be manually dispensed into each chamber), the appropriate tanks and pumps supplemented with the necessary measuring and computer control technology.

The cooking processes were evaluated by total yield, amount of undercook, kappa number and REA.

RESULTS AND DISCUSSION

In Figure 2, the impregnated liquor intake (g) of the wood chips is shown.

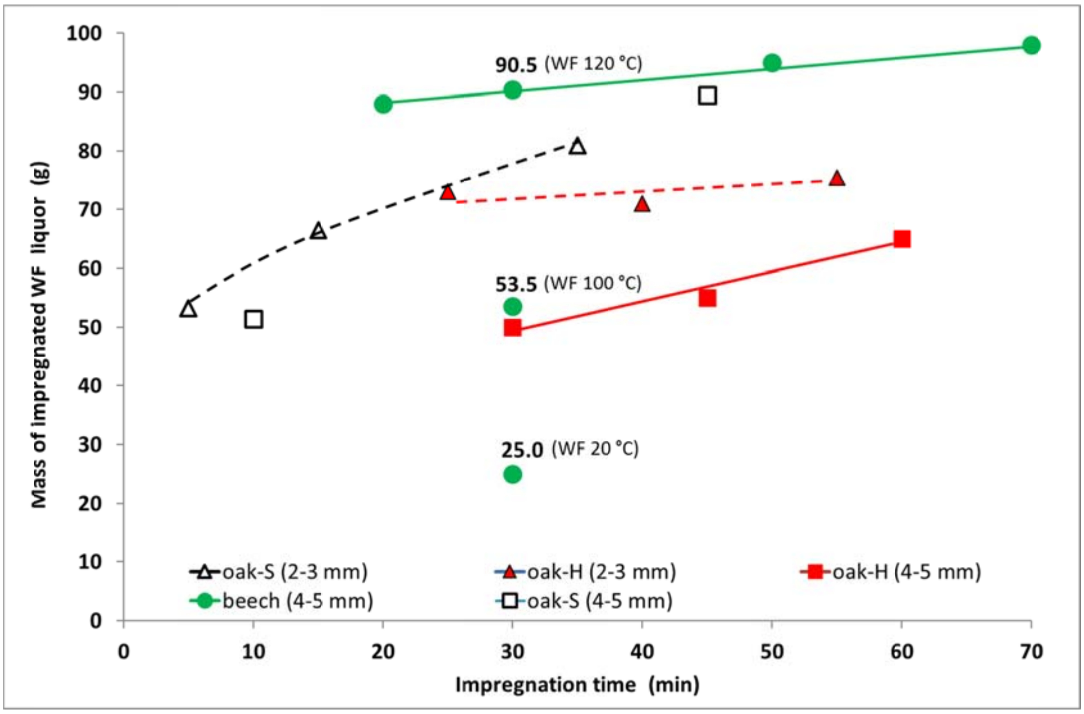

Figure 2: Process of WF liquor impregnation – mass of impregnated WF liquor

It can be seen from the picture that:

- the largest impregnated liquor (WF) intake had beech chips (4–5 mm) for which the intake of WF liquor after 70 minutes was 98 g,
- temperature of the impregnating solution has a pronounced impact on impregnation. At 30 minutes at t = 20°C, beech chips received 25 g of WF liquor, at t = 100°C, the WF of the pulp was 53.5 g, i.e. more than 2 times, and at t = 120°C, the WF intake was up to 90.5 g, i.e. 3.6-fold,

At 30 minutes at t = 20°C, beech chips received 25 g of WF liquor, at t = 100°C, the intake of WF liquor was 53.5 g, i.e. more than 2-fold, and at t = 120°C, the intake of WF liquor was up to 90.5 g, i.e. 3.6-fold,

- the intake of WF liquor seems to be greater for sapwood chips than for heartwood ones. At the impregnation time of 45 minutes at t = 120°C, sapwood chips (4–5 mm) received 89,5 g of WF liquor and heartwood chips (4–5 mm) received only 55 g, the difference was 34.5 g of WF liquor,
- the intake of WF liquor with 2–3 mm thick chips was higher for oak sapwood and heartwood oak as opposed to 4–5 mm thick chips,

- a significant difference is when comparing the impregnation of beech and oak wood chips when the beech chips are impregnated faster and easier,
- significantly slower and incomplete impregnation progress of oak-heartwood chips could be explained by different chemical and morphological 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 causes that the penetration of impregnation solution into chips is 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 (WF liquor with concentration REA 18 g/dm^3 NaOH).

Figure 3 shows the course of residual effective alkali (REA) after impregnation expressed as the concentration of NaOH in g/dm^3.

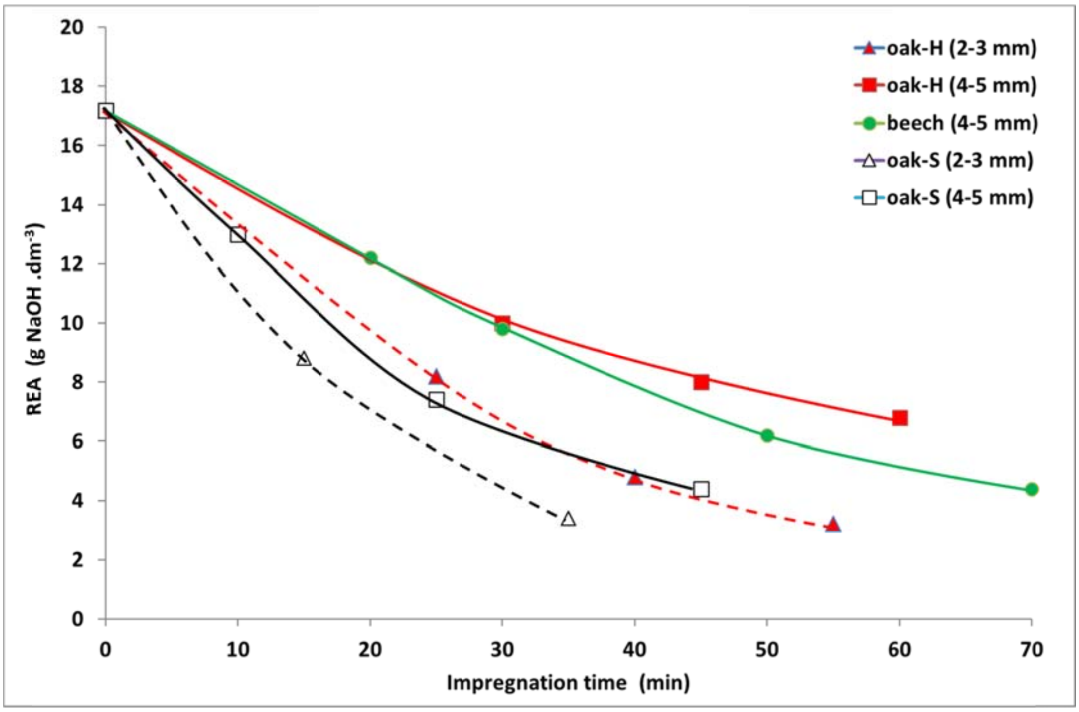

Figure 3: Influence of impregnation time oncontent of residual effective alkali (REA)

It can be seen from Figure 3 that:

- the most important chip dimension for achieving the best impregnation is its thickness,
- the most pronounced decrease in the REA was observed for 2–3 mm thick oak sapwood chips and heartwood chips when the final REA concentration was found to be 3.4 g/dm^3 after 35 min and 3.2 g/dm^3 after 55 min, respectively.
- REA decrease was more pronounced in thinner chips compared to the chips thicker. The optimal thickness of chips according to Bučko (2001) is about 3–4 mm. Chips thicker than 5 mm already make pulp quality significantly worse since they increase the amount of undercooks. Optimal length and width for optimal thickness of 3–4 mm are about 18–

20 mm. Decreasing of chips dimensions in conventional cooking is of any importance neither from the point of view of cooking process acceleration nor from the point of view of improvement of character and quality of produced pulp.

Figure 4 compares pulp yields prepared under laboratory conditions from the studied types of chips by conventional and CBC sulphate processes. It can be seen that:

- yields of pulp achieved by the CBC cooking were in all cases higher than conventional cooking,
- yields of pulp made from thinner chips were lower than yields of pulp made from thicker chips for the CBC cooking,
- yields of pulp made from oak sapwood chips were lower than yields of pulp made from oak heartwood,
- the highest values of pulp yield were found in the CBC cooking of a 4–5 mm thickness oak heartwood chips and also beech chips of 4–5 mm thickness.

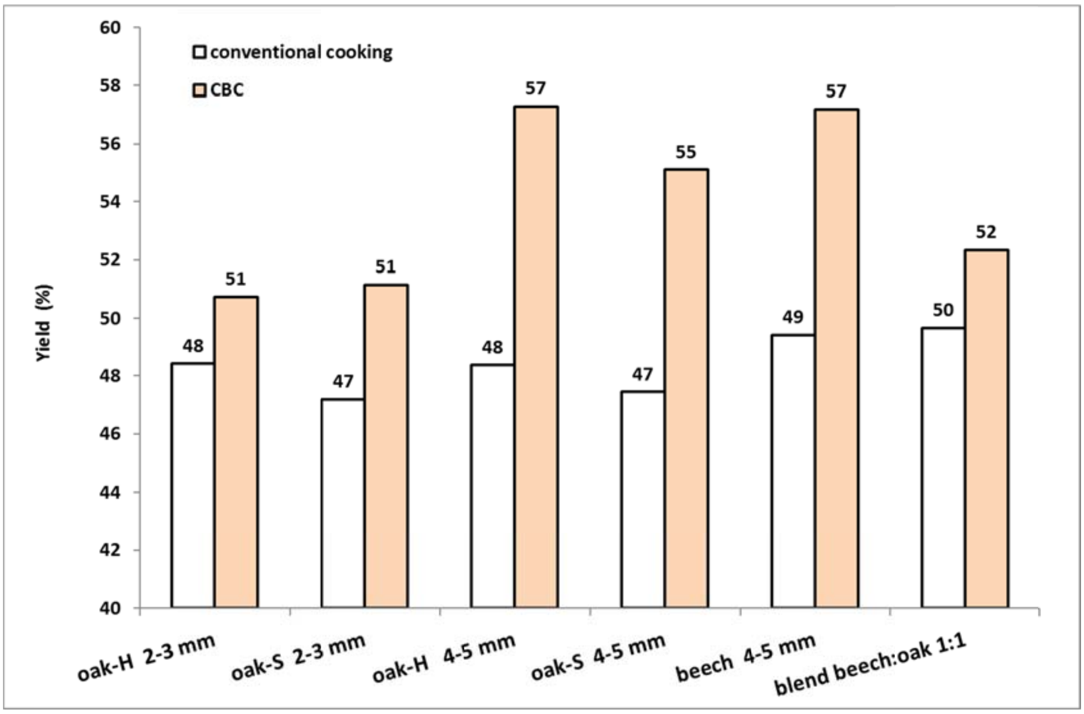

Figure 4: Dependence of yield on wood species and thickness of chips

A similar dependence as in pulp yield may be seen on kappa number (Figure 5), which is related with level of overcooking of various types of wood and residual lignin in pulp (Novák and Petrík 1987, Švec 1992, Potůček and Milichovský 2003). The best cooking was carried out with the oak sapwood chips.

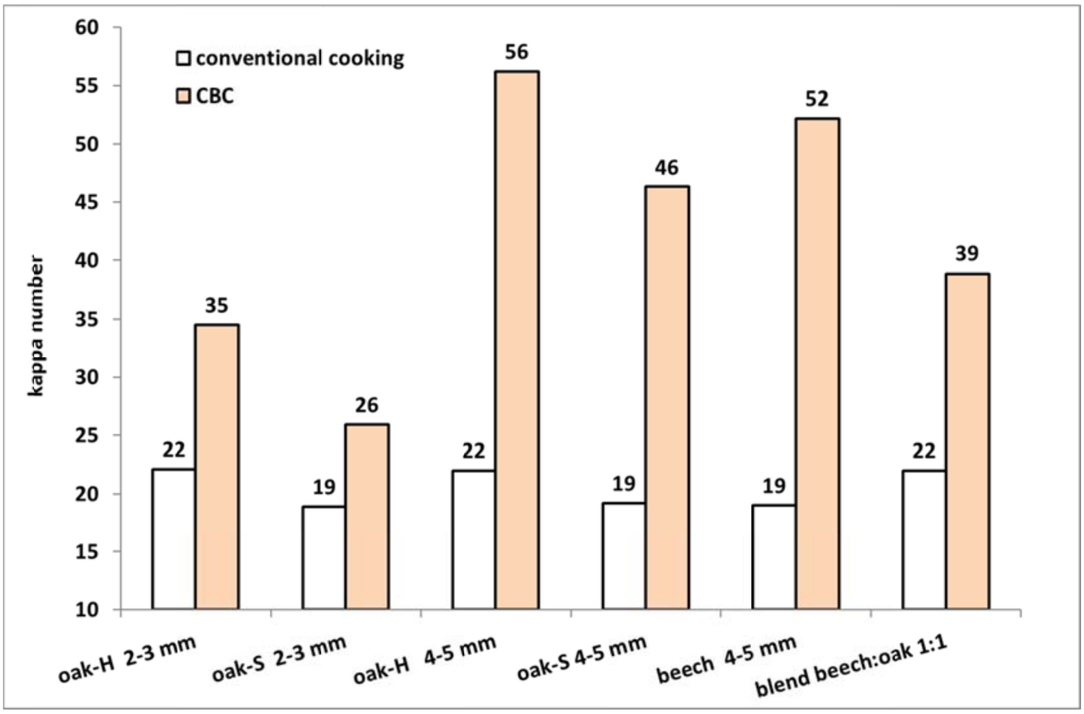

Figure 5: Dependence of kappa number on wood species and thickness of chips

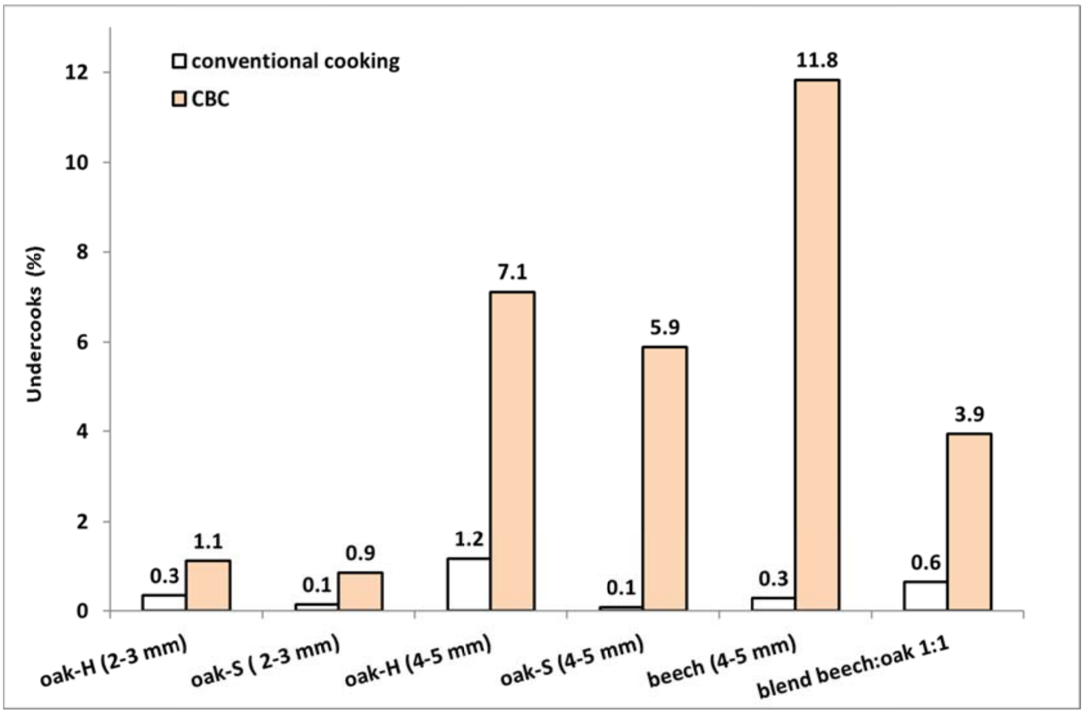

Figure 6: Dependence of amount of undercook on wood species and thickness of chips

The amount of undercooks is illustrated in Figure 6. It can be seen from Figure 6 that:

- amount of undercooks detected in conventional cooking was very low,
- for conventional cooking, the highest value (1.2%) was determined for pulp made from oak heartwood chips of 4 to 5 mm thickness,
- higher values of the amount of undercooks were determined for CBC cookings ranging from 0.9 to 11.8%,

- a larger amount of undercooks was determined for both types of cooking in the pulp from the oak heartwood chips,
- the highest undercook rate was determined for CBC beech chips of 4–5 mm thickness, consistent with the high values of yield (57%) and kappa numbers (52). This suggests that the thickness of 4–5 mm beech chips is no longer suitable for the preparation of pulp in a CBC way.

Thickness of chips directly defines the ratio of knots in pulp. Correct thickness of chips is important mainly for cooking at high temperature. There is need to choose the significantly thinner chips at using higher cooking temperatures, failing which dramatically increases ratio of knots (Hnětkovský1983).

Figure 7 shows residual effective alkali (REA) in black liquor as the concentration of NaOH (g/dm^3) after the conventional sulphate cooking has ended.

From Figure 7, it can be seen that:

- the highest REA value (5.4 g/dm^3) was determined in black liquor from a cooking of beech chips of 4–5 mm thickness, which correlates with a high yield (57%), kappa number (52) and amount of undercooks (11.8%),
- lower REA values as for cooking of beech chips were determined after a cooking of oak chips. The lowest value (3.0 g/dm^3) was found in the cooking of a 2–3 mm thick oak heartwood chips,
- this phenomenon can be explained by differences in morphology and especially in the chemical composition of wood of these wood species, as the cooking chemicals (effective alkali) are consumed in the sulphate cooking process not only for the removal of lignin, but also for the reactions with the substances deposited in heartwood.

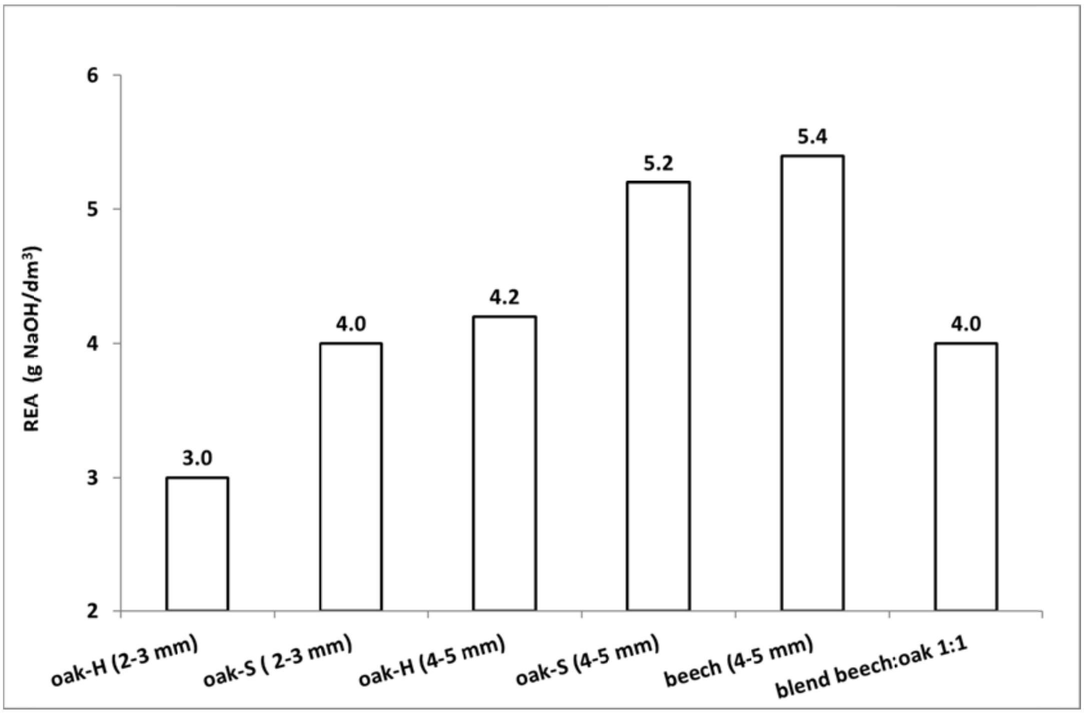

Figure 7: Dependence of REA on wood species and thickness of chips for conventional cooking

The obtained results showed that the values of the monitored cooking parameters (yield, Kappa number, undercooks and REA) are not averaged, and therefore the different quality chips affect each other during a cooking,

From measured data it is possible to point out that:

- no significant difference of monitored parameters between the cooking of thin and thick chips from oak and mixture cooking has been observed in conventional sulphate cooking under laboratory conditions. It can be explained 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,
- significantly different results were obtained by CBC laboratory cooking. These results showed incomplete process of delignification, what was confirmed by high values of monitored parameters – total yield, amount 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 dry matter value of used chips (between 86.8 to 89.3%) and this is also mentioned in the work by Gullichsen and Fogelholm (2000).

CONCLUSION

For impregnation phase of CBC cooking is very important the optimal thickness of well-impregnable sapwood chips 3–4 mm and recommended thickness for chips prepared from hard impregnable heartwood 2–3 mm.

Different progress of impregnation of chips with thickness of 2–3 and 4–5 mm can be explained primarily by different impregnation surface – surface of the fine chips found by calculation was greater by 34.6%.

There are no significant differences between a conventional cooking of chips with different size of the monitored wood species. Influence of the chip thickness and the type of wood on monitored parameters (yield, kappa number, amount of undercooks and REA) in CBC cooking was more evident, because of there was very high dry matter value of used chips.

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

REFERENCES

BUČKO, J. 2001. Chemical processing of wood. 1st ed. Zvolen: Technical University in Zvolen, 427 p. (in Slovak).

GULLICHSEN, J. and FOGELHOLM, C.-J. 2000. Chapter 3: Chemical Engineering Principles of Fiber Line Operations. In Gullichsen, J., 1st ed. Chemical Pulping, Book 6a, Fapet Oy, Helsinki, p. 245–330.

GULLICHSEN, J., HYVÄRINEN, R., and SUNDQVIST, H. 1995. On the non-uniformity of the kraft cook, Part 2. Paperi Puu 77(5), p.331–337.

GULLICHSEN, J., KOLEHMAINEN, H. and SUNDQVIST, H. 1992. On the nonuniformity of the kraft cook. Paperi Puu 74(6), p.486–490.

HARTLER, N. 1978. Extended delignification in kraft cooking – a new concept. Svensk Papperstidn. 81(15), p.483–484.

HARTLER, N. and ONISKO, W. 1962. The Interdependence of Chip Thickness, Cooking Temperature and Screenings in Kraft Cooking of Pine. Svensk Papperstidn. 65(22), p.905–910.

HNĚTKOVSKÝ, V. et al. 1983. Paper Handbook. 1st ed. Prague: SNTL, 1983, 864 p. (in Czech).

KULKARNI, G. R. and NOLAN, W. J. (1955). The mechanism of alkaline pulping. Paper Ind. 37(2), p. 142–151.

NOVÁK, J., PETRÍK, M. 1987. Vplyv skladovania štiepok na výťažok a kvalitu nebielenej buničiny (Influence of chip quality on the yield and quality of unbleached pulp). Papír a celulóza 42(11), p. 265–266.

OPERATING MANUAL, COOKING PLANT. SCP Ružomberok: CBC Retrofit, Lenzing Technik, 2003, 102 p.

POTŮČEK, F and MILICHOVSKÝ, M. 2003. Influence of wood chips quality on kraft pulp's yield and properties. Cellulose Chem. Technol. 37(3–4), p. 249–258.

POŽGAJ, A. et al. 1997. Structure and properties of wood. 2nd ed. Bratislava: Svornosť, 485 p. (in Slovak).

ŠVEC, Š. 1992. Vplyv hrúbky štiepok na niektoré parametre sulfátovej várky (Influence of the chip thickness on some parameters of the sulphate cooking). Papír a celulóza 47(7–8), p. 163–166.

ACKNOWLEDGEMENT

This work was supported by the Scientific Grant Agency VEGA of the Ministry of Education, Science, Research, and Sport of the Slovak Republic – No. 1/0563/16.

UNIVERSITY OF FORESTRY

FACULTY OF FOREST INDUSTRY

INNOVATION IN WOODWORKING INDUSTRY AND ENGINEERING DESIGN

1/2017

INNO vol. VI Sofia

ISSN 1314-6149
e-ISSN 2367-6663

CONTENTS