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CHEMICAL PROCESSING OF WASTE WOOD BASED AGGLOMERATES PART II: EVALUATION OF PROPERTIES OF FLUTING LINERS MADE OF SEMICHEMICAL PULP OBTAINED BY AN ALKALINE COOKING PROCESS

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ABSTRACT

The article describes the method of evaluation and preparation of fluting liners produced from semichemical pulp obtained from waste wood particle boards (PB) and oriented strand boards (OSB). The semichemical pulp was obtained using an alkaline cooking process from a sorted fraction of the 4-8 mm chips. Properties as thickness, bulk density, air resistance of paper sheet, tensile strength, tensile index, breaking length, burst index, CMT_{30} and SCT were monitored on lab sheets 127 g·m^{-2} and 170 g·m^{-2}. Values of pH and residual NaOH were determined in the batch leachate.

KEY WORDS: Waste PB and OSB, fluting, semichemical pulp, alkaline cooking process, delignification

INTRODUCTION

A major problem affecting the increasing cost of suitable wood fiber results from concerns about competing uses for forest lands, environmental impact of forest operations, and sustainable forest management (Ahmed et al. 1998). One of the possible solutions could be the use of non-wood fibers such as straw, kenaf, jute, bagasse, and flax (Atchison 1995, Ihnat et al. 2015a,b, Lubke et al. 2014). Waste PB and OSB can also be used for the production of fiber with a focus on their reuse for particleboards (Ihnat et al. 2017), medium-density particleboards (Mo et al. 2003), low density particleboards (Wang and Sun 2002), sound absorbing materials (Yang et al. 2003), respectively, if looking for an inexpensive replacement for a fluting (Balbercak et al. 2017).

There are several ways of a chemical processing of wood. For wooden mass, the neutral sulphite cooking process (NSSC) with Na_2SO_3 and Na_2CO_3 as main components of the cooking solution is the best for the semichemical pulp quality (Olszewski 1972a, b, Farkas et al. 1978, Janci et al.1988, von Koeppen 1986, Keskin and Kubes 1994, Lovelady 1991, Bierman 1996, Balbercak and Kuna 1998). However, regeneration of chemicals is complicated and is a major source of air pollution with hydrogen sulfide and other sulphur exhalates (Hojnos 1982). In addition, the recycling of wood waste is difficult due to a presence of harmful chemicals contained both in glue used during a manufacture process (Risholm-Sundman and Vestin 2005) and in additives which originally served to protect it from moisture content, wood decaying fungi, to increase fire resistance and so on (Erbreich 2004). A mildly alkaline sulphur-free technology, i.e., technology in which Na_2SO_3 is replaced by NaOH in the cooking solution (Balbercak and Kuna 2002a, b, Lindstrom and Rehnberg 2002) is a replacement of the neutral sulfite cooking process for the semichemical pulp production. The mildly alkaline sulphur-free technology is softer to the wood mass obtained from waste DTD and OSB (Balbercak et al. 2017).

Due to the fact, that it was proved, that cube-shaped samples of PB and OSB during the cooking of waste are very badly accessible to cooking chemicals and do not allow an sufficient impregnation (Balbercak et al. 2017), at this stage of the laboratory tests the disintegration (crushing) of waste material into chips and their sorting onto fractions was applied. Cured adhesives on the surface, but also inside the wood particles, caused a poor impregnation of the wood waste and thus a weak delignification of the PB and OSB cube-shaped samples.

MATERIAL AND METHODS

In the chemical processing of waste PB and OSB, the alkaline cooking process was used as a delignification method. The material was disintegrated before the chemical treatment and only a fraction of the chips (4-8 mm) was used. Laboratory batches were performed in 750 ml laboratory autoclaves. A 50% solution of NaOH was used to prepare a cooking solution for alkaline batches. Batching under the alkaline cooking process was carried out under the following conditions:

Content	100 g oven dry
Cooking solution	10-20% as Na_2O / o. d. wood
Hydromodul	4: 1
Heating from 100 °C to 170 °C	60 min
Impregnation time at 170 °C	0 – 60 min
Total batch time	20-60 min
Batch temperature	165 °C

The cooked samples were separated from the leachate after boiling and were washed several times with hot water. The yield was determined and the cooked samples were defibrated in a laboratory mixer. Individual samples were defibrated using Jokro mill for 30 min and sorted using a laboratory sorter Wewerk through slot screen with 0.25 mm slots. The substance was pulped on a Valley Laboratory Mill (Pažitný et al. 2011) at 30 °SR. Laboratory sheets weighing 127 $g \cdot m^{-2}$ were prepared from sample of semichemical pulp.

Thickness, bulk density, air resistance of paper sheet, tensile strength, tensile index, breaking length, burst index, CMT30 a SCT were measured. The pH values and residual NaOH were determined in batch leachate.

RESULTS AND DISCUSSION

Conditions and results of the laboratory alkaline cooking of sorted fraction 4-8 mm (Balbercak et al. 2017) chips obtained from the disintegrated waste PB and OSB are shown in Tab.1 and Tab.2.

Tab. 1: Conditions and resulting parameters of laboratory alkaline batches of chips from disintegrated PB

Batch No.	A5/1	A5/2	A5/3	A5/4	A5/5	A5/6	A5/7	A5/8	A5/9
Sample	PB	PB	PB	PB	PB	PB	PB	PB	PB
Heating from 100°C to 170°C (min)	60	60	60	60	60	60	60	60	60
Time of cooking at 170°C (min)	0	10	20	20	40	60	20	40	60
Content of active alkali, % Na_2O	10	10	10	16	16	16	20	20	20
Yield (%)	70.3	70.0	68.5	61.3	58.9	55.5	51.5	49.2	45.5
Content of non-cooked matter (%)	7.6	7.0	6.8	4.2	2.1	1.8	0	0	0
Residual lignin (%)	13.5	13.3	12.4	10.3	10.1	8.9	5.8	4.4	3.3
pH	7.9	7.9	7.8	8.1	8.1	8.1	8.2	8.2	8.1
Residual NaOH ($g \cdot l^{-1}$)	7.6	3.4	1.8	16.0	13.9	11.1	24.0	22.0	21.2
Weight ($g \cdot m^{-2}$)	127	127	127	127	127	127	127	127	127
Thickness (μm)	240	240	238	230	228	226	219	215	209
Bulk density ($g \cdot c^{-1} m^{-3}$)	0.55	0.55	0.55	0.54	0.54	0.56	0.58	0.58	0.59
Tensile strength ($kN \cdot m^{-1}$)	3.58	3.57	3.60	6.90	6.81	6.66	6.55	6.59	5.38
Tensile index ($Nm \cdot g^{-1}$)	27.1	27.2	30.0	51.2	50.1	49.9	49.6	48.9	39.1
Breaking length (km)	3.52	3.52	3.7	6.53	6.49	6.46	6.3	6.33	4.95
Burst index ($kPam^2 \cdot g^{-1}$)	1.1	1.1	1.3	2.73	2.70	2.68	2.63	2.60	2.13
CMT30, (N)	130	136	155	217	213	210	190	187	185
SCT ($kN \cdot m^{-1}$)	1.4	1.4	1.6	2.1	2.0	2.0	1.9	1.8	1.8
Air resistance of paper sheet (Gurley method) (s)	3.0	2.9	4.7	22	23	20	29	38	38

Tab. 2: Conditions and resulting parameters of laboratory alkaline batches of chips from disintegrated OSB

Batch No.	A5/1	A5/1	A5/1	A5/1	A5/1	A5/1	A5/1	A5/1	A5/18
Sample	OSB	OSB	OSB	OSB	OSB	OSB	OSB	OSB	OSB
Heating from 100°C to 170°C (min)	60	60	60	60	60	60	60	60	60
Time of cooking at 170°C, (min)	0	10	20	20	40	60	20	40	60
Content of active alkali, % Na_2O	10	10	10	16	16	16	20	20	20
Yield (%)	74.8	74.0	70.1	63.6	62.0	59.1	53.4	52.3	49.6
Content of non-cooked matter (%)	8.1	7.5	6.9	5.1	4.8	2.8	0	0	0
Residual lignin (%)	14.5	14.3	13.8	8.1	6.5	4.7	6.0	5.6	4.0
pH	7.9	7.8	7.8	8.1	8.1	7.9	8.1	8.2	17.1
Residual NaOH (g.l)	5.6	2.4	1.2	15.9	15.8	15.0	20.0	18.0	15.3
Weight ($g \cdot m^{-2}$)	127	127	127	127	127	127	127	127	127
Thickness (μm)	242	240	228	220	220	219	215	215	214
Bulk density ($g \cdot c^{-1} m^{-3}$)	0.56	0.55	0.55	0.54	0.56	0.51	0.51	0.52	0.50
Tensile strength ($kN \cdot m^{-1}$)	3.20	3.20	3.60	6.83	6.9	6.9	6.65	6.51	6.5
Tensile index ($Nm \cdot g^{-1}$)	25.5	25.4	27.5	50.2	51.3	50.8	49.9	49.1	39.3
Breaking length (km)	3.3	3.28	3.55	6.5	6.5	6.4	6.4	6.3	5.2
Burst index ($kPam^2 \cdot g^{-1}$)	0.9	1.0	1.1	2.69	2.7	2.63	2.66	2.63	2.58
CMT30, (N)	120	126	131	220	217	216	201	198	198
SCT ($kN \cdot m^{-1}$)	1.3	1.3	1.4	2.2	2.2	2.1	2.0	1.9	1.9
Air resistance of paper sheet (Gurley method) (s)	2.9	3.2	3.5	20	20	22	28	31	39

As shown in Tab. 1 and Tab. 2, with the increase content of active alkali (A.A.) and with the extension of the cooking time, the overcooking of disintegrated PB and OSB particles was more intensive (Balbercak et al. 2017). The yield of pulp, the content of non-cooked matter and residual lignin in the semichemical pulp gradually decreases too (Bierman 1996). This decrease of the yield, content of non-cooked matter and residual lignin associated with the increasing concentration of active alkali and the cooking time extension is also visible in Figs. 1 to 3 for PB processing and in Figs. 4 to 6 for OSB processing.

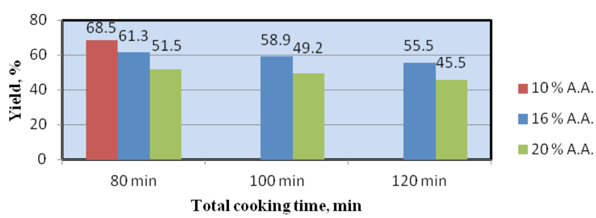

Fig.1: Influence of cooking time and the active alkali content (A.A.) on the yield of the pulp obtained from PB.

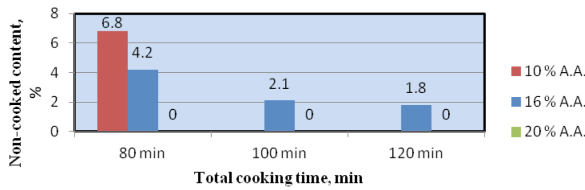

Fig. 2: Influence of the cooking time and the active alkali content (A.A.) on the content of non-cooked matter in the pulp obtained from PB.

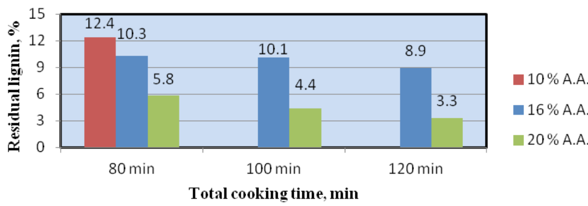

Fig. 3: Influence of the cooking time and the active alkali content (A.A.) on the residual lignin in the pulp obtained from PB.

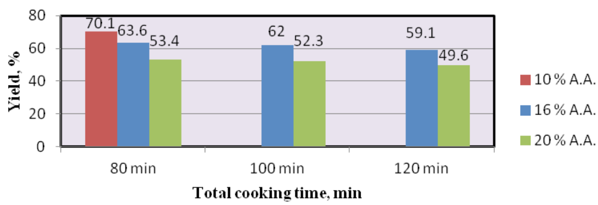

Fig. 4: Influence of the cooking time and the active alkali content (A.A.) on the yield of the pulp obtained from OSB.

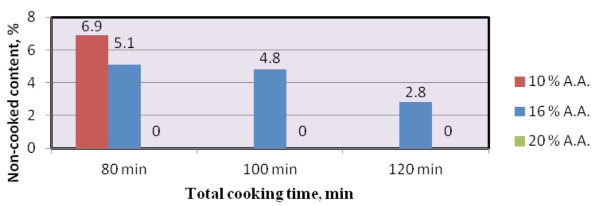

Fig. 5: Influence of the cooking time and the active alkali content (A.A.) on the content of non-cooked matter in the pulp obtained from OSB.

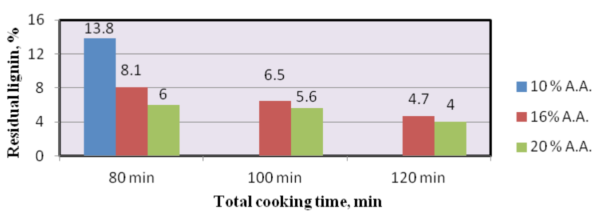

Fig. 6: Influence of the cooking time and the active alkali content (A.A.) on the residual lignin in the pulp obtained from OSB.

On average 3 % higher pulp yields were obtained from the disintegrated OSB waste under the same batch conditions compared to the disintegrated PB waste, as can be seen in Fig. 7. It is possible to see also the effect of active alkali addition (Pažitný et al. 2011) and the extending of the cooking time on the decrease of the yield of pulp prepared by the alkaline cooking.

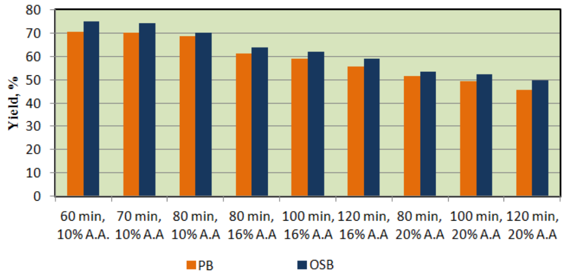

Fig. 7: Comparison of yields of the semichemical pulp prepared from chips obtained from disintegrated PB and OSB.

Strength parameters and their comparison are important for the use of prepared semichemical pulps using the alkaline delignification process (Balbercak and Kuna 1998). Tab. 1 and Tab. 2 shows all measured pulp strengths, prepared by alkaline delignification of PB and OSB disintegrated waste. The best strength parameters were achieved for pulps prepared with 16 % alkali content for both PB and OSB disintegrated waste as seen from the results in Tab. 1 and Tab. 2. Since the purpose of chemical processing of PB and OSB waste was to prepare a semichemical pulp suitable for the fluting liners production, we focused on the evaluation and comparison of strength parameters, especially on the values of the burst index (Pažitný et al. 2013), CMT_{30} and SCT. In view of evaluation of these parameters, 10 % content of active alkali appears as insufficient.

The values of burst index, CMT_{30} and SCT, which correspond to the nature appropriate for production of Brown Testliner 4, i.e., liners with the lowest strength parameters produced from the recycled paper or for the production of "Recycled Fluting Medium 2", were achieved at the 10 % content of active alkali in combination with the longest total batch time. The extending of the total cooking time over 80 min was not reasonable, as the residual NaOH in the leachate was close to 0 $g \cdot l^{-1}$.

Active alkali content of 20 % for the alkaline delignification of PB and OSB disintegrated waste caused a significant decrease of pulp yield with strength parameters better than at 10 % A.A., but with worse values of the burst index, CMT_{30} and SCT, as compared to 16 % A.A. The content of 20 % A.A. due to the significant loss of fibers (low yields) and the strength properties seems to be already unnecessarily high for the next preparation of fluting liners.

From the point of use of the semichemical pulp for the fluting/liners production, the best results were obtained with alkaline delignification of PB and OSB disintegrated waste with 16 % A.A. The strength parameters of both PB and OSB disintegrated waste pulp have matched parameters for the "Semi Chemical Fluting 2" production, and also for "Brown Testliner 2" production. The parameters were also achieved already for the total cooking time of 80 min. No further increase of the strength parameters has been achieved after the extension of the cooking time at 16% A.A. On the contrary, it has meant an undesirable significant decrease of the yield of the pulp.

Comparison of individual values obtained from the alkaline delignification with 16 % A.A. is shown in Figs. 8 - 11.

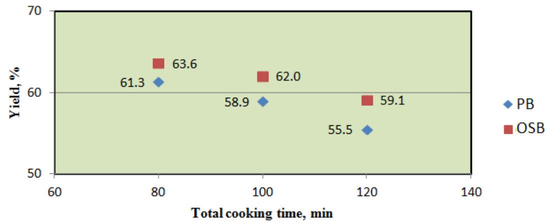

Fig. 8: Comparison of yields of the semichemical pulp prepared from chips obtained from disintegrated PB and OSB at the 16 % alkali content.

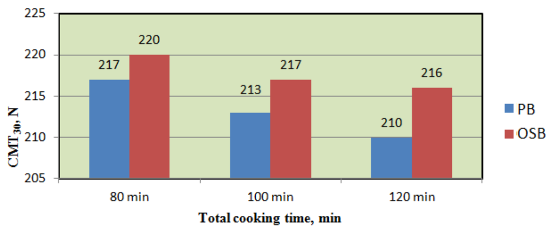

Fig. 9: Comparison of CMT30 of the semichemical pulp prepared from chips obtained from disintegrated PB and OSB at the 16 % alkali content.

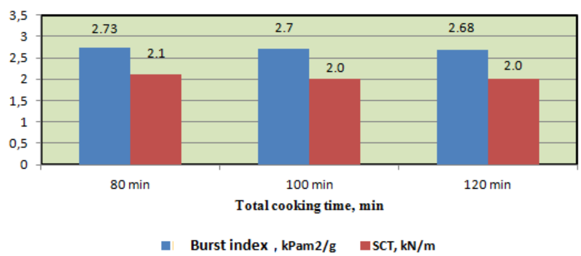

Fig. 10: Burst index and SCT of the pulp obtained from disintegrated PB at the 16 % alkali content.

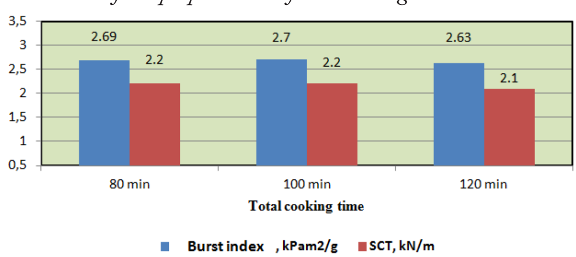

Fig. 11: Burst index and SCT of the pulp obtained from disintegrated OSB at the 16 % alkali content.

Evaluation of values shown in Figs. 8 - 11 revealed that under the same cooking conditions of the alkaline batch, at 16% A.A., the same strength parameters of pulp prepared from PB and OSB were achieved, with a difference corresponding to the pulp yield of OSB disintegrated waste was about 2.3 - 3.6 % higher than from PB.

CONCLUSIONS

The alkaline method of the delignification of chips of the 4-8 mm fraction obtained from disintegrated PB and OSB waste was used. Laboratory tests showed:

- The results of alkaline delignification of the PB and OSB disintegrated wood waste showed that the best strength parameters were achieved for pulps prepared with 16 % A.A. from both PB and OSB. Since the purpose of chemical processing of the PB and OSB waste was to prepare a semichemical pulp suitable for fluting/liners, the strength parameters – burst index, CMT_{30} and SCT were evaluated. In view of the evaluation of these parameters, the content of 10 % of the A.A. for the alkaline delignification appears as insufficient.
- In the alkali delignification of the PB and OSB waste at the 10 % A.A. even for the longest total batch time the values of burst index, CMT_{30} and SCT corresponded only to the parameter appropriate for the production of "Brown Testliner 4", i.e., liners with the lowest strength parameters produced from the recycled paper or for the production of "Recycled Fluting Medium 2". The extending of the total cooking time over 80 min was not reasonable, as the residual NaOH in the leachate was close to 0 $g \cdot l^{-1}$.
- The content of 20 % of the A.A. in the alkaline delignification of the PB and OSB disintegrated waste brings the decrease of yields but with better strength parameters. Worse values of the burst index, CMT_{30} and SCT are achieved than for the content of 16% A.A. Due to the significant loss of fibers (low yields) and the strength properties of the pulp, the content of the 20 % A.A. in alkaline delignification of the PB and OSB disintegrated waste seems to be already superfluous for the preparation of fluting pulp resp. liners.
- The best results were obtained with alkaline delignification of PB and OSB disintegrated waste with 16 % A.A. Already for a total cooking time 80 min the strength parameters of both PB and OSB disintegrated waste matched "Semi Chemical Fluting 2" and also "Brown Testliner 2". Extending of the cooking time at 16 % A.A. meant no further increase of strength parameters, however, it has meant an undesirable significant decrease of the yield of the pulp.

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