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The effect of liquor to wood ratio on NSSC pulp chemical composition and fibers distribution characteristic

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Abstract: *The effect of liquor to wood ratio on NSSC pulp chemical composition and fibers distribution characteristic.* The aim of this work was to find the differences in chemical composition and fiber's morphology obtained after pulping process with various liquor to wood ratio conditions. Cooking at low liquor to wood ratio (1.4) did not influenced the chemical composition and yield of NSSC pulp. The experiment with 1.2 and 2.0 liquor to wood ratio has shown the changes of fibers distribution which may cause differences in pulp strength properties.

Keywords: NSSC, liquor to wood ratio, pulp, statistical methods

INTRODUCTION

Neutral Sulphite Semi Chemical (NSSC) pulp share market is counted approximately 5-7% of the available paper pulp. Fibers of this high yield pulp show very good stiffness and are used for packaging grades called Fluting with destination of corrugated medium in multilayer cardboard. NSSC pulp may be applied, as an addition, during manufacturing various products such as writing and printing paper, tissue paper, bag grades and others products [Area et al. 1997].

Optimization analysis during cooking process in most of the plant fibers were based on delignification kinetics showing the influence of process variables on pulp strength properties [Jiménez et al. 2000]. There is still lack of literature describing the influence of technological factors (liquor to wood ratio, time, temperature) on fibers characteristic (e.g. length, curls, shives).

The aim of this study was to establish as well the chemical composition of pulp and its possible relations with changed liquor to wood (l/w) ratio during cooking process as fibers distributions in pulps obtained with the use of two extreme l/w ratios 1.2 and 2.0 (with and without red liquor addition to the impregnator).

MATERIAL

Industrial chips obtained from birch trees (*Betula verrucosa*) were used as raw material. The chips included following fractions: >O45 – 1.1%, >II8 – 5.7%, >O7 – 91.0%, >O3 – 2.1%, the rest – 0.1% (O and II mark holes and slots diameter in mm according to Brecht-holl classification) (SCAN–CM–40:94).

PULPING METHODOLOGY

All cooking experiments were carried out on industrial NSSC production line with controlled capacity and with the 82% average yield of the process.

Starting cooking liquor concentration was the same during all experiments (165g/dm^3 Na_2SO_3; 50g/dm^3 Na_2CO_3). After processing at 179°C for 14,5 min and at different conditions of liquor to wood ratio, the chips were defibred by disc refiner with 36% of concentration.

During examination of fibers characteristics of two pulps obtained with extremes l/w ratios, in one of them red liquor has been added.

STUDIED PARAMETERS

Pulp samples were collected after cooking with 1.4, 1.5, 1.7, 1.8 liquid to wood ratio (l/w). For each tested l/w the chemical components such as extractives (PN-62/P-50097), 1% NaOH solubility, α-cellulose (PN-62/P-50099 from holocellulose), lignin (PN-74/P-50092) and holocellulose (PN-74/P-50092) were determined. Collected pulp samples, after cooking with 1.2 and 2.0 with and without red liquor addition, were refined in PFI laboratory mill to gain four levels of pulp freeness: 20ºSR (Schopper-Riegler), 25ºSR, 30ºSR, 35ºSR. The fibers distribution was evaluated (ISO 16065-2) in all tested samples at various stages of pulp freeness as well as in reference sample which was obtained from the production line.

STATISTICAL ANALYSIS

In order to find the interaction between variable l/w ratio and chemical pulp components the analysis of variance (ANOVA) and mean values standard deviations were determined [Shapiro and Wilk 1965]. Analysis of the data was performed using the statistical package GenStat v. 10.1 (GenStat 2007).

RESULTS AND DISCUSION

It was recognized the l/w ratio and freeness have influenced CMT, SCT, Burst and Tear strength parameters [Joachimiak, et al. 2011]. In this work we studied relations between above mentioned variables, chemical composition of pulps and fibers distribution.

At the beginning the analysis of variance for all determined chemical components were calculated. As shown in Table 1 there is no significant differences between 1% NaOH solubility, α-cellulose, lignin, holocellulose and l/w ratio. Only extractives presented significant changes. The result indicates the higher l/w ratio the higher value of extracted substances could be gained.

Table 1 Mean squares analysis of variance for extract, 1% NaOH solubility, α-cellulose, lignin, holocellulose

Source of variation	Extractives		df	1% NaOH solubility	α-cellulose	Lignin	Holocellulose
	df	ms		ms	ms	ms	ms
l/w	3	0.047***	3	0.13164	1.298	0.286	0.34413
Residual	12	0.004	8	0.04263	0.484	0.302	0.09375

l/w – liquid to wood ratio, ms – mean squares, *** - significant at 0.001 level

Table 2 Mean values of chemical components and standard deviations (sd) for different l/w.

		l/w				$LSD_{0.05}$
		1.4	1.5	1.7	1.8	
Extractives	Mean	1.075	1.022	1.197	1.259	0.0976
	sd	0.04478	0.07551	0.07586	0.05101	
1% NaOH solubility	Mean	29.17	29.53	29.42	29.58	0.3367
	sd	0.2743	0.105	0.2369	0.1677	
α-cellulose	Mean	70.73	70.99	71.54	70.17	1.134
	sd	0.596	1.1131	0.4292	0.3946	
Lignin	Mean	15.45	15.07	14.97	14.82	0.896
	sd	0.2589	0.8101	0.6835	0.1323	
Holocellulose	Mean	77.53	77.43	77.04	77.74	0.4993
	sd	0.5458	0.1552	0.0954	0.2095	

l/w – liquid to wood ratio, LSD – least significant difference

The data in Table 2 show that the l/w ratio (in range 1.4 – 1.8) has not modified chemical structure of produced fibers. It means the production efficiency of the process remains unchanged in low 1.4 and higher 1.8 l/w ratio conditions. Basing on these results,

lower l/w ratio will not affect chemical structure of the fibers and from such perspective can be used in the production process. Nevertheless some tendencies were observed: when varying l/w ratio up to 1.7, α-cellulose content increases, at the same time lignin content decreases. Pulp cooked with 1.8 l/w brings some decrease of lignin and α-cellulose which may be cause of lower yield during cooking in higher l/w ratio conditions.

According to results in Table 1 and 2 it is not feasible to relate the changes of pulp strength properties, observed at various l/w ratios, to chemical composition of pulp. Possible explanation may be that different l/w modifies fibers in other way. At the same time they probably influence its susceptibility to refining process. To find the right answer the analysis of fiber length distribution were examined for pulp obtained during cooking with extreme l/w ratios 1.2 and 2.0 with and without red liquor addition to impregnator. Red liquor stream is the regular flow in the process that is way such option is taken into consideration.

Table 3 presents all results of fiber distribution collected from pulps obtained after PFI laboratory mill refining. The most interesting results show that for 1.2 l/w fines content is lower than in samples from 2.0 l/w. Short (for all freeness) and long (for 25 - 35°SR) fibers group is wider also for 1.2 l/w. The middle length of fibers is almost the same for both 1.2 and 2.0 l/w. This is the biggest group of fibers which deliver main strength for paper. Shives content is lower on each freeness level for 1.2 l/w. Lower shives content in the paper improve its quality by better runability, printability and smoothness [Tomoyoshi 1999].

Table 3 The effect of liquor to wood ratio on NSSC pulp fibers and shives characteristic

	Before PFI		20° SR		25° SR		30° SR		35° SR	
	2	1.2	2	1.2	2	1.2	2	1.2	2	1.2
Fiber length	1.04	1.04	0.98	0.97	0.94	0.95	0.94	0.95	0.93	0.93
Curl	6.0	5.5	4.8	5.2	5.0	5.0	5.1	5.3	5.2	5.0
Fines	6.3	5.5	4.1	4.0	4.5	4.2	4.5	4.2	4.7	4.4
Short	34.5	35	37.0	37.8	38.2	38.7	38.6	39	39.3	39.0
Middle	47.5	48.2	50.8	50.2	50.8	50.1	50.0	49.2	49.8	50.0
Long	11.7	11.3	8.1	8.1	6.5	7.0	6.9	7.6	6.3	6.5
Shives all	11.79	16.56	3.18	1.39	1.61	0.99	1.31	0.91	0.55	0.49
Break	11.08	15.82	2.85	1.12	1.31	0.65	1.12	0.65	0.38	0.29
Dust	0.71	0.74	0.33	0.28	0.26	0.34	0.18	0.26	0.17	0.19

Table 4 The effect of liquor to wood ratio on NSSC pulp fibers and shive characteristic (with red liquor addition)

	Before PFI		20° SR		25° SR		30° SR		35° SR	
	2	1.2	2	1.2	2	1.2	2	1.2	2	1.2
Fiber length	1.05	1.06	0.97	0.96	0.96	0.95	0.94	0.95	0.94	0.94
Curl	6.4	5.9	5.0	4.7	5.4	4.7	5.2	4.9	5.0	5.0
Fines	6.1	5.5	4.2	4.1	4.4	4.0	4.7	4.1	4.7	4.3
Short	35.1	35.0	37.2	37.8	37.8	38.5	38.4	38.4	38.4	39.1
Middle	46.7	47.2	50.7	50.8	50.1	50.6	50.0	50.7	50.0	50.0
Long	12.1	12.3	7.9	7.3	7.7	6.9	6.9	6.8	6.9	6.7
Shives all	16.67	16.05	2.14	2.05	1.44	1.42	0.59	1.08	0.94	0.60
Break	16.07	15.98	1.72	1.66	1.11	1.12	0.32	0.89	0.71	0.34
Dust	0.60	0.67	0.42	0.39	0.33	0.31	0.26	0.19	0.23	0.25

The second pair of 1.2 and 2.0 l/w ratio results with red liquor addition are collected in the Table 4. Group of short and middle fibers is higher for 1.2 l/w. There is even more middle fibers than in pulp from 1.2 l/w obtained without red liquor addition for each freeness level. Also content of long fibers is more favorable (lower) for 1.2 l/w with red liquor addition

comparing to 2.0 l/w and 1.2 l/w without red liquor excluding 35°SR freeness. It means that more separated fibers were treated in PFI laboratory mill refiner and some refining effect occurred with transferring long fibers group to another. However the shives content for 1.2 l/w ratio with red liquor addition is higher than in the appropriate chart for testing group without red liquor. The 2.0 l/w with red liquor results for 25°SR and 30°SR brings lower shives content than the sample from 2.0 l/w ratio without red liquor addition.

CONCLUSIONS

It has been proved that in conditions of variable liquor to wood ratio in range 1.4 – 1.8 chemical composition of fibers have not differed significantly and cannot be the explanation for strength pulp properties changes. Fiber distribution in pulp samples obtained from 1.2 and 2.0 l/w ratios and refined to four levels of freeness has shown changes which could be used to describe differences of paper strength properties.

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Streszczenie: *Wpływ modułu cieczy warzelnej na skład chemiczny i frakcyjność włókien masy obojetnosiarczywnowej (NSSC).* Celem pracy była ocena wpływu modułu cieczy warzelnej na zmiany składu chemicznego masy oraz charakterystyki morfologicznej włókien. Doświadczenia wykazały, że można prowadzić warzenie w skali przemysłowej przy niskim module 1.4 bez znaczących zmian w składzie chemicznym i wydajności masy. Stosując moduły 1.2 i 2.0 (z dodatkiem ługu czerwonego do impregnatora oraz bez dodatku tego ługu) stwierdzono zróżnicowanie morfologiczne włókien, z którym można wiązać odmienne właściwości wytrzymałościowe badanych mas.

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