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Studying the Effects of Refining Intensity on Fiber Properties of NSSC Pulp

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Abstract: This study evaluates the effects of refining intensity on fiber properties of Neutral Sulfite Semi-Chemical (NSSC) pulp, made from bagasse. Cooking process was implemented in the following conditions: cooking temperature 170°C, cooking time 30 minutes and cooking liquor 20%. The refining procedure used PFI mill with different revolution speeds of 2600, 3800, 4500 and 5500 rpm. Analysis of variance for fibers was conducted in a completely randomized design, followed by mean values comparison using Duncan's test. Obtained results revealed that there has been a significant difference at 95% level between pre-refining and post-refining values of fiber length and diameter, lumen diameter, fiber wall thickness. This study showed that increasing the rotation speed to 5500 rpm, will increase the fines content. Therefore, it was proposed to perform refining at lower revolution speeds. Finally, optimized refiner revolution speed of 3800 rpm was suggested with fiber properties and pulp freeness of 402 ml CSF.

Key words: Bagasse · Neutral sulfite semi-chemical (NSSC) pulp · Refining intensity

INTRODUCTION

Refining is believed as the essential phase of developing pulp fibers to their desired quality level during the pulping process. It causes a variety of simultaneous structural changes including internal fibrillation, external fibrillation, fines formation, fiber shortening or cutting and fiber curling or straightening [1-5]. Generally speaking, two operations are done simultaneously on fibers during a typical pulp refining, namely opening each fiber and opening the fiber layers to increase elasticity and flexibility characteristics [6, 7]. Refining may create major changes in pulp properties and therefore, it may have significant effects on formation of the paper. Refining will lead to internal fibrillation, external fibrillation, fiber shortening, fiber straightening and fines formation as well. It has been reported that the shortening effect of refining can improve paper formation due to decrease in the crowding number which would lead to lower tendency to flocculate [8, 9] in addition to smaller nodules [10]. An increase in refining intensity will reduce fiber's length and coarseness. This effect is most pronounced in the double disc refiner systems, not quite strong in the single disc systems with the weakest being in laboratory using a deflaker system [11]. By increasing the refining intensity, fibrillation process of thin fibers will be increased, while the overall gap occurs in thick fibers [12]. Shearing or cutting the primary wall of fibers during refining, results in better fibrillation and flexibility [13]. Vaziri (2008) concluded that there was significant difference at 1% statistical reliability level between the pre-refined and post-refined amounts of fiber length and diameters, lumen diameter and fiber wall thickness of *Brosia Pine* wood fibers. Increasing rotation speed of the refiner will weaken all properties of the fibers [14]. Moreover, numerous studies have shown similar results in the literature [6, 7, 15, 16]. This research was aimed to study the effects of refining intensity on the fiber characteristics of neutral sulfite semi-chemical (NSSC) pulp made from bagasse.

MATERIALS AND METHODS

Materials: The used bagasse (*Saccharum officinarum*) in this study was collected from a local pulp and paper mill (Pars Paper Company, Haft Tappeh, Iran).

Experimental: Wet samples were transferred to laboratory of the research center at Mazandaran Pulp and Paper factory. Neutral sulfite semi-chemical (NSSC) pulping using experimental rotation and cut off digester (HATTO)

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Table 1: Conditions of Neutral Sulfite Semi-Chemical (NSSC) pulping from bagasse

NSSC Pulp Condition		NSSC Pulp Condition	
Ratio L:W	10:1	Consumed chemicals (%)	20
Impregnation time (min)	30	Pressure (bar)	9.5
Na_2O (gr/l)	135	Initial pH	10.15
SO_2 (gr/l)	95	Final pH	8.95
Temperature (°C)	170	Yield (%)	74.95
Cooking time (min)	30	Chemical consumed	Sodium Sulfite (NA_2SO_3)

with 10 L capacity and 500 g of wet bagasse were implemented in each trial. Pulping time was measured after reaching the desired pulping temperature. Bagasse cooking was carried out using white liqueur from Mazandaran Pulp and Paper factory, including sodium sulfite (Na_2SO_3) and sodium carbonate (Na_2CO_3) at 2.77 to 1 weight ratio of sulfite to carbonate. Cooking conditions are summarized in Table 1.

Refining Conditions: PFI[1] mill (LABTECH model) was used to refine the pulps. Refining operation was performed under 4 different rotation speeds of 2600, 3800, 4500 and 5500 rpm.

Measurement of Fiber Biometry Properties: Some pieces of NSSC pulp obtained from 4 different rotation speeds were defibrated using a technique developed by Franklin (1954) [17], then fiber length, fiber diameter and lumen width were measured using a Leica Image Analysis System. The wall thickness of fibers was calculated as the halved difference between fiber diameter and lumen width. Thereby, dimensions of some 120 fibers were measured randomly.

Statistical analysis was conducted using SPSS software (Version 11.5) in conjunction with the analysis of variance (ANOVA). Duncan's Multiply Range Test (DMRT) was employed to test the statistical significance at α=0.05 level.

RESULTS

Effect of Refining Intensity on Fiber Length: The analysis of variance shows that the effects of refining intensity on the fiber length were significant at 95% confidence level (f=86.76, sig=0.000). Effect of the refining intensity on the fiber length is also shown in figure 1. It can be observed that the fiber length has been decreased with increase in the refining intensity.

Effect of Refining Intensity on Fiber Diameter: Analysis of variance shows significant effects of the refining intensity on the fiber diameter at 95% confidence level (f=16.364, sig=0.000). The effect of refining intensity on the fiber diameter is depicted in figure 2, which implies that the decreased fiber diameter has led to increase in the refining intensity.

Effect of Refining Intensity on Lumen Width: Analysis of variance shows that the effects of refining intensity on the lumen width were significant at 95% confidence level

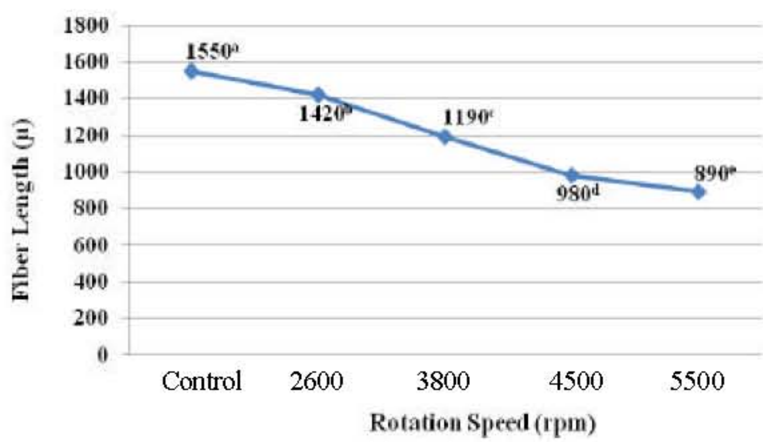

Fig. 1: Relation between the averaged fibers length and the refining rotation speed in the whole pulp sample

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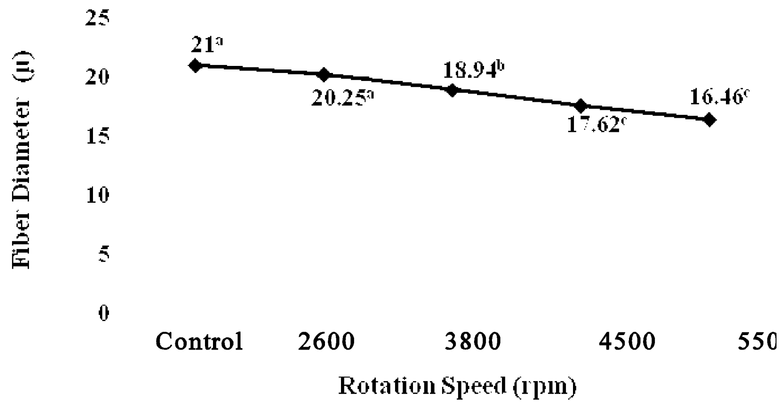

Fig. 2: Relation between the averaged fiber diameter and the refining rotation speed in the whole pulp sample

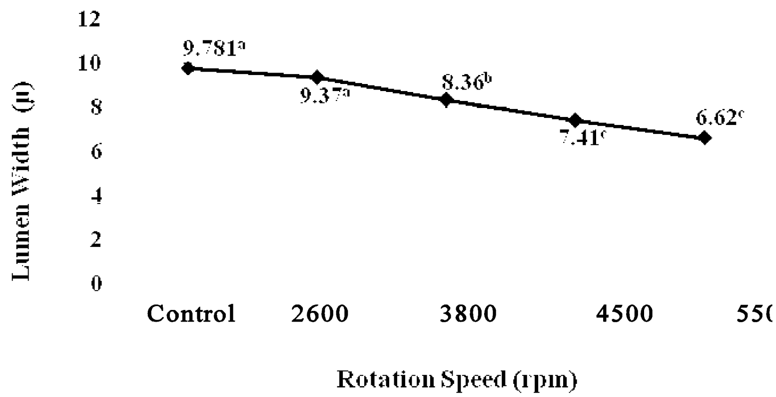

Fig. 3: Relation between the averaged lumen width and the refining rotation speed in the whole pulp sample

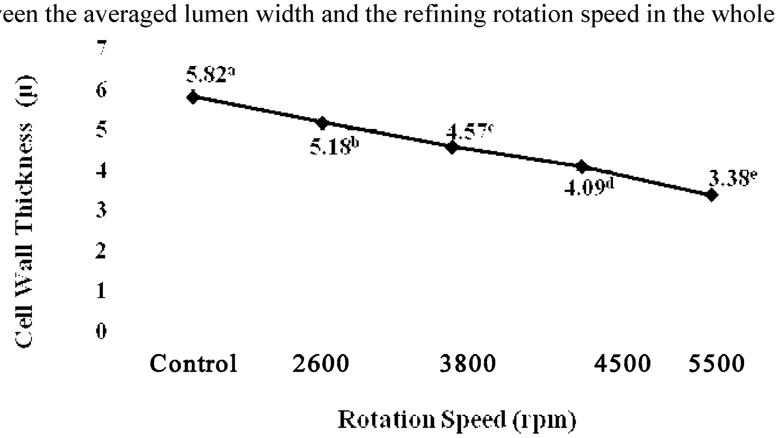

Fig. 4: Relation between the averaged cell wall thickness and the refining rotation speed in the whole pulp sample

(f=19.991, sig=0.000). The effect of refining intensity on the lumen width is shown in figure 3, which declares that the lumen width has been decreased once the refining intensity has been increased.

Effect of Refining Intensity on Cell Wall Thickness: Analysis of variance shows significant effects of the refining Intensity on thecell wall thickness at confidence level of 95% (f=40.985, sig=0.000). The effect of refining intensity on the cell wall thickness is depicted in figure 4. As can be seen, the cell wall thickness shows some decrease with increase in the refining intensity.

DISCUSSION

Refining is a mechanical process for establishing suitable physical properties in pulping process. The purpose of refining process is to create suitable physical specifications for paper structure [6]. The results of this research showed that by increasing the refining intensity, there will be a decrease in fiber length, diameters, lumen diameters and fiber all (Hosseini and Afra 2004, Molin and Daniel 2004, Vaziri *et al.*, 1999, Rushdan 2003, Tchepel *et al.*, 2004) [6, 7, 14-16]. This phenomenon has occurred since the primary wall has been removed after refining which can lead to increased water absorption of secondary wall followed by better fibrillation and swell of fibers and improvement in flexibility of fibers as well. On the other hand, continued refining process may create micro-fibrils on the surface of fibers, with an increasing effect on the total surface of refined fibers [7].

However, there might be unsuitable impacts during the refining procedure, including broken and shortened fibers attributed to shearing forces. In addition, the refining will increase the percentage of fines particles and thus water retention contents with reduced freeness values of the pulp [18].

CONCLUSIONS

This study showed that increasing the rotation speed of refiner to 5500 rpm will also increase the fines content; thus, refining should be performed in lower rotation speeds, since the best refining was obtained in freeness of 400 ml CSF in neutral sulfite semi-chemical (NSSC) pulps [19]. At last, optimizing the rotation speed of refiner to 3800 rpm was proposed in addition to fiber properties and pulp freeness of 402 ml CSF.

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