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Neutral Sulfite Semi-Chemical Pulping of Bagasse

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Abstract: The aim of this research was to investigate the properties of Neutral sulfite semi-chemical (NSSC) pulping of bagasse. Depithed bagasse (wet method) was prepared from Pars Pulp and Paper Mill which is located in Khuzestan province of Iran. Two pulping durations of 30 and 40 min and 2 chemical charges of 10% and 20% were used. Fixed Cooking temperature of 170 °C, Na_2SO_3 to Na_2CO_3 ratio of 2.77:1 and cooking liquor to bagasse ratio of 10:1 were used. The highest yield (84.41%) was obtained applying the treatment combination of 30 min pulping time and 10% chemicals charge and the lowest yield (72.76%) was observed with the 40 min pulping time and 20% chemicals. After the consideration of the pulp, the pulps were refined up to 410±25 ml CSF by using PFI Mill refiner. Then, 127 g m^{-2} handsheets were made from different samples of pulps and the strength properties of handsheets were measured. For measuring the strength properties of handsheets, the TAPPI standard methods were used. The results showed that, when the yield decreased, with the exception of tear strength, the strength indices of paper such as ring crush test (RCT), stiffness, tensile strength, burst strength and breaking length were increased. The cause of tear strength reduction is ascribed to refining.

Key words: Bagasse · Neutral sulfite semi chemical pulping · Strength indices · Ring crush test · Stiffness

INTRODUCTION

The paper industry of Iran gradually feels the Supply problem of raw materials and needs to use the new techniques and take the operative and effective steps for access to the new sources. The sugarcane stalk consists of two parts, an inner pith containing most of the sucrose and an outer rind with lignocellulosic fibers. During Sugar extraction processing, the sugarcane stalk is crushed to extract sucrose [1]. Bagasse, the sugarcane residue after sugar extraction, is one of the most available papermaking lignocellulosic fiber resources in some developing countries, e.g., Iran. Approximately, 4.3 million tons of bagasse is produced annually in Iran that is mainly centered in the southwestern province of Khuzestan [2]. Meanwhile, the quality and quantity of products should be improved. There is no doubt that the nonwood lignocellulosic sources can have an important role in paper industries and recently, there is increasing tendency to use agricultural by-products in pulp and paper industries. In this regard, bagasse is the best starting material for pulp and paper production. Because, besides technical advantages, it is very plenty in south west of the country. One of the important processes for production of pulp and paper is neutral sulphite semi-chemical (NSSC) process. This process is commonly used for high yield pulping of hardwoods and it is one of the important semi- chemical processes in the world. In this process that named NSSC, sodium sulphite liquor is used to neutralize the free organic acids produced by lignocellulosic materials during the cooking. These chemicals are used for elementary treatment of bagasse and at the end; the separation of fibers is done by mechanical processes. The pulp of NSSC process commonly is used for producing flouting papers. Flouting paper is mainly used in the middle layer of board products consumed for packaging industries. This layer provides the strength of cartoon. The chemical compositions of pure bagasse fiber bundles are cellulose (52.42%), lignin (21.69%), hemicelluloses (25.8%), ash (2.73%) and ethanol/dichloro methane extracts (1.66%) [3]. Roodi (2002) conducted a research to make paper by NSSC process from sun flower plant residues [4]. Hosseini (2004) studied the use of straw with NSSC process. In this

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study, cooking temperature was 165 and 175°C, cooking time was 20, 30, 40 minutes and the percentage of chemicals was in three level of sodium sulphite (Na_2So_3) 12, 14. 16. After the completion of cooking, 60 g m^{-2} hand sheet paper was made. It is clear that the cooking temperature of 175°C, 30 minutes time of cooking and 16 percent of sodium sulphite (Na_2So_3) cause the best results in Burst strength index and fold strength that are 5.3220 Kpa.m^2 gr^{-1} and 3.1 log respectively. The yield of above treatment was reported 51.1 [5]. Khassipour (2002) studied the use of bagasse with NSSC process in Mazandaran province. The results of 60 g m^{-2} paper properties of freeness 325 and 375 CSF was reported [6]. Hurter (2002) studied the pulp production from non wood materials, especially bagasse and the variety of straw. The results showed that the breaking length (m), Burst strength factor (Kpa.m^2 gr^{-1}) and ring crush test of flouting papers of bagasse was 5510, 32, 38 respectively and for rice straw obtained 3270, 20.8 and 26 [7]. Alkaline sulfate/AQ pulping and totally chlorine free bleaching were applied on wheat straw, rice straw and bagasse to develop an alternative pulping for these materials [8-10]. The properties of Bagasse fibers form NSSC pulp and paper production have never been investigated and reported in the studies. Therefore, the aimed of this investigation is to define the Neutral sulfite semi-chemical pulping properties of bagasse in the pulp and paper production.

MATERIALS AND METHODS

Raw Material: Depithed bagasse was collected from a local pulp and paper mill (Pars Paper Co. Haft Tapeh. Iran).

Pulping and Hand Sheet Forming: After bagasse transfer to the Research Center laboratory of Mazandaran Wood and Paper factory, Neutral sulfites semi chemical (NSSC) Pulping process using laboratorial rotating digester (HATTO) was performed. 500 grams of depithed bagasse used in each trial and pulping time was measured after reaching temperature of pulping. White liqueur of Mazandaran Wood and Paper Factory including sodium sulfite (Na_2SO_3) and bicarbonate ($NaHCo_3$) was used for Bagasse cooking. Bagasse cooking conditions are shown in Table 1. For each combination of variables, three pulp sample were prepared. At the end of each cooking, the content of each cylinder was discharged into twenty liter container and then mixed with sufficient volume of boiling water and then defibered using laboratory single disc refiner. Pulp suspension was screened using 12 mesh screen on top and 200 mesh screen at the bottom. Whatever remained on the 12 mesh screen was considered as rejects (shives) and the fibers passed the 12 mesh screen and remained on the 200 mesh screen was considered acceptable. The dry weight of each part was measured and reported.

For handsheet making, required freeness was estimated almost 410 ± 25 CSF. Therefore, to achieve the desired freeness, PFI Mill was used. According to the Tappi standard No.205 om-88, eights handsheet papers (with basic weight 127 g m^{-2}) was made. The hand sheet's paper conditioned at 23°C and 50% RH for 24 hours. Then, the Basis Weight, Caliper, Ring crush test, Stiffness, tensile index, tear index, burst index, Breaking length of handsheets were examined according to TAPPI T410 om-88, T411 om-97, T818 om-87, T494 om-88, T494 om-88, SCAN P11:73, T403 om-91 and T494 om-88 Test Method, respectively. The reported results represent the average values of five hand sheets. Finally, to compare the results of paper strength test, analysis of variance test and Duncan's multiple range using SPSS software was performed.

Table 1: Conditions of neutral sulfite semi-chemical pulping from bagasse

Cooking condition	NSSC pulping	Cooking condition	NSSC pulping
Chemicals	Sodium sulfite (Na_2SO_3) and bicarbonate ($NaHCo_3$)	Chemical charge (%)	10 and 20
Liqueur-to-chips ratio	10:1	Time of Impregnation (min)	30
(°C) Cooking temperature	170	Cooking time at maximum temperature (min)	30 and 40

Table 2: Different cooking conditions for NSSC of bagasse

Cooking conditions				Freeness (ml CSF)		
Cooking temperature°C	Cooking time (min)	Chemical percent (%)	Average yield (%)	Before Refining	After Refining	PFI revolution
170	30	10	84.41	710	427	10400
		20	74.95	640	433	2600
	40	10	81.73	690	420	9000
		20	72.76	635	428	2900

RESULTS

Pulp and Pulp Properties

Yield: Pulping conditions and digester yield is summarized in Table 2. Data in Table 2 indicates that pulp yield after defibration varies between a minimum of 72.76% and maximum of 84.41%. The analysis of variance on the yield of pulp and paper were significant at the 95 percent confidence level (F= 183.529, Sig = 0.000). The comparison of means shows that the yield mean of pulp and paper treatment are filled in all four groups. The Figure 1 shows the results of Duncan's test. In addition, the value of yield in 30 min and 10 % chemical charge is maximum. With increasing chemical charge, the amount of yield is decreased.

Ring Crush Test (RCT): The analysis of variance on the RCT of pulp and paper were significant at the 95 percent confidence level (F= 11.642, Sig= 0.003). The Duncan's mean separation test reveals a significant difference in the RCT between treatments (30min, 10%) and (40 min, 10%) are twining in one group and statistically have no significant variety. The (30 min, 20%) and (40 min, 20%) treatments are twin in one group and statistically have no significant variety (Figure 2). The value of RCT in 40 min and 20% chemical charge is maximum. With increasing chemical charge, the mean of RCT is increased.

Tensile Indexes: The analysis of variance on the tensile strength of pulp and paper were significant at the 95 percent confidence level (F= 186.614, Sig= 0.000). The Duncan's mean separation test reveals a significant difference in the tensile strength between treatments (30min, 10%) and (40 min, 10%) and are in one group and statistically have no significant variety. The (30 min, 20%) and (40 min, 20%) treatments are twining in one group and statistically have no significant variety (Figure 3). The value of tensile strength in 40 min and 20% chemical charge is maximum. With increasing chemical charge, the mean of tensile indexes is increased.

Tear Indexes: The analysis of variance on the tear strength of pulp and paper were significant at the 95 percent confidence level (F= 5891.997, Sig= 0.000). The Duncan's mean separation test reveals a significant difference in the tear index of four types of paper, there is no statistically significant variation in 5% area. The comparison between means shows that, the tear index mean from treatments is in four groups (Figure 4). In addition, the value of Tear indexes in the time 30 min and 20% chemical charge is maximum.

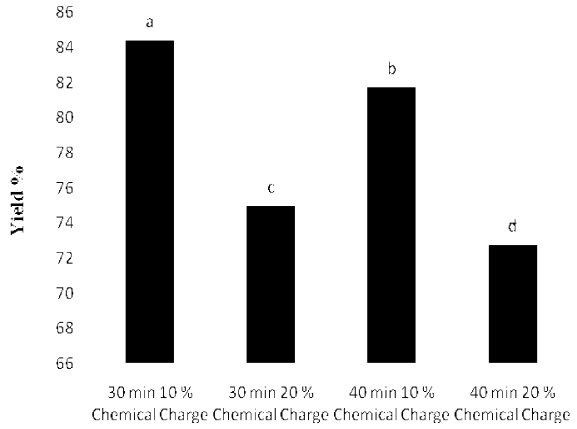

Fig. 1: Comparison of pulp and paper average yield

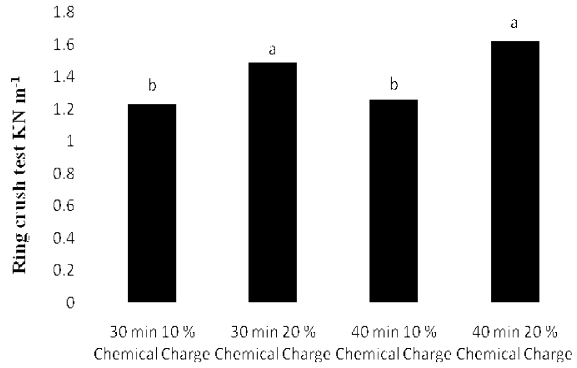

Fig. 2: Comparison of Ring crush test average of pulp and paper

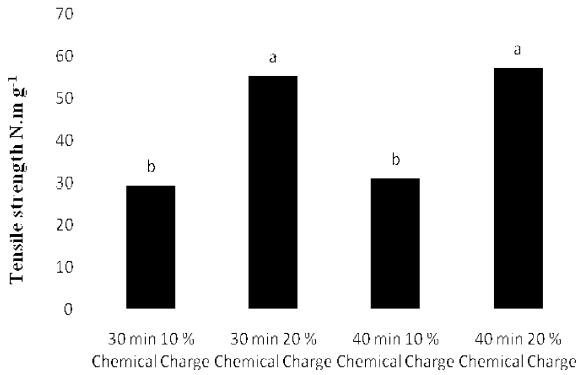

Fig. 3: Comparison of Tensile strength average of pulp and paper

Burst Index: The analysis of variance on the burst strength of pulp and paper were significant at the 95 percent confidence level (F= 328.120, Sig= 0.000). The Duncan's mean separation test reveals a significant difference in the tear strength between the treatments (30 min, 10%) and (40 min, 10%) treatments in 5% areas and they are twining in one group. However, the (30 min, 20%) and (40 min, 20%) treatments have a statistically

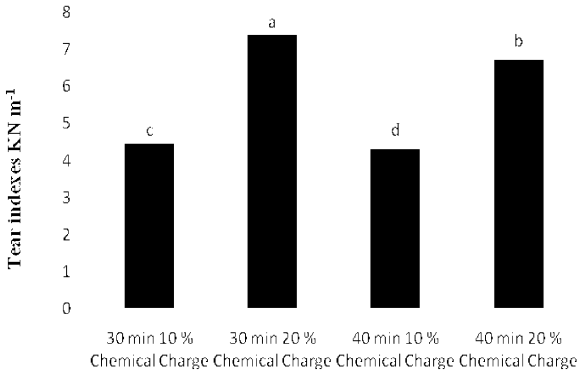

Fig. 4: Comparison of Tear strength average of pulp and paper

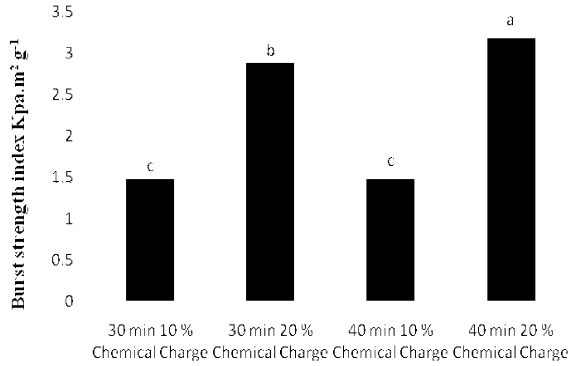

Fig. 5: Comparison of burst strength average of pulp and paper

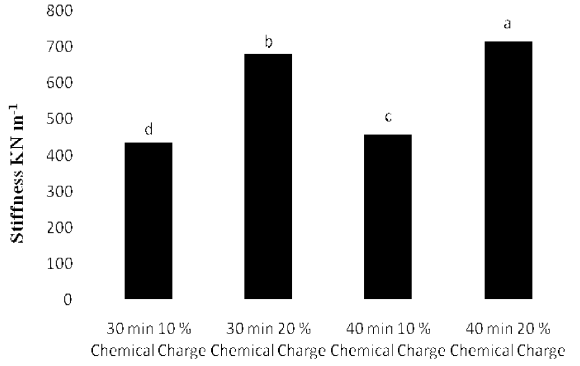

Fig. 6: Comparison of stiffness average of pulp and paper

significant variety (Figure 5). The value of burst index in the time 40 min and 20% chemical charge is maximum. Increasing of chemical charge cause the increasing of the burst index mean.

Stiffness: The analysis of variance on the Stiffness of pulp and paper were significant at the 95 percent confidence level (F= 30709.116, Sig= 0.000). The Duncan's mean separation test reveals a significant difference in

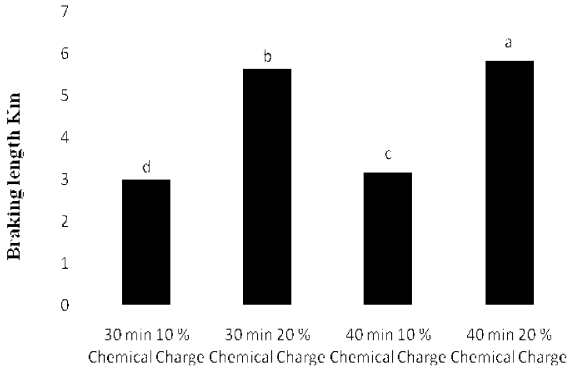

Fig. 7: Comparison of Braking length average of pulp and paper

the Stiffness of four types of paper, there is no statistically significant variation in 5% area. The comparison between means shows that, the Stiffness index mean from treatments is in four groups (Figure 6). The value of Stiffness in 40 min and 20% chemical charge is maximum. Increasing of chemical charge cause the increasing of stiffness mean.

Breaking Length: The analysis of variance on the breaking length of pulp and paper were significant at the 95 percent confidence level (F= 1003.905, Sig= 0.000). The Duncan's mean separation test reveals a significant difference in the breaking length of four types of paper and there is no statistically significant variation in 5% area. The comparison between means shows that, the Braking length mean from treatments is in four groups (Figure 7). The value of breaking length in the time of 40 min and 20% chemical charge is maximum. Increasing of chemical charge cause the increasing of breaking length mean.

DISCUSSION AND CONCLUSION

The results show that, by increasing the percent of chemicals in cooking time, the yield of pulp was decreased. Low refining led to acceptable freeness in the paper making process. The study of NSSC resistance properties of papers from bagasse show that (40 min, 20% chemicals) cause better resistance properties consist of ring crush test, stiffness, tensile strength index, burst strength index, Breaking length. The reason of resistance properties improvement is because the lignin going out increases in cooking process. Since the presence of lignin led to fiber stiffness, limitation of swelling in water, negative effect of fiber connectivity with hemicelluloses therefore cause low resistance of

paper and high opacity. Only the tear strength index of (40 min, 20% chemicals) treatment was lower than (30 min, 20% chemicals) treatment and it is caused by more refining in first treatment. We know that the more refining led to decreasing the fiber length and effects on tear strength index. Then NSSC pulping trials were performed applying different chemical charges and pulping times. The results indicated that bagasse are suitable for NSSC pulping and application of 20% Chemical charge, 30 min pulping time at 170°C pulping temperature will produce pulp suitable as supplement pulp for unbleached paper production. Ring crush Test, Tensile index, tear index, burst index, stiffness and breaking length of this pulp (74.95% total yield) were measured as 1.49 KN/m, 55.29 $N.mg^{-1}$, 7.39 mN m^2g^{-1} and 2.88 $kPam^2g^{-1}$, 680.4 KNm^{-1} and 5.6 Km. Finally, it is clear that bagasse is a byproduct of sugar production from sugarcane that is abundant in south of Iran. And lead to more paper resistance comparison to flouting paper. It can be the alternative resource for flouting paper production.

REFERENCES

1. Boophthy, R., 2004. Use of post-harvest sugarcane residue in coastal reclamation: A feasibility study. J. Sugar Cane International, pp: 9-13.
2. Najafi, G., B. Ghobadian, T. Tavakoli and T. Yusaf, 2009. Potential of bioethanol production from agricultural wastes in Iran. Renewable and Sustainable Energy, 13(6/7): 1418-1427.
3. Rezayati-Charani, P. and J. Mohammadi-Rovshandeh, 2005. Effect of pulping variables with dimethyl formamide on the characteristics of bagasse-fiber. Bioresource Technol., 96: 1658-1669.
4. Roodi, H., 2002. Study of NSSC pulp production from sun flower plant and determines that for production the flouting paper in mazandaran wood and paper industries. M.Sc thesis tarbiyat Moddares University.
5. Hosseini, E., 2004. Study of pulp production from straw in NSSC process for making the flouting Paper. M.Sc thesis tarbiyat Moddares University.
6. Khassipour, F., 2002. Study of bagasse NSSC pulp production from mazandaran bagasse and determine that for making the flouting paper in mazandaran wood and paper industries. M.Sc thesis tarbiyat Moddares University.
7. Hurter, P., 2002. Physical Properties of Corrugating Medium Content Papers Produce With Nonwood Pulp. Hurter Consult Incorporated.
8. Hedjazi, S., O. Kordsachia, R. Patt, A.J. Latibari and U. Tschirner 2008a. Bagasse alkaline sulfite-anthraquinone (AS/AQ) pulping and totally chlorine free (TCF) bleaching. Holzforschung, 62: 142-148.
9. Hedjazi, S., O. Kordsachia, R. Patt, A.J. Latibari and U. Tschirner, 2008b. alkaline sulfite-anthraquinone (AS/AQ) pulping of wheat straw and totally chlorine free (TCF) bleaching of pulps. Ind. Crops Prod., 29: 27-29.
10. Hedjazi, S., O. Kordsachia, R. Patt, A.J. Latibari and U. Tschirner, 2009. Alkaline sulfite/anthraquinone (AS/AQ) pulping of rice straw and TCF bleaching of pulps. Appita J., 62: 137-145.