Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 3159-0040
Vol. 2 Issue 8, August - 2015

Research On The Suitability Of Broomcorn Stalks For Paper Production And The Effects Of Hot-Water Pre-Treatment On Paper's Properties

Ayhan GENÇER
Bartin University, Faculty of Forestry,
Department of Forest Product Engineering, 74100, Bartin, Turkey
ayhangencer61@hotmail.com.

***Abstract*—In this study, paper has been manufactured by using broomcorn (Sorghum bicolor (L.) Mohench) stalks. Before the production of pulp, after one-, two- and three-phase pre-treatment of the broomcorn stalks with 80ºC hot water, the washing ratios of the stalks have been calculated to be 14.03%, 16.05% and 18.80%, respectively. Then, from pre-treated and non-treated samples, pulp has been produced at 140ºC in 120 min. with NaOH (14% of total dry sample weight). The screened yield of these pulps have been calculated to be 50.30% for two-phased implementation, 49.00% for single-phase implementation, 45.30% for three-phase implementation, and 43.00% for non-treated samples. When compared to non-treated samples, the opacity value has decreased and whiteness has increased as the number of pre-treatment has increased.**

Keywords—pulp and paper, hot water, broomcorn stalks

I. INTRODUCTION

The non-wood fibrous raw-material that is most widely used in paper production is the crop stalks. That's because they are necessarily raised for human and animal nutrition, and significant amount of fibrous raw-material having same properties is obtained as a result of this production. Some of the stalks and similar fibrous raw-materials obtained from these crops have not found any area of use yet. Broomcorn stalks are one of these raw-materials. In this study, it has been aimed to produce paper from idle broomcorn stalks.

II. LITERATURE SURVEY

The annual plants other than wood, which are used in paper production, are named "non-wood" [1]. Paper can be produced from most of herbal fibers. But, when the actual amounts of these plants, and the quality and cost of the paper to be obtained are considered, the number of plant that can be used in paper production is limited. For this reason, in countries having limited forest resources, the wastes of plant that are grown for agricultural purposes are an important raw-material source for paper industry [2]. Another plant that is grown for its fruit is the kiwi. The pulp has been produced with Kraft method from pruning residuals of Kiwi, and the screened yield has been calculated to be 44.39% and 38.50% for the samples without and with bark, respectively [3]. Especially in recent century, in countries having agriculture-based economy and limited forest resources, the agricultural wastes have started to be used in paper production, and many factories manufacturing paper from annual plants have been established. One of the criteria of paper production from any lingo-cellulosic raw-material is the length of fiber. Wheat straw [4], cotton stalk [5], and sorghum stalk [6] have been reported to have fiber lengths of 0.74, 1.01 and 2.31 mm, respectively.

III. PROBLEM IDENTIFICATION

The first reason to raise broomcorn plant in our country is the production of traditional domestic broom. Second purpose is to use its seeds in order to meet the feed needs in animal husbandry. This plant consists of the panicle part consisting of numerous very thin straws, where the seeds are located, and the body parts [7]. In broom production, its tip having 60-80 cm length is used. The resting body part having 150-200 cm length is completely idle and cannot be used even in feeding animals. After the harvest, these stalks must be removed from the planting area. Otherwise, some of harmful insects and fungi utilize them as host. This poses a serious threat to the harvest of following year. For this reason, even if burning the stubble is forbidden, these stalks are burnt. The burning operation, besides the risks arising during the burning process, may lead severe biological damages in soil. Utilizing these wastes in paper production can support the farmers from economical aspect. Some of inorganic and organic matters existing at high concentration in corn stalks consume too much chemical materials during the pulp production. These matters consisting generally of silica and basic sugars also cause difficulties in waste water treatment. As a result of the removal of these matters via pre-treatment, production of higher-quality pulp and water treatment become easier. In a study, by pre-treating the wheat

straw with 80ºC hot water, it has been stated that the amount of silica, which leads to important problems in waste water treatment and pulp production, has been significantly decreased [8]. Taking that study as base, it has been tried to eliminate the impurities, which can negatively affect the cooking process, by pre-treating the broomcorn stalks with hot water before pulp production. Moreover, by producing from non-treated samples, the differences have been examined.

IV. METHODOLOGY

4.1 Some of Chemical and Physical Properties of Broomcorn Plant

The stalks of broomcorn (Sorghum bicolor (L) Mohench) have been cut into 5cm-long pieces. The pre-treatment and cooking operations have been carried out within a lab-type cooking boiler having 2-rpm speed. Pre-treatment operation has been executed before the production of pulp. From the air-dried samples, holo-cellulose [9], lignin [10], alpha cellulose [11], ash [12], and cold- and hot-water solubility values [13] have been determined.

4.2 Pre-Treatment

The pre-treatment has been repeated for 1, 2 and 3 times with different samples. The samples taken out of the boiler have been washed for 10 min. on the sieve.

Single-Phase Pre-Treatment

For the pre-treatment, the samples having 700 g. dry-weights have been placed into the boiler with water (the portion of water to dry-weight of the stalks was 15/1). The peak temperature (80ºC) in boiler has been achieved in 40 minutes, and continued for 20 minutes at same temperature level. Then, after opening the boiler, the content has been poured onto the sieve, and the water has been removed. Then the moisture and washing rate have been determined by washing the samples.

Two-Phased Pre-Treatment

After completing the single-phased pre-treatment, by calculating the water and stalk amounts required for second pre-treatment, the second process has been executed with the same solution under same conditions with first process. The weight of completely dried stalks loaded into boiler was 700 g. at each time.

Three-Phased Pre-Treatment

After second repetition, the washed samples have been pre-treated again with same solution under same conditions, and then washed. Samples exposed to single-, two- and three-phased pre-treatment have been left for drying under room conditions. It has been determined that the samples have reached the equilibrium moist level after 24 days. After pre-treatments, the washing ratios of the samples, dry weights of which have been determined, have been calculated. In single, two and three repeat samples, the washing results, the changes in sample amounts and washing ratios are presented in Table 2.

4.3 Pulp Production

While producing pulp from broomcorn stalks, the optimum cooking conditions, except the NaOH portion, of the pulp production from sorghum that is a similar plant have been utilized [6]. The reason of using lower NaOH portion was the opinion that pre-treatment operation would significantly eliminate the impurities of the raw-material and milder cooking could be executed. Accordingly, the portion of complete-dry stalk weight to NaOH has been taken as 14%. By taking solution/stalk ratio as 7/1, cooking temperature as 140±2˚C, and coking duration as 120 min., the pre-treatment has been executed, and the pulps have been produced from treated and non-treated samples. The maximum temperature has been achieved in 60 minutes in cooking operation, and continued for 60 minutes at this temperature.

4.4 Paper Production

By beating the obtained pulps in Hollander at up to 35 SR°', 2.4 g. papers have been manufactured in Rapid- Köthen lab-type machine. Whiteness [14] and opacity [15] properties and tear [16], burst [17] and breaking [18] values of the paper have been determined.

V. RESULT AND DISCUSSION

5.1 Some of the Chemical and Anatomical Properties of Broomcorn Plant

Fiber length of Sorghum halepense has been found to be 1.76 [19], while that of sorghum bicolar has been reported to be 2.31 [6]. In our study, the fiber length has been measured to be 1.27 mm, and it is longer than kiwi 1.58 mm [20], Eucalyptus globus (3) 1.0 mm, Betula verrucosa (3) and Qercus robur 1.10 mm [21]. Some of chemical components and solubility values of broomcorn and sorghum [6] are presented in Table 1.

Table 1 Comparison of some of chemical components and solubility values of broomcorn and sorghum

COMPONENT	MATERIALS	
	Broomcorn(1) %	Sorghum(2) %
Holo-cellulose	78.90	71.00
Alpha-cellulose	46.45	40.30
Lignin	13.75	13.00
Hot water solubility	10.50	19.70
Cold water solubility	8.00	15.10
Ash	10.30	-

1: Findings, 2: [6]

5.2 Pre-Treatment

The dry-weights before the pre-treatments and dry-weight portions after single-, two- and three-phased

pre-treatments, and the washing ratios of each of phases are presented in Table 2.

Table 2: Dry-weights before and after the pre-treatments and washing ratios

Sample	First Dry-Weight	Final Dry-Weight	Washing Ratios (%)
1 phase	700	604	14.03
2 phase	700	602	16.05
3 phase	700	594	18.80

Washing has been calculated to be 14.03% in single-phased pre-treatment. No significant increase has been observed as a result of two- and three-phased pre-treatments.

5.3 Pulp Production and Some of the Properties of Manufactured Papers

In Table 3, some of the properties of pulp obtained from treated and non-treated samples and the paper manufactured from that pulp are presented.

Table 3 Mean screened yields of pulps and some of the properties of manufactured papers

Pre-Treatment Repetition	Screened yield (%)	Brightness (%)	Opacity (%)	Tear index ($mN.m^2/g$)	Burst index ($kPa.m^2/g$)	Breaking length (N.m/g)
1	**49.00**	**40.88**	**98.07**	**3.00**	**4.70**	**81.70**
2	**50.30**	**42.40**	**97.09**	**3.03**	**5.20**	**82.10**
3	**45.00**	**45.09**	**97.4**	**3.14**	**5.27**	**83.00**
0	**43.30**	**37.60**	**98.30**	**3.40**	**4.63**	**75.7**

In pulps obtained from pre-treated stalks, the yield of single-phase has been found to be 49 % and 50.30% in two-phased. Significant decrease has been observed in three-phased operation, and the yield has been found to be 45.00 %. In pulps obtained from non-pre-treated stalks, the yield values have been found to be lower than each of those of pulps obtained from treated stalks. For this reason, it can be said that single-phased pre-treatment is enough. Brightness value has increased as the number of pre-treatment repetitions has increased, and the brightness values of the papers obtained from pre-treated pulps have been found to be higher than those of pulps obtained from non-pre-treated stalks. Casey [22] has reported that brightness value of 51 was enough for machine chromo book papers. He has stated that higher brightness would lead to glare in readers. The opacity value is at the highest in papers manufactured from non-pre-treated pulps. As the number of repetition increased, the opacity decreased in papers obtained from pre-treated pulps. Tear index has been found to be the highest in non-pre-treated samples. In pre-treated samples, it has increased as the number of repetition has increased. Burst index was higher in pre-treated samples than non-pre-treated samples. It has increased in first and second repetitions. But, it has decreased in third repetition. For packaging and bag papers, this value is desired to be high. Breaking index was higher in pre-treated samples, and it has increased as the number of repetition has increased.

VI. CONCLUSION

From the broomcorn stalk, pulp can be manufactured by cooking for 120 minutes at 140±2˚C temperature by using 14% NaOH (in proportion to complete dry stalk weight). According to performed chemical analyses, the highest alpha cellulose concentration in pulp is at the level of other annual plants having important place in paper industry. The contribution of pre-treatment before pulp production to pulp yield is at a considerable level. Pre-treatment has improved the brightness value, burst index and breaking index and decreased the opacity value and shearing index. In many experiments with papers pulp, no significant improvement has been observed after first repetition of pre-treatment. For these reasons, it can be said that single-phased pre-treatment is enough. Execution of pre-treatment at different temperatures and for different durations may change the results. For this reason, we recommend to use different temperature and duration parameters in further studies. Moreover, we suggest the use of different solvents for pre-treatment operation.

VII. REFERENCES

[1] L. Jimenez, E. Ramos, A. Rodriguez, M.J. De La Torre and J.L. Ferrer, ‘’ Optimiziation of pulping conditions of abaca. An alternative raw materialfor producing cellulose pulp’’ Bioresource Technology, 96, 977-983, 2005

[2] P. Bajpai, S.P. Mishra, O.P. Mishra, S. Kumar, P.K. Bajpai and S. Singh, ‘’ Biochemichal pulping of wheat straw,’’TAPPI Journal, 3(8)36, (2004)

[3] A. Gençer, ‘’ The utilization of kiwi (Actinidia deliciosa) pruning waste for kraft paper production and the effect of the bark on paper properties’’ Drewno, Vol. 58, No. 194, 103-113, 2015.

[4] İ. Deniz, H. Kırcı, S. Ates, ‘’Optimisation of wheat straw Triticum drum kraft pulping’’. Industrial Crops and Products 19 [3]: 237–243, 2004.

[5] A. Gençer, H. Eroğlu and R. Özen, ‘’Medium density fiberbord manufacturing from cotton stalks,’’ Inpapper International, 5(2), 26-28, 2001.

[6],A. Gençer, M. Şahin, "Identifying the conditions required for the NaOH method for producing pulp and paper from sorghum grown in Turkey," *BioRes.* 10(2), 2850-2858, 2015.

[7]. A. Balkan, T. Gençtan, ‘’Evaluation of Some Agronomic Characteristics of Broomcorn (Sorghum bicolor (L.) Mohench var. technicum (Körn.) Genotypes Grown in Trakya Region,’’ TARIM BİLİMLERİ DERGİSİ , Ankara University Fakulty of Agriculture, 14 (2) 163-168, 2008.

[8] H. Eroğlu, I. Deniz, 1993. ‘’Predesilication of wheat straw (Triticum aestivum L.) with NaOH,’’ Das Papier, 47, Nov. 645-650, 1993.

[9] L.E. Wise, E.C. Jahn, ‘’ *Wood Chemistry,”* 2rd ed., Vol. 1-2, Reinhold Publication Co. New York, U.S.A, 1330, 1952.

[10] TAPPI T 222 om–02 [2002] Acid-insoluble lignin in wood and pulp.

[11] TAPPI T 203 cm-99 [1999] Alpha-, beta- and gamma-cellulose in pulp.

[12] TAPPI T 211 om–02 [2002] Ash in wood, pulp, paper and paperboard: combustion at 525°C.

[13] TAPPI T 207 cm–99 [1999] Water solubility of wood and pulp

[14] TAPPI T525 om–02 [2002] Diffuse Brightness of Pulp (d/0)

[15] TAPPI T519 om–02 [2002] Diffuse Opacity of Paper (d/0 paper backing)

[16] TAPPI 414 om–98 [1998] Internal tearing resistance of paper (Elmendorf-type method)

[17] TAPPI 403 om–02 [2002] Bursting strength of paper

[18] TAPPI T494 om–01 [2001] Tensile Properties of Paper and Paperboard (Using Constant Rate

[19] S. Abert, A. Padhiar and D. Gandhi, ‘’Fiber properties of *Sorghum halepense* and its suitability for paper production’’ Journal of Natural Fibers, 8,263-271, (2011)

[20] B. Yaman and A. Gençer, ‘’ Fiber morphology of kiwi (Actinidia deliciosa (A.Chev.) C. F. Liang& A. R. Ferguson) grown in Trabzon,’’ *Süleyman Demirel University, Journal of Faculty of Forestry*, A (2): 149-155, 2005.

[21] S. A. Rydholm, ‘’ Pulping processes,’’ First Edition, Interscience Publishers,121-253,1965.

[22] J. P. Casey, ‘’*Pulp and Paper Chemistry and Chemical Tekhnology,”* Vol. 1. Third Edition, Wiley Interscience Publisher Inc, New York, 1980, pp.1090-1146.,1960