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Kraft pulping of *Albizia richardiana* wood species in a mixture with *Bambusavulgaris*

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Abstract: The use of wood along with bamboos is now new a dimension of research for decreasing the raw material crisis in pulp industry to run the mill to its full daily production capacity. With this aim, kraft pulping of *Albizia richardiana* (rajkoroi) wood species in a mixture with *Bambusa vulgaris* (baizzya) was assessed to incorporate the former species as pulping raw material. Chemical analysis showed that alpha-cellulose content of *B. vulgaris* is low but lignin content is high compared to *A. richardiana*. Pulps were made in kraft process maintaining 25% sulphidity by varying the alkali doses. The temperature was maintained at 170°C during pulping. The chip in the mixture were in the ratio of *B. vulgaris* : *A. richardiana* (100:00; 70:30; 50:50; 30:70 and 00:100). Hand sheets were made and the physical strength properties likely tear, tensile and burst were evaluated at two freeness level. The active alkali requirement for bamboo was higher than *A. richardiana* for same degree of delignification. The pulp yield was low but superior quality pulp could be obtained from *B. vulgaris*. On the other hand pulp yield for *A. richardiana* was high but quality was low. Mixing of *B. vulgaris* chips in a proportion of 30%, pulp yield decreased but strength properties like tear, tensile and burst increased. On further increase of bamboo chips in the furnish, a similar trend was observed. The optimum ratio of chips of *B. vulgaris*: *A. richardiana* could be either 30:70 or 50:50 based on pulp yield and quality. The pulp making characteristics of the two species being different, further research on blending the pulps together after individual cooking of the species is recommended.

Key words: Albizia richardiana, Bambusa vulgaris, kraft pulping, pulp yield, strength properties.

INTRODUCTION

The demand for forest resources is increasing continuously as the population increases in Bangladesh. However, there is a huge gap between the incremental rates of the demand and the supply of our natural resources. As a result, forest resources are becoming scarce everyday. On the other hand, the consumption of paper, paperboard and newsprint has been growing at a rate of 20% annually during the last five years (Anon 2010). This incremental trend is going to continue in the future as the government has adopted a massive illiteracy reduction program and implementation of the same in the rural areas. The present per capita consumption of paper is about 6 kg/year (Anon 2010) for the160 million people of the country.

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In Bangladesh, three pulp mills out of four, failed to continue their operations due to shortage of raw material and lack of fresh investment, and the Government was forced to close down these units. The Karnaphuli Paper Mill (the largest in the country) is also not in a position to run at its full daily production capacity due to insufficient supply of raw material. This entire crisis along with the growing demand of paper products warrant immediate attention and needs continued efforts to ensure sustained supply of raw materials to these paper mills. The Karnaphuli paper mill exclusively used the muli bamboo (*Melocanna baccifera*) for pulp production since its inception. Later on, various wood species were used widely along with bamboos but information regarding the optimum use of bamboo mixed with wood in producing chemical pulp is not available. Previous studies (Guha *et al.*, 1966; Pasaribu and Silitonga 1974; Guha *et al.*, 1980 and Jahan *et al.*, 2015) have shown that chemical pulp having high pulp yield and good strength properties was obtained from the chips of bamboo and hardwood in mixture. The addition of bamboo chips in the furnish varied from 20 to 60%. Krishnamachari *et al.*, (1975) pointed out that satisfactory kraft pulps have been obtained with either a mix of 70 per cent bamboo (*Dendrocalamus strictus*), 15 per cent Mysore gum (*Eucalyptus tereticornis*) and 15 per cent dadup (*Erythrina suberosa*) or 50 per cent bamboo, 20 per cent *Acacia arabica,* 15 per cent Mysore gum and 15 per cent dadup. Guha *et al.* (1980) added that pulp from bamboo (*D. strictus*) chips combined with different proportions of mixed hardwoods showed satisfactory properties for the manufacture of writing, printing, wrapping paper and 3-layer boards. In a study, it was found that bleachable grade kraft pulp from *A. richardiana* was obtained even with 14% active alkali with a pulp yield of 48.2% (Biswas *et al.*, 2012). However, the strength of the pulp produced from the species was inferior compared to the hardwood species commonly used for pulping. It was suggested that pulp quality might improve if chips of the species could be mixed with that of other hardwood or bamboo during pulping. With this aim in view this study has been undertaken to determine optimum ratio of bamboo and wood with respect to both pulp yield and quality for using as pulping raw material.

MATERIALS AND METHODS

Raw material processing

Rajkoroi logs were collected from Chittagong with bark on. These were debarked and converted into planks and then chipped using a laboratory chipper. The chips were screened to remove oversized and pin chips and finally hand sorted to remove all pieces of knots, bark and decayed wood and then air dried. The accepted chips were about 20 ± 0.15 mm in length, 12 ± 0.13 mm in width and 2 ± 0.06 mm in thickness. Chips of *B. vulgaris* were supplied by Karnaphuli Paper Mills Ltd., Bangladesh.

Chemical analysis

Part of the *B. vulgaris* chips was used for determining the percentage of chemical constituents. Holocellulose contains all carbohydrate of plant material. For the determination of holocellulose percentage, the bamboo meal was taken in a 250 ml conical flask and then added 160 ml of water, 1.5 g $NaClO_2$ and 0.5 ml glacial acetic acid. The mixture was heated for 1 hour at 70°C to 80°C. After 1 hour, 1.5 g $NaClO_2$ and 0.5 ml glacial acetic acid was added again and the heating continued for an additional hour. Four such treatments were required for delignification. Then the holocellulose, a white residue, was obtained. The residue was dried and weighed. The percent holocellulose was calculated as follows.

$$\text{Holocellulose} = (A-B)/A100\ \%$$

where,

A = Initial oven dry weight of the specimen, g

B = Oven dry weight of test specimen after extraction, g

For alpha-cellulose determination, the never dried sample of holocellulose was treated with 17.5% NaOH followed by 8.5% NaOH. The residue was then dried and weighed, Alpha-cellulose was calculated as follows.

$$\text{Alpha-cellulose} = (A-B)/A100\%$$

where,

A = Initial oven dry weight of the specimen, g

B = Oven dried weight of test specimen after extraction, g

The lignin content and 1% NaOH solubility of *B. vulgaris* chips were measured by following TAPPI test methods T222 and T212

Pulping

The pulping experiments were carried out with 250 g of oven dry chips in 2 liter stainless steel autoclaves heated in a temperature controlled air bath. The chips of *B. vulgaris* were mixed with *A. richardiana* in five different ratios (w/w) such as 00:100; 30:70; 50:50; 70:30; and 100:00 prior pulping. Analytical grades of Na_2S and NaOH were used as cooking chemicals. A cooking temperature profile of 90 min. from room temperature to 170°C and 90 min. at 170°C was used to match an H-factor of approximately 2000 for all cooking conditions. The liquor to wood ratio was 4:1 in all the cooks (L/kg). A sulphidity of 25% was used in all the kraft cooks. The active alkali for neat *B. vulgaris* and the mixture was 16 to 20% with the increment of 2% and for neat *A. richardiana*, it was 14 to 18% with the increment of 2%.

After cooking, the chips were discharged and the black liquor was collected for residual alkali determination. The cooked fibers were taken in a screen box and washed overnight with droplets of water to wash out the residual liquor. The approximate water requirement was about 12 litre/hour. In the next day the cooked chips were stirred slightly with water in a bucket by a slow speed electric mixer. The pulp slurry was then screened in a Johnson vibratory screen to separate any uncooked material from the pulp. The wet pulp was passed through a screw press to remove excess water, and then samples were taken for estimating dry matter content. The pulp yield was determined. The screening rejects were collected, dried and then weighted. The kappa number of pulp was determined using Tappi test methods T 236 cm-85.

Hand sheet making and physical testing

The prepared pulps samples were beaten in a PFI mill to achieve a Canadian Standard Freeness (CSF) of 250 and 450 ± 3 ml (SCAN-C 21:65) and hand sheets were made. These were then conditioned at 23±1°C temperature and 50±2% relative humidity and tested according to SCAN-C 28:69 to evaluate the strength properties.

RESULTS AND DISCUSSION

Chemical composition

The chemical compositions of *B. vulgaris* chips were determined and the values are reported in Table 1. These are compared with the values of *A. richardiana* (Biswas *et al.*, 2012). It was found that 1% caustic soda soluble and lignin content of *B. vulgaris* were higher compared to *A. richardiana*. The α-cellulose content of *A. richardiana* was higher than *B. vulgaris* grown in Bangladesh. It suggested that pulp yield might be higher in case of *A. richardiana*.

Table 1. Chemical composition of chips of *B. vulgaris* and *A. richardiana*

Species	*B. vulgaris*	*A. richardiana*
Chemical component	% on OD wood	
% caustic soda solubles	18.5	16.3
Alcohol-tolune solubles	4.2	3.7
lignin	27.6	22.7
Alpha-cellulose	42.7	44.7
Holo-cellulose	68.3	79.6

Pulping

The yield and kappa number of pulps made from *B. vulgaris* and *A. richardiana* alone and in mixture are presented in Table 2. At 14% active alkali, the kappa number was

19.0 with the corresponding pulp yield of 48.2% for *A. richardiana*. The amount of rejects was negligible. There was slight decrease in kappa number with an increase in cooking chemical concentration from the level of 16 to 18%. When 30% bamboo chips were mixed, the requirement of cooking chemical increased. At 16% active alkali, the kappa number was 23.7 with the corresponding pulp yield of 48.9%. With further increase of proportion of bamboo chips from 30% to 50%, the kappa number was high at same alkali concentration. On addition of 70 percent bamboo chips, bleachable grade pulp could not be produced at similar alkali label. The amount of uncooked material was also high resulting high kappa number. It indicated that the delignification was found much easier in case of *A. richardiana* compared to *B. vulgaris* alone and also in mixture. In case of *B. vulgaris* alone, the requirement of cooking chemical was high for producing bleachable grade pulp (Table 2). At 20% active alkali the pulp yield was 44.7% having kappa number 18.9.

It is interesting to note that pulp yield of *A. richardiana* was high compared to bamboo. The high yield of the species is probably due to the higher cellulose content of the species compared to bamboo. The other reason is that the cooking chemical requirement for bamboo is high to achieve the same degree of delignification. Probably the high doses of alkali degrade the cellulose resulting lower pulp yield. The pulp yield of bamboo is slightly lower, however in the mixture it compares favorably to most hardwood species for making bleachable grade pulp. Jahan (2015) also reported the similar trend for pulp yield and kappa numbers of *Trema orientalis* and bamboo in mixed pulping.

Strength properties

The tear, tensile and burst strength properties of pulp of *B. vulgaris*, *A. richardiana* and their mixture at 450 and 250 CSF are given in Table 3. It showed that tear strength is low and both tensile and burst strength are high at 250 CSF for all cooks as usual. This was because the tear strength depends on the strength of individual fiber, which decreases on beating. On the other hand, the tensile and burst strengths depend on strong fiber to fiber bonding resulting the increase of bond potential with the progress of beating. In the present study the tear index of pulps made from *A. richardiana* alone was very poor around 7 $mN.m^2/g$ (Table 3). On addition of bamboo chips, the tear, tensile and burst index increased. However, the incremental rate of tear index was high compared to tensile and burst strength. For neat bamboo chips, the tear index was very high which was nearly doubled to that of *A. richardiana*. This is probably due to the anatomical variation of the raw material.

Bamboo pulp gave good strength properties especially tear strength probably because it contains long fiber. Many researchers pointed out that fiber length is one of the most important parameters for pulp strength (Wimmer *et al*., 2002; Haygreen and Bowyer, 1982). The fiber length of *A. richardiana* is 1.01 mm (Das, 1990) which is lower than

Table 2. Pulp yield and kappa number of *B. vulgaris* and *A. richardiana* wood alone and in mixture

Chips composition (%)		Active alkali (%)	Chemical consumption (%)	Screened yield (%)	Kappa number	Reject (%)
B. vulgaris	*A. richardiana*					
00	100	14	12.5	48.2	19.0	1.03
		16	13.2	46.8	18.5	0.51
		18	13.5	44.6	16.3	Nil
30	70	16	15.6	48.9	23.7	1.32
		18	17.6	47.8	18.9	1.30
		20	19.4	46.7	17.9	0.44
50	50	16	15.6	48.7	28.7	3.41
		18	17.5	47.5	21.3	2.28
		20	19.5	46.6	18.5	1.25
70	30	16	15.6	46.5	29.1	3.05
		18	17.6	45.1	19.3	2.00
		20	19.4	42.3	19.0	1.70
100	00	16	15.7	47.0	30.3	2.95
		18	17.5	46.3	25.2	2.10
		20	19.5	44.7	18.9	1.52

the 2.02 mm of *B. vulgaris,* (Sakyere, 1994). This resulted superior quality pulp from the bamboo. A comparison of strength properties of *B. vulgaris* and other hardwood species at 250 and 450 CSF is shown in Table 4. It is found that the strength properties of bamboo particularly tear index was so high compared to hardwood species commonly used for pulping. On the contrary, the tear, tensile and burst strength properties of pulp of *A. richardiana* were poor. At 30% bamboo chips addition, the strength properties increased slightly. Further increase of bamboo chips at about 50% improved the tear strength but burst and tensile strength remained unchanged. The report of Guha *et al.,* (1980) that decreasing the percentage of hardwoods in the mixture with bamboo chips increases the strength properties but lowers the pulp yield, supports the finding of the present investigation. Gulsoy and Tufek (2013) also found higher tear index for the mixture of both hardwood and softwood chips.

The optimum ratio of *B. vulgaris*: *A. richardiana* might be 30:70 or 50:50 where the active alkali requirement was 16% and 18% respectively. At that condition, the pulp yields were 48.9% and 47.5% and the corresponding kappa number 23.7 and 21.3 respectively (Table 4). So, *A. richardiana;* could be mixed along with bamboo in pulp production in Bangladesh. However, it is important to note that the cooking chemical requirement for *A. richardiana* was low. On the contrary, bamboo needed higher quantities of cooking chemical for producing bleachable grade pulp. For high proportion of bamboo chips in a mixture, the requirement of cooking chemical might be high otherwise homogeneous cooking of the furnish may not be possible.

Table 3. Strength properties of the pulps made from *B. vulgaris* and *A. richardiana* wood alone and in mixture

Chips composition (%)		A.A (%)	Tear index (mN m^2/g)		Tensile index (N m/g)		Burst index (KPa.m^2/g)	
			CSF, mL		CSF, mL		CSF, mL	
B. vulgaris	*A. richardiana*		250	450	250	450	250	450
00	100	14	6.68	7.40	54.5	45.1	4.60	3.5
		16	6.35	7.32	49.1	40.2	4.46	3.3
		18	5.83	7.20	45.5	38.5	4.17	3.1
30	70	16	6.97	7.07	76.9	55.6	4.97	3.3
		18	6.64	7.16	74.5	58.4	5.34	3.4
		20	6.67	7.89	74.5	51.8	5.11	3.8
50	50	16	8.47	9.39	77.8	56.1	6.02	3.3
		18	7.98	9.32	76.5	54.7	5.19	3.9
		20	7.11	7.73	76.5	55.5	4.83	3.7
70	30	16	10.29	12.07	80.5	63.0	5.20	4.1
		18	10.08	12.04	73.2	61.7	5.03	3.5
		20	9.41	11.71	75.6	59.8	5.48	3.7
100	00	16	13.05	16.59	79.4	64.4	6.36	5.8
		18	12.73	16.37	72.0	60.7	6.45	5.9
		20	11.64	14.70	70.6	58.4	5.78	4.8

Table 4. Comparison of strength properties of *B. vulgaris, A. richardiana* and other hard wood species at 250 & 450 CSF

Wood Species	A.A (%)	Sulphidity (%)	Screened yield (%)	Kappa number	Tear index (mN m^2/g)		Burst index (kPa.m^2/g)		Tensile index (mN/g)	
					CSF, mL		CSF, mL		CSF, mL	
					250	450	250	450	250	450
B. vulgaris	20	25	44.7	18.9	11.6	14.7	5.78	4.82	70.6	58.4
A. richardiana	14	25	46.8	19.0	6.68	7.40	4.50	3.53	54.5	45.1
B. vulgaris: A. richardiana 30:70	16	25	48.9	23.7	6.97	7.07	4.97	3.31	76.9	55.6
B. vulgaris:A. richardiana 50:50	18	25	47.5	21.3	7.98	9.32	5.19	3.92	76.5	54.7
[1]*Chakua koroi (A. chinensis)*	14	25	50.5	25.7	5.78	7.05	8.75	5.45	101.5	70.5
[1]Kada (*A. chinensis*)	14	25	49.8	28.0	6.46	7.72	7.48	5.80	95.7	80.0
[2]Simul *(S.malabarica)*	15	20	46.7	*22.5*	9.81	10.1	4.97	4.01	75.6	62.9
[2]Minjiri *(C.siamea)*	20	20	43.4	22.4	8.25	7.80	3.93	2.39	68.7	44.1

[1]Akhtaruzzaman et al., (1997); [2]Hossain et al., (1977)

CONCLUSION

This study indicated the kraft pulping potential of *A. richardiana* wood species in a mixture with *B. vulgaris*. It was found that high dose of cooking chemical was needed for delignification of *B. vulgaris* compared to *A. richardiana*. Alpha-cellulose content of A. *richardiana* was high resulting higher pulp yield. As the percentage of bamboo in the mixture increased, the pulp yield decreased. The strength properties of *B. vulgaris* alone were high due to long fiber length. The species could be used as raw material for making superior quality pulp. *A. richardiana* was a less suitable species for making kraft pulp but on inclusion of *B. vulgaris*, pulp the physical properties likely tear, tensile and burst were improved. The optimum proportion of *B. vulgaris* and *A. richardiana* chips in mixture would be either 30:70 or 50:50 and corresponding active alkali requirement would be 16% and 18% to get bleachable grade pulp.

The cooking characteristics of *B. vulgaris* and *A. richardiana* were different and further research on blending the pulps together after individual cooking of the species is recommended.

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