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Pulp making characteristics of stem and branches of rubber tree (*Hevea brasiliensis*)

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Abstract:

The suitability of stem and branches of rubber tree for pulp production was assessed. The chemical composition of both stem and branches were determined. Fiber length was measured for both stem and branches. Pulps were made in a kraft process maintaining 25% sulphidity by varying the alkali doses from 14 to 20%. The temperature was maintained at 170°C during pulping. The chips were cooked well at high alkali doses. It was found that the pulp yield of both stem and branches of rubber wood was comparable to other hardwood wood species widely used in Karnaphuli Paper Mill. The kappa number varied from 14 to 32. Bleachable grade pulp can be made for 18% active alkali.
The hand sheets were made and the physical strength properties likely tear, tensile and burst were evaluated at two freeness levels. The pulps produced from stem and branches of rubber trees possessed moderate strength properties. These could be used for producing moderate quality writing, printing and wrapping papers. Future research on the response of bleaching chemicals to the pulp is needed.

Key words: Rubber tree (*Heveabrasiliensis*), stem, branches, chemical composition, kraft pulping process, pulp yield, kappa number, strength properties.

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1. Introduction:

Rubber (*Hevea brasiliensis*) is now widely cultivated in Asia, especially in Southeast Asia [1], and has recently become an important economic crop in Bangladesh. Rubber applications include latex and wood production. The natural rubber made from latex has been used for vehicle tires, medical appliances, shoes, condoms, and cosmetics etc. Rubber wood is normally used to manufacture furniture and wood paneling. Recently, medium density fibreboard, particleboard, and oriented-strand board have been produced from rubber wood [2]. Rubber wood is obtained by cutting old rubber trees (25–30 years of age) after the latex production has decreased. After 25 years, rubber trees usually have a clear bole of 3–10 m, depending on the tree and the growing conditions [3]. Variation in wood properties depends upon specific environmental and genetic factors [4]. For example, wood chemical properties depend upon factors including species, age, height, and their growth environment [5]. The main chemical components of wood are cellulose, hemicelluloses, lignin, and extractives. In general, softwoods from gymnosperms have higher cellulose and lignin, and lower pentose levels compared to hardwoods or angiosperms [6].
Bangladesh Forest Industries Development Corporation (BFIDC), Chittagong Hill Tract Development Board and other private organizations have planted rubber trees (*Hevea brasiliensis*) on a large scale for latex production. The present rubber plantation of the corporation is 32,635 acres in the fallow, hilly and semi-hilly areas of greater Chittagong, Sylhet and Mymensingh districts having in all 41,00,000 rubber trees. The private planters have raised about 33.000 acres of rubber gardens having over 4 million rubber trees [7]. The trees are harvested at the age of 30 years when tapping becomes uneconomical. The tree is light yellowish white on fresh cut, but turns into reddish brown on exposure. The sapwood and heartwood are indistinguishable by color [8]. The rubber trees may be a suitable source for Karnaphuli Paper Mills (KPM), which is the only pulp mill in Bangladesh. In greater Chattogram there are eight (08) rubber gardens in Cox's bazar Ramu, Raozan Chattogram, Fatikchhari. Chattogram and Rangamati district

2. Materials and Methodology:

2.1. Raw material collection and processing

The stem and branches of a freshly cut rubber tree was collected from Datmara Rubber Estate, Fathikchari, Chattogram. These were debarked and chipped separately using a laboratory chipper. The chips of stem and branches were screened to remove oversize and pin chips. Finally, the screen chips are hand sorted to remove all pieces of knots, barks and decayed wood. The accepted chips are about 20 mm in length, 10 mm in width and 3 mm in thickness. The chips are then air dried and stored in a sealed polythene bag for pulping.

2.2 Chemical Analysis

Rubber chips were ground in a Wiley Mill and screened. The fraction that passed through the 40mesh screen and was held on the 60 mesh screen was used for determining its chemical composition. The cold water and hot water solubility(T207), 1% caustic(T212), acid soluble lignin(UM 250), klason lignin(T211 om83), ash content(T211 os 76), extractive(T204 om88), were determined in accordance with tappi test methods. Holocellulose(UM249) and alpa-cellulose(T203) were determined by treating the extractive free wood mix with $NaClO_2$ solution. Fiber measurement was carried out in accordance with the procedure which is applied for the fiber analyser.For the measurement of fiber length, the sample was macerated in a solution containing 1:1 HNO_3 and $KClO_3$. A drop of macerated sample was taken in a slide a fiber length was measured in image analyzer Labomed LX 400 equipped with software digipro4.0.

2.3 Pulping

250g of oven dry chips were charged in the 2 liter stainless steel autoclaves placed in an electrically heated air bath. Analytical grades of Na_2S and NaOH were used as cooking chemicals. Cooking time was 120 and 150 min. at 170°C. The time required to raise this temperature from room temperature was 90 min. The liquor to wood ratio was 4:1 in all the cooks (L/kg). Four doses of active alkali were used to obtain different levels of delignification. A sulphidity of 25% was used in all the kraft cooks. For longer cooking time 0.1% anhraquinonone (AQ) was used with 14% active alkali.
After each cook, 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 under running water to wash out the residual liquor. These were stirred slightly with water in a bucket by a slow speed electric mixture. 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 dry matter content. The pulp yield was determined. The screening rejects were collected and dried for calculating total pulp yield. The kappa number was determined using Tappi methods T236 cm-85.

2.4 Hand sheet making and physical testing

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

3. Results and Discussion

3.1Chemical constituents:

Rubber wood morphology and chemical composition is shown in Table 3. Fiber length is considered as an important parameter for pulp and paper properties. Machine runnability, tear strength, and paper strength are influenced by fiber length [31]. The rubber wood fiber length was 0.86 mm in stem and 0.98 mm in branch which were within the range of tropical hardwoods (0.7-1.5mm) considered as short fiber [32].
Cold water solubility, hot water solubility was found higher in branches than stems in rubber wood. Higher water-soluble extractives indicate the presence of higher percentages of tanning's, gums, cyclotrons, sugar, organic salts, and pectin like materials, starch and other hygroscopic salts. So, rubber wood branches contain a high amount of extractive materials. A tree with higher 1% NaOH solubility is not suitable for pulping of paper making. For pulping purposes the stem of rubber wood is more suitable compared to rubber branch wood due to less percentage of 1% NaOH solubility (stem 18.7%, branch 19.3%) in stem.

The total lignin content in the branches was 28.5% and 27.3% in the stem. The lignin content is similar to that of softwood species. The α-cellulose percent in trees directly correlates with pulp yield. The hollocellulose and α-cellulose in the stem of rubber wood were 74.5% and 42.8% respectively which was slightly higher than that of branches (Table 3). The cellulose content in rubber wood was nearly similar to other hardwood grown in Bangladesh [33]. Ku et.al [34] showed that the α-cellulose in the stem is higher than the branches.
The ash content was found 2.2% in Stem and 1.3% in Branches which are within the range of usual tropical species (1-3%) [35].

Table 3: Morphology and chemical composition of Rubber wood

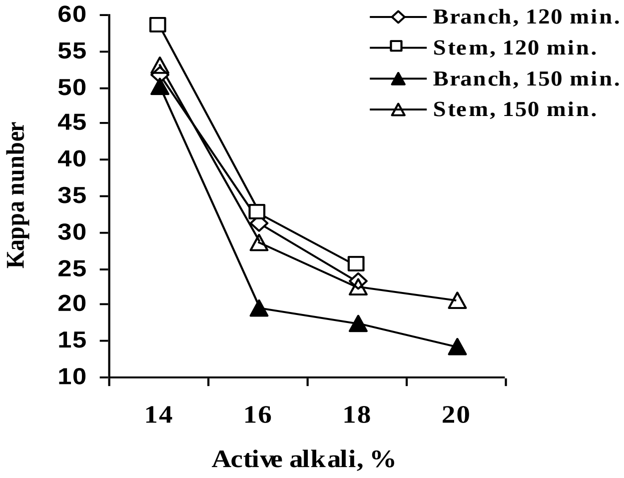
Parameters	Stem	Branch
Fiber length (mm)	0.86	0.98
Cold water solubility (%)	3.2	3.9
Hot water solubility (%)	8.02	9.10
1% NaOH (%)	18.7	19.3
Hollocellulose (%)	74.5	72.3
α-cellulose (%)	42.8	41.02
Total lignin (%)	27.3	28.5
Ash (%)	2.2	1.3

3.2. Pulping

The pulp yield and kappa number of pulps made from stem and branches of rubber wood are presented in Table 1. It was found that the chips of stem and branches were not cooked at 14% active alkali. The pulp yield was very poor with a lot of screening rejects. Longer cooking time and addition of 0.1% anthraquinone did not work at all. In previous studies many hard wood species were found suitable for pulping with an alkali charge of 14% maintaining 25% sulphidity [36, 37]. It seems that for pulping of rubber stems and branches, a high alkali dose is required.
With the increase of total alkali from 14% to 16% both the branch and stem cooked giving very coarse pulp and pulp yield becomes 49.5% for branch and 48.7% for stem. With further increase of alkali the pulp yield lowered to 1.4 percent point for branches and 1.3 percent point for stem. The pulp was well cooked. The lower pulp yield is probably due to the depolymerization of cellulose molecules in an alkaline environment. The same trend was observed for both stem and branches when cooking is done at 150 min. However the pulp yield is comparable to some widely used hardwood species (Table 3).
The color of the pulp is slightly brownish. There were some hardened rubber particles found during pulp washing. It seemed that during cooking the latex leached out from the chips and on cooling it became hardened.

Table 4. Pulping results of stem and branches of rubber tree (*Heveabrasiliensis*)

Cooking time (Minute)	Tree component	Active alkali (%)	Alkali consumption (%)	Screened yield (%)	Rejects (%)	Kappa no
120	Branches	14	13.4	30.6	32.2	51.7
		16	15.3	49.5	2.3	31.4
		18	17.3	48.1	Nil	23.3
	Stem	14	13.5	34.3	25.2	58.5
		16	15.6	48.7	5.7	32.7
		18	17.7	47.4	2.3	25.4
150	Branches	14	13.7	30.4	27.0	50.1
		14 +0.1% AQ	13.7	34.7	23.0	49.6
		16	15.7	48.7	0.87	19.5
		18	17.6	47.6	Neg.	17.5
		20	19.5	45.5	Nil	14.3
	Stem	14	13.7	33.6	25.0	53.2
		14 +0.1% AQ	13.5	38.8	21.5	51.8
		16	15.6	47.0	2.8	25.7
		18	17.7	45.8	0.90	22.5
		20	19.6	45.5	Nil	20.6



Kappa numbers of the cooked or delignified pulps against active alkali dose are given in Figure 9. It was found that the desired level of delignification could not be reached with a total alkali charge of 14% even with a longer cooking time. However, the kappa number decreased with the increase of alkali concentration for both branches and stem. The delignification was found easier in case of branches compared to stem. This is probably due to the difference in lignin structure of branches and stem which needs to be examined. Both stem and branches produced bleachable grade pulp at 18% active alkali dose for 120 min cooking time and for longer cooking time the alkali requirement was reduced.

Table 5. Physical strength properties of the pulp at 450 ml. and 250ml. CSF

Cooking time (Miniute)	Tree component	Active alkali (%)	Tear index mNm^2/g		Burst index $kPa.m^2/g$		Tensile index mN/g	
			450	250	450	250	450	250
120	Branches	16	9.61	8.40	4.62	6.13	55.6	73.6
		18	9.72	8.62	4.68	6.05	56.3	72.8
	Stem	16	9.95	8.95	4.45	5.79	64.0	75.4
		18	9.60	8.85	4.15	5.85	63.6	72.4
150	Branches	16	9.00	7.98	5.25	6.60	62.2	74.2
		18	9.83	7.44	4.70	6.28	59.5	72.5
		20	8.35	7.16	4.73	5.81	55.3	70.5
	Stem	16	9.52	8.42	4.65	6.05	66.8	78.0
		18	9.30	8.05	4.61	6.05	62.1	75.0
		20	9.10	8.29	4.73	5.62	54.4	73.8

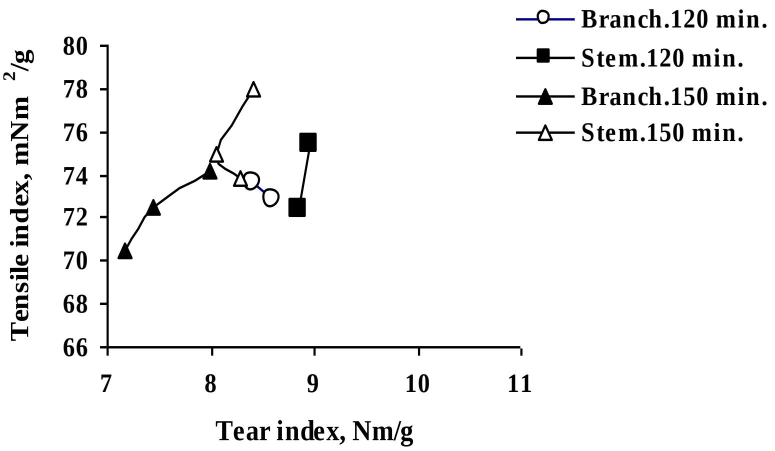


Figure 10. Tear-Tensile plots at 250 ml CSF for stem and branches of rubber tree pulped at two different times.

3.3 Strength properties

The tear, tensile and burst strength properties at 450 and 250 CSF are shown in Table 5. It showed that tear strength decreased and, both tensile and burst strength increased with the decrease of CSF. This is because the tear strength depends on the strength of individual fiber cells, which decreases with beating. On the other hand the tensile and burst strength depends on strong fiber to fiber bonding results in the increase of bond potential with the progress of beating. In the present study the tear and burst index of stem pulp are more or less similar to branch pulp however the tensile index of pulps made from stem is found slightly higher than that of branch pulp. This is due to the longer fiber length of the rubber stem. These results correlate well with the Nalita (*Tremaorientalis*) wood species [38]. With the increase of active alkali the strength properties decreased for both stem and branch.
It is recognized that the properties of the pulp are interdependent. So, the quality of the pulp is assessed by tear-tensile relationship. Such a comparison for the pulp at 250 CSF is shown in table 6. It showed that the stem pulp is a little bit superior in all cases.

Table 6. Comparison of strength properties of kraft pulps of stem and branches of rubber tree (*Heveabrasiliensis*) with other hard wood species.
(Pulping time 2hrs and temperature 170ºC)

Wood Species	Active alkali (%)	Sulphidity (%)	Screened yield (%)	Kappa number	Tear index mNm^2/g	Burst index $kPa.m^2/g$	Tensile index mN/g
Rubber stem	18	25	47.4	23.3	8.85	5.85	72.4
Rubber Branch	18	25	48.1	25.4	8.62	6.05	72.8
Kadam[1]	19	25	47.7	14.4	8.85	8.50	91.8
Simul[2]	15	20	46.7	22.5	9.81	4.97	75.6
Minjiri[2]	20	20	43.4	22.43	8.25	3.93	68.7
Mixed hardwood[3]	18	25	46.0	20.5	--	--	--

[1]Biswas *et al.* 2011; [2]Hossain *et al.* 1978;

4. Conclusion

This study indicated the pulp making characteristics of stem and branches of rubber trees. Based on the results the following conclusions were drawn.
The rubber wood (*Hevea brasiliensis*) stem is characterized with lower lignin, higher α-cellulose and longer fiber length than those of branches. The chemical composition of rubber wood indicates rubber wood has potential for use in the pulp and paper and chemical industries.
Stem and branches of rubber wood did not cook at low alkali doses. However the bleachable grade pulps were made with the increase of cooking chemicals. Longer cooking time lowered the alkali requirement to attain a similar kappa number.
Pulp yield of stem and branches was comparable but strength properties are slightly lower compared to other widely used hardwood species.

Pulp from stem was slightly stronger than branch considering physical strength properties however both stem and branches of rubber wood are suitable for producing moderate quality pulp. Besides, the pulp could also be blended with imported pulp for making writing, printing and industrial papers. Future research on the response of bleaching chemicals to the pulp is needed.

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