Guayule Bagasse—A potential raw material for paper making

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ABSTRACT

Parthenium argentatum gray, commonly known as guayule is a rich source of rubber, wax and resin. Present study is aimed at exploring the potential of guayule bagasse for paper making. Results of proximate chemical analysis, pulping, black liquor analysis and the quality of paper obtained by blending guayule bagasse with bamboo pulp are presented.

Introduction

Guayule is a member of Sunflower family compositae and belongs to genus parthenium, it is of argentatum species. It is a perinnial shrub with narrow leaves covered with drought protecting white wax. Usually only about 2 feet (60 cm) high, it is long-lived and hardy[1]. It may survive 30-40 years under desert conditions where annual rainfall may be less than 10" (250 mm). The diameter of trunk at the base is 7/8 - 2 1/4", the tap root of the plant penetrates the soil more than 20 feet supplemented by extensive fibrous roots that spread about 10 feet laterally It allows the plant to absorb moisture from large volume of desert soil and thus withstand periodic droughts[2].

It is one of the two major plant species known to contain rubber in quantities substantial enough for commercial use. The other species is hevea tree which grows principally in South east Asia Unlike, the hevea tree where rubber is contained in ducts and can be collected by bleeding without destroying the plant, the rubber in guayule is stored in closed cells[3]. For collecting the rubber, the entire bush must be harvested and processed to a stage of total disintegration of the wood morphology[4,5]. Since, the rubber makes up only a small fraction of the entire plant (15% by weight average), the economy of the process depends, therefore, on the so-called "whole plant utilization" i,e. all the components of guayule shrub must be fully utilized for the highest possible return. The components other than rubber and wax include the resin, cork and bagasse. Bagasse is by far the most abundant and makes up about one-half of the total dry mass of the plant. Thus it was in this context, thought worthwhile to evaluate the potential of guayule bagasse for paper making.

Experimental

Plant Material

Sample of guayule bagasse left over after complete extraction of rubber and resin was taken for these studies. The material was in the form of chips which were screened. The screened chips (2-3 cm) were used for all the experiments.

Proximate Chemical Analysis

Wood chips were oven dried and milled in a wiley mill. The wood dust passing through 60 mesh was collected. Proximate analysis was carried out as per TAPPI (Technical Association of Paper Industry) standards.

Microscopic Analysis

The fibre dimensions viz length, diameter, lumen etc. of guayule bagasse were determined using pira

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fibre length counter and projection microscope (magnification upto X 400).

Pulping

Pulping experiments were carried out on the chips in a series digester consisting of six bombs each of 2 5 litres capacity, rotating in electrically heated polyethylene glycol bath. In each bomb, 300 gm oven dried chips were taken (2 bombs each) and pulped at 13, 15 and 17% active alkali.

The pulping was carried out under the following conditions

wood chips charged in each bomb	300g
Active alkali as Na_2O, %	13,15 & 17
Sulphidity, %	24
Liquor to wood ratio	3:1

The total cooking time was 3 hours including half an hour to raise the temperature upto 100°C from room temperature followed by 10°C rise in every 15 min. till 165°C. The cooked material was washed with hot water, disintegrated and screened over flat laboratory screen plate having 0.3 mm slots width. Total pulp yield, screen rejects and screened pulp yield were determined. The black Liquor formed was also collected and evaluated.

Kappa Number of Pulp

Kappa number determination was carried out on screened pulps according to TAPPI standard T–236-05-76.

Black Liquor Evaluation

Black liquors were examined for total solids, residual alkali and total sodium and lignin contents using TAPPI standards.

Pulp Evaluation

For evaluating the physical strength of the pulp following standards were used—

Hand sheets for testing were made as per ISO DP 5269 and dried on plates in stack under conditions of standards ISO.R-187. Further testing carried out as per ISO standards, was for tensile index, tear and burst index, air resistance etc.

Pulp Blending

Guayule bagasse pulp obtained by using 15% chemical was blended with standard bamboo pulp in the ratio of 3:7 and 7:3 respectively. The handsheets were prepared and evaluated for strength properties.

Results and Discussion

The results of the proximate analysis are summarised in Table-1 and compared to other papermaking raw materials[6]. The ash content which gives indication of mineral constituents in raw material is quite low for guayule bagasse (1.20%) as compared to rice straw (16.10%) and wheat straw (6.0%) but is compa: rable to that of sugarcane bagasse (1.90) and bamboo (2.35%). The low ash content is desirable, because higher ash represents higher mineral content (mainly silica), which causes inconvenience in paper making and effects strength properties of the paper. The content of water solubles (hemicelluloses and cyclitols) in guayule bagasse is low as compared to other raw materials. This is important for the determination of yield by mechanical pulping process. The alkali solubility of wood throws light on the amount of extractive present, as their major portion is removed by alkali. In addition, some of the short chain hemicellulose components and a portion of lignin is also removed which gives useful information on changes undergone by these components. It also gives extent of wood decav. The alkali solubles in guayule (26 50%) are moderate as compared to wheat straw (40 20%) and rice straw (45.20%.) This may be due to lesser amount of short chain hemicelluloses present in guayule (Table–1).

The alcohol-benzene solubility, signifing the content of waxes, fats, resins and gums, for guayule is quite low (1 25%) as compared to other paper making raw materials. This may be due to use of pre extracted guayule material for analysis. Lignin content for guayule bagasse is relatively higher, which indicates

TABLE—1

Promixate Chemical Analysis of Guayule Bagasse

Parame ers	Guayule bagasse	Rice Straw	Wheat Straw	Sugarcane bagasse	Bamboo
Cold water solubility %	2.35	9.50	—	3.80	3.29
Hot water solubility %	4.44	12.60	9.30	6.30	6.12
1 % NaoH solubility %	26.50	45.20	40.20	35.40	21.35
Alcohol benzene solubility %	1.25	3.47	4.60	2.90	2.70
Pentosans %	17.00	22.70	23.00	22.60	15.06
Lignin %	30.00	12.80	21.00	19.20	25.85
Hollocellulose %	61.00	63.00	64.00	69.20	65 30
Ash %	1.20	16.10	6.00	1.90	2.35

that these molecules should be pulpable under conditions required for woody materials with high lignin content (25-32%). Straws, bamboo and sugarcane bagasse, however, have lower lignin content and thus are relatively easier to pulp. The amount of hemicelluloses in guayule (17.0%) is comparable to that in hardwoods but is relatively lower than that in rice straw and wheat straw (Table–1). The hollocellulose content in guayule bagasse was found to be 61%, which is quite comparable to other raw materials viz. rice straw (63.0%), sugarcane bagasse (65.2%) and wheat straw (64.0%).

The results of the analysis made on guayule bagasse showed values of various parameters quite comparable to different commercial raw materials used for paper making, thus it was subjected to pulping studies.

The different fibre dimensions viz length, diameter, wall thickness and lumen as given in Table–2, reveal that guayule bagasse has very low fibre length (0.6m). The fibres contain numerous parenchyma cells and tiny rubber particles. The lower values of length may lead to lower tearing strength of the paper made from this material. However, paper of desired strength could be made by blending guayule fibres with other long fibrous materials.

TABLE—2

Fibre Dimensions of Guayule Bagasse

Age, years	2.5
Fibre length, mm	
Maximum	0.8
Minimum	0.4
Average	0.6
Fibre diameter,	12.0
Wall thickness,	3.0
Lumen diameter,	6.0

The pulping results recorded in Table-3 revealed that with the increase in active alkali charge, the pulp yield, kappa number and screeen rejects decreased as expected. The higher yield coupled with higher kappa

TABLE—3

Pulping Conditions, Pulp Yield and Kappa Number of Pulp From Guayule Bagasse

Age, Years	2.5	2.5	2.5
Active alkali as Na_2O%	13	15	17
Sulphidity, %	24	24	24
Bath ratio	1:3	1:3	1:3
Maximum—temperature,°C	165	165	165
Time, Hr.	2.5	2.5	2.5
Total yield, %	42.7	42.5	42.9
Screened rejects %	12.8	5.5	5.4
Screened yield,%	30.4	37.0	37.5
Kappa number	35.5	26.0	25.0

number when cooked using 13% active alkali could be attributed to higher amount of lignin. As far as cooking conditions are concerned, the results showed that relatively higher alkali percentage (15%) is required for obtaining optimum results. Pulping with 13% alkali charge left a lot of uncooked pulp (evident from 16% screened rejects), while pulping with 17% active alkali charge resulted in about the same yield as obtained with 15% alkali charge. Thus, 15% active alkali charge was found most optimum for maximum yield and least degradation. The analysis of black liquor (Table-4) indicates that residual active alkali content in the three conditions of pulping varied considerably. The residual alkali content gives an idea about how much reagent is required for optimum pulping. A higher residual alkali (more than 8%) is highly undesirable, because that indicates loss of costly chemical and also, that an optimum pulping could be done using lesser chemical. However, very less residual alkali is also not desirable (less than 5%) for it makes the liquor more viscous thus causing problem in pulp washing, its rheological behaviour and evaporation. Thus an active residual alkali between 5-8% is desirable (as in the case of 15% active alkali pulping) which keeps the pH of liquor at 11-12 keeping the lignin in soluble form. At lower pH lignin tends to coagulate, causing various handling problems. The total sodium gives an idea about the recoverable chemical, and if economy permits this chemical can be recovered successfully by causticising.

TABLE—4

Black Liquor Evaluation

Active alkali, % as Na_2O		13	15	17
Total solids, %	w/w	19.1	20.0	20.0
Residual alkali,	g/l	1.48	4.96	6.75
Sodium	g/l	44.0	48.0	48.0
Lignin	g/l	100	100	105
Total volume,	ml	855	875	890

The physical strength properties (Table-5) show that the pulps obtained from guayule bagasse lacked desired strength properties. However, pulp made under 15% active alkali charge was the strongest among the three pulps obtained under different conditions of alkali charge (13 and 17%). The low strength properties of the pulps can be attributed to very short fibre length (0.6 mm) of guayule bagasse. It is, however, expected that a paper of satisfactory quality could be made if guayule bagasse pulp is blended with some long fibred pulp viz. soft wood, bamboo etc. Thus in this context blending studies were undertaken.

TABLE—5

Physical Strength Properties of Unbleached Pulps From Guayule Bagasse

Particulars			
Age, year	2.5	2.5	2.5
Active alkali as Na_2O %	13	15	17
PFI revolutions			
CSF, ml.	500	500	500
Basis weight, g/m²	60	60	60
Apparent density, g/m³	0.56	0.66	0.61
Tensile index, N.m/g	6.0	18.5	14.0
Stretch, %	0.5	0.7	0.6
Tear index, mNm²/g	0.6	1.90	1.15
Burst, KPam²/g	0.3	0.7	0.5

TABLE—6

Physical Strength Properties of Blends of Guayule Bagasse Pulp with Bamboo Pulp

Blend							
Guayule bagasse pulp %	Bamboo Pulp %	Freeness CSF	Apparent density g/cm³	Burst index KPam²/g	Tensile index N.m/g	Stretch %	Tear index
100	0	395	0.64	0.45	12.0	1.4	1.10
70	30	250	0.67	1.60	27.5	3.4	5.15
30	70	280	0.68	2.90	47.5	4.6	10.20
0	100	345	0.70	4.65	59.4	4.7	15.85

The guayule bagasse pulp obtained by cooking with 15% chemical was blended with bamboo pulp in the ratio of 3:7 and 7:3, and the handsheets prepared. The physical strength properties of these blended sheets as given in Table-6 indicate that guayule bagasse pulp blended with bamboo pulp in the ratio of 7:3 affords paper of satisfactory strength which could be used for making writing and printing paper. However, the same blend in the ratio of 3:7 (guayule : bamboo) provides much stronger paper.

Conclusions

Proximate chemical analysis of guayule bagasse showed encouraging results with 58% hollocellulose, 17% pentosans and 30% lignin. Unbleached pulp of 26 kappa number could be produced with 15% active alkali at 165°C with a yield of 35%. The pulp, however, showed low strength properties which was attributed to low fibre dimensions as found from morphological studies. The paper of satisfactory strength properties can be made by blending guayule bagasse pulp with 30% bamboo (long fibred) pulp.

References

1. Martin G Chem Abstr 38 28433(1944).
2. Guayule—An alternative source of natural rubber. National Academy of Sceinces Washington DC, 2, (1977).
3. Backnaus, R A ; Walsh, S; Bot Gaz (Chicago) 144, 391-400(1983).
4. Compos-Lopéz, E; Neavez-Camacho, E.; Maldonado Gracia, R; In Guayule: 'Recon Cuentro en. al. Deiserton; Camposlopez, E; McGinnies,W; CIQA: Saltillo, Coatiuila, Mexico, Pub 371, (1978).
5. Naqui, H. H; In "El guayulero: ; Naqui H. H.; Ed., Guayule Society Publications University of California Riverside, CA, Vol 6, pp 6-B, (1984).
6. Frickson, M. ; Mikshe, G.E. and Somfai, I; Holzforschung, 28(4): 113 (973).