Some Studies on Pulping Characteristics of Jute and other Allied Non-Wood Plant Fibres for Paper Manufacture in the Handmade Paper Mills

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ABSTRACT

Jute is mainly grown in Eastern part of India. It has been used for packaging materials for various agricultural, food & industrial commodities and also to some extent for carpet backing, hessian, decorative fabrics etc.

The existence of jute fibre in its conventional use is challenged by the synthetic fibres and its export has gradually decreased. Therefore, it is necessary to find some new uses of jute fibre and its by-product. It has been established that jute fibre in the form of jute caddies, root cuttings, jute feshwa, jute whole plant etc. having high percentage of cellulose and long fibre are quite suitable as non-wood fibrous raw materials for manufacture of different grades of paper and board. Attempts were also done to evaluate the paper making qualities of some other allied fibres as non- conventional paper making raw materials. In this paper, a comparative study on the pulping characteristics and properties of the resulting paper has been made to utilise jute fibre as well as some allied fibres viz. coir, bagasse, mesta, sisal, ramie and pine apple fibres by hand made process. The technique of hand made paper making is gaining wide acceptance as it is based on rural technology and is quite inexpensive. It has a solution to the problem of energy and pollution unlike big paper mills. It saves deforestation and gives quality paper of high strength and durability.

INTRODUCTION

The demand for pulp, paper, board in our country is increasing day by day with rapid growth of civilization. This demand has always been found to be higher than their production in the country. The supply of the conventional paper making raw materials like wood and bamboo are short due to environmental preservation and our protest against deforestation. Moreover, the tropical forests are disappearing at a rapid rate due to high demand of raw materials required for the production of pulp and paper. There

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is world wide increase in capacity for production of non-wood plant fibre pulps for paper making has abruptly increased, since 1975, going from 6.9% of total paper making pulp capacity in 1975 to 8.6% in 1988, 10.6% in 1993 and is projected to go to 11.2% in 1998. This is mainly due to population increase in China and India and it has been far greater than the most optimistic projections.

Among the leading countries, using non-wood plant fibre for pulp and paper, China has gone much ahead with capacity for producing 6.8 million tonnes of pulp from different fibres, whereas India has capacity for producing only 0.090 million tonnes of pulp which is only 1.07% of the total world production.

Under this circumstance, we have to go for non-conventional raw materials e.g. agricultural residues and other allied non-wood plant fibres which represent another renewable source.

These raw materials are generally soft materials, they have lesser lignin content and can be easily converted to a pulp with lesser cost of chemicals and energy. The yield of the pulps are also higher in comparison to the conventional paper making raw materials. The strength and other properties of the pulps have been found to be acceptable. It has been established that jute fibre in the form of jute caddies, root cuttings, feshwa etc. having high percentage of cellulose and long fibre are suitable as non-wood fibrous raw materials for making different grades of paper and paper board. Attempts were also done to evaluate the paper making characteristics of some other allied fibrous raw materials. With an objective of meeting the ever-growing demand for various cellulosic products, over coming the shortage of the conventional raw materials and in order to diversify the use of the textile based fibres like jute, and allied fibres - bagasse, coir, mesta, pineapple, ramie, sisal, experimental pulp and paper making and evaluation of strength properties study of above raw materials have been undertaken in this paper. Hand-made paper is a prominent village industry based on decentralised production and rural technology. It is popular for its sophisticated look, exquisite beauty, strength and durability. Despite the advancement of large scale paper technology, Hand-made Paper Industry has ample scope of employment generation with very less capital investment. It has a solution to the problem of energy and pollution unlike big paper mills. Until now, cotton rags, tailor cuttings and recycled secondary fibre have been the major components of fibre materials for this industry. Our objective is to use jute and allied fibres viz. coir, bagasse, mesta, ramie, pineapple, sisal either alone or in admixture with cotton rag, hosiery cuttings etc. in handmade paper mills.

RAW MATERIALS

Jute

(a) Jute Caddies : During the processing of jute in the jute mills there are wastage at different stages which are called jute caddies. They are generally of short unspinnable fibre with high oil content. This raw material is a good source of cellulose for making pulp, paper and board.

(b) Jute root cuttings : About 10-15% of the jute crop from the farmer's field contain hard barky roots at the bottom portion of the fibre which are known as root cuttings. they are excellent raw materials for making various speciality papers.

(c) Jute feshwa : After the jute fibre is extracted from the jute plant by the retting process, some short fibres of jute is still found to be adhered to jute stick which are called feshwa.

Coir:

Coir or conconut fibre belongs to the group of hard structural fibres. It is an important commercial product obtained from the husk of the coconut. In India, coir is a traditional industry, which has taken deep roots in the economic structure of the rural areas in the coastal states. Coir has very high lignin content and lignin is the main constituent responsible for the stiffness of the coir as well as for the natural colour of the fibre.

Bagasse

Bagasse is the residue of the sugarcane after extraction of the sugar. This material when pulped and depithed yields a serviceable fibre similar to straw in general characteristics, which is used in the production of wrapping paper, liner board and even glassine. In India, bagasse can prove to be the second biggest source of the short-fibred pulp for paper making. The country produces about 125 million tonnes of sugarcane.

Mesta

Kenaf or mesta fibres are growing in Andhra

Pradesh, Orissa and Tamilnadu. These fibres are inferior to jute fibre in their strength properties and are used a cheep substitutes for jute fibre in the manufacture of bags, socks, cordage and netting. Kenaf plant can also be used for manufacture of newsprint and other grades of paper and it is hoped that kenaf will be accepted by pulp and paper industry as a major alternative or supplementary technology.

Sisal

Sisal is a leaf fibre of about 2-5 mm long. Large scale production of both bleached and unbleached pulp from sisal in a mill in Brazil shows that an excellent long fibres pulp can be produced from sisal and this pulp is marketed for speciality papers viz. electrical insulation paper, cement bags, industrial filter paper, cigarette papers etc.

Ramie

The individual ramie fibres occur in the form of bundles which are held in place and to each other by gum, waxes and pectins. Due to higher gum content, degumming is essential. Ramie is a wonder fibre and stronger than any other known fibre. The fibre is absolutely white and lusturous. It is principally used for high grade fabrics and replaces silk in certain cases.

Pineapple

Pineapple is a herbaceous perennial plant widely cultivated for the fruit in the tropical and subtropical regions of the world. In India, Cultivation of pineapple is found in the eastern and southern regions. Principal uses of the fibre are in making twine ropes, threads, fabrics etc.

The chemical composition of all these natural fibres are given in Table-1. The morphological characteristics of different Non-wood Fibres are also shown in Table-1A

MATERIALS AND METHODS

(i) Materials : The different natural fibres viz. coir, bagasse, mesta, sisal, ramie and pineapple fibre were procured along with jute from the respective regional agricultural stations. .

(ii) Methods : 500 gm of each raw material was converted to pulps by hot and cold soda chemi-mechanical processes under suitable conditions. Bleaching was done using sodium hypochlorite solution of 4% strength (purchased from the market) in single or double stages followed by washing of the pulp with clean water to remove any adhering chemicals. The pulps were next beaten using a laboratory beater to a 40°-42° SR freeness and then standard paper sheets were formed by hand-made process and were tested to evaluate the strength properties of the resulting paper.

Table-1

Composition of jute and allied fibrous raw materials

Sl.NO.	Raw material	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Ash (%)
1.	Jute	60	25	11.5	1.6
2.	Mesta	60	23.5	10	0.7
3.	Sisal	63	27	9	0.7
4.	Ramie	87	10	0.5	1.1
5.	Bagasse	42.5	32	20	3.3
6.	Coir	43.4	0.25	45.8	NA
7.	Pineapple	70	23	4.5	0.8

RESULTS AND DISCUSSION

It can be seen from Table-2 that in case of bagasse pulp, the hot soda process of digestion gives better results in terms of tensile strength as compared

Table-1A

Morphological Characteristics of different Non-wood Fibres

Name of Fibre	Average fibre length (mm)	Breadth x (10^{-3}mm)	Length/Breadth (Average value)
Bagasse	1.4	22	66
Coir	0.5-4	7 - 30	95
Jute	0.8 - 6.0	5 - 25	110
Mesta	2 - 11	13 - 34	140
Pine apple	3.0 - 9.0	4 - 8	450
Ramie	20 - 25	15 - 80	3500
Sisal	0.5 - 6.0	5 - 40	150

Table-1B

Pulping and bleaching conditions of jute and allied fibres

Sample	Process	Experimental conditions of pulping and bleaching		
		Temperature °C	Time	Chemical (%)
A1	Pulping	97 - 98	2 hrs.	10
A2	Bleaching	52 - 55	45 min.	5
A3	Bleaching	50	40 min.	5 + 5
A4	Bleaching	50	30 min.	10
A5	Bleaching	50	20 min.	10 + 10
B1	Pulping	Room Temperature	3 days	10
B2	Bleaching	52 - 55	45 min.	5
B3	Bleaching	50	40 min.	5 + 5
B4	Bleaching	50	30 min.	10
B5	Bleachging	50	20 min.	10 + 10

to the cold soda process of digestion, which may be due to higher delignification of bagasse. The unbleached paper exhibits better strength than bleached paper due to subsequent attack on cellulosic fibres while using sodium hypochlorite as strong bleaching agent. Also, it can be observed that the addition of the bleach in a single stage helps to retain greater strength than when the bleach is added in two stages. However, a discrepancy is observed between the bleach concentration, when added in single or double stages, lower concentration of bleach imparts better tensile strength to paper when added in two stages. On the other hand, higher concentration of bleach imparts better tensile strength to paper when added in one single stage. Single stage bleaching has a positive effect on bursting strength of paper than double stage bleaching. It is also seen that hot method of digestion imparts greater density to paper than cold method which may be due to the fact that here more hydration takes place due to presence of high properties of

Table-2

Density and strength results of paper from bagasse pulp

Sample	Yields of Pulp (%)	Average Tensile Strength (Kg)	Tensile Index (Nm/g)	Average Burst Strength (Kg/cm)	Burst Index ($kPam^2/g$)	Density (gm/cc)
A1	63.0	5.73	25.37	2.67	1.773	0.70
A2	--	3.53	19.38	2.45	2.017	0.60
A3	--	3.90	19.06	2.30	1.685	0.61
A4	--	4.50	26.67	2.20	1.955	0.65
A5	--	2.93	16.58	2.53	2.146	064
B1	72.00	4.23	13.54	2.40	1.152	0.58
B2	--	2.17	10.32	2.27	1.62	0.47
B3	--	2.10	11.32	2.33	1.882	0.51
B4	--	2.10	13.86	2.33	2.305	0.55
B5	--	2.20	8.59	2.40	1.405	0.67

Note :- A Hot Soda Digestion
A1 Unbleached
A2 5% Sodium Hypochlorite
A3 5%+5% Sodium Hypochlorite
A4 10% Sodium Hypochlorite
A5 10%+10% Sodium Hypochlorite

B Cold Soda Digestion
B1 Unbleached
B2 5% Sodium Hypochlorite
B3 5%+5% Sodium Hypochlorite
B4 10% Sodium Hypochlorite
B5 10%+10% Sodium Hypochlorite

hemicellulose in the pulp.

In case of coir pulp, The hot method of digestion gives better results than cold method in most of the cases except when the pulp is bleached in two stages with 5% bleach and when 10% bleach is used in a single stage which may possibly due to the higher extent of delignification in the hot soda process than the cold one (Table-3) in case of coir pulp, in general, the bleached paper exhibits better strength properties than the paper mode from unbleached coir pulp. The hot soda digestion imparts better bursting strength to paper than cold soda digestion. Table-3 indicates that higher density paper is made by cold method of digestion.

Table-4 indicates that in general jute shows good overall tensile strength, irrespective of the different conditions of paper making. The hot soda digestion demonstrates higher strength when bleached at 10% concentration which may be due to more attack on cellulose by the strong bleach. The cold method of digestion displays better burst index than the hot method except in the case of unbleached paper. It is also noticed that in general the hot soda digestion produces a denser paper than digestion under cold condition which may be due to the presence of more hydrated pulp in the hot soda process.

Table-5 illustrates that mesta also shows good overall tensile strength irrespective of the different conditions of paper making. The cold soda digestion process displays comparatively better strength than hot soda process probably due to inadequate delignification, the strength of the unbleached paper made by the latter process is lower than when it is bleached. In general, pulp by hot soda process yields better burst strength than the pulp by cold soda

Table-3
Density and strength results of paper from coir pulp

Sample	Yield of Pulp (%)	Average Tensile Strength (Kg)	Tensile Index (Nm/g)	Average Burst Strength (Kg/cm)	Burst Index (kPam²/g)	Density (gm/cc)
A1	61.63	1.77	5.12	2.22	0.96	0.48
A2	--	1.10	3.65	2.00	0.994	0.41
A3	--	1.60	5.39	2.22	1.125	0.50
A4	--	1.65	5.85	2.20	1.169	0.41
A5	--	2.83	9.14	2.23	1.079	0.44
B1	66.77	1.20	3.52	2.00	0.878	0.46
B2	--	6.45	10.27	2.43	0.58	0.60
B3	--	2.33	3.92	2.13	0.537	0.63
B4	--	3.73	6.67	2.57	0.689	0.68
B5	--	1.75	3.43	2.82	0.827	0.64

Note :-
A Hot Soda Digestion
A1 Unbleached
A2 5% Sodium Hypochlorite
A3 5%+5% Sodium Hypochlorite
A4 10% Sodium Hypochlorite
A5 10%+10% Sodium Hypochlorite

B Cold Soda Digestion
B1 Unbleached
B2 5% Sodium Hypochlorite
B3 5%+5% Sodium Hypochlorite
B4 10% Sodium Hypochlorite
B5 10%+10% Sodium Hypochlorite

Table-4
Density and strength results of paper from jute pulp

Sample	Yield of Pulp (%)	Average Tensile Strength (Kg)	Tensile Index (Nm/g)	Average Burst Strength (Kg/cm)	Burst Index (kPam²/g)	Density (gm/cc)
A1	62.1	13.60	30.96	7	2.38	0.59
A2	--	11.47	27.19	6	2.13	0.64
A3	--	10.23	22.07	4.90	1.58	0.72
A4	--	8.47	19.94	4.13	1.45	0.65
A5	--	9.33	24.24	4.50	1.75	0.61
B1	81.95	5.40	20.26	3.40	1.91	0.26
B2	--	6.25	28.23	3.73	2.52	0.31
B3	--	5.50	21.38	3.47	2.02	0.35
B4	--	4.50	21.82	3.33	2.42	0.29
B5	--	5.65	21.93	3.73	2.17	0.33

Note :-
A Hot Soda Digestion
A1 Unbleached
A2 5% Sodium Hypochlorite
A3 5%+5% Sodium Hypochlorite
A4 10% Sodium Hypochlorite
A5 10%+10% Sodium Hypochlorite

B Cold Soda Digestion
B1 Unbleached
B2 5% Sodium Hypochlorite
B3 5%+5% Sodium Hypochlorite
B4 10% Sodium Hypochlorite
B5 10%+10% Sodium Hypochlorite

Table-5
Density and strength results of paper from mesta pulp

Sample	Yield of Pulp (%)	Average Tensile Strength (Kg)	Tensile Index (Nm/g)	Average Burst Strength (Kg/cm)	Burst Index ($kPam^2/g$)	Density (gm/cc)
A1	76.59	6.30	21.27	4.40	2.22	0.40
A2	--	3.87	24.26	3.33	3.12	0.30
A3	--	4.00	21.80	3.47	2.83	0.44
A4	--	3.93	22.22	3.20	2.71	0.34
A5	--	5.07	26.93	3.67	2.92	0.47
B1	86.22	7.425	26.29	4.20	2.22	0.36
B2	--	5.70	28.82	4.13	3.13	0.35
B3	--	5.60	22.34	3.53	2.11	0.37
B4	--	7.47	24.05	4.17	2.01	0.30
B5	--	6.52	27.57	3.60	2.28	0.37

Note :- A Hot Soda Digestion
A1 Unbleached
A2 5% Sodium Hypochlorite
A3 5%+5% Sodium Hypochlorite
A4 10% Sodium Hypochlorite
A5 10%+10% Sodium Hypochlorite

B Cold Soda Digestion
B1 Unbleached
B2 5% Sodium Hypochlorite
B3 5%+5% Sodium Hypochlorite
B4 10% Sodium Hypochlorite
B5 10%+10% Sodium Hypochlorite

Table-6
Density and strength results of paper from pineapple pulp

Sample	Yield of Pulp (%)	Average Tensile Strength (Kg)	Tensile Index (Nm/g)	Average Burst Strength (Kg/cm)	Burst Index ($kPam^2/g$)	Density (gm/cc)
A1	72.66	7.925	43.92	3.73	3.09	0.31
A2	--	6.25	33.68	4.20	3.39	0.64
A3	--	2.80	18.92	3.60	3.64	0.40
A4	--	6.60	39.04	3.60	3.19	0.53
A5	--	5.70	29.09	3.30	2.52	0.56
B1	89.83	5.53	37.11	3.07	3.08	0.51
B2	--	4.87	30.01	3.50	3.23	0.51
B3	--	5.57	25.43	3.60	2.46	0.51
B4	--	3.00	13.77	3.47	2.38	0.50
B5	--	2.57	16.14	3.13	2.94	0.47

Note :- A Hot Soda Digestion
A1 Unbleached
A2 5% Sodium Hypochlorite
A3 5%+5% Sodium Hypochlorite
A4 10% Sodium Hypochlorite
A5 10%+10% Sodium Hypochlorite

B Cold Soda Digestion
B1 Unbleached
B2 5% Sodium Hypochlorite
B3 5%+5% Sodium Hypochlorite
B4 10% Sodium Hypochlorite
B5 10%+10% Sodium Hypochlorite

Table-7
Density and strength results of paper from ramie pulp

Sample	Yield of Pulp (%)	Average Tensile Strength (Kg)	Tensile Index (Nm/g)	Average Burst Strength (Kg/cm)	Burst Index ($kPam^2/g$)	Density (gm/cc)
A1	76.00	4.13	18.25	8.00	5.29	0.62
A2	--	7.53	33.65	4.80	3.21	0.67
A3	--	5.45	21.35	4.93	2.89	0.73
A4	--	3.30	18.02	4.60	3.76	0.30
A5	--	5.23	16.76	4.73	2.27	0.76
B1	90.80	4.40	26.10	3.93	3.49	0.52
B2	--	2.60	18.41	4.07	3.32	0.49
B3	--	3.70	25.41	4.07	4.19	0.60
B4	--	3.20	17.33	3.93	3.19	0.48
B5	--	3.60	24.69	4.40	4.52	0.48

Note :-
A Hot Soda Digestion
A1 Unbleached
A2 5% Sodium Hypochlorite
A3 5%+5% Sodium Hypochlorite
A4 10% Sodium Hypochlorite
A5 10%+10% Sodium Hypochlorite

B Cold Soda Digestion
B1 Unbleached
B2 5% Sodium Hypochlorite
B3 5%+5% Sodium Hypochlorite
B4 10% Sodium Hypochlorite
B5 10%+10% Sodium Hypochlorite

process. It was also found that addition of bleach in two stages impart higher density to paper than when it is added in single stage.

Table-6 shows paper made from pineappple fibre to have a wide range of tensile strength under different experimental conditions. Here hot soda process exhibits better strength than the cold soda prcess. The unbleached paper has greater strength when compared to bleached paper, probably because bleaching damages the cellulose and thus destroy the strength property. It was found that bleaching improves the burst index of paper made by hot soda process. It was noticed that bleaching decreases the density of paper made by the hot soda digestion process.

Table-7 explains that cold soda digestion for ramie imparts better strength to paper than hot soda process, except when 5% bleach concentration is used. It also revealed that unbleached paper exhibited better bursting strength than bleached paper only when hot digestion process is employed. The density of bleached paper by hot soda process is found to be greater than cold soda process which may be due to more delignification in hot process that may lead to more formation of fines which ultimately results in the formation of denser, well bended sheet.

From Table-8 it is evident that, in general, unbleached paper displays better stength than bleached paper except in case of cold digestion process using 5% bleach, added in one stage. It also indicates that cold soda process exhibits better burst strength when compared to the hot soda process which may be due to better inter-fibre bonding. The hot method of digestion imparts greater density to paper when compared to the cold method of digestion, except when the paper is not bleached. Bleach, when added in two stage yields more dense paper by the cold soda method of digestion.

CONCLUSION

The hand-made paper industry in gaining wide acceptance in our country. For example, in 1953, the value of production of hand-made paper was hardly Rs. 5.00 lakhs and it was more than Rs. 150 million in 1996-97. In 1998, the production of hand-made

Table-8
Density and strength results of paper from sisal pulp

Sample	Yield of Pulp (%)	Average Tensile Strength (Kg)	Tensile Index (Nm/g)	Average Burst Strength (Kg/cm)	Burst Index ($kPam^2/g$)	Density (gm/cc)
A1	60.25	6.40	18.09	4.67	1.97	0.56
A2	--	4.55	8.67	4.67	1.33	0.70
A3	--	5.25	12.52	4.65	1.66	0.67
A4	--	6.85	13.27	5.00	1.45	0.72
A5	--	5.53	11.55	4.47	1.40	0.60
B1	75.42	7.33	21.18	6.60	2.85	0.65
B2	--	5.57	26.25	4.27	3.01	0.53
B3	--	3.63	20.50	4.27	3.61	0.58
B4	--	7.80	20.20	5.00	1.94	0.50
B5	--	6.80	16.63	5.07	1.85	0.52

Note :- A Hot Soda Digestion
A1 Unbleached
A2 5% Sodium Hypochlorite
A3 5%+5% Sodium Hypochlorite
A4 10% Sodium Hypochlorite
A5 10%+10% Sodium Hypochlorite
B Cold Soda Digestion
B1 Unbleached
B2 5% Sodium Hypochlorite
B3 5%+5% Sodium Hypochlorite
B4 10% Sodium Hypochlorite
B5 10%+10% Sodium Hypochlorite

Table-9
Density and strength results of paper from cotton rag pulp

Sample	Yield (%)	Average Tensile Strength (Kg)	Tensile Index (Nm/g)	Average Burst Strength (Kg/cm^2)	Burst Index ($kPam^2/g$)	Density (gm/cc)
A1	96.00	14.00	87.18	9.31	8.70	0.69
A2	--	12.00	74.73	8.25	7.70	0.63
B1	97.00	7.80	48.54	6.00	5.60	0.59
B2	--	7.00	43.59	5.00	4.66	0.61

Note :- A Hot Soda Digestion
A1 Unbleached
A2 5% Sodium Hypochlorite
B Cold Soda Digestion
B1 Unbleached
B2 5% Sodium Hypochlorite

paper and board would be about 15,000 tonnes valued at Rs. 280 million. The export value of hand-made paper and products would be Rs. 100 million indicating the high potential of the industry as an exportable commodity.

Originally, cotton rag, hosiery cuttings etc. were the prime raw materials for hand-made paper industry in India. Due to the non-availability and high price of rag now-a-days, attempts may be done to utilise jute and other allied fibrous raw materials to manufacture different grades of hand-made paper and

board either alone or in admixture with some rag pulp in different proportions.

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