Studies on the Pulp Characteristics and Properties of the Handmade Paper made from Natural Fibres

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Abstract

Handmade pulps have been prepared from coir, bagasse, jute mesta, sisal, pineapple and ramie. The physical and chemical properties of the pulps have been determined and the results have been discussed in terms of their suitability as alternate raw materials for papermaking.

INTRODUCTION

Various studies have been carried out from time to time to evolve newer and better techniques for paper making. The effectiveness of the various raw materials, digestion processes, chemical used, etc. in paper making have also been analysed. On appraising the literature, related to paper making, it has been found that the unconventional raw materials i.e. agricultural and industrial wastes likejute (6,7,8,13,14,16,17,18), sisal(3), mesta(12), coir (15), pineapple (2), ramie, bagasse (1,9,10,11) are at par with the unconventional materials (wood, bamboo, etc) with respect to the paper making qualities and hence have high potentialities as raw materials in the paper and pulp industry. The literature survey has also shown that a pulping stage between chemical and mechanical processes, i.e. chemi-mechanical pulping has greater advantage of being fairly non-polluting, easily adaptable for small scale production and provides good yield and properties to pulp and paper(10).

EXPERIMENTAL

The various steps, in the sequential order, performed for making paper included the followings :-

Preliminary Treatments

a) Sorting : The raw materials were sorted by hand to remove the foreign materials.

b) Cutting:Thesorted materials were cut into small uniform pieces of 1" to 1.5" using a pair of scissors and a

Table 1 : Table showing the composition of some of the conventional and unconventional raw materials used for paper making.

Raw Material	Lignin (%)	Cellulose (%)	Hemicell -ulose	Pentosan (%) (%)	Alcohol Benzene Extractable	Silica (%) (%)	Ash (%)
Bamboo	25	57	-	14	2	1-1.5	2
Pine (Wood)	26	5-10	-	11	1	0.1-0.3	1
Coir	40-45.8	43.4	0.25	-	-	-	-
Bagasse	20	39	32	-	-	-	3.3
Jute	11-12	61	12	-	-	-	1.6
Mesta	10	61	22	-	-	-	0.7
Sisal	9	64	29	-	-	-	0.7
Pineapple	4.5	70	-	-	-	-	0.8
Ramie	0.5	87	10	-	-	-	1.1

chopper.

c) Dusting : The cut materials were dusted by hand to remove the dust particles using a 'dusting frame', covered with 6 wire meshes.

d) Digestion / Pulping : The main objective of this process is extraction of non-fibrous materials (such as resinous materials, lignin, oil, pithy substances, etc.) from the raw materials without any degradation of the cellulosic matter. The pulping was carried out by two methods:-

i) Hot soda digestion : The cut and dusted raw materials were cooked in a solution containing 10% (o.w.f) of caustic soda at 90-95°C, for 2 hours, using an MLR of 1:20.

ii) Cold soda digestion : In this method, the materials were soaked in a solution containing 10% (o.w.f) of caustic soda at room temperature, for 48 hours, using an MLR of 1:16.

e) Washing : The digested raw materials were washed thoroughly with tap water to remove the excess alkali and other non-fibrous substances. Finally, the pulp was squeezed to remove the excess water by means of screw-press machine.

Beating of the pulp

The pulp was beaten to a freeness of above 40° SR (Shopper-Reiglar) by a laboratory beater.

Bleaching

The pulp was bleached with an aim to obtain a brighter coloured pulp due to further removal of lignin and other materials, which might have been left behind even after the soda digestion. The pulp was bleached for 30 minutes, using 5% and 10% (o.w.f.) sodium hypochlorite (NaOCl) of 4% concentration, at a temperature of 60-65°C and a ph of 9-10, both in single as well as multiple stages. In the latter case, the single stage bleached pulps was bleached again correspondingly with 5% and 10% (o.w.f.) NaOCl respectively, maintaining the same treatment conditions as in the single stage. Finally, the bleached pulp was washed thoroughly first with bisulphite (to remove excess chlorine and chloro-lignin that may have been formed), followed by water to remove any adhering chemicals.

Lifting and Couching

The pulp mixture was evenly spread on a mould which was later drained out of water and the paper was placed on a wet felt.

Pressing

The couched paper was transferred to the book binder's screw press to further remove excess water and to prevent the individual sheets of paper from curling and rippling.

Drying

The papers were 'Plate Dried.'

Separation and Calendering

After drying, the plate dried papers were carefully separated from the plate and given a smooth surface by the process of calendering.

Testing

Once the handmade paper was ready, it was evaluated for it various physical properties i.e. Tensile Strength, Bursting Strength and Density using the Tensile Strength Testing machine (Model No. FDP 40), Bursting Strength Tester and Thickness Gauge (Dial type), respectively.

RESULTS AND DISCUSSION

The various properties (Density, Tensile Index and Bursting Index) of the papers made from the different fibre types have been analysed on the basis of the following parameters:-

Comparison between hot and cold method of soda digestion for making pulp. Comparison between paper made from bleached and unbleached pulp. Comparison between different amounts of the bleach used i.e 5% & 10%. Comparison between single & multiple stages of bleaching of the pulp.

Analysis of percentage yield of pulp

Table 2 indicates that the percentage yield of the pulp after beating is always higher in case of the cold soda digestion process as compared to the hot soda digestion process in case of all the fibres. This could be due to more delignification of the raw materials when they are in contact with the caustic soda solution for a higher period of time in the former case; in the hot soda digestion process only two hours were allowed for the digestion as against 48 hours in the cold soda digestion process. Thus, with the yield of the pulp being higher, the latter process (cold soda digestion) was used for further investigation.

Fig. 1 confirms the above statement. Further, it also indicates the percentage pulp yield of the different fibres under both the conditions. Cold soda digestion gives the highest pulp yield in case of bagasse and ramie and lovest in case of coir. This maybe due to the higher amount of lignin present in coir, while ramie contains the lowest amount of lignin among all the other fibres under investigation. Therefore delignification is higher in case

Table 2 : Table showing the pulping results of the hot and cold soda chemi-mechanical process.

Fibre Type	Process	Yield (%)	Freeness
	Hot	33.00	
Bagasse	Cold	42.51	38-40
	Hot	61.63	
Coir	Cold	66.77	38-40
	Hot	62.10	
Jute	Cold	81.95	38-40
	Hot	76.59	
Mesta	Cold	86.22	38-40
	Hot	72.66	
Pineapple	Cold	89.83	30-35
	Hot	76.00	
Ramie	Cold	90.80	30-35
	Hot	60.25	
Sisal	Cold	75.42	38-40

of ramie, which results in higher pulp yield.

Analysis of density of the papers made from different fibres

From table 3, the following two inferences can be drawn:-

a) When the amount of lignin present in the selected fibres is high (between 20 to 40%), medium density of the resulting paper is obtained.

b) When the amount of lignin present in the selected fibres is low (between 0.5 to 4.5%), highest density of the paper results.

It is known that the density of lignin is slightly lower than the density of cellulose. Thus, it is evident that with the amount of lignin present in the fibre being higher, the paper made from these fibres will show the density to be on the higher side to some extent (medium density). This maybe due to the incomplete removal of the low density lignin. On the other hand, with fibres having low lignin content (viz, pineapple and ramie), where expectedly all the lower density lignin is removed, maximum density of paper results. Surprisingly, fibres having moderate amount of lignin (9 to 12%) like jute, mesta and sisal give lowest density in the paper than when the paper is made from fibres having higher lignin content. This perhaps is due to some physical effect (more voids, etc.) in Jute, mesta and sisal along with the incomplete removal of lignin in case of these fibers.

On bleaching the pulp, there is not much change in the density of the resultant papers made from pineapple and ramie. Thus, lignin content being less, during bleaching the chances of its removal and breakage of the lignin - cellulose ester linkages is also less. This chance is maximum in casc of Sisal having medium extent of lignin which is thus readily accessible to the bleaching liquors. However, unlike sisal which has a higher amorphous content, jute and mesta do not become denser with increasing vigorosity of the bleaching condition.

Significant increase in the density of paper made from coir and bagasse on bleaching can be identified from table 3 Thus, since the two fibres have a high amount of lignin, accessibility of the same towards the lighter hypochlorite liquor is less and thus the increase in the density is not much. However with the increase in the bleaching vigorosity, the effect of increasing density is pronounced perhaps due to the removal of lignin from the relatively higher accessible zone resulting in a more compact structure formation as a whole.

Analysis of tensile and bursting index of the different papers

From Fig. 3 and 4, the following inferences can be drawn:-

a) The tensile index and the bursting index is always lower for the unbleached paper than for the bleached ones probably because the former has a higher percentage of lignin which has more non-uniformity in the fibre. After bleaching this non-uniformity is partly removed and the structure is homogenized.

b) In case of all the papers made from the different fibres, the tensile index and the bursting index is always higher when 5% (o.w.f) of the bleach (4% NaOCl) is used than when 10% (o.w.f) of 4% NaOCl is used, thereby indicating that on increasing the amount of NaOCl, further of breaking of different

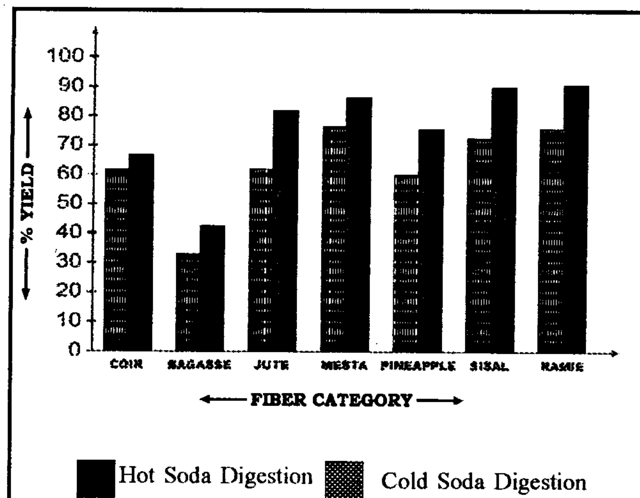

Fig. 1 Graph showing the pulping characteristics of the different fibre wastes in terms of percentage yield of the pulp

inter unit linkages takes place thereby decreasing the strength. The same trend can be seen from table 3, where single stage bleaching gives higher strength as compared to when bleaching is carried out in two stages.

c) Among the different fibres, pineapple & mesta gives paper with higher tensile index under all the different conditions, which is probably due to their lower lignin content. With lower amounts of lignin, its removal is also easier.

d) An interesting trend can be noted in case of Fig. 4, on arranging the papers made from the different fibres according to the decreasing amount of percent lignin it inherently contains, it can be seen that the bursting index is higher when the fibres are left unbleached.

CONCLUSION

The cold soda digestion process gives good yield of pulp which is maximum for paper made from ramie and lowest those made from coir having highest amount of lignin. Generally low density paper is preferred over the heavy ones, and so paper made from fibres having a lower lignin content (ramie, etc) are more acceptable as their density is also lower. Papers from jute and mesta are the best papers among all the fibre wastes used and they also have low amounts of lignin.

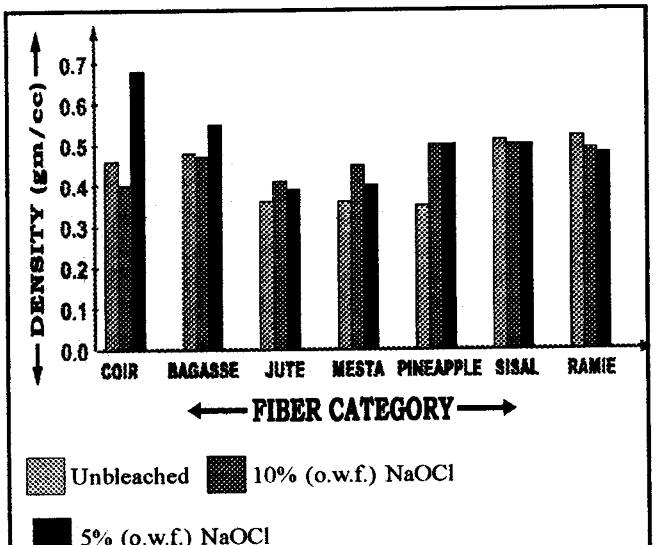

Fig. 2 Graph showing the Density (gm/cc) of the papers made from different fibre types under different conditions of bleaching.

Properties	Density (gm/cc)							Tensile Index (Nm.g)							Burst Index KPam²/gm						
Samples	Cori	Bagasse	Jute	Mesta	Sisal	Pineapple	Ramie	Coir	Bagasse	Jute	Mesta	Sisal	Pineapple	Ramie	Coir	Bagasse	Jute	Mesta	Sisal	Pineapple	Ramie
Lignin (%) Conditions	40%	20%	12%	10%	9%	4.5 to 5%	0.5 to 1%	40%	20%	12%	10%	9%	4.5 to 5%	0.5 to 1%	40%	20%	12%	10%	9%	4.5 to 5%	0.5 to 1%
Unbleached	0.46	0.48	0.36	0.36	0.35	0.51	0.52	3.52	13.54	20.26	26.29	20.18	27.11	16.1	0.378	1.152	1.91	2.22	2.85	3.08	3.49
5% (o.w.f.) NaOCl bleached	0.40	0.47	0.41	0.45	0.50	0.51	0.49	10.27	14.32	21.23	28.82	26.25	30.01	18.41	0.580	2.920	2.52	3.13	3.01	3.23	4.32
10% (o.w.f.) NaOCl bleached	0.68	0.55	0.39	0.40	0.50	0.50	0.48	6.67	13.86	21.82	28.00	20.20	28.77	17.33	0.689	2.305	2.42	2.01	2.94	3.28	4.1
5% (o.w.f.) NaOCl followed by another 5% (o.w.f.) NaOCl	0.63	0.57	0.35	0.37	0.58	0.51	0.50	3.92	11.82	21.38	22.34	20.50	25.43	25.41	0.537	1.882	2.02	2.11	3.01	2.46	4.10
10% (o.w.f.) NaOCl followed by another 10% (o.w.f.) NaOCl	0.64	0.67	0.38	0.37	0.52	0.47	0.48	3.43	8.59	21.13	17.57	16.63	16.14	24.69	0.627	1.405	2.17	2.08	1.85	2.94	4.12

M Desity = Weight / Volume, Volume = Area x Height or Thickness

P Tensile Index = Breaking length (Km) / 10.2

Breaking length = Average tensile strength in kg x 66700 / weight i.e. grams per square meter

I Bursting Index = Bursting Factor / 0.102

Bursting Index = Average bursting strenth in gm/cm² / weight i.e. grams per square meter

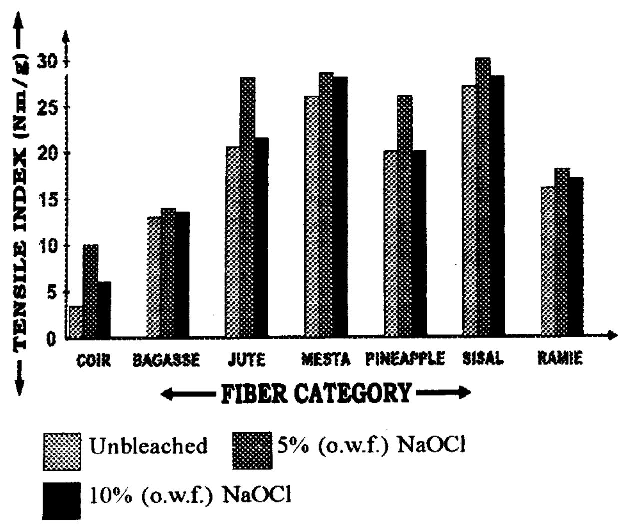

Fig. 3 Graph showing the tensile index (Nm/lg) of the papers made from the different fibre types under different conditions of bleaching

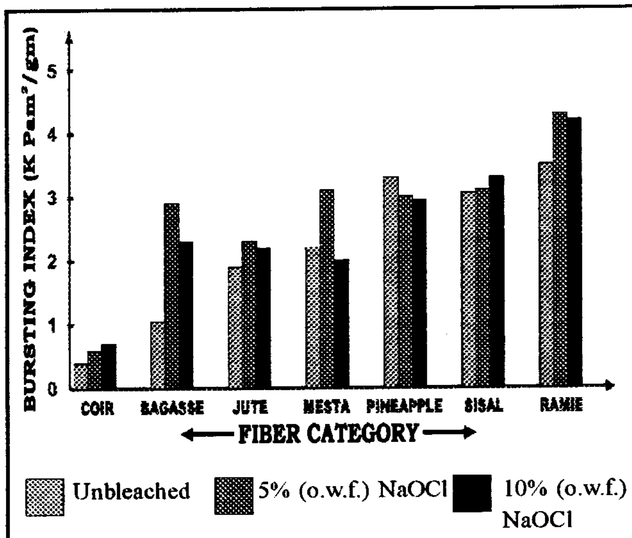

Fig. 4 : Graph showing the bursting index (K Pam^2/gm) of the papers made from different fibre types under different conditions of bleaching.

Bleaching of paper under milder conditions give better quality paper in terms of the tensile and bursting strength. However this change is not much significant. Further, on bleaching, the density of paper increases to some extent which is undesirable.

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