Effect of Nonfibrous Tissue on the Papermaking Properties of Bagasse and Straws

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ABSTRACT

Non—wood fibres are generally slender, shorter and acompanied by a high proportion of nonfibrous tissue. Fibre length and width in some species are only one fourth that of softwood and the nonfibrous content is about 20 times greater than that of softwood. Intrinsic strength of these fibres (zero span tensile) also is poor compared to the softwood fibres These properties of non-wood fibres, especially in straws leads to runnability problems with inferior quality of the end product.

Nonfibrous content largely contributes to the inferiority of the pulp produced from the agro-raw materials In this context it becomes imperative to examine the effect of the nonfibrous content on the papermaking properties of these raw materials Three pulp compositions i e whole pulp, long fibre fraction (i. e. +50 BM fraction) and middle fraction (i. e +200 BM fraction) are investigated for the generation of fines, structural changes and strength development during beating of these pulp compositions from the three agricultural residues. In the case of straws only a very slight beating in PFI mill increases number of fines produced. This increase is due to loosening of parenchyma aggregates. The no. of fibre particles per gram, arithmetic fines and weighted fines (<200 μm) measured by Kajaani FS—100 fiber length analyser increase very sharply especially for rice straw

Fines content increase during the initial stages of beating for the middle fraction. But with increased beating there is a little or no increase in fines content. However, when the long fiber fractions from the three pulps were subjected to beating it was found for bagasse and wheat straw fibre, weighted fines increase by 1 5 to 2 0%. During the course of beating, average fibre length remained about the same, for bagasse and Wheat Straw and this would mean that microfibrills get disengaged from the fibres resulting in fines In contrast the long fibre fraction from rice straw was found to be very weak. When beaten, the amount of weighted fines increased by over 5%. Fibre length was also found to decrease upon beating Photomicrographs of unbeaten and beaten pulps show that wheat straw and bagasse fibres develop excellent fibrillation as the beating progresses Cross sectional analysis of wheat straw fibres from whole pulp and long fibre pulp indicate that the straw fibres can be refined, if the nonfibrous tissue is reduced in the pulp. The structural changes in the fiber during beating can be correlated with the tear and tensile vs CSF relationship, which showed strength development. As we tend to remove more fines strength properties improve As for optical properties, it was seen that rice straw pulp has an exceptionally high scattering coefficient, where as bagasse pulp has the lowest.

Fiber from agricultural residues so far considered inferior can be used to produce better strength papers provided we are able to control the amount of fines either by raw material pre—treatment or by a suitable pulp treatment methods. Rice straw pulps have exceptionally high scattering coefficients, and this advantage can be taken to improve the optical properties of bagasse chemical pulp which otherwise have very low scattering coefficient.

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Introduction

India is the second largest producer of bagasse and straws in the world. These agricultural wastes are a potential source for papermaking. With more mechanised agriculture and efficient boilers, it is expected that large quantities of agricultural residues can be made available for papermaking. However a factor mitigating their use is the collection and transport costs, and relatively low bleached pulp yield.

Non-wood raw materials have lesser fibre content compared to wood and are hetrogeneous in nature. The fibre dimensions of softwoods are higher and fibre dimensions of non-woods are small and comparable to hardwoods. Non-wood pulp, in addition to fibres also contain large amounts of vessels, parenchyma and epidermal cells which constitute the fines. The fiber length of non-woods is about one third to that of softwood fibre and non-fibre cell content is about 20 times greater. With these weak points they are not suitable for high strength papers.

Present study was undertaken to examine and compare papermaking from bagasse, wheat straw and rice straw with a view to improve their paper quality. In this study we have examined three pulp compositions i. e. whole pulp, long fibre fraction (i.e +50 BM fraction) and middle fraction (i.e. +200 BM fraction) and investigated the generation of fines, structural changes in fiber and strength development during beating of these pulp compositions.

Experimental

Pulping :

Bagasse, wheat and rice straw were pulped in series digestor under standard pulping conditions. Optimum pulps were produced from pulping of bagasse, wheat and rice straw using 12, 14 and 10% NaOH respectively. After cooking schedule was completed the cooked material was transferred into a terelyne cloth and washed tho-oughly. After washing the pulp was dewatered, shredded and total yield determined. The pulp was screened on a 'Serla' flat screen with a screen slot width of 0.25 mm.

Separation of Long and Middle Fibre Fraction :

The long fibre fraction (i e. retained on 50 mesh) and middle fiber fraction (i e. retained on 200 mesh) were collected separately by classification on a Bauer & McNett classifier.

Pulp Evaluation :

Different pulp compositions i e. whole pulp, +50 fraction and +200 fraction obtained from screening of pulps of bagasse, wheat and rice straw were evaluated by beating in PFI mill to various freeness levels under standard conditions as per ISO 5269. Strength and optical properties of handsheets were tested as per ISO standard methods.

Measurement of Fines :

Morphological parameters of fibers viz. coarseness, average fiber length fibre length distribution, arithmetic fines and weighted fines were determined using Kajaani FS-100 Fiber Length Analyser.

Observation of Structural Changes During Beating :

Structural changes in fibres, viz. extent of fibrillation and generation of microfibrils were examined under optical microscope and scanning electron microscope. For observation under Scanning Electron Microscope the samples were coated with gold for 5-7 min with about 7 mA current in a Hitachi Sputter Coater and examined in Hitachi S-2300 SEM at an accelerating voltage of 15 kV.

RESULTS AND DISCUSSION

Generation of Fines During Beating :

Beating has a strong effect on generation of fines, particularly so for non-wood pulps. While the generation of microfibrils improve the strength properties by increasing bonded area, but it also influences dewatering affecting drainage character of pulp. Proper beating is a key factor in papermaking from straws. Unlike wood pulp, straw and bagasse fibres are considered to be fragile. In addition to fibrous constituents, the presence of non-fibrous cell elements such as vessels, parenchyma and epidermal cells which are usually present as aggregates undergo changes during beating, and their presence can not be neglected. In the present study, three pulp compositions of bagasse, wheat and rice straw i. e. whole pulp, long fibre fraction (+50 BM fraction) and middle fraction (+200 BM fraction) were investigated. Table-I illustrates

When the long fibre fraction from rice straw, wheat straw and bagasse pulps are beaten the weighted fines increase by 1.5–2.0% for bagasse and wheat straw, and over 5% for rice straw. The fines content increase only during the initial stages of beating and then remain constant. The fiber length of the rice straw long fibre decreased but remain the same for bagasse and wheat straw. Even on extensive beating the fines generation is not high, indicating that bagasse and wheat straw fiber can be beaten to improve strength. Structural changes in the fibre upon beating were examined under electron microscope and are illustrated in Figure 3. It was seen that wheat straw and bagasse develop excellent fibrillation with beating, but rice straw fibre donot. The increase in fines content during beating was due to microfibrils in the case of wheat straw and bagasse, but in the case of rice straw it was due to fibre shortening. Beating of bagasse and wheat straw pulp also induced considerable micro compressions suggesting that the beaten fibres are more flexible.

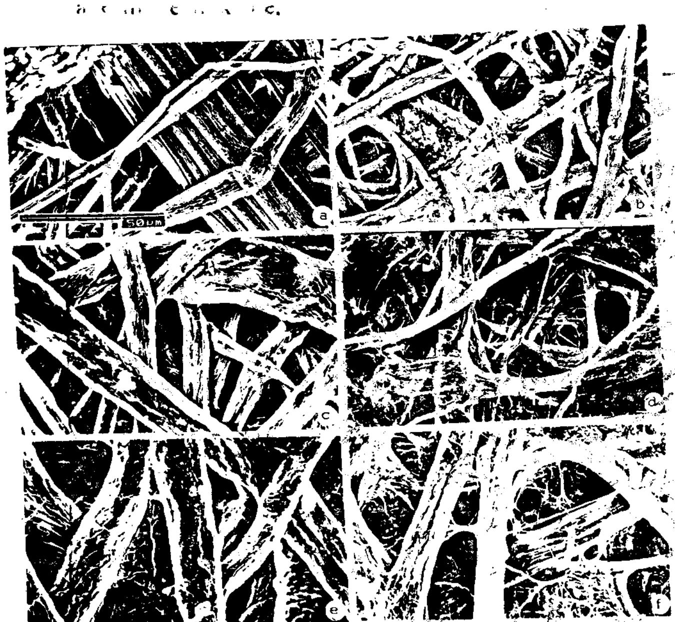

Fig-3
Photomicrographs of long fibre fraction: a, c, e - unbeaten pulps of rice straw, wheat straw and bagasse; b, d, f - beaten pulps of rice straw, wheat straw and bagasse (Scale: All the micrographs have same magnification as shown in a)

Changes in cross-sections of the long fiber fraction of wheat straw as a response to refining were analysed using a VAX image processing system[3]. These results show that the width of the fibres tend to increase with the refining action along with reduction in the fiber thickness. This trend shows that the wheat straw fibre collapse as a response to refining The increase in total wall area and rectangular area of the fibre with progressive beating action indicate good swelling nature of wheat straw fibers.

Strength Properties :

Usual practice followed by small mills in India which are using straw pulps is not to refine them because any such action leads to freeness drop. As a consequence of this such pulps are not considered suitable for strength critical grade papers. With a view to suitably process these pulps for use in different grades of paper we investigated the strength and optical properties of different pulp compositions i.e. whole pulp, long and middle fraction of pulp. Results of beating of the individual pulp fractions are illustrated in figs. 4, 5 & 6, which show the strength and optical properties relationship to beating. Tear and tensile strength were found to improve with beating. But because of limited beating action of whole pulps only moderate values are obtained. When we studied strength development in the case of +200 BM fraction and +50 fraction that is pulps which have lesser amount of fines in them, we found that such pulps can withstand larger beating action. Beaten pulps had better strength values. A simple screening system to remove non–fibrous fines, preceding the refining treatment will help produce better strength paper from agricultural residues.

Rice straw pulp which otherwise had poor strength properties, show good optical properties Scattering coefficient values are exceptionally high, and improve further on removal of fines (due to their thin walled and transparent nature). Wheat straw and bagasse pulps had considerably lower scattering coefficient. Bagasse pulps which have good strength properties, usually posses very poor optical properties, which do not improve significantly even on removal of pith and other non–fibrous material. It is quite likely that rice straw pulp can be added in suitable amounts so as to improve scattering coefficient of bagasse pulps without impairing its strength properties to considerable extent.

Conclusions

Fibres in straw pulps can not be refined in presence of nonfibrous tissue. Increase in fines content during beating is mainly due to loosening of parenchythe classification of bagasse and straw pulps on Bauer & McNett classifier. The percentage of fines (i.e. passing 200 mesh) for straw pulps is relatively high, understandably so because such pulps have an abundance of non–fibrous fines. It is quite likely that a figure of 25–30% for the long fiber fraction may be misleading. There is every chance that aggregates of parenchyma and epidermal cells, may exist as single long particles to be accounted in the +50 fraction.

Results of beating bagasse and straw pulps and generation of fines there off are given in Table 2-4 and in Figures 1 and 2. In the case of whole straw pulps it was not possible to beat them for more than 500 revs. because the freeness dropped suddenly. Arithmatic and weighted fines increase appreciably for rice straw, but remain about the same for bagasse and wheat straw. No. of fibres per gram increase for rice straw and wheat straw due to loosening of parenchyma aggregates (1-2). Observations under electron microscope indicate little or no external fibrillation for either bagasse or straw whole pulps when beaten. This fact precludes whole pulp refining to develop strength properties.

In another set of experiments, straw and bagasse pulps were fractionated in Bauer & McNett classifier to collect long fiber fraction (i e. +50 fraction) and a middle fraction (i.e. +200 fraction). These pulps were beaten in PFI mill. Comparison of the arithmetic and weighted fines for the unbeaten and beaten pulps respectively indicate that for the rice straw as was the case in whole pulp, the fibre length decreased and fines content increased as the beating progressed. The slope of the fines generated vs beating curve was however less than for the whole pulp. In contrast bagasse and wheat straw pulp when refined do not generate more fines. Fibre length is about same, and whatever fines content increase is, it is due to the external fibrillation.

Whole Pulp

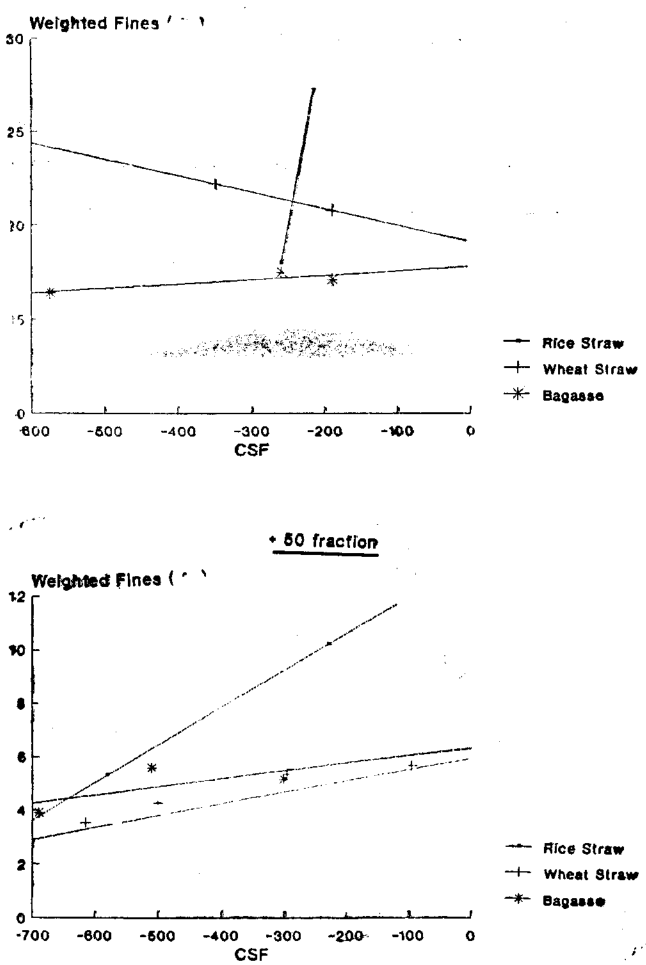

Fig. 1 Generation of Weighted Fines During Refining of Bagasse and Straw Pulp

Whole Pulp

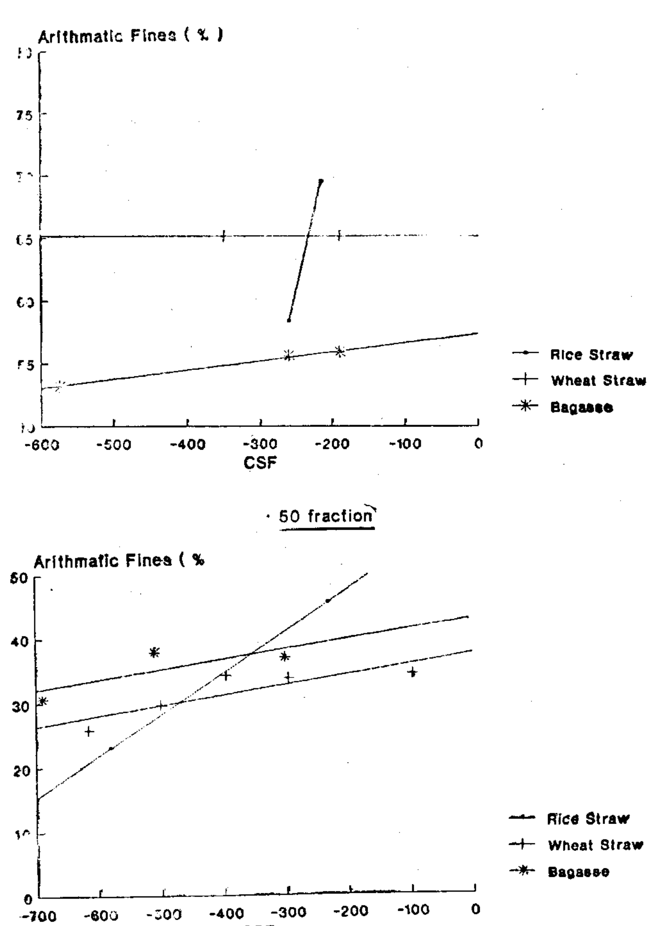

Fig. 2 Generation of Arithmatic Fines During Refining of Bagasse and Straw Pulps

TABLE 1
Bauer McNett Classification of Bagasse and Straw Pulps

S.No.	Bauer Mcnett Fraction	Bagasse	Wheat Straw	Rice Straw
1.	+ 50	31.3	20.7	33.3
2.	+100	37.3	25 3	16.9
3.	+200	19.8	19.0	5.3
4.	—200	11.9	35.0	44.2

TABLE 2
Generation Of Fines During Refining Of Wheat Straw Pulp

Pulp Type	PFI (Revs)	CSF (ml)	D W. Length (mm)	Weighted Fines (%)	Airthmetic Fines (%)
Whole Pulp	0	350	0.9	22.2	65.2
	500	190	0 9	20 8	65.2
+50 Fraction	0	615	1.2	3 5	25 9
	500	500	1.1	4.2	29.7
	1000	395	1.1	5 8	34 3
	2000	295	1.2	5 4	33.9
	4000	195	1.1	5.8	?4 5

TABLE 3
Generation Of Fines During Refining Of Bagasse Pulp

Pulp Type	PFI (Revs)	CSF (ml)	D.W. Length (mm)	Weigh ed Fines (%)	Airthmetic Fines (%)
Whole Pulp	0	575	1.03	16.4	53.2
	500	260	1.02	17.5	55.6
	1000	190	1.01	17.1	55 9
+200 Fraction	0	640	1.4	8.7	37.8
	500	355	1.0	12.7	42.6
	1000	260	1.1	11 1	39 8
	2000	160	1 0	12.4	42.4
+50 Fraction	0	690	1 3	3 9	30 7
	1000	510	1.3	5.6	37.9
	2500	300	1.3	5.2	37.2

TABLE 4
Generation Of Fines During Refining Of Rice Straw Pulp

Pulp Type	PFI (Revs)	CSF (ml)	D.W. Length (mm)	Weighted Fines (%)	Airthmatic Fines (%)
Whole Pulp	0	260	0 88	18 0	58 4
	500	215	0.75	27.3	69.6
+200 Fraction	0	515	0.82	13.5	42.1
	500	365	0.73	17.2	5 .4
	1000	290	0.77	16.8	51.6
	1500	215	0.77	18.6	54.7
+50 Fraction	0	580	1.02	5 3	23 1
	1000	295	—	—	—
	1500	230	0.95	10 3	45 7

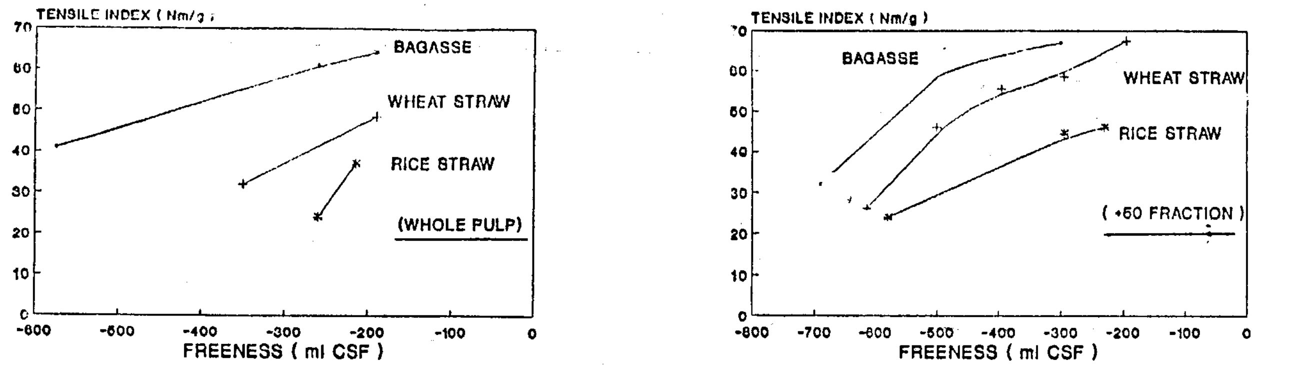

FIG. 4. TENSILE VS CSF RELATIONSHIP DURING BEATING OF DIFFERENT COMPOSITION OF BAGASSE AND STRAW PULPS

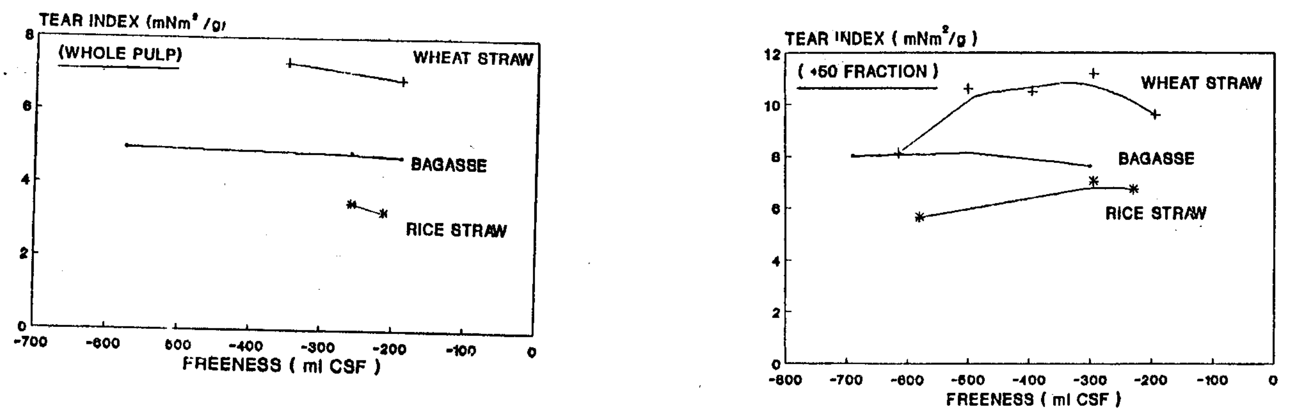

FIG. 5. TEAR VS CSF RELATIONSHIP DURING BEATING OF DIFFERENT COMPOSITION OF BAGASSE AND STRAW PULPS

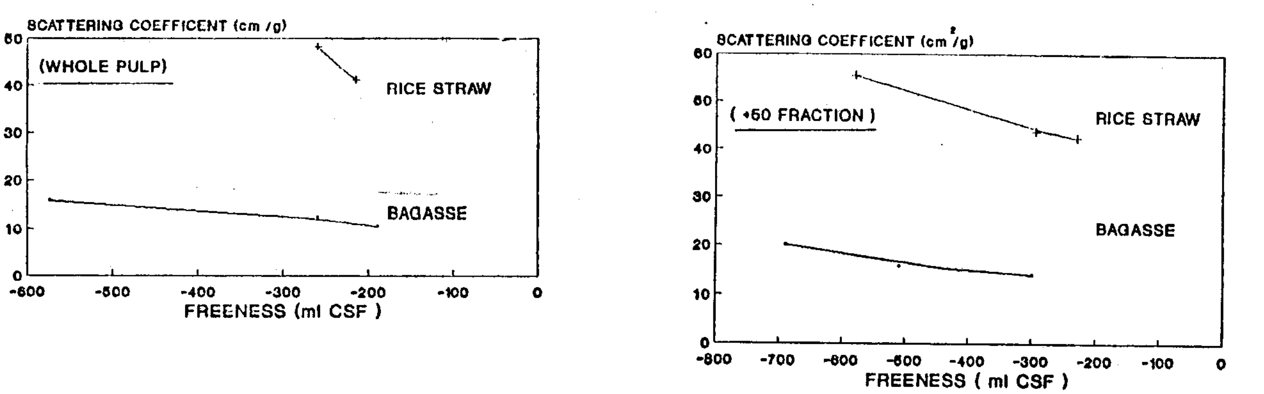

FIG. 6. SCATTERING COEFFICIENT VS CSF RELATIONSHIP DURING BEATING OF DIFFERENT COMPOSITION OF BAGASSE AND STRAW PULPS

ma aggregates in whole pulps. Fines content increase during early stages of beating of long fiber fraction. Weighted fines increase by 1.5-2.0% for bagasse and wheat straw and over 5% for rice straw.

Fines generation in bagasse and wheat straw is due to external fibrillation and for rice straw it is due to fiber shortening. Fibrous fraction in bagasse and wheat straw fibrillate well as the beating progresses.

Reduction of nonfibrous fines from the whole pulp leads to improved beating action and considerable strength development. A simple screening system preceding refining can improve beating response of straw pulp and make them suitable for high strength papers as well.

Rice straw pulp have exceptionally high scattering coefficients, and this advantage can be taken to improve the optical properties of bagasse chemical pulp which otherwise have low scattering coefficient.

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References

1. CPPRI Research Report No. 32, "Paper making quality of wheat straw." 1992.

2. Zhao,Z, Olberg, L, Gunrel, R; TAPPI Jan. (1992) P 153-160.

3. Kibblewhite, R.P. and Donald G. Bailey, Appita (July 1988), vol 41, no 4,p 297—301.