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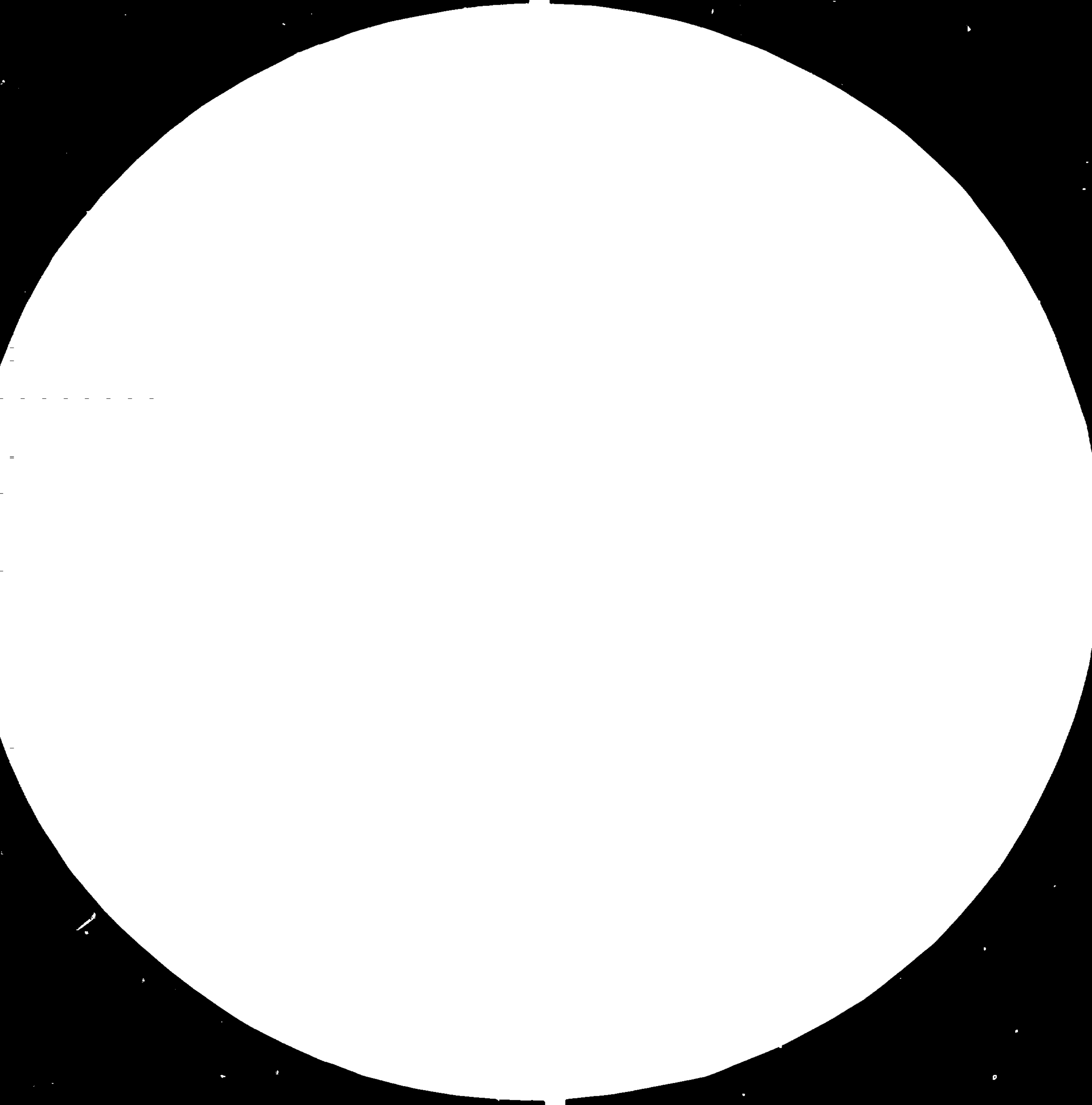

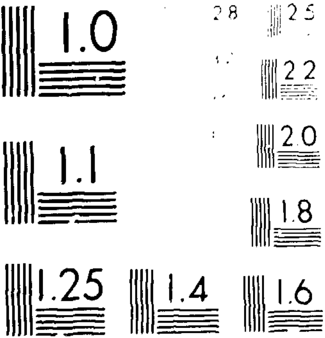
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RICE STRAW PULPING AND BLEACHING IN SMALL PAPER MILLS IN INDIA*

by

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With the increasing demand for paper and paper boards and the high capital investment needed for starting new large paper mills, attention has now turned towards the establishment of small paper mills, especially in developing countries where finances are not easy to find.

The low cost of setting up a small paper mill can be traced to many facts, the most important of them being:

1. Most of the mini paper mills (i.e., with capacities up to 30 TPD) do not have a recovery unit which substantially decreases the initial cost.

2. The raw materials used do not need drastic conditions of cooking/ bleaching as needed by the conventional raw materials like bamboo and wood and consequently, the capital cost of the pulp mill equipment is considerably low.

In a developing country like India, therefore, this idea has caught the imagination of many entrepreneurs and a number of these small paper mills have and are still coming up. As the delegates themselves are aware, in this conference there is a paper on second-hand equipment and its opportunities. Increasing low-cost mills show that a small paper mill can be set up easily at low cost by importing a second-hand machine of lower capacities and by putting up a less expensive pulp mill with facilities to pulp easily pulpable raw materials; mainly agricultural residues (also known as annual plants) like rice straw, wheat straw, bagasse, jute, and secondary fibres like waste papers gunny and rags which require less drastic pulping conditions.

The reasons why agricultural residues are not so popular as raw materials are technical as well as techno-economical. The economic reasons being that the material is bulky, therefore, expensive to handle, collect and transport and that it tends to deteriorate rapidly on storage, thereby diminishing its fibre value.

The technical aspects which thwart the use of rice and wheat straw as potential raw materials are:

a) The small cell dimensions of these straw fibres. The average fibre length of the rice straw fibre (from straw growing in the Andhra Pradesh region of India) is 1.15 mm, and the cell diameter is only 9 m as compared to the fibre length of 2.0 mm and fibre diameter of 18.5 m for bamboo (Dendrocalmus strictus) and 0.9 to 1.3 mm and 17 to 20 m for hard-woods from Andhra Pradesh. (1) Further, the paper making fibres constitute only 35 to 40% of the rice straw and the rest, being vessel elements, parenchyma cells, etc., have no paper making value. (2) Hence, use of these straws can not be used in the production of paper of high strength properties.

b) The presence of outer cuticula rich in silica will also present technical problems in recovery. The high silica content in rice straw (as evident from the proximate analysis presented in Table-I) will get dissolved out in the alkali during the cooking stage and will find its way into the spent liquor in the form of sodium silicate. Such a black liquor rich in silica can not be processed in conventional recovery units for obvious reasons.

The present Paper examines the ways and means of overcoming most of these difficulties and how a suitable methodology can be established to achieve the twin objectives of lower production costs and tolerable strength properties of paper made from these agricultural residues, especially rice straw.

In a predominantly agricultural country like India which produces about 135 million tons of grains out of which about 55 million tons is rice, there is no dearth of these straws, rice straw and wheat straw. It is known that for every ton of grain produced, 1.5 tons of rice straw and 2.5 tons of wheat straw are produced.

RESULTS AND DISCUSSIONS:

As stated in the introduction itself, rice straw cell dimensions are considerably less than the cell dimensions of the conventional paper paper making fibres like bamboo and hardwood.

A perusal of the proximate chemical analysis of rice straw and wheat straw (vide Table I) indicates that the lignin content especially in the rice straw is much lower than that found in conventional raw materials thereby indicating the applicability of less severe cooking conditions for pulping this. The high 1% NaoH solubility ($\sim$38%) as compared to 20% for bamboo and mixed hardwoods, (3) points out the use of mild pulping process lest most of the material will be dissolved out.

It is interesting to note that the rice straw from Andhra Pradesh has a much lower pentoson content when compared to Egyptian rice straw (4) (31.6%), and American rice straw (23.4%) (5).

The rice straw can therefore be subjected to mild cooking conditions (as given, table-II) which are easily attainable in the pulping sections of small Paper Mills.

The strength properties of these rice straw pulps are predictably much lower. The cooked rice straw pulp by itself can not be used exclusively for manufacturing the unbleached varieties of paper, which are mostly used for packaging purposes. The basic requirements for the packaging paper are higher burst and high tensile strength — attributes which are seldom found in rice straw pulp.

To get over this difficulty, we suggest that this rice straw pulp can be blended with gunny pulp up to the extent of 40% and when this blend is run on the slow speed machines which are in operation in most mini Paper Mills, it will produce packaging papers of tolerable burst and tensile.

In Table II, we present the pulping conditions for gunny and the strength characteristics of the resulting pulp. In Tables V, VI, and VII, we present the effect of blending of rice straw pulp with gunny pulp (a raw material easily available) which could be a way to get a pulp of acceptable strength characteristics.

BLEACHING OF RICE STRAW PULP

The bleaching of rice straw pulps has received little attention. It has been reported that the rice straw pulps could be bleached by either a single stage hypochlorite 6,7 or by the conventional CEH sequence 5,8 to intermediate brightness ranging between 70 and 75% GE. Systematic study of bleaching of rice straw soda pulps for the production of fine papers has been reported by El Taraboulsi and Abou Salem[9]. These authors have subjected both commercial rice straw pulp as well as mild experimental rice straw soda pulps to the following bleaching sequences, CEH, CCEH, CE/H, CCE/H, CED, CCED, CEDH, CCEDH, C-E/H-P and CC-E/H-P. They have found that both the pulps could be bleached to a brightness of about 85% by applying a CC-E/H-P sequence. The conventional C-E-H sequence gave only a brightness in the region of 75% . Double chlorination was found to be more effective than single chlorination.

There are also reports in literature of bleaching of rice straw pulps of Kappa number 8-10 double stage hypochlorite bleaching to a brightness level of 70-75% GE[10]. There has also been another report on the bleaching of non-wood pulps including the bleaching of rice straw pulps which refers to mill experiences in the bleaching of rice straw pulps. Bleaching of rice straw pulp made in a soda chlorine mill in Yogoslavia has been described by Viola[12]. The pulp made with 7-8% active alkali is bleached in a CEHH system, employing about 9% chlorine in a down flow chlorination tower and about 1.5% chlorine as the hypochlorite in the hypo stages of bleaching.

In our experiments we have bleached rice straw pulps to a brightness level of 70% GE by single stage hypochlorite bleaching. The conditions of bleaching and the characteristics of the resulting pulp are presented in Table IV. We have confined ourselves to a single stage hypochlorite bleaching because most of the small Paper Mills in the country do not have elaborate arrangements for bleaching.

From the perusal of the results it is to be seen that the rice straw pulps can be bleached to a brightness level of 70% by a single stage hypochlorite treatment. The strength properties of these bleached pulps are also again on the lower side.

The strategy of blending to further improve the strength characteristics can be successfully applied in the case of bleached pulps also.

As the bleached pulps are employed mostly for the manufacture of the writing and printing varieties of paper, the approach that has to be adopted is to be such that both the tearing strength and the folding endurance are increased.

This can be done by blending the bleached rice straw pulp with bleached cotton linters pulp (another one from annual plants). The cotton linters can be easily pulped and bleached under the condition that can be normally achieved with the machinery found in mini paper mills. In Table IV are presented the pulping and single stage bleaching conditions of the first cut cotton linters.

From the results, it is to be observed the cotton linter pulp can be bleached to a brightness level of 73% and the pulp has high tearing strength and good folding endurance.

The effect of blending of these bleached cotton linters pulp with bleached rice straw pulp is given in Tables VIII to X. It can be seen from the results that bleached rice straw pulps and bleached cotton linter pulps can be blended in the ratio of 1:1 to produce a pulp which can be used in the production of popular varieties of writing papers.

Another strategy that can be employed to further improve the economy of the small paper mills with rice straw as raw material is to resort to anthraquinone pulping. It is well known that addition of anthraquinone or anthraquinone derivatives in alkaline pulping increases the yield and also brings down the kappa number of the unbleached pulp; as a result the cooking chemical dosage can be brought down.[14] There have been a number of papers published on this AQ pulping, and these have been reviewed as well.[14,15] However, there has not been any report on the AQ pulping of agricultural residues, especially rice straw.

Preliminary studies in our laboratory[16] have shown that AQ has a beneficial effect on the rice straw pulping. It is found that use of Anthraquinone increases the yield as well as causes a small reduction in the permanganate number. It follows therefore that lesser cooking chemicals (as Na_2O) are required when Anthraquinone is used as a catalyst for delignification. This will have a two-fold beneficial effect on the economy of small paper mills: (1) Increase in yield increases the output for the same quantity raw materials used; (2) Decreases in cooking chemicals decrease the cost of production considerably, as these small paper mills do not have a recovery system, and so the spent liquor is always drained. We are therefore looking into the AQ pulping of agricultural residues in detail and we feel that this will be one of the best methods of pulping for small paper mills for better economy as well as ecology.

From the foregoing discussions, it is clearly evident that the straws — especially rice straw — indeed look to be the most promising raw materials for the mini-and medium-sized paper mills from the techno-economic point of view. This paper has attempted to highlight some of the strategies that can be adopted to overcome the difficulties faced by the use of these straws.

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TABLE I: PROXIMATE ANALYSIS OF RICE STRAW AND WHEAT STRAW

Sl. No.	Particulars	Andhra Pradesh rice straw	Rajasthan** wheat straw
1.	Ash	17.89	6.0
2.	Acid Insolubles	15.15	-
3.	Silica	13.20	-
4.	A-B Extractives	5.12	2.9
5.	Lignin	12.8	21.0
6.	Holocellulose	66.1	44.2*
7.	Hot water solubility	9.52	9.5
8.	1% NaOH solubility	38.1	40.1
9.	Pentosans	14.5	23.0

All the results are expresssed as percentage on over dry basis.

*Cross and Bevon Cellulose.
**From reference 13.

TABLE II: RICE STRAW AND GUNNY SODA COOKING CONDITIONS AND RESULTS

S.No.	Particulars		Rice straw 1	Rice straw 2	Rice straw 3	Gunny 4
1.	Chemical used (NaOH)	%	6	8	10	8
2.	Bath ratio		1:5	1:5	1:5	1:4
3.	Cooking period (which incluses 1/2 Hr. to raise up to 140°C	Hrs.	2.5	2.5	2.5	2.0
4.	Cooking Temperature	°C	140	140	140	140
5.	Pulp Yield	%	60	54	52	62
6.	Permanganate Number		15.5	13.7	11.6	25
7.	Unbleached Pulp Viscosity (0.5% CED)	cps	13	13.2	13.6	
8.	Unbleached Pulp hand sheets brightness	%GE	36	40	41	22
9.	STRENGTH PROPERTIES at 40° SR					
i.	Burst Index kPa m^2/g		1.41	1.43	1.34	3.96
ii.	Breaking length, K.m		2.970	3.040	3.270	6.350
iii.	Tear Index, mNm^2/g		2.0	2.8	3.0	9.3
iv.	Folding endurance (double folds)		2	3	3	254

TABLE III: SINGLE STAGE HYPO BLEACHING CONDITIONS AND RESULTS OF RICE STRAW PULPS

S.No.	Particulars		Rice straw 6% soda pulp	Rice straw 8% soda pulp	Rice straw 10% soda pulp
1.	Chlorine added as hypo	%	7	6	6
2.	Consistency	%	10	10	10
3.	Temperature	^oC	40± 1	40± 1	40± 1
4.	Retention time	Hrs	2	2	2
5.	Buffer added as NaOH	%	1.0	0.6	0.6
6.	Residual chlorine	gpl	0.21	0.41	0.47
7.	Brightness	GE^o	66.5	70	70.5
8.	Viscosity (0.5% CED)	cps	9.4	10.7	9.4
9.	STRENGTH PROPERTIES AT 40^oSR				
i.	Burst index kPa m^2/g		1.59	1.73	1.75
ii.	Breaking length (K.m)		2.630	2.690	2.990
iii.	Tear Index mNm^2/g		2.8	2.3	3.0
iv.	Folding Endurance		3	2	2

TABLE IV: FIRST CUT COTTON LINTERS PULPING AND BLEACHING RESULTS

S. No.	Particulars		
1.	Chemical used as NaOH	%	6.0
2.	Bath ratio		1:6
3.	Cooking period (which includes 1 Hr to 140°C)	Hrs	8
4.	Cooking Temperature	^oC	165
5.	Pulp Yield	%	78.0
6.	BEATER BLEACHING		
i.	Chlorine add as hypo	%	4.0
ii.	Retention time	Hrs	2.0
iii.	Chlorine consumed	%	3.0
iv.	Brightness	^oGE	73.0
v.	Viscosity	cps	38.2
7.	STRENGTH PROPERTIES AT 40^oSR		
i.	Burst index kPa m^2/g		1.92
ii.	Breaking length (Km)		2.520
iii.	Tear index mNm^2/g		15.9
iv.	Folding endurance (double folds)		29

TABLE V: STRENGTH PROPERTIES OF RICE STRAW AND GUNNY PULP AND THEIR BLENDINGS EVALUATED AT 40°SR 6% SODA COOKING OF RICE STRAW

S. No.	Particulars	Rice Straw 100%	R.S. 75% G. 25%	R.S. 50% G. 50%	R.S. 25% G. 75%	Gunny 100%
1.	Burst Index kPa m^2/g	1.41	1.98	2.7	3.4	3.96
2.	Breaking length (k.m)	2.970	3.860	4.690	5.510	6.350
3.	Tear Index mNm^2/g	2.0	3.68	4.9	6.3	9.3
4.	Folding Endurance (double folds)	2	5	22	48	254

TABLE VI: STRENGTH PROPERTIES OF RICE STRAW AND GUNNY PULPS AND THEIR BLENDINGS EVALUATED AT 40°SR 8% SODA COOKING OF RICE STRAW

S. No.	Particulars	Rice Straw 100%	R.S. 75% G. 25%	R.S. 50% G. 50%	R.S. 25% G. 75%	Gunny 100%
1.	Burst Index kPa m^2/g	1.43	2.0	2.7	3.4	3.96
2.	Breaking length (k.m)	3.040	3.350	4.490	5.340	6.350
3.	Tear Index mNm^2/g	2.8	2.9	6.0	7.1	9.3
4.	Folding Endurance (double folds)	3	7	29	73	254

TABLE VII: STRENGTH PROPERTIES RICE STRAW AND GUNNY PULPS AND THEIR BLENDING EVALUATED AT 40^{o} SR: 10% SODA COOKING OF RICE STRAW

S. No.	Particulars	Rice straw 100%	R.S. 75% G. 25%	R.S. 50% G. 50%	R.S. 25% G. 75%	Gunny 100%
1.	Burst Index kPa m^2/g	1.84	2.27	3.145	3.69	3.96
2.	Breaking length (k.m)	3.270	4.330	4.585	5.545	6.350
3.	Tear Index mNm^2/g	3.0	3.23	5.9	7.9	9.3
4.	Folding Endurance (double folds)	3	7	23	62	254

TABLE VIII: STRENGTH PROPERTIES OF BLEACHED RICE STRAW AND ITS ADMIXTURES WITH BLEACHED COTTON LINTER PULPS: 6% SODA COOKING OF RICE STRAW

S. No.	Particulars	Rice straw 100%	Rice straw 75% C.linters 25%	Rice straw 50% C.linters 50%	Cotton linters 100%
1.	Burst Index kPa m^2/g	1.59	1.61	1.78	1.92
2.	Breaking length (k.m)	2.630	2.600	2.510	2.520
3.	Tear Index mNm^2/g	2.8	6.4	8.2	1.59
4.	Folding Endurance (double folds)	3	8	16	29

TABLE IX: STRENGTH PROPERTIES OF BLEACHED RICE STRAW AND ITS ADMIXTURES WITH BLEACHED COTTON LINTER PULPS 8% SODA COOKING OF RICE STRAW

S. No.	Particulars	Rice straw 100%	RS 75% CL 25%	RS 50% CL 50%	Cotton linters. 100%
1.	Burst Index kPa m^2/g	1.75	1.74	1.86	1.92
2.	Breaking length (k.m)	2.690	2.640	2.600	2.520
3.	Tear Index mNm^2/g	2.3	5.1	8.7	15.9
4.	Folding endurance (double folds)	2	9	17	29

TABLE X: STRENGTH PROPERTIES OF BLEACHED RICE STRAW AND ITS ADMIXTURES WITH BLEACHED COTTON LINTER. PULP 10% SODA COOKING OF RICE STRAW

S. No.	Particulars	Rice straw 100	RS 75% CL 25%	RS 50% CL 50%	Cotton linters 100%
1.	Burst Index kPa m^2/g	1.76	1.87	1.88	1.92
2.	Breaking length (k.m)	2.990	2.610	2.770	2.520
3.	Tear Index mNm^2/g	3.0	5.[illegible]	8.1	15.9
4.	Folding endurance (double folds)	2	6	16	29