Kenaf—a substituent for conventional fibrous raw materials

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SUMMARY

Kraft pulping of kenaf shows that with 16% Chemical at 165°C for 75 minutes at a H factor of 960, bleachable grade pulp of Kappa number 27 can be obtained at an yield of 45.5%. Less chemicals and milder conditions are required than for babmoo and mixed hardwoods. Strength properties of kenaf pulps are far superior to hardwoods pulp. They are better than for Bamboo pulp except in tear strength. Bleachability of kenaf is far better than bamboo. Even three stage CEH bleaching is sufficient to attain a pulp brightness of 80% ISO. Blending experiments revealed that 40% of kenaf can replace bamboo in the kenaf : bamboo pulp blend with improved strength properties and without adversely affecting the drainage characteristics. Blend of Kenaf to hardwoods pulp improves the strength properties of the blend. NSSC pulp of kenaf at an yield of 62% possess strength properties on par with mixed hardwoods kraft pulp Cold soda pulp of kenaf is superior to *Eucalyptus tereticornis* and *E. grandis*. Blend of 70 : 30 kenaf cold soda, bamboo pulp possesses strength properties comparable to commercial news print grade pulp.

Worldwide research on alternative raw materials focussed attention on agricultural residues and annual plants. Kenaf, also called Mesta, has been studied as a fibre source in many countries including USA, Philippines and India.

LITERATURE

Kenaf (*Hibiscus Caunabinus*) has been traditionally grown as a fibre crop for the manufacture of twine and rope. Northern Regional Research Laboratory, Peoria, III., USA in its crops screening programme, after evaluating over 650 samples of potential fibre crops, found kenaf as the most promising pulping raw material[1]. Regional Research Laboratory, Jammu conducted trials on some exotic and indigenous varieties of kenaf and found HC-583 variety as most promising under the agro-climatic conditions prevailing in Jammu[2]. Kenaf is an annual crop which takes about 6 to 8 months for growth. About 13-22 tonnes of kenaf can be produced per hectare of land. The bast fibre content of kenaf ranges from 18-29%[3]. Since the bast fraction normally gives a higher pulp yield than the woody component of the stalk, the final pulp should contain 30 to 40% bast pulp. Kenaf may be pulped to produce pulps with properties and performance equal to most softwoods and superior to most hardwoods. Kenaf may be used as a blending agent to improve lower quality pulps[4]. Bond paper can be made from kenaf sulfate pulps blending with wood pulp. Kenaf pulp in the furnish improves strength of the resulting paper and also smoothness, elongation and tensile energy absorption of the bond paper[5]. Newsprint grade pulp can be prepared from blends of bleached kenaf thermomechanical pulp containing 15% kenaf soda pulp[6,7].

RESULTS AND DISCUSSION

Physical data on kenaf has been furnished in table 1. For comparison bamboo, mixed hardwood and rice straw are also included.

Bulk density and basic density of kenaf are low compared to bamboo and mixed hardwoods, which may impair the capacity of the digester and pose problems in baling, transportation and storage. In proximate analysis data viz low lignin, high pentosans and high alkali solubility it is similar to agricultural residues. But ash content is less.

Kraft pulping conditions and results are given in table 2, where in comparison is made with bamboo and mixed hardwoods.

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TABLE—1. PHYSICAL DATA ON KENAF AND OTHER RAW MATERIALS

Bast portion	% =	37.0	
Woody portion	% =	63.0	
(On AD basis)			

	Kenaf	Bamboo	Mixed hardwoods
1. Basic density of chips Kgs/m³	302	541	551
2. Bulk density of chips Kgs/m³	108	225	245

PROXIMATE ANALYSIS	Kenaf	Bamboo	Mixed hardwoods	Rice straw
1. Ash	1.4	3.4	2.1	10.9
2. Solubility in				
i) Alcohol Benzene	8.2	—	—	2.7
ii) Methanol	—	5.7	10.3	—
iii) N/10 NaOH	38.5	23.5	27.6	47.3
3. Holocellulose	70.7	62.1	63.8	66.8
4. i) Klasson Lignin	15.0	25.7	25.4	14.7
ii) Acid Soluble Lignin	1.8	—	—	2 4
5. Pentosans	17.4	14.5	12.3	15.8

(Results expressed as % on O. D. raw material)

TABLE—2. PULPING DATA ON KENAF, BAMBOO AND MIXED HARDWOODS

S. No. Particulars	Kenaf	Bomboo	Mixed hardwoods
1. Chemical as Na_2O %	16.0	17.0	18.0
2. Chips to liquor ratio	1:4	1:3	1:3
3. Sulfidity of the cooking liquor %	20	20	20
4. Cooking temperature °C	165	165	170
5. H factor	960	1150	1660
6. Unscreened pulp yield %	45.5	43.4	43.8
7. Screen rejects %	0.4	—	0.4
8. Kappa number of the unbleached pulp	27.0	22.1	30.8
9. Black liquor			
i) Total solids % w/w	16.3	20.9	21.3
ii) Residual active alkali as Na_2O g/l (at 200 g/l total solids)	5.5	10.7	8.4

COOKING SCHEDULE FOR KENAF	FOR BAMBOO	FOR MIXED HARDWOODS
To 100°C min : 30	To 100°C min : 30	To 100°C min : 30
From 100°C to 165°C min ; 100	From 100°C to 120°C min : 30	From 100°C to 170°C min : 105
At 165°C min : 75	At 120°C min : 45	At 170°C min : 90
	From 120°C to 165°C min : 70	
	At 165°C min : 90	

For kenaf, because of low bulk density, higher bath ratio is maintained. Kenaf needs comparatively lesser chemicals and milder conditions than for bamboo and hardwoods. Pulp yield of 45.5% is higher than for hardwoods but lower than for bamboo which will be 47-48% but in the present case the withered bamboo from one of the mills resulted in somewhat lower yield. The spent liquor contained suspended solids (13 g/l), which may be due to the pithy material from the portion going alongwith black liquor.

Fibre classification data is given in table 3.

Kenaf contains more of fines fraction (—200) and also long fibred fraction (+28) than hardwoods pulp, long fibred fraction, being the contribution from the bast fibre.

Black liquor characteristeristics of kenaf are given in table 4 and compared with black liquors of other raw materials.

Kenaf black liquor can be concentrated upto 55% and viscosity is low compared to *E. hybrid* and mixed hardwoods. On further, concentration, there is ten fold increase in viscosity showing thixotropic behaviour at higher concentrations above 55%. No granulation was observed unlike in mixed hardwoods black liquor.

Strength properties of unbleached kenaf pulp is given in table 5 and compared wi h bamboo and mixed hardwoods, and represented graphically in figs. 1 to 4.

As can be seen from figs. 1 to 3 kenaf possesses strength properties much superior to hardwoods in burst, tensile and tear strength where as it is superior to bamboo in all other properties except tear strength. There is rapid initial strength development in the case of kenaf. From the tensile-tear relationship given in fig. 4 it can be observed, though tear strength of kenaf is lower than bamboo, when compared at high tensile (70 Nm/g), tear strength of kenaf approaches that of bamboo. Kenaf takes more time for draining than bamboo and mixed hardwoods, which may be the limiting factor in making paper out of 100% kenaf. Kenaf forms dense, compact sheet compared to bamboo and mixed hardwoods.

Bleachability of kenaf is compared with bamboo and mixed hardwoods in table 6.

Three stage CEH bleaching is sufficient for kenaf to attain a final pulp brightness of 80% ISO. In bleachability kenaf is superior to bamboo needing lesser chlorine. NaOH and hypochlorite to attain

TABLE—3. BAUER MCNETT FIBRE CLASSIFICATION OF DIFFERENT PUL PS

Fraction	Kenaf	Bamboo	Mixed hardwoods
+ 28 mesh	44.95	63.35	35.70
— 28 + 48 mesh	14.65	8.00	21.56
— 48 + 100 mesh	8.80	4.25	13.22
—100 + 200 mesh	1.08	1.45	3.42
—200 mesh	30.52	22.95	23.10

(Results expressed as % on O.D. pulp basis)

TABLE—4. BLACK LIQUOR CHARACTERISTICS OF KENAF AND OTHER RAW MATERIALS

	Kenaf	Mixed hardwoods	E. hybrid	Pine
Viscosity at different % solids				
35% w/w cps	5.2	4.0	6	3
45% w/w cps	13 0	15.0	21	9
50% w/w cps	—	35.0	57	18
55% w/w cps	44.0	87.0	224	37
65% w/w cps	515.0	—	—	—
Precipitation point at % solids	Nil	43	Nil	Nil
Residual active alkali as Na_2O g/l (at 200 g/l total solids)	5.5	6.1	5.5	8.9

STRENGTH PROPERTIES OF UNBLEACHED PULPS

FIG.1

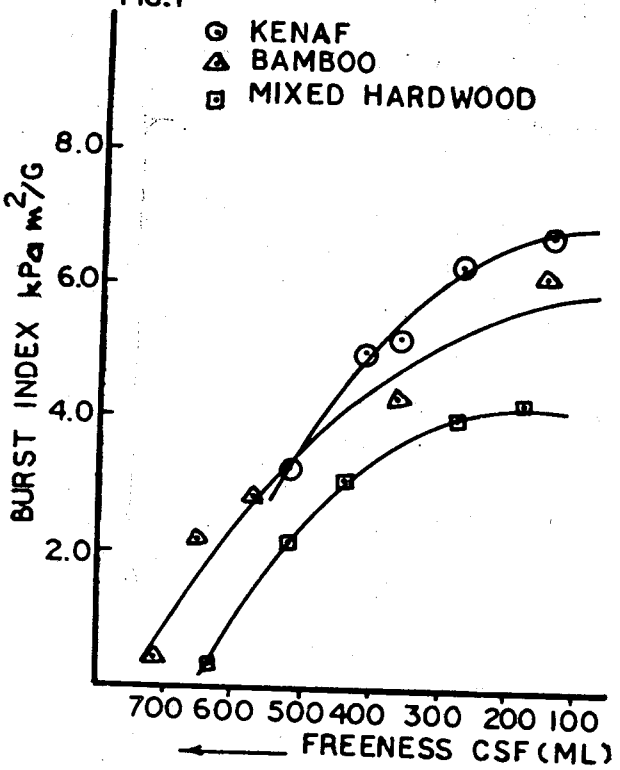


FIG.2

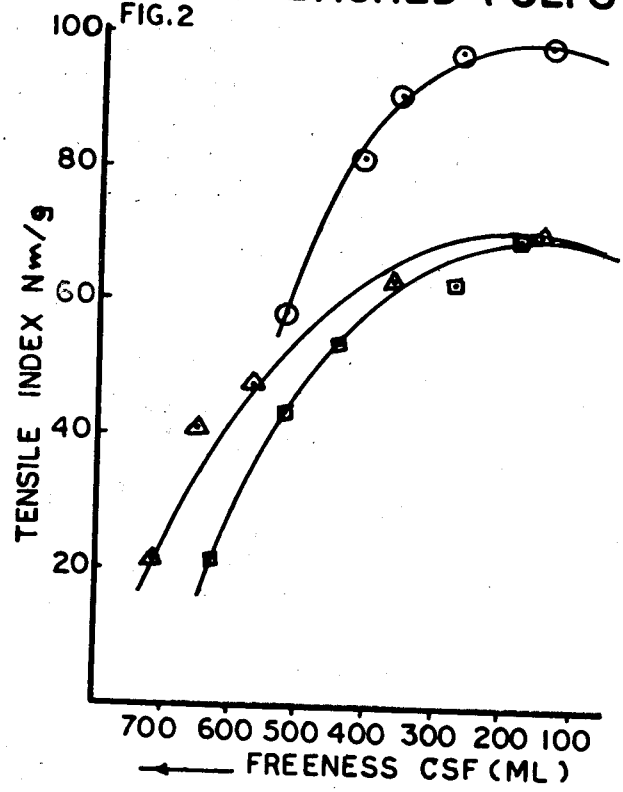


FIG.3

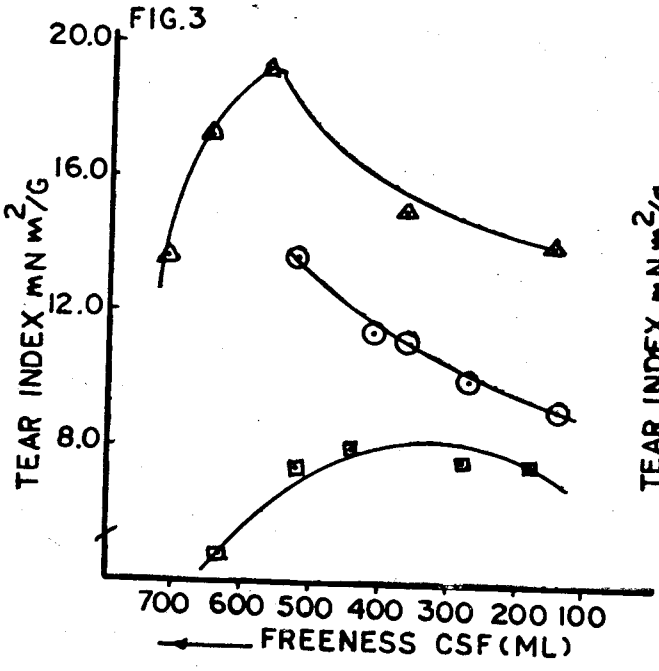
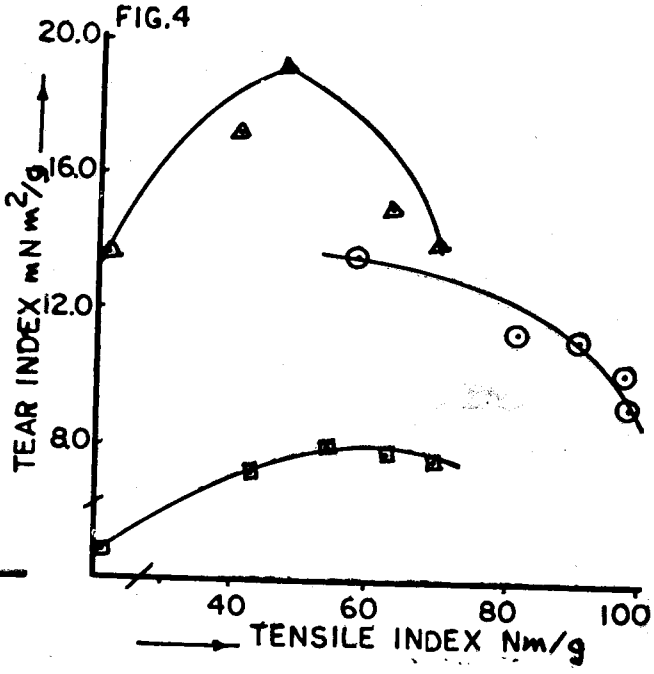


FIG.4



TABLE—5. STRENGTH PROPERTIES OF UNBLEACHED PULP

Particulars	PFI (rev)	Freeness CSF	D. time secs	Apparent density g/cm³	Burst index kpa m²/g	Tensile index Nm/g	Tear index mN.m²/g	Fold KM Log.	Air res. Gurley (s/100 ml)
Kenaf pulp	0	525	4.77	0.70	3.25	58.0	13.54	2.51	38 5
	500	415	7.40	0.75	5.00	81.5	11.33	2.77	118.0
	1000	360	9.37	0.76	5.20	90.5	11.13	3.28	248.0
	2000	275	13 32	0.79	6.30	97·5	10.10	3.29	611.0
	4000	145	29.58	0 83	6.75	98.0	9.20	3.31	>1800
Bamboo pulp	0	715	3.39	0.49	0.45	21.5	13.54	0.60	—
	1000	655	3.51	0.58	2.20	40.5	17.24	1.79	1.0
	2000	575	3.69	0.61	2.85	47.5	19.14	2.08	2 3
	4000	370	5.11	0.62	4.30	63.0	15.00	2.80	18 9
	8000	150	14.54	0.64	6.15	70.0	14.00	2.97	119.0
Mixed hardwoods pulp	0	635	3.54	0.53	0.35	21.0	4.80	0.48	1.0
	1000	525	4.08	0.61	2.15	43.0	7.14	1.18	3.9
	2000	445	4.97	0.67	3.10	53.5	8.00	1.54	14.5
	4000	280	6.61	0.71	4.00	62.5	7.81	2.14	45.0
	6000	185	10.29	0.72	4.25	69.5	7.54	2.36	120.0

TABLE—6. BLEACHING DATA ON KENAF, BAMBOO AND MIXED HARDWOODS PULPS

	Kappa number of the unbleached pulp	Kenaf 27.1	Bomboo 22.1	Mixed hardwoods 30.8
1.	**Chlorination**			
	Chlorine applied/consumed % on pulp	5.4/5.3	5.5/5.0	6.30/6. 3
2.	**Alkali Extraction**			
	Sodium hydroxide applied %	2.0	2.5	2.0
	pH-Initial/Final	11.3/10.5	10.8/10.6	10.8/10.6
3.	**Hypo I Stage**			
	Hypochlorite applied/consumed as chlorine %	1.20/0.91	1.10/1.06	1.80/1.69
	Buffer used as NaOH	0.32	0.37	0.59
4.	**Hypo II Stage**			
	Hypochlorite applied/consumed as chlorine %	—	0.50/0.35	1.00/0.44
	Buffer used as NaOH %	—	0.10	0.2
5.	Yield loss during bleaching %	8.7	5.8	10.6
6.	Total chlorine applied/consumed %	6.60/6.21	7.10/6.41	9.1/8.26
7.	Total sodium hydroxide used %	2.32	2.97	2.79
8.	Brightness of the pulp % ISO	80.3	79.2	78.2
9.	Intrinsic Viscosity of the pulp cm³/g	696	582	440

the same brightness. Viscosity of the kenaf bleached pulp is higher than for bamboo and mixed hardwoods pulps.

Bleached pulp strength properties are presented graphically in fig. 5 and strength properties at 300 ml CSF is given in table 7.

From the table it can be observed that bleached pulp strength properties are superior to unbleached pulp except tear strength, which is somewhat lower.

Blending experiments were carried out with a view to suplement bamboo with pkenaf. Unbleached bamboo and kenaf pulps were blended in the proportions 90 : 10, 80 : 20, 70 : 30, 60 : 40 and 50 : 50 and blended pulp was refined to 300 ml CSF. In the set of experiments bamboo was kept at high tear at 560 ml CSF and kenaf was beaten to 115 ml CSF separately and then blended in the above proportions. The blending results are presented graphically in fig 6.

TABLE—7. STRENGTH PROPERTIES OF UNBLEACHED AND BLEACHED KENAF PULP

Particulars	(At 200 ml CSF) Unbleached	Bleached
Burst Index kPa m^2/g =	6.0	6.7
Tensile Index Nm/g =	95.0	100.0
Tear index mN m^2/g =	10.4	9.2

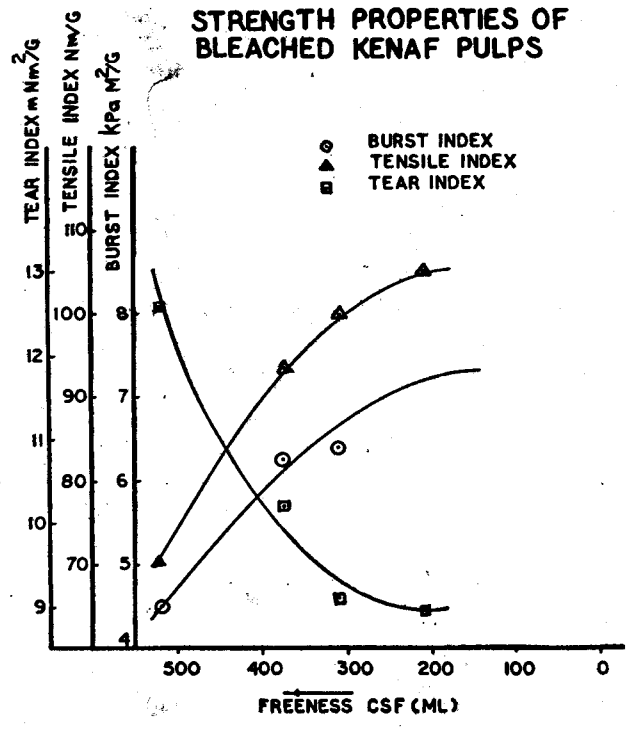


FIG. 5

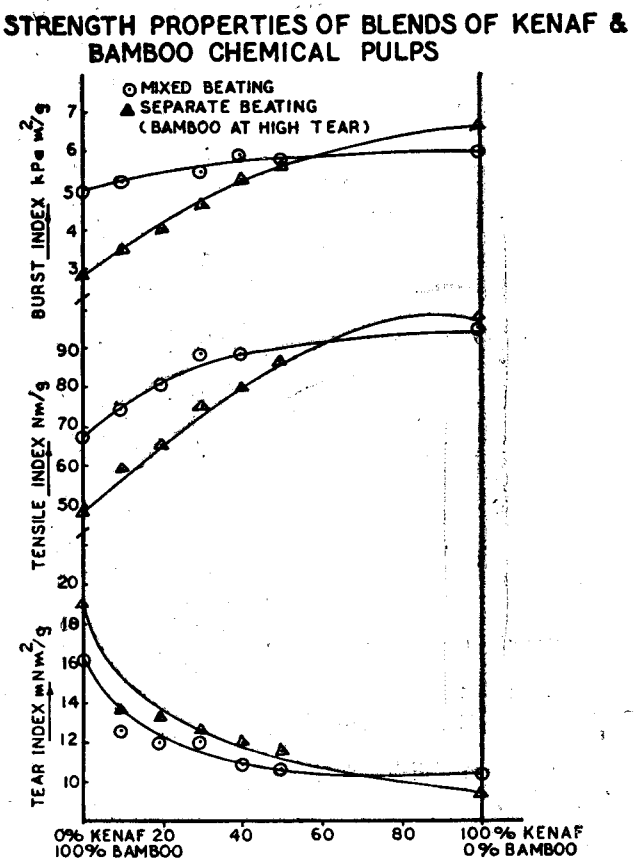


FIG. 8

In mixed beating, addition of kenaf improves the pulp properties like burst and tensile strength but there is drop in tear. Because of low drainage characteristics of kenaf, drainage time is increased. 40% Kenaf can replace bamboo with improved strength properties, and sufficiently high tear strength and without adversely affecting the drainage characteristics of the blended pulp. In the case of separate beating, strength properties of bamboo at high tear strength are low and addition of kenaf substantially improves the strength properties. But at Bamboo : Kenaf ratio of 60 : 40, strength properties are less than in mixed beating, keeping bamboo at high tear.

The higher long fibre fraction (+28) in kenaf and its high tear strength than hardwood pulps, prompted us to use kenaf as a long fibred component to mixed hardwoods pulp. Mixed beating was carried out on kenaf mixed hardwoods pulp blended in the ratio 90 : 10, 80 : 20, 70 : 30, 60 : 40 and 50 : 50. In another set of experiments kenaf was kept at high tear (380 ml CSF) and hardwoods beaten to 160 ml CSF. The results are presented graphically in fig. 7.

In mixed beating 50 : 50 kenaf hardwood blend strength properties are considerably more than 100% mixed hardwoods, as is to be expected and there is a slight improvement in tear strength and drainage time is some what increased. In separate beating of kenaf and mixed hardwoods, 50 : 50 kenaf hardwood blend strength properties are some what lower than those obtained in mixed beating with a slight improvement in tear strength.

Results of NSSC pulping of kenaf are given in table 8 and strength properties presented graphically in fig. 8.

STRENGTH PROPERTIES OF BLENDS OF KENAF & MIXED HARDWOODS CHEMICAL PULPS

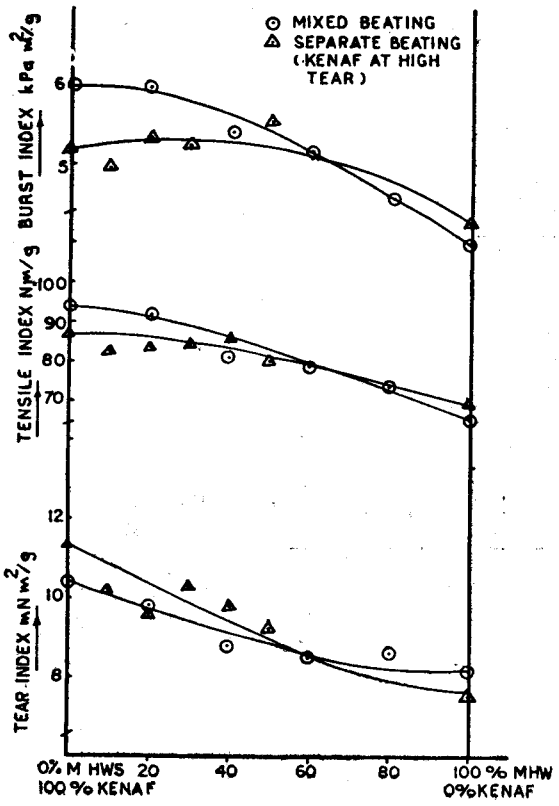


FIG. 7

TABLE—8. NSSC PULPING OF KENAF

Na_2SO_3 %	=	10.0
Chips to liquor ratio	=	1:4
Cooking temperature °C	=	160
Cooking Schedule		
To 100°C min	=	30
From 100°C to 160°C min	=	90
At 160°C min	=	90
H factor	=	710
Total pulp yield %	=	62.2
Screen rejects %	=	1.9
Kappa number of the pulp	=	118.3
Brightness of the pulp % ISO	=	43.0
Spent liquor		
Total solids % w/w	=	10.0
Residual Na_2SO_3 g/l	=	0.9
Strength properties at 300 ml CSF		
Burst index kpa m^2/g	=	3.65
Tensile index Nm/g	=	68.0
Tear index mN m^2/g	=	8,0

STRENGTH PROPERTIES OF KENAF NSSC PULPS

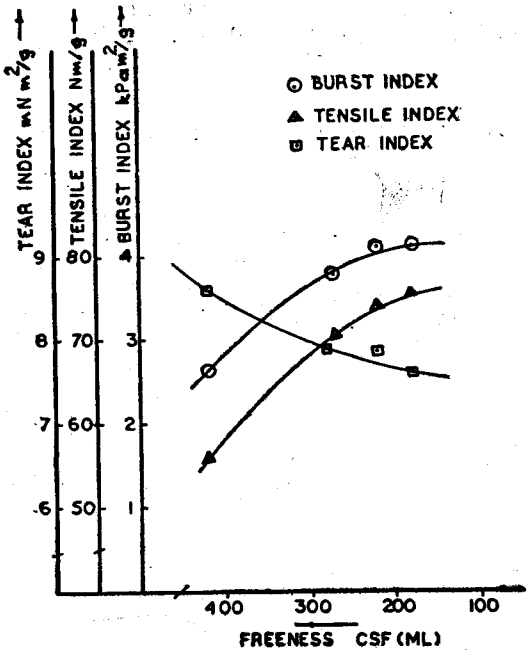


FIG. 8

As can be seen from the table, yield is high and from figure 8 and table 8 it can be observed that strength properties of kenaf pulp are on par with mixed hardwoods kraft pulp, in burst, tensile and tear strength, in addition to the advantage of higher yield and considerably higher brightness (43% ISO) of the unbleached pulp. This can be made use of for making newsprint grade pulp with NSSC kenaf as one of the components in the furnish.

Cold soda pulping of kenaf is given in table 9 and compared with Eucalyptus species.

Strength properties of kenaf cold soda pulps are better than *Eucalyptus tereticornis* and *E. grandis* and on par with *E. globulus*. Brightness of the unbleached pulp is more than for *E. tereticornis* and *E. grandis*.

Cold soda pulps were blended with bamboo chemical pulps (at high tear) in the ratio 90 : 10, 80 : 20, 70 : 30, 60 : 40, and 50 : 50. The results are presented graphically in fig. 9.

As can be observed the resultant blends are having higher tensile than the 100% components ie the addition of fines of cold soda pulp to bamboo pulps, improves the bonding characteristics and thereby the tensile strength or there is synergestic effect felt. Bamboo : kenaf 30 : 70 pulp blend possesses strength properties comparable to newsprint grade quality pulp.

Cold soda pulps were blended with kenaf chemical pulp (at high tear) as a long fibre component in the ratio 90 : 10, 80 : 20, 70 : 30, 60 : 40, and 50 : 50. Results are represented graphically in fig. 10.

30 : 70 blend of chemical and cold soda kenaf pulps possess strength properties similar to 30 : 70 blend of kenaf cold soda : bamboo chemicals pulp, except tear strength which is some what lower. But drainage time is more than kenaf bamboo blend (15.5 secs and 7.2 secs respectively).

STRENGTH PROPERTIES OF BLENDS OF KENAF COLDSODA & BAMBOO CHEMICAL PULPS

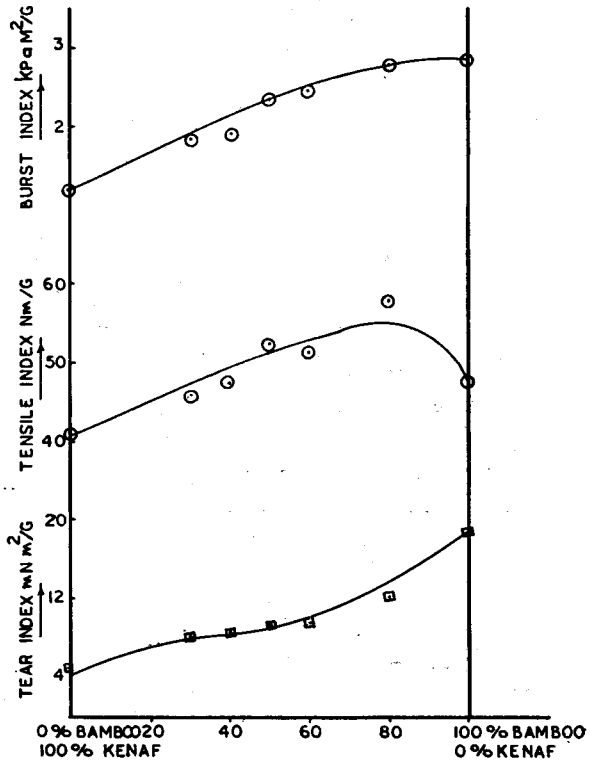


FIG. 9

TABLE—9. COLD SODA PULPING OF KENAF AND HARDWOODS

S. No.	Species Name	Bath ratio	NaOH g/l	Yield %	Brightness of unbleached pulp % ISO	Burst index kPam²/g	Tensile index Nm/g	Tear index mNm²/g	Initial wet web tensile index Nm/g
1.	*Kenaf*	1:7	15.0	87.2	35.7	1.2	41.0	4.7	0.54
2.	*Eucalyptus tereticornis*	1:4	15.0	87.1	27.1	0.2	7.1	0.9	0.13
3.	*E grandis*	1:4	15.0	90.1	27.9	1.16	28.5	3.2	0.41
4.	*E. globulus*	1:4	15.0	90.7	47.0	1.55	29.5	4.4	0.48

STRENGTH PROPERTIES OF BLENDS OF KENAF COLD SODA & CHEMICAL PULPS

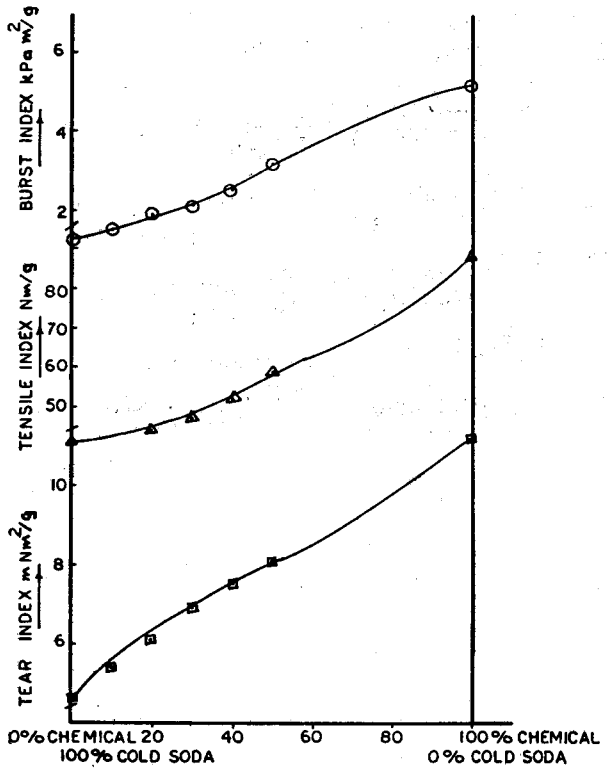


FIG. 10

CONCLUSIONS

1. With 16% chemical at 165°C for 75 min, bleachable grade pulp can be prepared from kenaf at an yield of 45.5%.
2. Strength properties of kenaf are very much superior to hardwoods. Except tear strength kenaf pulp is superior to bamboo pulp.
3. Bleachability of kenaf pulp is very good compared to bamboo and three stage CEH bleaching itself is sufficient to attain a pulp of 80% ISO brightness.
4. Bleached pulp strength properties are very high and even superior to unbleached kenaf pulps except tear strength.
5. Bamboo pulp can be replaced to the extent of 40% by kenaf chemical pulp, resulting in improved strength properties, reasonable tear and without adversely affecting the drainage characteristics. Mixed beating can be carried out.
6. Kenaf can improve the strength properties of mixed hardwoods pulp, including tear strength and 50 : 50 kenaf : hardwoods pulp is better than 100% mixed hardwoods pulp.
7. Kenaf is suitable for NSSC pulping. At 62% yield, the strength properties are on par with mixed hardwoods kraft pulp. Brightness of the unbleached NSSC pulp is quite high (43% ISO) which can be made use of in newsprint furnish.
8. Kenaf cold soda pulps are superior in strength properties and brightness to *E. tereticornis* and *E. grandis*.
9. Blend of 70 : 30 kenaf cold soda : bamboo chemical pulps possess, strength properties comparable to newsprint grade quality pulp.
10. Blend of 70 : 30 kenaf cold soda and chemical pulps possess similar strength properties as 70 : 30 kenaf cold soda, bamboo pulp blend but the drainage time is more.

EXPERIMENTAL

Material : Mesta sample was received from Andhra Pradesh Paper Mills Ltd.

Chip preparation : For laboratory studies, hand chopping of kenaf was carried out manually, so as to obtain chips of 1" size with bast portion intact and the chips representing the whole kenaf as present orginally.

Pulping : Pulping was carried out in a series digester consisting of six bombs of 2.5 lits capacity rotating in a electrically heated polyethylene glycol bath. Washing of the pulps was carried out with cold water for kenaf and bamboo. But hot water was used for hardwoods to have efficient washing to remove the coloring matter.

NSSC and Cold Soda Pulping

NSSC pulp after washing was further refined in 12" sprout waldron disc refiner keeping a disc clearance of 5 thou. Cold soda pulp was prepared by soaking the Chips in NaOH (15 g/l) overnight and then refining in sprout waldron disc refiner keeping a disc clearance of 2 thou. in a single pass.

Kappa number was determined on screened pulps according to Tappi method T-236-OS-76.

Bleaching was carried out under optimum conditions, based on the small scale studies, to attain a bleached pulp brightness of about 78-80% ISO.

The following conditions at different stages were used.

	Chlorination	Alkali extraction	hypochlorite
Consistency %	3.0	8	8
Temperature °C	30	60	40
Time min	30	60	120

Intrinsic viscosity of the bleached pulps was carried out in CED solution according to SCAN-C 15 : 62 method.

Black liquor analysis was carried out according to TAPPI method T-625-ts-64. Viscosity was determined using Brook-field synchro lectric viscometer at 80°C, varying the solids content from 35% to 65%.

Pulp evaluation : Beating of the pulps was carried out in PFI mill under standard conditions as per ISO DP 5264. Testing of wet web properties and sheet strength and optical properties were carried out as per ISO and SCAN standards given in the manual of laboratory research methods[8].

ACKNOWLEDGEMENTS

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