Newsprint Grade Pulps from Whole Mesta Plant of Sabdariffa Hibiscus Variety Part-II Pilot Plant Studies on High Yield Pulp Production

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SUMMARY

Today the plantation grown *E. teriticornis* constitute main raw material for the production of high yield pulp component of the newsprint pulp furnish. The high yield pulps produced do not posess the required mechanical strength properties. Further with alleviating shortage of forest produce, it has become highly essential to assess the prospects of renewable annual plants, which can yield high strength mechanical pulps, as an alternative raw material base. Mesta/Kenaf, which belongs to the family of Jute, is one such annual plant which has attracted the attention of newsprint manufacturer around the world. The present paper discusses an experience in the production of ultra high yield pulps from whole mesta on pilot plant scale. High yield pulps were produced by thermomechanical (TMP), chemithermomechanical (CTMP) and chemimechanical (CMP) pulping processes. The raw material had 37% bast fiber and 122 Kg/m^3 and 273 Kg/m^3 bulk and basic densities respectively. In all the high yield pulping processes the common problem observed was the nonuniform feeding of the raw material. Plate pattern and chop length had profound influence on the feeding rate. With more open type plate pattern and chop length reduced from 5-8 cm to 2-3 cm improved the feeding rate. Modification of the agitator in preheater of the TMP unit further facilitated the uniform feeding. In CTMP and CMP processes the intake of the raw material was reduced due to slippery plate by the presence of alkali. Mild dosages of very dilute alum solution (5g/l) alongwith raw materials improved the refining efficiency. Chemical (NaOH) concentrations, applied in CTMP and CMP processes, were very low-12g/l and 16g/l respectively.

Even the energy intensive TMP process required specific energy less than 1000 KWh/t due to more open ultracelluler structure of the raw material. The TMP produced pulps with yield over 90% while CTMP and CMP produced pulps with the yields over 86%. The pollution load in TMP was lower compared to pollution loads generated in CTMP and CMP processes. All the three high yield pulps were easily bleached to brightness level over 50% with 10% hypochlorite. Initial brightness of TMP was 42% while CTMP and CMP had 33.5% and 35.3% respectively. The TMP and CTMP had superior strength propertes compared to chemimechanical pulps, and were comparable with TMP from conifers. Mesta kraft pulp prepared for blending with high yield pulps had superior strength properties compared to bamboo Kraft pulp. Blending of 10% mesta kraft pulp with TMP and CTMP showed a sharp rise in the strength properties of blends. Blend had good wet web strength and optical properties. Pilot plant studies reveal that it would be possible to produce high strength mechanical pulps by TMP and CTMP processes, suitable for the newsprint and other wood containing grades of paper, from whole mesta with low energy and chemical inputs.

During the recent years, in India, significant progress had been made towards self-relience in the manufacture of newsprint. However, today a substantial proportion of the demand is met through import. The growth of newsprint industry in India had been very slow and is largely attributed to non availability of suitable raw material base. By the turn of century the newsprint demand is likely to go up to one million tonnes

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indicating a need for massive expansion of the newsprint sector[1] In developed countries there is an increased use of high yield pulps not only in the manufacture of newsprint but also in mass produced varieties like writing and printing papers. This has led not only to a substantial reduction of furnish costs but also to more economic use of wood supply, reduced effluent problems and improved sheet properties-2. Plantation grown *E. tereticornis* constitute the main raw material for production of high yield pulp component of the newsprint pulp furnish. Due to dense ultra cellular structure, it is not possible to produce high strength mechanical pulps from this species. To a certain extent, a better understanding of this wood and application of right conditions of treatment enabled us to produce high yield pulps. Today our newsprint industry needs an alternative raw material base, which can produce high strength ultra high yield pulps, to permit the expansion of newsprint industry. In the recent years kenaf (*Hibiscus cannabinus* and mesta (*Hibiscus Sabdariffa*) have drawn considerable attention around the world including the developed countries. United states, inspite of stable suppy from Canada and vast reserves of pine in Southern U.S., has been conducting research in the use of kenaf, what promises to be an excellent substitute for traditional softwood pulp. The findings of successful research in U.S, on the use of kenaf for the manufacture of newsprint, conforming to acceptable standards and at a competitive price, are valid for the application to Indian conditions-(3). Kenaf is no stranger to us and has been cultivated extensively in our country and has best prospects of commercial exploitation. A project on agronomic research of mesta plantation and newsprint manufacture from this annual plant was jointly launched by ICAR/JTRL, CPPRI and Research Institute for Newsprint Development (RIND), Madras. CPPRI with its modern TMP facilities took the job of pilot plant studies on high yield pulp production. Extensive studies on agricultural aspects of mesta plantation have been conducted by JTRL Objective of pilot plant studies is to establish the appropriate process technology for production of high yield pulps of acceptable strength and optical properties with low energy and chemical inputs and reduced pollution loads.

The fiber yield per hactare from mesta is much more even compared to conifers[1]. Mesta yield reported ranges between 13—22 t/hectare[7] Mesta/kenaf produces to easily bleachable kraft pulps stronger compared bamboo pulps[8] Studies conducted earlier[9] have confirmed that TMP produced from mesta without bast had inferior properties. Thus the bast portion is desirable to have stronger pulps. The paper machine trials with 65% peroxide bleached kenaf TMP and 35% soda pulp in U.S., were very successful[10]. Chemithermomechanical pulp produced with compacted kenaf cubes with density as high as 640 kg/m³ had strength properties comparable to TMP pulps from Southern pine[10]. Thus cubing of kenaf makes it more easy for handling and transportation and even in uniform feeding of the raw material. Extensive studies conducted abroad have recorded fair degree of confidence in kenaf as a promising fiber source alternate to conifers.

RESULTS AND DISCUSSION

A combination of basic raw material properties and appropriate technology is the only way for successful production of high yield pulps. It is necessary to identify the optimization strategies at each stage right from the raw material treatment to final product quality. Even on plant scale optimization at each stage has helped to increase the production rate by 30%[11]

Raw material :

The physical properties of the mesta are given in Table 1.

TABLE—1

RAW MATERIAL DATA

Chop length—Avg cms. (Consignment—1)	—	5.0
Chop length, Avg. cms. (Consignment—2)	—	2.7
Bast fiber %	—	37.0
Bulk density, kg/m³ (Cons—1)	—	122
Bulk density, kg/m³ (Cons—2)	—	158
Basic density, kg/m³	—	273

The mesta plant contained appreciable amount of bast fibers (37%). The bast portion is characterised by relatively fine long fibers which vary from 1—10 mm in length with an average value of 2.5 mm. Central woody portion has much shorter fiber 0.5 to 0.6 mm. In addition to small core of pith there was evidence of collapsed parenchyhra cells[12]. The bulk density of mesta was very low. On reducing the chop length to 2.7 cm from 5 0 cm, the bulk density increased from 122 kg/m³ to 158 kg/m³. Chemical composition of mesta (Table—2) shows high amounts of alkali and hot water solubility.

The lignin was on lower side with a good amount of holocellulose. Moisture uptake studies indicated that the raw material could be saturated

TABLE—2

CHEMICAL COMPOSITION OF MESTA

Particulars	% on O.D. raw material
Hot water solubility	8.5
0.1 N alkali solubility	31.2
Klason lignin	20.4
Holocellulose (chlorite)	66.6
Silica	0.2

to 60—70% moisture. Chip moisture has a profound influence in TMP and CTMP process. It has been established that the wood should be fully saturated with water[13].

Pilot plant studies :

Table—3 gives the refining conditions maintained during TMP, CTMP and CMP processes.

TABLE—3

REFINING CONDITIONS DURING HIGH YIELD PULPING

Particulars	Process		
	TMP	CTMP	CMP
Production rate, kg/hr.	54	54	*
Pressurized refining			
Preheater temperature, °C	120-123	120-123	—
Disc clearance, mm	0.3	0.25	0.5
Disc pattern	5821	5821	5811G
Energy, KWh/t pulp	363	380	*
Atmospheric secondary stage refining			
Temperature °C	80-90	80-90	Around80
Disc clearance, mm	0.15	0.15	0.25
Disc pattern	5811G	5811G	5811G
Energy, KWh/t pulp	525	685	*
Total specific energy consumed, KWh/h	888	1065	*
Pulp properties			
Initial freeness, ml CSF	570	480	710
Initial brightness, %ISO	41.6	33.4	35.8
Pulp yield, %	91.0	86.4	86.0

*Could not be determined accurately as material was fed manually.

Optimization strategies are very important. Thermomechanical pulping is an energy intensive process and careful understanding of each step would be necessary. The important optimization strategies of TMP and other high yield processes are i) Maximization of production rate, ii) Maximization of pulp quality iii) Minimization of disturbances iv) Minimization of energy consumption and v) Maximization of heat recovery—14. The pre heating temperature for TMP & CTMP was between 120—123°C with 2—3 minutes retention time. Different plate patterns studied are given in Figure—1.

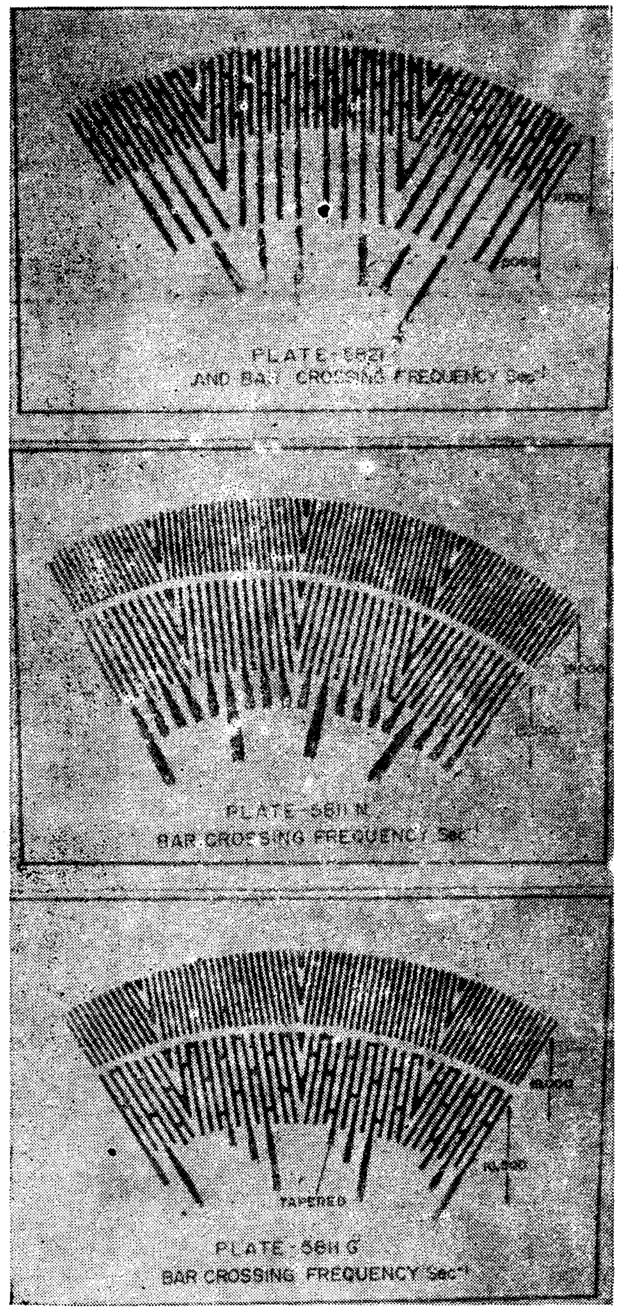


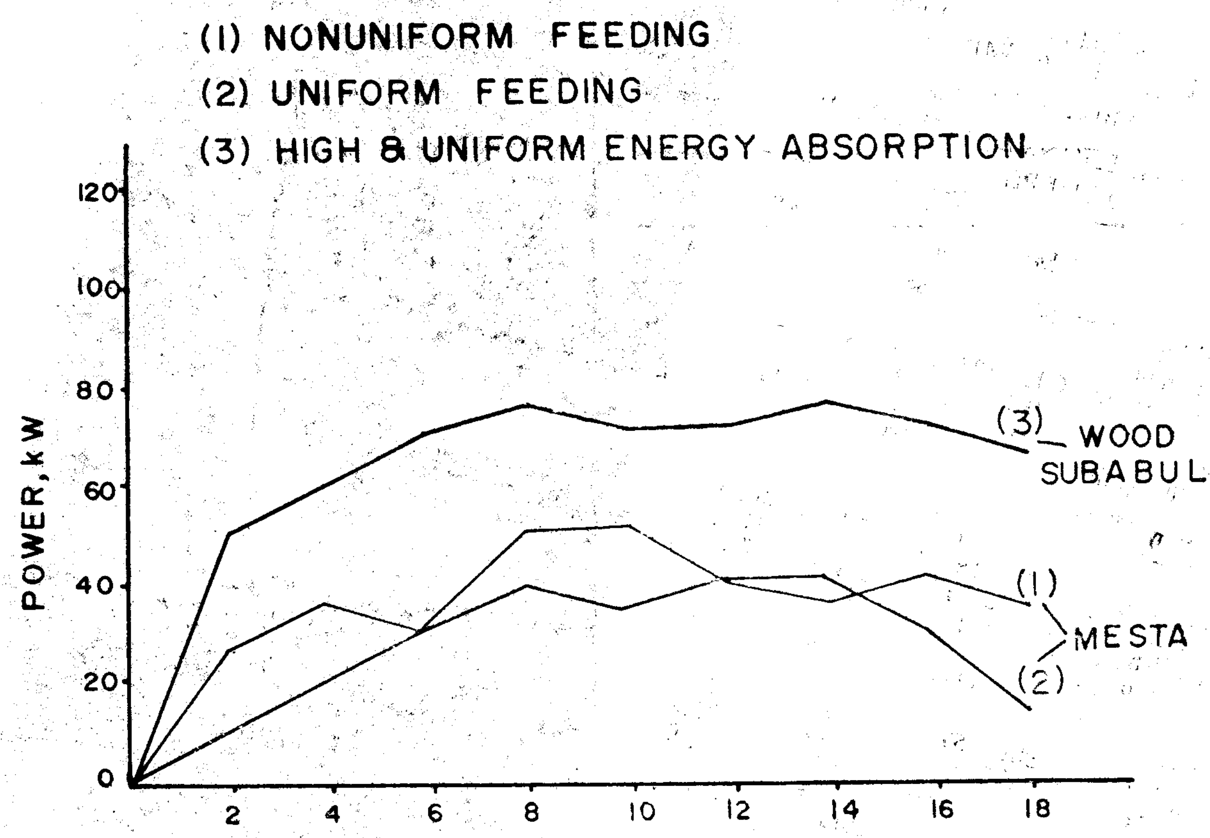
FIG.—1, DIFFERENT PLATE PATTERNS

Plate pattern 5821 was more open type with lower bar crossing frequency. Plate pattern 5811 N had fine pattern with higher bar crossing frequency. Disc 5811 G had same pattern as of 5811 N except that the breaker bars were partially removed. 5811 N showed excessive clogging with mesta sticks. In second stage refining 5811 G was found to be more efficient. Disc clearances were adjusted for maximum production rate and lower freeness values. The energy requirement in TMP was around 900 k Wh/t and 1065 kWh/t in CTMP process. Energy absorption was very low, presumably due to more open ultracellular structure of mesta. In CMP process the raw material was fed manually hence energy requirement was not calulated as feeding was non uniform. However from the effective power load noted, it appeared that the energy requirement would be below 1000 kWh/t. The yields of the pulps calculated were 91.0%, 86.4% and 86.0% for TMP, CTMP and CMP respectively. The pulp was clean with very low quantity of rejects. The TMP had initial brightness over 41% while CTMP and CMP pulps had lower brightness values 33.4 and 35.3 respectively.

Influence of operating variable :

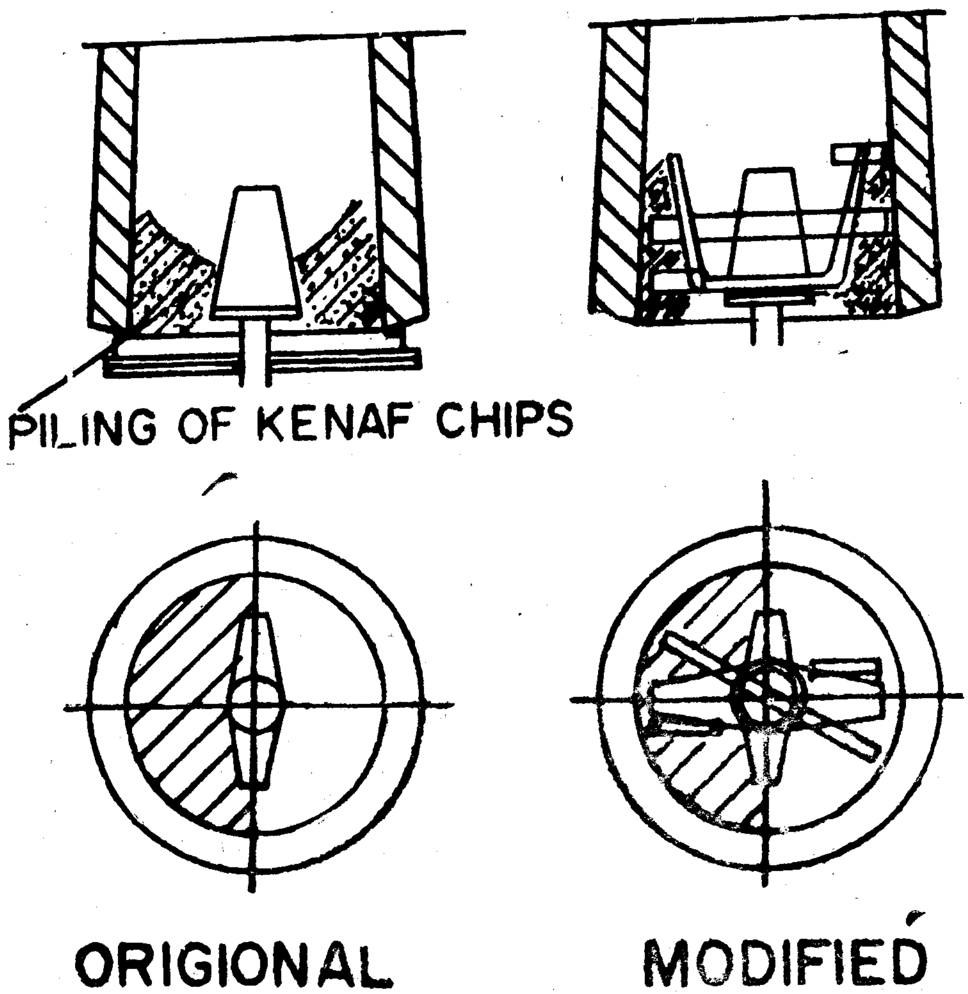
In all the three processes the common problem observed was non-uniform feeding rate. The energy absorption profile was erratic (Fig. 2)

FIG-2, ENERGY PROFILE CURVES OF T.M.P.



There was non-uniform energy and load varied between 50—100 kW. When absorption the manwhole of the preheater of TMP unit was opened, it was observed that there was a formation of pocket around the agitator and raw material was piled up along the walls of preheater. Two factors were responsible for this non uniform feeding. The grinding disc was clogged completely leading to reduced intake of raw material. Piling of the chips also indicated that due to round shape and low density of chips the agitator was not capable of scrapping the chips into screw conveyer leading to discs. The plate pattern 5811 N was replaced with more open type plate pattern 5821 and additional agitator was fixed on the existing one in the preheater (Fig. 3)

FIGURE - 3



PREHEATER AGITATOR

These modification helped to increase the feeding rate from 48 kgs to 54 kg/hr. It was also observed that by reducing the chop length of the raw material to 2—3 cm facilitated uniform feeding rate. Uniform feeding also helped to raise the discharge consistency from 6 to 12%. Due to lower production rate consistencies more than 20% could not be achieved. Thus chop length, plate pattern and agitator design were important variables which influenced the production rate. It is felt that horizontal presteaming tube with plug screw feeder will be more suitable for mesta.

In CTMP and CMP, it was noticed that the refiner plates became slippery due to alkali, leading to lower intake of raw material. This problem was overcome by introducing dilute alum solution (5 g/l) along with chips. In all the case, plate pattern was a dominant machine variable. Matsuo etal[15] have shown that even in the case of bagasse chemithermomechanical pulping the plate pattern was important from the point of stability of motor load. For efficient energy absorption it is recommended that there should be 50 : 50 energy split between primary and secondary refiners[4]. In case of mesta energy in first stage was less compared to second stage.

Pollution loads :

Pollution loads in different high yield pulping processes are given in Table 4.

TABLE—4*

POLLUTION LOADS IN DIFFERENT PROCESSES

Process	TMP	CTMP	CMP
Pulp yield, %	91	86.4	86.0
Total dissolved solids, kg/t	92	137	140
COD, Kg/t	64	81	95

*All results are expressed on per tonne of the raw material.

The pollution load in TMP is on lower side compared to CTMP and CMP processes. Even for TMP the COD load is on higher side compared to pine TMP—41 kg/t[16]. The increased COD load might be due to more amount of water soluable components. Jervinen[16]. etal have established that the pollution load is sensitive to to presteaming temperature. However, over all pollution loads in mesta high yield pulping were on very much lower side compared to the COD value of 150 kg/t in *E. teriticornis* cold soda pulping[17].

Bleaching of high yield pulps :

The results of bleaching are given in Table—5. Either single stage or two stage Ca—hypochlorite bleaching is practiced in mills. Important properties to be preserved in bleached pulps are opacity and scattering coefficient. Mesta TMP, CTMP and CMP pulps were bleached to a brightness level over 50% with 10% hypochlorite. The yield loss during bleaching was on higher side for TMP.

TABLE—5

BLEACHING OF HIGH YIELD PULPS

Pulp	TMP	CTMP	CMP
Initial brightness,%	41.6	33.4	35.3
Hypochlorite applied/consumed %	10/9.95	10/9.98	10/9.99
Final brightness,%	53.6	49.6	51.9
Bleached pulp yield%	85.1	82.7	81.0

It was observed that no brightness gain was achieved with higher dosages of Ca-hypochlorite. Hypochlorite requirement is comparaitively less when compared to *E. teriticornis* chemimechanical pulps which require about 15% of hypochlorite.

Fiber and fines proportion :

For high yield pulps it is necessary to maintain balanced fiber and fines proportion. Fines help in preserving wet web strength and opacity. The fiber classification results are given in Table 6.

TABLE—6

FIBER CLASSIFICATION (Bauer McKNett)

Pulp	R28	P28/ R48	Fraction %P48/R100	P100/ R150	P150
TMP	23.5	13.5	14.5	6.6	41.9
CTMP	35.0	15.0	12.0	8.0	30.0
CMP	10.5	24.5	16.5	3.1	45.4

Results show that in CTMP relatively lower proportion of fines content was produced. CTMP and TMP had more of R28 fraction. In CMP R28 fraction was less due to extensive cutting of fibers. CMP also had highest fines proportion.

The photomicrographs 1, 2, 3 shows the fiber characteristics. The TMP photomicrograph shows distinct separation of fibers. It can be noticed that there are two types of fibers, long and fine fibers are from bast portion while the short one from woody stalk. Photo micrograph—2 of CTMP show fibrillation of fibers to a certain extent.

FIG -4, PHOTOMICROGRAPHS
1—MESTA TMP, 2—MESTA CTMP,
3—MESTA CMP

Photomicrograph—3 show extensive cutting of fibers in CMP process.

Strength properties :

Strength, optical and wet web properties of different high yield pulps from mesta are given in Table—7.

Thermomechanincal and chemithermomechanical pulps had superior strength properties. CTMP had slightly lower tensile and burst due to higher freeness value. Chemimechanical pulps had lower strength properties. Except for tearing strength the TMP and CTMP posessed strength properties almost comparable with TMP from pine (Southern U.S.). TMP and CTMP from mesta had strength properties almost two times more than the strengths of **E. teriticornis** cold soda pulps. All the three pulps showed opacity values more than 94%. Only CTMP posessed lower scattering coefficient value.

Most of the modern newsprint mills employ twin wire formers. These twin wire formers have no draw or short draw passes.

No draw or short draw machines help in efficient runnability even with weaker pulps[1]. However certain amount of wet web strength is desired for smooth running of paper machine. CTMP had very good wet web strength. TMP also had acceptable wet web strength. Thus the pressurized refining helps to produce stronger pulps.

Table 8 shows the strength, optical and wet web properties of blends of mesta high yield and kraft pulps.

Except for tear the mesta kraft pulp was stronger compared to bamboo kraft pulp. Blending of 10% mesta kraft pulp with 90% TMP, improved strengths of blends—tensile by 34%, tear by 27% and burst by 68% Addition of 20% kraft pulp produced a blend with an excellent strength properties. Blend of 10% kraft and 90% CTMP had superior properties in all respects, compared to blend of kraft and TMP. By blending of kraft pulps only a marginal decrease in opacity was observed. Blending of kraft pulp with CMP also showed increase in strengths Blending of TMP with CMP did not help much in improving the strengths.

CONCLUSIONS :

1. Pilot plant studies reveal that it is possible to obtain high strength mechanical pulps form whole mesta suitable for newsprint manufacture, by TMP and CTMP processes with low energy and chemical inputs.

TABLE—7 STRENGTH AND OPTICAL PROPERTIES OF HIGH YIELD PULPS

Pulp	Freeness ml. CSF	Strength Properties Tensile index	Tear index	Burst index	App. dersity	Optical properties Brightess	Opacity	Sc. scatt. coeff.	Wet web strength Initial wet webtensile index
		N. m/g	mn. m²/g	kPam²/g	g/cm³	%	%	m²/kg	N. m/g
1. Mesta TMP	150	29.0	3.6	0.95	0.52	53.4	94.9	42.6	0 38
2. ,, CTPM	195	23.0	4.10	0.70	0.57	47.1	94 0	36.3	0.52
3. ,, CMP	155	15.0	1.2	0.1	0.46	54.5	96 4	47.9	0.19
4. E. teriticornis[18] (CPM)	150	11.0	1.3	low	—	56.0	—	47.1	0 21
5. Pine, TMP [10]	140	34	9.7	1.5	—	54.0	—	50.0	0.58

TABLE—8 STRENGTH AND OPTICAL PROPERTIES OF BLENDS OF HIGH YIELD AND KRAFT PULPS

S. No. pulp blend	Freeness ml. CSF	Strength Properties Tensile index N. m/g	Tear index mNm²/g	Burst index kPa. m²/g	Optical Properties Brightness %	Opacity %	Sp. scatt. coefficient m²/kg	Wet web strength Initial wet web tensile index N m/g
1. 90%TMP + 10% Kraf	145	39.0	4.6	1.6	53.5	93.7	39.1	0.41
2. 80% TMP + 20% Kraft	140	47.0	5.7	2.4	52.8	93.2	38 0	0 63
3. 90% CTMP + 10% Kraft	140	44.5	4.7	1.6	46.4	93.2	32 3	0 85
4. 90% CMP + 10% Kraft	155	24.0	1.9	0.5	53.6	95 6	45.4	0.23
5. 70% CMP + 30% TMP	140	21.0	1.8	0.4	54.4	95.8	46 1	0 22

2. Blending of 10% mesta kraft pulp with TMP and CTMP produced blend with, excellent strength, optical and wet web properties. Combination of TMP and kraft pulp (maximum 10%), should. form possible newsprint furnish.

3. By appropriate compromise between plate pattern, chop length, and disc clearance, it would be possible to increase the production rate. 2—3cm long chops with plate pattern 5821 in first stage and 5811 G in second stage will be ideal.

4. Compaction of mesta into high density cubes should solve the raw material handling, transportation and feeding problems.

Raw material :

Mesta was supplied by Agricultural Research Station at Amadavalse (A.P.). The plant was harvested after 50% flowering stage (130—140 days) and was air dried. Air dried plant was cut into 1—2" size manually. Care was taken to keep the bast portion intact during cutting.

About 200 kgs of the chopped mesta was sent to CPPRI for pilot plant studies. The measurement of bulk density, basic density and mois ure uptake and proximate analysis were carried out according so procedure mentioned in laboratory mannual of CPPRI[4].

Pilot Plant Trials :

For thermomechanical pulping the chips were soaked in water for 5—6 hours to attain moisture saturation. For chemithermomechanical and chemimechanical pulping processes the chemical concentration, to soften the chips, was optimized, NaOH concentrations 12 g/l and 16 g/l were applied for CTMP and CMP respectively. The detailed description of CPPRI's TMP unit is discussed elsewhere[5]. In each experiment about 20 kgs of raw material was used. Raw material from metering bin is fed into preheater of TMP unit through rotary valve feeder. Chips were retained in preheater for 2—3 minutes at 120—123°C for TMP and CTMP processes. Chips from preheater were fed to grinding discs of pressurised refiner through a screw feeder with variable RPM. The pulp from pressurised refiner blown into cyclone was fed to secondary stage open discharge refiner (RO-20). Both the pressurised (ROP—20) and atmospheric refiners (RO—20), have 500 mm diameter grinding discs and are powered by 200 kW motors. The pulp from secondary stage refiner was collected in the bottom chest. Samples were collected for 1st and IInd stage refining for freeness, consistency and pollution load measurements.

In chemimechanical pulping process the chemically impregnated raw material was fed manually to secondary stage refiner. The pulp obtained in first pass was again fed to secondary stage refiner. Different plate patterns, varying disc clearences and feeding rates were used to obtain uniform feeding and energy absorption with satisfactory quality pulps.

Measurement of pollution loads :

The chemical oxygen demand and total dissolved solids in soaking liquor and fiberizing were measured according to standard procedures mentioned in[6]. Pulp yields were calculated from the amount of the material dissolved during soaking and refining.

Bleaching of pulps :

The unbleached pulps were screened on SARALA—vibratory flat screen. Tne screened pulps were bleached by single stage calcium hypochlorite treatment. Hypochlorite dosages were optimized by small scale experiments. Large scale bleaching experiments were carried out with 10% Ca-hypochlorite under following constant conditions :—

Consistence	—	8%
Temperature	—	40 °C
Retention time	—	60 Minutes
NaOH as buffer	—	2 5
pH	—	79.0

Post refining of pulps :

Bleached pulps with freeness values more than 500 ml CSF, were beaten in PFI mill to obtain freeness values below 200 ml, CSF. Handsheets of 60 g/m^2 were prepared with back water recycling to ensure that fines were retained in hand sheets.

Blending of high yield and kraft pulps :

For blending studies mesta kraft pulp was prepared by a chemical charge of 16% Na_2O with 25% sulfidity and cooking at 165 °C. The pulp was bleached by CEH sequence with a total chlorine of 6 %. The brightness of bleached kraft pulp was 63%. Varying amounts of kraft pulp was blended with TMP, CTMP and CMP pulps. The blends were beaten in PFI mill for evaluation.

Pulp testing :

Wet web strength measurement and testing of the conditioned handsheets for physical and optical properties, were carried out according to ISO and SCAN stnadard methods in the CPPRI's manual of laboratory research methods[4].

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LITERATURE CITED :

1. Sawhney R.S. Ippta, 20 (3) : 1 (1983)
2. Atack and Heitner C. International Symposium on wood and pulping chemistry, May 83, Japan Vol. II, 22—27.
3. Reddy, C.G.K. Substitute for newsprint, Times of India, New Delhi—18.10.82.
4. Field Working document, No. 27 IND/703/012. "Manual of laboratory Research methods in papermaking raw material research".

5. Fellegi J and Rao A.R.K.—"Papermaking raw material Research using modern equipment"—Ippta, Souvenir : 23 (1978)

6. Standard method for examination of water and waste water—APHE, 13th Ed. (1971)

7. Dutta A.K. and Fotadar, Ippta 16 (4) : 185 (1979).

8. Rao, N.R.M., Kishore. H., Moorthy K.S., Kulkarni A.G. and Pant R. Ippta 20 (2) 17 (1983).

9. Kulkarni A G., Rao N.R.M., Moorthy K.S. Agarwal G. C. and Pant R. Ippta 20 (1), 37 (1983).

10. Lawford WoH, and Tombler G, Pulp and Paper Canade, 83 (12) : T 355 (1981).

11. Skinner R. Tappi. 66 (11) : 41 (1983):

12. Uhr S.C. "Kenaf and the Paper industry". 30th Annual chemurgic Conference, Chicago, 1968.

13. Hartler N.—International Mechanical Pulping Conference Proceeding Vol. II 6 : 1.

14. Skinner R. Tappi (11) : 41 (1983).

15. Kobayashi T, Nishiyama, M. and Matsuo R. Investigation on chemithermomechanical pulping of bagasse, G.I R I. Report, Shikoku—Japan.

16. Javrinen R, Mannstrom B, Vatitila M. and Sudholm J, Pulp and Paper 81 (3) : 39 (1980).

17. Kulkarni A.G. ; Raghunath V. ; Kolambo S.L. Mantri T.C. and Guha S.R.D., IPPTA, 19 (2) : 19 (1982).

18. Reserch Report No: 8 of CPPRI "Cold soda pulping of **E. teriticornis**".