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APPLIED SCIENTIFIC RESEARCH CORPORATION OF THAILAND

CLASSIFIED INVESTIGATION NO. 2
BLEACHED CHEMICAL PULP FROM KENAF

REPORT NO. 7
CHEMICAL PULP FROM KENAF BY KRAFT AND POLYSULPHIDE PROCESSES

BY
CHIEN CHU
NAIYANA NIYOMWAN
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By Chien Chu*, Naiyana Niyomwan*, and Anchalee Puangvichit*

SUMMARY

Bleached kraft pulps were prepared from Cuban kenaf (Hibiscus cannabinus) and Thai kenaf (Hibiscus sabdariffa) by two modified kraft processes. One was polysulphide process. It gave higher yield of pulp than conventional kraft process. Cooking yields about 50% on chip weight were obtained from both Cuban kenaf and Thai kenaf by cooking at 170°C for 1½ hours. The polysulphide pulps with permanganate no. about 20 were bleached by DC/E/D sequence with about 8 to 9% equivalent chlorine to brightness 75-87%. The strength of bleached kenaf polysulphide pulps and kraft pulps was comparable to softwood bleached kraft pulp except for bursting strength.

The other modified kraft process was alkaline pretreatment with about 2% sodium sulphide on chip weight at 110-120° C for 30-60 minutes before alkaline pulping by soda, kraft, or polysulphide process at 170°C for 60-90 minutes. The pretreatment improved bleachability and strength of the pulps.

INTRODUCTION

Kraft process is the most widely used process for production of wood pulp. The process is distinguished for its high pulp strength but low yield, dark colour, and high bleach consumption. Thus paper from kraft wood pulp is usually used for industrial packaging and no bleaching is required for such purpose. With the advent of modern chlorine dioxide bleaching, bleached kraft wood pulp by multistage bleaching has attained high brightness with good strength.

Clark et al. (1962) reported pulping of Cuban kenaf by kraft process and compared that by neutral sulphite process and soda process. The kraft pulping of air-dry Cuban kenaf (H. cannabinus) with 16-19%

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Na_2O with liquor ratio 6:1 indicated good strength but high bleach consumption (Clark and Wolff 1965).

Monsalud et al. (1965) worked on kraft pulping of Cuban kenaf with 15-18% NaOH and 5-6% Na_2S, showing good strength quality with unbleached yield about 42-46%. But no bleaching result was reported.

Kraft pulping of Thai kenaf (H. sabdariffa) has not yet been recorded in the literature. Hence this study was made to compare kraft pulping with both Thai and Cuban kenaf and to explore modifications of standard kraft process for higher yield and better bleachability.

One modified kraft process employs two-stage pulping with or without washing between the two stages. The process is aimed at reducing bleach consumption.

Another modified kraft process is the polysulphide process, which reduces alkaline hydrolysis of hemicellulose and provides a higher yield (Clayton and Sakai 1969).

A third modified kraft process involves pretreatment of wood chips with H_2S gas under pressure for a short time before standard kraft pulping for higher yield. Commercial development of this process has not yet been reported (Vinje and Worster 1969).

In standard kraft process the chemicals used in cooking are caustic soda and sodium sulphide. These chemicals are recovered by the recovery system as soda ash and sodium sulphide. In polysulphide pulping, the recovered chemicals from chemical recovery system are also sodium sulphide and sodium carbonate in the green liquor. The polysulphide can be produced from sodium sulphide by oxidation of sodium sulphide in the green liquor with manganese dioxide (Barker 1970). Thus the study of kraft process for kenaf was extended to include these new developments in respect to regeneration of polysulphides in a kraft recovery system.

EXPERIMENTAL

Fresh and air-dry kenaf stalks were shredded into small chips about 2 cm long. Cooking and bleaching conditions are shown in Table 1.

For standard kraft process, only caustic soda and sodium sulphide were used in one-stage or two-stage cooking. The two-stage process had sodium sulphide cooking in the first stage followed by caustic soda cooking in the second stage with or without any sodium sulphide. In most cases, no washing was made between the two stages. However, several experiments had washing between the stages.

For polysulphide process, the cooking liquor was prepared with the addition of sulphur at 60-80°C for ½ hour to the sodium sulphide kraft liquor with or without caustic soda to form polysulphides. The polysulphide kraft liquor had an orange colour as compared with the greenish colour of standard kraft liquor containing sodium sulphide and caustic soda.

In one-stage polysulphide pulping, all the caustic soda required for pulping was contained in the cooking liquor, whereas in the two-stage cooking most of the caustic soda for pulping was applied in the second stage. The two-stage polysulphide process as indicated in cooks nos. 403, 366, and 428 was intended to avoid excessive alkalinity at the start of pulping for higher yield and better bleachability.

Instead of adding sulphur to sodium sulphide solution to make polysulphides as described above, technical grade manganese dioxide containing about 80% MnO_2 was reacted with sodium sulphide kraft liquor, with or without caustic soda, at 70-80°C for ½ hour to effect oxidation of sodium sulphide in the solution to polysulphide. The following equation indicates the reaction (Barker 1970):

$$4Na_2S + O_2 + 2H_2O \longrightarrow 2Na_2S_2 + 4NaOH$$

$$MnO + \tfrac{1}{2}O_2 \rightleftharpoons MnO_2$$

The hot polysulphide liquor was cooled and filtered to remove the manganese dioxide residue, which was oven-dried to regenerate the MnO_2 and reused in many cycles. About 16 cycles of manganese dioxide

oxidation of sodium sulphide liquor were tried without any appreciable loss of yields. The sulphidity of the solution before oxidation to polysulphides was about 30-50% or 5-12% Na_2S with 0-18% NaOH. One example was cook no. 463 for MnO_2 oxidation of kraft liquor containing 9% Na_2S and 15% NaOH.

Also to avoid the high sulphidity before polysulphide conversion by MnO_2 oxidation, sulphur was added after the MnO_2 oxidation and filtration to remove the MnO_2 residue. The sulphur added amounted to about 1-2% on chip weight, which is about half the amount usually required for equivalent make-up as salt cake in the kraft recovery system. Cook no. 444 is an example featuring 10% Na_2S and 15% NaOH in kraft liquor before MnO_2 oxidation to polysulphide and then 1% sulphur was added to the polysulphide liquor to form more polysulphides.

As reported in the pulping of kenaf by soda process, pretreatment of kenaf chips before cooking with dilute sodium sulphide solution improved bleachability. Cook no. 457 for polysulphide process was preceded by pretreatment with dilute sodium sulphide solution containing about 2% Na_2S on chip weight. The sulphide solution was prepared from waste sodium sulphide liquor from Summit Petroleum Refinery. The chips were treated in the solution at 120°C for 45 minutes. The waste liquor was drained and the chips were washed. The treated chips were cooked with the polysulphide cooking liquor prepared by MnO_2 oxidation of a kraft liquor containing 10% Na_2S and 15% NaOH. The cooking conditions were impregnation at 110°C for 45 minutes and cooking at 170°C for 60 minutes.

The simplest bleaching sequence was the 3-stage C/E/H sequence as shown by the bleaching of polysulphide kraft pulp from cook no. 457 with 7% chlorine. In this case, the chlorination (C) was done in 3% pulp consistency at room temperature about 30-35°C for $\frac{1}{2}$ hour with 5% chlorine from acidified sodium hypochlorite solution at pH 1.8. The chlorinated pulp was washed. The caustic extraction (E) was done at 10% pulp consistency at 70°C for $\frac{1}{2}$ hour. The extraction solution contained 2% NaOH on pulp weight. The hypochlorite bleaching (H) was carried out at 40°C for 3 hours in sodium hypochlorite solution containing 2% available chlorine on pulp weight. A final acid wash with

0.2% SO_2 on pulp weight in sulphurous acid solution at 30°C for $\frac{1}{2}$ hour completed the bleaching process.

The bleaching of pulp for cook no. 366 was performed also in three stages C/EP/H sequence but with peroxide bleaching included in the caustic extraction stage. The chlorination (C) was the same as the above example but with 8% chlorine. The second stage (EP) was a combination of alkali extraction and peroxide bleaching at 10% pulp consistency and 70°C for 2 hours with 1% sodium peroxide on pulp weight. The peroxide solution was buffered with 5% sodium silicate and 0.2% magnesium sulphate. The third bleaching stage was hypochlorite bleaching (H) with 2% available chlorine in the same way as the above example.

The bleaching procedures in other experiments were more elaborate, featuring ClO_2 in chlorination stage, and followed essentially the same way as previously described in this series of study on kenaf pulps by soda process and bisulphide process. The details of bleaching sequences are shown in Table 1.

TABLE 1. PULPING AND BLEACHING CONDITIONS IN THE KRAFT PULPING OF KENAF

Cook no./Raw material[1]		329/ATK[3]	366/ACK	379/ATK	403/ATK	407/FCK
Process[1]		2-stg Kr	2-stg Ps	1-stg Ps	2-stg Ps	1-stg Ps
Cooking liquor composition:						
1st stage	Na_2S, %	12.0	3.6[4]	3.0	3.5	3.0
	S, %	-	4.0	4.0	4.5	4.0
	NaOH, %	-	3.0	20.0	3.8	20.0
	MnO_2 oxidation, cycle no.	-	-	-	-	-
2nd stage	NaOH, %	19.0	15.0[4]	-	15.7	-
	Na_2S, %	-	2.0[4]	-	2.5	-
	S, %	-	-	-	-	-
	MnO_2 oxidation, cycle no.	-	-	-	-	-
Liquor to chip ratio (ml/g, ovendry basis)	1st stage	4:1	3:1	3:1	3:1	5:1
	2nd stage	5:1	4:1	-	4:1	-
Impregnation temperature, °C		100	130	110	110	110
Time to/at impregn. temp., min		30/30	30/60	25/60	30/60	25/60
Washing after impregnation		Wash	Wash	-	W,press	-
Max. cooking temperature, °C		170	160	170	170	170
Time to/at max. cooking temp., min		90/90	30/120	30/90	30/120	30/120
Cooking yield, % on ovendry chips		46.1	50.1	51.9	51.5	52.0
Permanganate number		17.85	24.25	22.70	17.85	22.30
Bleaching sequence		C/E/H	C/P/H	DC/E/D	DC/E/D	C/E/D
Total equivalent chlorine applied, %		8.0	10.0	10.0	8.0	7.0
Chlorination stage (DC)(3% pulp consist., 30°C, ½ h)	ClO_2, %	-	-	0.75	0.75	-
	Cl_2, %	6.0	8.0	6.0	4.0	5.0
Alkaline extraction stage(E) (10% pulp consist.,70°C,½ h)	NaOH, %	1.5	1.0[5] 2.0	1.5	1.5	1.5
ClO_2 bleaching stage(D)(10% pulp consist.,40°C, 3-4 h)	ClO_2, %	-	-	0.75	0.75	-
Hypochlorite blchg.stg.(H) (10% pulp consist.,40°C,3 h)	Available Cl_2, %	2.0	2.0	-	-	-
Bleaching yield	% on ovendry unbl. pulp	82.7	81.3	82.5	82.4	85.0
	% on ovendry chips	38.3	43.2	42.8	42.4	44.0
Paper number		156	163	165	181	198
Physical properties of handsheets[2] (23°C, 50% r.h., TAPPI standard):						
Initial freeness, S-R, ml		910	820	700	760	730
Final freeness, S-R, ml		400	260	250	520	440
Time of beating, min		8	7	6	3.5	3
Basis weight, g/m^2		77.2	76.2	76.0	77.7	76.7
Bulk, ml/g		1.19	1.04	1.05	1.26	1.08
Burst factor		36.1	56.0	43.6	72.5	58.3
Tear factor		85.8	91.0	80.8	177.0	99.4
Breaking length, m		6942	8712	8894	9908	9558
Folding endurance		35	1210	733	1087	596
Brightness, %		72.4	70.0	80.0	78.0	76.6

1/ TK=Thai kenaf; CK=Cuban kenaf; A=air-dry; F=fresh; Kr=kraft; Ps=polysulphide.
2/ Sizing of sheets: 0.3% Whiten (optical bleach), 1.5% rosin size, 2% TKP, 3% alum.
3/ Big stems. 4/ Waste Na_2S liquor used in both stages. 5/ Na_2O_2, %.

TABLE 1 - continued

Cook no./Raw material[1]	428/ACK	428/ACK	435/FCK	437/FCK	441/ATK
Process[1]	2-stg Ps	2-stg Ps	1-stg Ps	1-stg Ps	2-stg Ps
Cooking liquor composition:					
1st stage: Na_2S, %	3.5	3.5	2.4	10.0	12.6
1st stage: S, %	4.5	4.5	2.9	-	1.0
1st stage: NaOH, %	4.0	4.0	17.2	17.0	-
1st stage: MnO_2 oxidation, cycle no.	-	-	-	1[3]	1[3]
2nd stage: NaOH, %	16.0	16.0	-	-	13.0
2nd stage: Na_2S, %	2.5	2.5	-	-	-
2nd stage: S, %	-	-	-	-	-
2nd stage: MnO_2 oxidation, cycle no.	-	-	-	-	-
Liquor to chip ratio (ml/g, ovendry basis): 1st stage	3:1	3:1	5:1	3:1	3:1
Liquor to chip ratio (ml/g, ovendry basis): 2nd stage	4:1	4:1	-	-	4:1
Impregnation temperature, °C	120	120	120	120	110
Time to/at impregn. temp., min	30/90	30/90	25/60	30/45	30/60
Washing after impregnation	-	-	-	-	-
Max. cooking temperature, °C	170	170	170	170	170
Time to/at max. cooking temp., min	30/90	30/90	30/120	30/120	30/90
Cooking yield, % on ovendry chips	50.7	50.7	49.0	48.1	52.7
Permanganate number	21.9	21.9	22.05	19.05	22.4
Bleaching sequence	C/E/D	DC/E/D	C/E/D	DC/EH/D	DC/E/D
Total equivalent chlorine applied, %	6.0	8.0	7.0	8.0	8.0
Chlorination stage (DC)(3% pulp consist., 30°C, ½ h): ClO_2, %	-	1.12	-	0.38	0.75
Chlorination stage (DC)(3% pulp consist., 30°C, ½ h): Cl_2, %	4.0	3.0	5.0	4.0	4.0
Alkaline extraction stage(E) (10% pulp consist., 70°C, ½ h): NaOH, %	1.5	2.0	1.5	2.0	2.0
ClO_2 bleaching stage(D)(10% pulp consist., 40°C, 3-4 h): ClO_2, %	0.75	0.75	0.75	0.75	0.75
Hypochlorite blchg.stg.(H) (10% pulp consist., 40°C, 3 h): Available Cl_2, %	-	-	-	1.0[4]	-
Bleaching yield: % on ovendry unbl. pulp	88.5	80.3	92.8	86.0	82.7
Bleaching yield: % on ovendry chips	44.7	41.0	45.5	41.2	43.6
Paper number	200	242	230	223	231
Physical properties of handsheets[2] (23°C, 50% r.h., TAPPI standard):					
Initial freeness, S-R, ml	730	620	700	815	700
Final freeness, S-R, ml	460	415	500	415	500
Time of beating, min	3	3	2	6.0	2.5
Basis weight, g/m²	77.9	78.4	75.7	75.9	79.7
Bulk, ml/g	1.17	1.17	1.09	1.26	1.3
Burst factor	72.4	74.9	77.4	65.1	73.1
Tear factor	142.0	142.0	131.8	130	142.5
Breaking length, m	9842	9976	10615	8534	8763
Folding endurance	1442	978	566	451	633
Brightness, %	77.2	82.5	85.0	81.0	80.9

1/ TK=Thai kenaf; CK=Cuban kenaf; A=air-dry; F=fresh; Kr=kraft; Ps=polysulphide.
2/ Sizing of sheets: 0.3% Whiten(optical bleach), 1.5% rosin size, 2% TKP, 3% alum.
3/ Local. 4/ Combined in alkaline extraction stage.

TABLE 1 - continued

Cook no./Raw material[1]		444/ATK	444/ATK	446/ATK	448/FCK	449/FCK
Process[1]		1-stg Ps	1-stg Ps	2-stg Ps	2-stg Ps	Kraft
Cooking liquor composition:						
1st stage	Na_2S, %	10.0	10.0	12.0	8.4	2.4
	S, %	1.0	1.0	1.0	0.9	-
	NaOH, %	15.0	15.0	-	-	21.5
	MnO_2 oxidation, cycle no.	4	4	5	1	-
2nd stage	NaOH, %	-	-	14.0	11.3	-
	Na_2S, %	-	-	-	-	-
	S, %	-	-	-	-	-
	MnO_2 oxidation, cycle no.	-	-	-	-	-
Liquor to chip ratio (ml/g, ovendry basis)	1st stage	3:1	3:1	3:1	5:1	6:1
	2nd stage	-	-	4:1	-	-
Impregnation temperature, °C		110	110	120	110	-
Time to/at impregn. temp., min		30/45	30/45	30/60	25/60	-
Washing after impregnation		-	-	-	-	-
Max. cooking temperature, °C		170	170	170	170	170
Time to/at max. cooking temp., min		30/90	30/90	30/90	30/90	90/120
Cooking yield, % on ovendry chips		51.2	51.2	51.3	53.7	45.6
Permanganate number		20.20	20.20	19.90	23.50	18.50
Bleaching sequence		C/E/H	DC/EH/D	DC/EH/D	DC/E_1/D_1/E_2/D_2	DC/E/D
Total equivalent chlorine applied, %		8.0	7.0	9.0	10.0	8.0
Chlorination stage (DC)(3% pulp consist., 30°C, ½ h)	ClO_2, %	-	0.38	0.75	0.75	0.75
	Cl_2, %	6.0	3.0	4.0	4.0	4.0
Alkaline extraction stage(E) (10% pulp consist., 70°C, ½ h)	NaOH, %	1.5	2.5	2.0	E_1 1.5 E_2 1.0	1.5
ClO_2 bleaching stage(D)(10% pulp consist., 40°C, 3-4 h)	ClO_2, %	-	0.75	0.75	D_1 0.75 D_2 0.75	0.75
Hypochlorite blchg.stg.(H) (10% pulp consist., 40°C, 3 h)	Available Cl_2, %	2.0	1.0[3]	1.0[3]	-	-
Bleaching yield	% on ovendry unbl. pulp	80.2	92.0	76.0	87.3	88.3
	% ovendry chips	41.0	47.0	39.0	47.0	40.2
Paper number		243	212	199	225	220
Physical properties of handsheets[2] (23°C, 50% r.h., TAPPI standard):						
Initial freeness, S-R, ml		720	600	740	690	728
Final freeness, S-R, ml		400	520	540	380	500
Time of beating, min		5	1	5	2	5
Basis weight, g/m²		77.2	75.1	77.2	77.5	77.8
Bulk, ml/g		1.2	1.3	1.27	1.09	1.25
Burst factor		57.0	62.4	61.0	75.0	64.8
Tear factor		112.5	118.0	142	96.6	122
Breaking length, m		8256	8555	8858	9830	8822
Folding endurance		353	909	815	754	701
Brightness, %		82.9	76	76	79	75

1/ TK=Thai kenaf; CK=Cuban kenaf; A=air-dry; F=fresh; Kr=kraft; Ps=polysulphide.
2/ Sizing of sheets: 0.3% Whiten (optical bleach), 1.5% rosin size, 2% TKP, 3% alum.
3/ Combined in alkaline extraction stage.

TABLE 1 - continued

Cook no./Raw material[1]	456/ACK	457/ACK	463/ACK	471/ACK	488/ACK
Process[1]	Kraft[3]	1-stg Ps[3]	1-stg Ps	1-stg Ps[3]	2-stg Kr
Cooking liquor composition:					
1st stage: Na_2S, %	2.0[4]	2.0[4]	9.0[5]	2.0[4]	4.0
1st stage: S, %	-	-	-	-	4.0
1st stage: NaOH, %	-	-	15.0	-	-
1st stage: MnO_2 oxidation, cycle no.	-	-	12	-	-
2nd stage: NaOH, %	15.0	15.0	-	15.7	15.0
2nd stage: Na_2S, %	2.0	10.0	-	7.5	1.5
2nd stage: S, %	-	-	-	-	-
2nd stage: MnO_2 oxidation, cycle no.	-	8	-	15	-
Liquor to chip ratio (ml/g, ovendry basis): 1st stage	3:1	3:1	3:1	3:1	3:1
Liquor to chip ratio (ml/g, ovendry basis): 2nd stage	4:1	4:1	-	4:1	4:1
Impregnation temperature, °C	110[4]	110[4]	120	120[4]	130
Time to/at impregn. temp., min	30/45[4]	25/45[4]	30/45	30/45[4]	30/60
Washing after impregnation	W,press	W,press	-	Wash	Wash
Max. cooking temperature, °C	170	170	170	170	170
Time to/at max. cooking temp., min	30/90	30/60	30/90	30/60	30/90
Cooking yield, % on ovendry chips	45.2	50.9	50.3	51.2	45.5
Permanganate number	19.95	20.90	22.70	21.40	20.40
Bleaching sequence	DC/E/D	DC/E/D	DC/E/D	DC/E/D	DC/E/DH
Total equivalent chlorine applied, %	8.0	9.0	9.0	8.0	9.0
Chlorination stage (DC)(3% pulp consist., 30°C, ½ h): ClO_2, %	0.75	-	1.12	0.75	1.12
Chlorination stage (DC)(3% pulp consist., 30°C, ½ h): Cl_2, %	4.0	5.0	4.0	4.0	3.0
Alkaline extraction stage(E) (10% pulp consist.,70°C,½ h): NaOH, %	1.5	1.5	1.5	1.5	2.0
ClO_2 bleaching stage(D)(10% pulp consist.,40°C, 3-4 h): ClO_2, %	0.75	-	0.75	0.75	0.75
Hypochlorite blchg.stg.(H) (10% pulp consist.,40°C,3 h): Available Cl_2, %	-	2.0	-	-	1.0
Bleaching yield: % on ovendry unbl. pulp	90.2	81.0	81.8	83.0	87.7
Bleaching yield: % on ovendry chips	40.8	41.2	41.0	42.7	39.8
Paper number	221	233	229	228	222
Physical properties of handsheets[2] (23°C, 50% r.h., TAPPI standard):					
Initial freeness, S-R, ml	695	630	670	715	810
Final freeness, S-R, ml	405	480	350	500	440
Time of beating, min	3	2	3	3.5	5
Basis weight, g/m^2	74.9	85.4	71	72.7	76.2
Bulk, ml/g	1.11	1.26	1.04	1.25	1.22
Burst factor	75.8	75.6	65.1	78.0	62.7
Tear factor	110	148	103	141.2	106
Breaking length, m	11090	9398	10345	9290	8932
Folding endurance	868	949	810	1058	483
Brightness, %	74	87	80	87	80

1/ TK=Thai kenaf; CK=Cuban kenaf; A=air-dry; F=fresh; Kr=kraft; Ps=polysulphide.
2/ Sizing of sheets: 0.3% Whiten (optical bleach), 1.5% rosin size, 2% TKP, 3% alum.
3/ With pretreatment. 4/ Pretreatment stage; Waste Na_2S liquor used.
5/ Waste Na_2S liquor used.

TABLE 1 - continued

Cook no./Raw material[1]		490/ACK	494/ACK	500/ATK[5]	501/ACK	502/ACK
Process[1]		2-stg Kr	Kraft	1-stg Ps	2-stg Ps	2-stg Kr
Cooking liquor composition:						
1st stage	Na_2S, %	3.0[3]	2.27	6.0	3.7	2.0[7]
	S, %	-	-	1.5	4.5	-
	NaOH, %	-	21.0	18.0	4[6]	-
	MnO_2 oxidation, cycle no.	-	-	12	-	-
2nd stage	NaOH, %	18.0	-	-	18.0	18.0
	Na_2S, %	-	-	-	-	-
	S, %	-	-	-	-	-
	MnO_2 oxidation, cycle no.	-	-	-	-	-
Liquor to chip ratio (ml/g, ovendry basis)	1st stage	3:1	3:1	3:1	3:1	3:1
	2nd stage	4:1[4]	-	-	4:1[4]	4:1[4]
Impregnation temperature, °C		100	120	120	120	130
Time to/at impregn. temp., min		30/60	60/30	30/30	30/30	30/30
Washing after impregnation		Wash	-	-	-	Wash
Max. cooking temperature, °C		170	170	170	170	170
Time to/at max. cooking temp., min		30/90	30/120	30/90	30/90	30/120
Cooking yield, % on ovendry chips		49.8	43.2	48.9	46.6	47.5
Permanganate number		19.05	17.35	19.65	13.30	16.20
Bleaching sequence		DC/E/D	DC/E/DH	DC/E/DH	DC/E/DH	DC/E/D
Total equivalent chlorine applied, %		8.0	9.0	9.0	9.0	8.0
Chlorination stage (DC)(3% pulp cosist., 30°C, ½ h)	ClO_2, %	1.12	1.12	1.12	1.12	1.12
	Cl_2, %	3.0	3.0	3.0	3.0	3.0
Alkaline extraction stage(E) (10% pulp consist.,70°C,½ h)	NaOH, %	2.0	2.0	2.0	2.0	2.0
ClO_2 bleaching stage(D)(10% pulp consist., 40°C, 3-4 h)	ClO_2, %	0.75	0.75	0.75	0.75	0.75
Hypochlorite blchg.stg.(H) (10% pulp consist.,40°C,3 h)	Available Cl_2, %	-	1.0	1.0	1.0	-
Bleaching yield	% on ovendry unbl. pulp	83.0	81.0	84.4	85.5	90.6
	% on ovendry chips	41.5	35.0	41.3	40.0	43.0
Paper number		218	235	236	237	238
Physical properties of handsheets[2] (23°C, 50% r.h., TAPPI standard):						
Initial freeness, S-R, ml		670	730	790	740	680
Final freeness, S-R, ml		400	480	500	440	500
Time of beating, min		4	6	3	4.5	4.5
Basis weight, g/m^2		86.1	77.46	76.0	75.0	76.7
Bulk, ml/g		1.08	1.32	1.26	1.27	1.26
Burst factor		69.0	52.5	54.0	51.8	53.0
Tear factor		104	114.5	127.2	111.0	113.4
Breaking length, m		10028	7488	8426	7784	8398
Folding endurance		1119	240	669	318	340
Brightness, %		80	87.3	84.6	84.5	85.9

1/ TK=Thai kenaf; CK=Cuban kenaf; A=air-dry; F=fresh; Kr=kraft; Ps=polysulphide.
2/ Sizing of sheets: 0.3% Whiten (optical bleach), 1.5% rosin size, 2% TKP, 3% alum.
3/ Waste Na_2S liquor used. 4/ Estimated. 5/ Small stems. 6/ Na_2CO_3, %. 7/ Na_2S flakes.

TABLE 1 - continued

Cook no./Raw material[1]	503/ACK	504/ACK	507/ATK[4]	510/ACK[4]	513/ACK
Process[1]	1-stg Ps	1-stg Ps[3]	1-stg Ps	2-stg Ps	1-stg Ps[3]
Cooking liquor composition:					
1st stage: Na_2S, %	6.0	2.0	10.0	8.0	2
1st stage: S, %	1.5	-	1.5	1.5[5]	-
1st stage: NaOH, %	18.0	-	15.0	3.0[5]	-
1st stage: MnO_2 oxidation, cycle no.	-	-	16	19	-
2nd stage: NaOH, %	-	16.8	-	15.0	15.0
2nd stage: Na_2S, %	-	8.0	-	-	7.0
2nd stage: S, %	-	-	-	-	1.5
2nd stage: MnO_2 oxidation, cycle no.	-	13	-	-	22
Liquor to chip ratio (ml/g, ovendry basis): 1st stage	3:1	3:1	3:1	3:1	3:1
Liquor to chip ratio (ml/g, ovendry basis): 2nd stage	-	4:1	-	4:1	4:1
Impregnation temperature, °C	120	110	110	110	120
Time to/at impregn. temp., min	30/30	30/10	31/30	25/45	30/20
Washing after impregnation	-	W,press	-	-	W,press
Max. cooking temperature, °C	170	170	175	170	175
Time to/at max. cooking temp., min	30/90	30/60	32/60	35/90	30/30
Cooking yield, % on ovendry chips	53.1	48.0	45.6	46.5	44.4
Permanganate number	16.85	15.40	17.20	15.85	17.10
Bleaching sequence	DC/E/DH	DC/E/D	DC/E/DH	DC/E/D	DC/E/DH
Total equivalent chlorine applied, %	9.0	8.0	9.0	8.0	9.0
Chlorination stage (DC)(3% pulp consist., 30°C, ½ h): ClO_2, %	1.12	1.12	1.12	1.12	1.12
Chlorination stage (DC)(3% pulp consist., 30°C, ½ h): Cl_2, %	3.0	3.0	3.0	3.0	3.0
Alkaline extraction stage(E) (10% pulp consist.,70°C,½ h): NaOH, %	2.0	2.0	2.0	2.0	2.0
ClO_2 bleaching stage(D)(10% pulp consist., 40°C, 3-4 h): ClO_2, %	0.75	0.75	0.75	0.75	0.75
Hypochlorite blchg.stg.(H) (10% pulp consist.,40°C,3 h): Available Cl_2, %	1.0	-	1.0	-	1.0
Bleaching yield: % on ovendry unbl. pulp	87.6	91.4	86.5	85.0	83.2
Bleaching yield: % on ovendry chips	46.5	43.8	40.4	39.5	37
Paper number	239	240	246	241	244
Physical properties of handsheets[2] (23°C, 50% r.h., TAPPI standard):					
Initial freeness, S-R, ml	760	765	905	710	680
Final freeness, S-R, ml	480	490	425	440	465
Time of beating, min	3.5	5	6	5	4
Basis weight, g/m²	75.7	79.8	77.5	76.3	81.5
Bulk, ml/g	1.16	1.22	1.28	1.21	1.24
Burst factor	61.8	59.9	48.2	66.5	61.4
Tear factor	99.2	128.4	106.8	122	126
Breaking length, m	9530	8454	7706	8840	9092
Folding endurance	369	990	130	855	381
Brightness, %	87.1	80.9	80.5	82.5	86.1

1/ TK=Thai kenaf; CK=Cuban kenaf; A=air-dry; F=fresh; Kr=kraft; Ps=polysulphide.
2/ Sizing of sheets: 0.3% Whiten (optical bleach), 1.5% rosin size, 2% TKP, 3% alum.
3/ With pretreatment. 4/ Small stems. 5/ Na_2CO_3, %.

TABLE 1 - continued

Cook no./Raw material[1]	514/ACK	515/ACK	516/ACK	517/ACK	528/ATK[4]
Process[1]	1-stg Ps	1-stg Ps[3]	1-stg Ps[3]	1-stg Ps	1-stg Ps[3]
Cooking liquor composition:					
1st stage: Na_2S, %	8.0	2.0	2.0	8.0	-
1st stage: S, %	1.5	-	-	1.5	-
1st stage: NaOH, %	16.0	-	-	16.0	1.5
1st stage: MnO_2 oxidation, cycle no.	23	-	-	26	-
2nd stage: NaOH, %	-	16.0	15.0	-	15.0
2nd stage: Na_2S, %	-	6.0	7.0	-	8.0
2nd stage: S, %	-	1.5	1.5	-	1.5
2nd stage: MnO_2 oxidation, cycle no.	-	24	25	-	33
Liquor to chip ratio (ml/g, ovendry basis): 1st stage	3:1	3:1	3:1	3:1	3:1
Liquor to chip ratio (ml/g, ovendry basis): 2nd stage	-	4:1	4:1	-	4:1
Impregnation temperature, °C	120	120	110	130	120
Time to/at impregn. temp., min	30/30	30/30	30/45	36/30	25/45
Washing after impregnation	-	Wash	Wash	-	Wash
Max. cooking temperature, °C	170	175	175	175	175
Time to/at max. cooking temp., min	30/90	33/25	33/30	33/30	25/30
Cooking yield, % on ovendry chips	48.5	46.5	48.6	46.0	48.4
Permanganate number	16.80	18.60	17.00	16.85	19.45
Bleaching sequence	DC/E/DH	DC/E/DH	DC/E/DH	DC/E/DH	DC/E/DH
Total equivalent chlorine applied, %	9.0	9.0	9.0	9.0	9.0
Chlorination stage (DC)(3% pulp consist., 30°C, ½ h): ClO_2, %	1.12	1.12	1.12	1.12	1.12
Chlorination stage (DC)(3% pulp consist., 30°C, ½ h): Cl_2, %	3.0	3.0	3.0	3.0	3.0
Alkaline extraction stage(E) (10% pulp consist., 70°C, ½ h): NaOH, %	2.0	2.0	2.0	2.0	2.0
ClO_2 bleaching stage(D)(10% pulp consist., 40°C, 3-4 h): ClO_2, %	0.75	0.75	0.75	0.75	0.75
Hypochlorite blchg.stg.(H) (10% pulp consist., 40°C, 3 h): Available Cl_2, %	1.0	1.0	1.0	1.0	1.0
Bleaching yield, % on ovendry unbl. pulp	89.5	88.5	83.5	86.6	85.2
Bleaching yield, % on ovendry chips	48.5	41.0	40.5	40.0	41.2
Paper number	245	247	254	255	301
Physical properties of handsheets[2] (23°C, 50% r.h., TAPPI standard):					
Initial freeness, S-R, ml	720	670	690	640	750
Final freeness, S-R, ml	390	500	310	465	385
Time of beating, min	5	3	5	4	4.1
Basis weight, g/m^2	77.0	78.9	75.84	77.68	74.1
Bulk, ml/g	1.05	1.11	1.08	1.21	1.2
Burst factor	63.3	63.3	68.4	58.6	47.9
Tear factor	98.3	94.5	101.4	107	131
Breaking length, m	9472	10278	9794	8748	7518
Folding endurance	625	620	510	308	473.2
Brightness, %	82.5	86.7	80.52	84.8	86.1

1/ TK=Thai kenaf; CK=Cuban kenaf; A=air-dry; F=fresh; Kr=kraft; Ps=polysulphide.
2/ Sizing of sheets: 0.3% Whiten (optical bleach), 1.5% rosin size, 2% TKP, 3% alum.
3/ With pretreatment. 4/ Small stems.

TABLE 1 - continued

Cook no./Raw material[1]	532/ATK[3]	534/ATK[3]	536/ATK[3]	552/ATK[3]	553/ATK[3]
Process[1]	2-stg Ps	1-stg Ps	1-stg Ps	Kraft	1-stg Ps
Cooking liquor composition:					
1st stage: Na_2S, %	8.0	10.0	10.0	6.0	6.0
1st stage: S, %	1.5	1.5	1.5	-	1.5
1st stage: NaOH, %	3.0[4]	15.5	15.5	18.0	18.0
1st stage: MnO_2 oxidation, cycle no.	37	1	39	-	17
2nd stage: NaOH, %	15.0	-	-	-	-
2nd stage: Na_2S, %	-	-	-	-	-
2nd stage: S, %	-	-	-	-	-
2nd stage: MnO_2 oxidation, cycle no.	-	-	-	-	-
Liquor to chip ratio (ml/g, ovendry basis): 1st stage	3:1	3:1	3:1	3:1	3:1
Liquor to chip ratio (ml/g, ovendry basis): 2nd stage	4:1	-	-	-	-
Impregnation temperature, °C	120	110	110	120	120
Time to/at impregn. temp., min	25/30	25/45	30/45	25/30	25/30
Washing after impregnation	-	-	-	-	-
Max. cooking temperature, °C	175	175	175	175	175
Time to/at max. cooking temp., min	25/30	25/30	25/30	30/25	30/25
Cooking yield, % on ovendry chips	51.4	45	42.5	47.7	48.9
Permanganate number	21.90	17.30	16.55	16.10	16.15
Bleaching sequence	DC/E/DH	DC/E/DH	DC/E/DH	DC/E/DH	DC/E/DH
Total equivalent chlorine applied, %	10.0	9.0	11.2	9.0	9.0
Chlorination stage (DC)(3% pulp consist., 30°C, ½ h): ClO_2, %	1.12	1.12	1.38	1.12	1.12
Chlorination stage (DC)(3% pulp consist., 30°C, ½ h): Cl_2, %	3.0	3.0	3.75	3.0	3.0
Alkaline extraction stage(E) (10% pulp consist., 70°C, ½ h): NaOH, %	2.0	2.0	2.5	2.0	2.0
ClO_2 bleaching stage(D)(10% pulp consist., 40°C, 3-4 h): ClO_2, %	0.75	0.75	0.94	0.75	0.75
Hypochlorite blchg.stg.(H) (10% pulp consist., 40°C, 3 h): Available Cl_2, %	2.0	1.0	1.25	1.0	1.0
Bleaching yield: % on ovendry unbl. pulp	90.6	79.5	87.8	90.0	86
Bleaching yield: % on ovendry chips	46.5	35.8	37.4	47	42
Paper number	302	271	303	287	288
Physical properties of handsheets[2] (23°C, 50% r.h., TAPPI standard):					
Initial freeness, S-R, ml	800	860	790	770	795
Final freeness, S-R, ml	350	440	455	460	460
Time of beating, min	5.1	5	5	5	4
Basis weight, g/m^2	75.18	75.60	74.2	75.92	75.66
Bulk, ml/g	1.17	1.43	1.33	1.24	1.33
Burst factor	47.5	43.5	39.1	48	41.9
Tear factor	120	102	141	129	117.5
Breaking length, m	8568	6180	7024	7748	7188
Folding endurance	4786	73	181	524	264
Brightness, %	80.0	86.0	89.1	81.0	83.0

1/ TK-Thai kenaf; CK=Cuban kenaf; A=air-dry; F=fresh; Kr=kraft; Ps=polysulphide.
2/ Sizing of sheets: 0.3% Whiten (optical bleach), 1.5% rosin size, 2% TKP, 3% alum.
3/ Small stems. 4/ Na_2CO_3, %.

TABLE 1 - continued

Cook no./Raw material[1]		554/ATK[3]	555/ATK[3]
Process[1]		Kraft	1-stg Ps
Cooking liquor composition:			
1st stage	Na_2S, %	6.0	6.0
	S, %	-	-
	NaOH, %	18.0	18.0
	MnO_2 oxidation, cycle no.	-	1
2nd stage	NaOH, %	-	-
	Na_2S, %	-	-
	S, %	-	--
	MnO_2 oxidation, cycle no.	-	-
Liquor to chip ratio (ml/g, ovendry basis)	1st stage	3:1	3:1
	2nd stage	-	-
Impregnation temperature, °C		110	110
Time to/at impregn. temp., min		25/45	25/45
Washing after impregnation		-	-
Max. cooking temperature, °C		170	170
Time to/at max. cooking temp., min		30/90	30/90
Cooking yield, % on ovendry chips		48.2	47.5
Permanganate number		18.00	20.25
Bleaching sequence		DC/E/DH	DC/E/DH
Total equivalent chlorine applied, %		9.0	9.0
Chlorination stage (DC)(3% pulp consist., 30°C, ½ h)	ClO_2, %	1.12	1.12
	Cl_2, %	3.0	3.0
Alkaline extraction stage(E) (10% pulp consist.,70°C,½ h)	NaOH, %	2.0	2.0
ClO_2 bleaching stage(D)(10% pulp consist., 40°C, 3-4 h)	ClO_2, %	0.75	0.75
Hypochlorite blchg.stg.(H) (10% pulp consist.,40°C,3 h)	Available Cl_2, %	1.0	1.0
Bleaching yield	% on ovendry unbl. pulp	89.5	89.6
	% on ovendry chips	43.2	42.5
Paper number		289	290
Physical properties of handsheets[2] (23°C, 50% r.h., TAPPI standard):			
Initial freeness, S-R, ml		750	730
Final freeness, S-R, ml		475	440
Time of beating, min		4	4
Basis weight, g/m^2		75.7	77.3
Bulk, ml/g		1.35	1.28
Burst factor		42.3	41.8
Tear factor		100.0	128
Breaking length, m		6955	6838
Folding endurance		270	343
Brightness, %		85.0	84.0

1/ TK=Thai kenaf; CK=Cuban kenaf; A=air-dry; F=fresh; Kr=kraft; Ps=polysulphide.
2/ Sizing of sheets: 0.3% Whiten (optical bleach), 1.5% rosin size, 2% TKP, 3% alum.
3/ Small stems.

RESULTS AND DISCUSSION

Table 1 shows data of all experimental results of pulping, bleaching, and physical tests. Tables 2 and 3 compare the various pulps made by several processes and raw materials. From Table 2, it appears that the polysulphide process gave the best yield and strength. From Table 3, kenaf polysulphide pulp compares favourably in pulp strength with most other pulps, except for tearing strength of Pinus merkusii pulp and Casuarina equisetifolia pulp.

The kraft pulp from kenaf by the conventional process had good strength but rather low yield as indicated in cook no. 494. The yield was improved by the two-stage kraft process as indicated in cooks nos. 502, 490, 488, and 329.

The polysulphide process appears effective for higher yield when compared with that by conventional kraft process. Chemical application was slightly higher due to the additional sulphur needed for the formation of polysulphides; otherwise it requires a high sulphidity above 25% for manganese dioxide oxidation of the sulphide into polysulphides. The amount of polysulphide sulphur needed for the high yield of pulp was about 4-6% on chips. This was compensated by the higher pulp yield, about 6-8% on chips above the yield by conventional kraft process.

Chemical recovery system for the polysulphide process is essentially the same as that for conventional kraft process, except for additional treatment of the green liquor or white liquor to convert the sodium sulphide in the liquor into polysulphides. This can be done either by adding sulphur to the green liquor or by manganese dioxide oxidation of the green liquor. A combination of manganese dioxide oxidation and sulphur addition is also applicable. This combination can reduce the amount of sulphur in the polysulphide conversion to the level of about 1-2% which is usually used as make-up in conventional kraft recovery system.

Several experiments in polysulphide pulping applied about 4-5% sulphur for reacting with sodium sulphide to make polysulphides. In the chemical recovery system with the polysulphide process, the sulphur loss as SO_2 in the flue gas of the recovery boiler will be higher than

TABLE 2. PHYSICAL PROPERTIES OF HANDSHEETS PREPARED FROM KENAF PULPS BY VARIOUS PROCESSES

Cuban kenaf (Hibiscus cannabinus)

Process	Freeness, S-R, (ml)		Breaking length (m)	Tear factor	Burst factor	Folding endurance	Cooking yield (% on chips)	Bleach applied (% equivalent Cl_2)	Bleach sequence	Brightness (%)	Remarks
	Initial	Final									
Polysulfide with pretreatment	715	500	9,290	141	78	1,058	51	8	DC/E/D	87	
Polysulfide with pretreatment	630	480	9,398	148	76	949	51	9	DC/E/D	87	
Two-stage polysulphide	730	460	9,842	142	72	1,442	51	6	C/E/D	77	No wash between stages
Two-stage kraft	670	400	10,028	104	69	1,119	50	8	DC/E/D	80	1st stage Na_2S, 2nd stage NaOH cooking
One-stage polysulphide	670	350	10,345	103	65	810	50	9	DC/E/D	80	
Kraft with pretreatment	695	405	11,090	110	76	868	45	8	DC/E/D	74	
Kraft	730	480	7,488	115	53	240	43	9	DC/E/DH	87	
One-stage polysulphide	700	500	10,615	132	77	566	49	7	C/E/D	85	Fresh Cuban kenaf, cook at 170°C, 2 hr
Kraft	728	500	8,822	122	65	701	46	8	DC/E/D	75	Fresh Cuban kenaf
Soda	750	455	9,125	122	62	579	48	8	C/E/H	70	Fresh Cuban kenaf
Two-stage soda	865	490	8,496	105	55	547	52	9	DC/E/DH	78	Airdry Cuban kenaf
Soda with pretreatment	680	500	8,398	113	53	340	48	8	DC/E/D	86	
Neutral sulphite	510	425	8,915	142	89	357	55	11	DC/E/DH	84	
Sodium bisulphite	660	400	9,284	68	53	274	55	12	DC/E/DH	77	

TABLE 2 - continued

Cuban kenaf (Hibiscus cannabinus)

Process	Freeness, S-R, (ml) Initial	Final	Breaking length (m)	Tear factor	Burst factor	Folding endurance	Cooking yield (% on chips)	Bleach applied (% equivalent Cl_2)	Bleach sequence	Brightness (%)	Remarks
Sodium bisulphite	675	490	9,522	93	50	520	62	10	C/E/HD	75	Fresh Cuban kenaf
Magnesium bisulphite	740	465	6,830	61	33	20	53	8	C/E/D	73	Airdry Cuban kenaf
Ammonium bisulphite	720	500	6,672	91	35	172	52	8	C/E/HD	83	
Ammonium bisulphite	710	407	7,924	97	55	460	56	10	DC/E/D	76	Fresh Cuban kenaf
One-stage polysulphide	600	520	8,555	118	62	909	51	7	DC/E/D	75	MnO_2 + S for polysulphide
One-stage polysulphide	720	400	8,256	113	57	353	51	8	C/E/H	83	
One-stage polysulphide	815	415	8,534	130	65	451	48	8	DC/EH/D	81	MnO_2 only for oxidation
One-stage polysulphide	700	250	8,894	81	44	733	52	10	DC/E/D	80	
Two-stage polysulphide	760	520	9,908	177	73	1,087	52	8	DC/E/D	78	Wash between stages
Two-stage polysulphide	740	540	8,858	142	61	815	51	9	DC/EH/D	76	No wash between stages
Two-stage kraft	830	575	7,518	113	48	301	46	7	CEH	75	
Soda with pretreatment	900	490	6,572	96	35	14	46	6	CEH	73	
Soda	850	480	9,128	145	67	571	52	10	DC/E/DH	81	
Soda	790	610	7,380	174	52	434	48	10	CD/EH/D	71	
Neutral sulphite	840	200	8,022	59	53	260	62	13.5	CEHD	77	
Sodium bisulphite	700	395	6,266	65	32	17	47	10	DC/E/DH	70	
Kraft	750	475	6,955	100	42	270	48	9	DC/E/DH	85	

TABLE 3. PHYSICAL AND STRENGTH CHARACTERISTICS OF PULPS

Fibrous material	Pulping process	Freeness, S-R, (ml)		Breaking length (m)	Burst factor	Tear factor	Folding endurance	Brightness (%)	Pulp yield, unbleached (%)	Bleach applied (% eqiv. Cl_2)	Bleach sequence	Reference
		Initial	Final									
Cuban kenaf	Two stage polysulphide	730	460	9,842	72	142	1,442	77	51	6	CED	Cook no. 428
Cuban kenaf	Polysulphide with pretreatment	715	500	9,290	78	141	1,058	87	51	8	DC/E/D	Cook no. 471
Cuban kenaf	Kraft with pretreatment	695	405	11,090	76	110	810	80	50	9	DC/E/D	Cook no. 456
Thai kenaf	One stage polysulphide	720	400	8,256	57	113	353	83	51	8	C/E/H	Cook no. 444
Casuarina equisetifolia (Broad leaved species)	One stage polysulphide	900	490	7,282	58	151	384	88	46	9	DC/E/DH	Cook no. 540
Casuarina equisetifolia	Kraft	880	435	5,520	32	111	131	85	47	8	DC/E/D	Cook no. 561
Pinus merkusii (pine)	Kraft	875	250	6,756	46	177	958	79	44	9	DC/E/DH	Cook no. 576
Benquet pine	Kraft	-	356	9,812	71	114	729	75	-	-	-	FPRI, Philippines
Thyrostachys siamensis (bamboo)	Polysulphide	905	360	7,890	49	98	179	74	52	10	C/E/H	Cook no. 387
Eucalyptus	Kraft	-	300	8,000	52	95	160	Bleached	-	-	-	Paper Trade J. 30 Aug. 1971, p. 30
North-east softwood	Kraft	-	300	11,100-12,600	83-94	84-94	-	Bleached	-	-	-	

TABLE 3 - continued

Fibrous material	Pulping process	Freeness, S-R, (ml) Initial	Final	Breaking length (m)	Burst factor	Tear factor	Folding endurance	Brightness (%)	Pulp yield, unbleached (%)	Bleach applied (% eqiv. Cl_2)	Bleach sequence	Reference
Bagasse	Kraft	-	250	5,081	35	44	-	88	-	-	-	TPPC ABX grade market pulp
Rice straw	Kraft	770	465	3,840	18	61	1	87	45	6	C/E/H	Cook no. 542
Softwood	Kraft	-	550	10,000	76	109	1,140	85-90	-	-	-	market pulp
Softwood	Sulphite	695	550	5,800	43	97	210	91	-	-	-	market pulp (Weyerhaeuser)
Hardwood	Kraft	-	450	6,200	35	72	41	88	-	-	-	market pulp, (U.S.A.)

that in the conventional kraft process. Recovery of this SO_2 in flue gas with soda ash solution to make neutral sulphite solution or bisulphite solution may be applicable if the kraft mill has also neutral sulphite (NSSC) pulp or bisulphite pulp production.

The recovery of chemicals from two-stage kraft and two-stage polysulphide processes calls for separation of sodium sulphide from soda in the green liquor of kraft recovery system by fractional crystallization of soda as monohydrate from clarified green liquor. Although this is a little more complicated, it may have some advantages, especially if the kraft mill has also NSSC pulp or bisulphite pulp production.

If waste sodium sulphide effluent from petroleum refinery is available to the pulp industry at low cost, the kraft pulp mill may use this waste effluent for pretreatment at 100-120°C for 45-60 minutes. The waste liquor may be discarded, and the treated chips are washed and pressed for subsequent cooking with caustic soda with or without additional sodium sulphide. The black liquor from cooking can be recovered in the normal way used in conventional kraft process. As indicated in cooks nos. 456 and 457, the pulps have high bleached yield and good bleachability. As indicated in cooks nos. 456, 490, and 502, two-stage kraft pulping gave improved bleachability and better strength. This was also true with one-stage polysulphide pulping following alkaline pretreatment. Cooks nos. 455 and 457 compared the results of pretreatment for the two processes. Yield and strength were significantly better for the polysulphide pulping with alkaline pretreatment.

As indicated in cook no. 471, polysulphide pulping with pretreatment resulted in high yield and good bleachability. However, the disposal of waste effluent from the pretreatment stage must be properly made to avoid pollution.

Cooks nos. 536, 553, 513, 515, 516, and 517 were high-temperature short-time polysulphide pulping at 175° for 25-30 minutes. They showed little advantage on pulp yield when compared with cook no. 552 for conventional kraft pulping at high temperature of 175°C for 25 minutes; but pulp strength appeared better with the polysulphide process as indicated in cook no. 515 for Cuban kenaf.

CONCLUSIONS

1. Pulping Cuban kenaf and Thai kenaf by standard kraft process with 15-18% Na_2O and sulphidity 10-15% gets cooking yield 42-43% for airdry kenaf and 45-46% for fresh Cuban kenaf. The cooking conditions applied are heating to a maximum temperature of 170°C in $1\frac{1}{2}$ hours and cooking at the maximum temperature (170°C) for $1\frac{1}{2}$-2 hours.

The pulp from fresh kenaf has better bleachability requiring 8% chlorine for 80% brightness, whereas pulp from dry kenaf needs about 9% chlorine in DC/E/D bleaching sequence for brightness above 80%.

2. Polysulphide process can be applied for pulping kenaf at about 170°C for higher yield of pulp with better strength. The cooking liquor can be prepared by adding sulphur to the standard kraft liquor to form polysulphides or by oxidation of standard kraft liquor of high sulphidity at 25-50% with about 12% manganese dioxide on chips. The spent manganese dioxide can be regenerated by air oxidation when dried. A combination of MnO_2 oxidation and sulphur addition for preparation of polysulphide from kraft liquor is also applicable for higher polysulphides content.

3. At higher temperature of 175°C and short time cooking for 25-30 minutes, the advantages of polysulphide over kraft process are not significant in respect to pulp yield.

4. Alkaline pretreatment with dilute sodium sulphide (about 2-3% on pulp weight) before kraft or polysulphide pulping improves bleachability and pulp strength. This applies also to two-stage kraft pulping with advantages of both higher yield and better bleachability.

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