

## Biokraft Pulping of Kenaf and its Bleachability

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### Abstract

Kenaf is an alternative non-wood source of fiber for various grades of paper. We found kraft pulps of whole kenaf and bast kenaf to be comparable to hardwood kraft and softwood kraft, respectively. Whole kenaf was treated with the white-rot fungi, *Ceriporiopsis subvermispora* and *Phlebia subserialis* and bast kenaf was treated with *P. subserialis*. The bleachability of the pulp in DED, DEDED and DEDP stages was evaluated. The mechanical properties of fungi treated whole kenaf kraft pulp were similar to those of the controls. The mechanical properties of bast fiber pulp (fungi-treated or control) showed significantly high tear values when compared with whole kenaf. The brightness of biokraft bast fiber was about 8% higher than control for a similar three (DED) or four (DEDP) stage bleaching. The brightness of biokraft pulp of whole kenaf and bast kenaf was in the range of 86 to 88% compared to 78 to 81% for control with similar bleaching treatment. Whole kenaf kraft pulp yield was in the range of 42 to 44% with kappa numbers between 17 to 22, whereas bast kenaf pulp yield was between 50 to 52 with kappa numbers of 12 to 14. That means, kenaf pulp needs substantially less chemicals during bleaching in comparison to softwood kraft pulp. The mechanical properties of kenaf kraft, especially the bast, are close to softwood pulp and far superior to those of hardwood pulp.

### Introduction

Kenaf is a non-woody annual plant that grows favorably in tropical and subtropical regions where sufficient rainfall or irrigation is available. Kenaf stem consists of bast (35 to 40%) and core (60 to 65%) components, both of which yield fiber suitable for papermaking and other paper products. The bast fiber (3 to 4 mm long and slender) are similar to softwood fiber, whereas core fibers (0.5 to 0.7 mm long) are similar to hardwood fiber. Kenaf is a potential alternative source of paper-making fiber in many underdeveloped or developing countries where wood pulp is unavailable or only locally available (1). Extensive research works by scientists from the USDA Agricultural Research Service led to the conclusion that most conventional pulping techniques, such as Kraft, soda, neutral sulfite, mechanical such as thermomechanical pulp (TMP), chemico-thermomechanical pulp (CTMP), Chemicomechanical pulp (CMP), are suitable for kenaf pulping (2,3,4).

Biokraft pulping (fungi treated material pulped by using kraft process) has been investigated for whole kenaf as well as for bast kenaf. Untreated materials were used as the control. The objective of this study was to evaluate the benefit of using the treated

kenaf instead of non-treated kenaf in terms of pulp quality, yield, and bleachability of the pulp.

## Experimental

### Raw materials:

All pulping trials used kenaf grown in Louisiana. The kenaf, dried and packed tightly as coil, was stored outside under a plastic cover for about 3 years. The kenaf stems were dark colored and partially rotten. The whole kenaf stems were chopped into 25 to 50 mm long pieces. The chopped kenaf was then dispersed in warm water in a pulper and drained in a sieve box to remove dirt, dust and fine non-cellulosic materials separated from the kenaf due to mechanical action. The washed materials were ready for fungal treatment or for use as an untreated control.

### Fungal treatment:

Fungal inoculum are described elsewhere (5). A sample consisting of 833 g washed wet kenaf (300 g o.d. basis) was placed in a bioreactor (6) and autoclaved for 90 min. The washed kenaf was used as control. The white rot fungi used in our experiments were *C. subvermispora* L-14807-SS-3 and *P. subserialis*-RLG-6074-SP. The flask-grown white rot fungi from the flask was initially diluted to 50 ml (A), and one gram of (A) further diluted to 100 ml (B). For *C. subvermispora* 5.0 ml of (B) was finally diluted with 300 ml of water plus 3g of corn steep liquor (CSL) and mixed with kenaf in the bioreactor. Temperature within the bioreactor was maintained using humidified air at 27°C for two weeks. In case of white-rot fungi (*P. subserialis*), 4.5 ml of (B) was diluted with 300 ml water plus 3 g CSL and then mixed with kenaf in the bioreactor. The materials in the bioreactor was treated for 2 weeks under the same conditions just described. 1 g of fungus per ton of kenaf was used in these experiments.

### Cooking conditions:

The fungi treated kenaf was washed with warm water to remove any water soluble product such as acid and lignin components produced during fungal treatment. After washing, the consistency of treated kenaf was around 27%, and the control kenaf was around 34%. The cooking chemicals were 25% sulfidity and 20% active alkalinity. The liquor to kenaf ratio was 6:1. Three bomb reactors, each containing 130 g (oven dry basis) kenaf, were fitted inside a large trembling reactor used to heat the reactor bombs with steam as well as to keep the liquor in contact with the kenaf material during cooking. The cooking temperature was ramped to 171°C in 60 min and maintained for 55 min. The cooking conditions, yield and kappa number are shown in Table 1.

### Fiber preparation:

The pulp was washed and disintegrated with sufficient hot water. The CSF of the pulp was in the range of 630 to 670 ml. The pulp was then refined in a PFI refiner at various revolutions to reduce pulp CSF to between 440 and 480 ml. The pulp was bleached following the chlorine dioxide (D) and/or hydrogen peroxide (P) process.

Handsheets were prepared following the Tappi Test Methods. Mechanical and optical properties were also measured following Tappi Test Methods.

#### Bleaching:

The PFI refined pulp was bleached by using various bleaching stages as shown in Table 2. The quantity of chlorine dioxide in D<sub>1</sub> stage was calculated on the basis: % Cl<sub>2</sub> = 0.2\* kappa number. In the subsequent stages, chlorine dioxide used was 100,75 Or 50% of the D<sub>1</sub> stage.

#### Results and discussion

The cooking conditions and chemical charge applied to whole kenaf and bast kenaf (white-rot fungi treated and untreated) were constant, as shown in Table 1, which also contains yield and kappa numbers. Pulp yield of whole kenaf was in the range of 41 to 42%, whereas the yield of bast kenaf was around 50% regardless of treatment. The kappa number of control whole kenaf pulp was around 17 compared to 19 for pulp from white rot fungi treated materials. Similarly, the kappa number of pulp from white-rot fungi treated bast was 1 point higher than that of control. These preliminary results imply that white-rot fungi treatment was not effective in showing positive pulp yield and kappa number results. However, the response of kraft pulp obtained from white-rot fungi treated whole and bast kenaf towards chlorine dioxide bleaching was quite different to that of control non-treated.

Table 1

Sample	sulfidity,%	A.Alk. %	Liquor / kenaf ,ratio	Ramp time min	cookin g, time min	cookin g, temp. °C	Yield %	Kappa Number
Kenaf, control	25	20	6	60	55	171	41.8	17.1
Kenaf, SS-3 treated	25	20	6	60	55	171	41	19.3
Kenaf, PS-6074, treated	25	20	6	60	55	171	42.3	19
Bast, control	25	20	6	60	55	171	50.7	12.6
Bast, PS-6074 treated	25	20	6	60	55	171	50.3	14.3
Aspen	25	20	4	79	71	171	50.0	15.1
Spruce	25	20	4	60	81	171	45.0	39

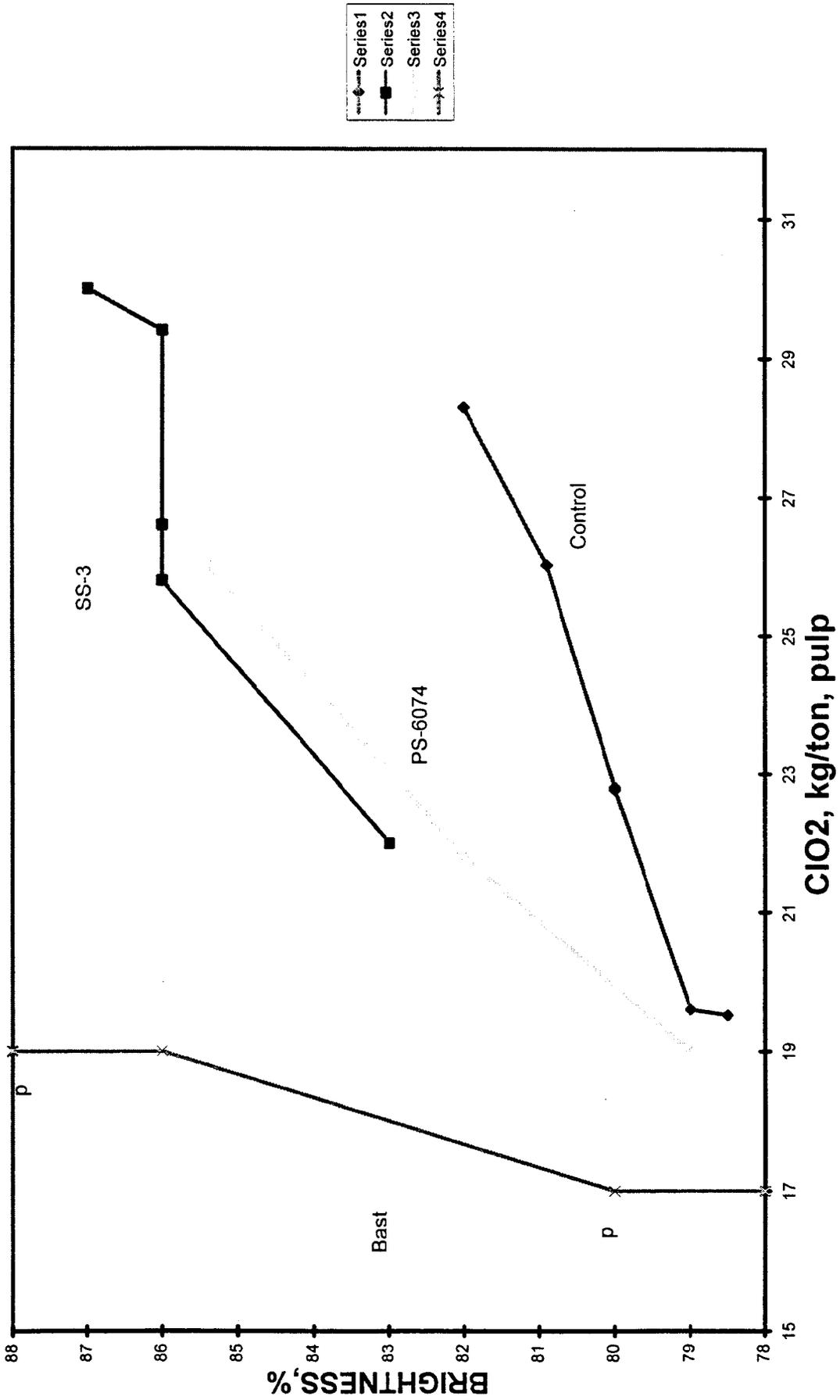
Kraft pulps from white rot fungi treated kenaf were bleached to 86 to 88% ISO brightness level compared to 78 to 80% for control using similar bleaching stages. Table 2 shows the quantity of chemicals used, the number of stages applied and the final brightness achieved. Figure 1 shows the effects of total chlorine dioxide applied at

different bleaching stages on pulp brightness. Kraft pulp derived from white-rot fungi treated kenaf was bleached to higher brightness level than did the control for the same amount of chlorine dioxide used. The results were even dramatic in case of bast kenaf, with 50% yield range and 12 to 13 kappa number, only needed a minimum amount of chlorine dioxide to reach 78 - 80% brightness to 78 to 80% level. Pulp from white-rot fungi treated bast could be bleached to 86% compared to 78% ISO brightness for control bast pulp in DED bleaching stages, and 88% compared to 80% ISO brightness for control by applying DEDP stages. This implies that the white-rot fungi might partially reduce the extractives and modify the lignin into a form suitable for removal during bleaching with chlorine dioxide and/or hydrogen peroxide. Indeed, the white-rot fungi partially removes the extractives (7) and modifies the lignin structure (8) when applied to wood.

Table 2

sample	ClO2 D1(%)	NaOH E1(%)	ClO2 D2 (%)	NaOH E2 (%)	ClO2 D3(%)	H2O2P (%)	Bright ness(%)
Bast (control) DED	0.96	1.6	0.72	-	-	-	78
Bast (control) DEDP	0.96	1.6	0.72	-	-	1.5	80
Bast(Ps-6074)DED	1.09	1.7	0.82	-	-	-	86
Bast(Ps-6074)DEDP	1.09	1.7	0.82	-	-	1.5	88
kenaf,cont.(0) DE	1.3	2.0	-	-	-	-	62
Kenaf,cont.(1)DED	1.3	2.0	1.3	-	-	-	81
Kenaf, cont.(2) DED	1.3	2.0	0.98	-	-	-	80
Kenaf,cont.(3)DED	1.3	2.0	0.65	-	-	-	79
Kenaf,cont.(1) DEDED	1.3	2.1	1.0	1.6	0.53	-	82
Kenaf,cont(2) DEDED	1.3	2.1	0.67	1.2	0.53	-	80
Kenaf,SS-3(1) DEDED	1.4	2.1	1.05	1.7	0.56	-	87
Kenaf, SS-3 (2) DEDED	1.4	2.1	0.7	1.2	0.56	-	86
Kenaf, SS-3(0) D	1.47	2.2	-	-	-	-	63
Kenaf,SS-3(1) DED	1.47	2.2	1.47	-	-	-	86
Kenaf,SS-3(2)DED	1.47	2.2	1.1	-	-	-	86
Kenaf,SS-3(3)DED	1.47	2.2	0.73	-	-	-	83
Kenaf,PS-6074(1) DED	1.09	1.7	1.09	-	-	-	82
Kenaf,PS-6074(2) DED	1.09	1.7	0.8	-	-	-	79
Kenaf,PS-6074(3) DED	1.09	1.7	0.54	-	-	-	76
Aspen (kraft) DED	1.15	1.8	1.15	-	-	-	83
Spruce (kraft) DED	2.9	4.2	2.9	-	-	-	75

# ClO2 Consumed vs Brightness



To assess the behavior of hardwood and softwood kraft towards chlorine dioxide bleaching, We prepared aspen and spruce krafts and bleached them same as kenaf kraft. Aspen kraft showed an initial kappa number of around 15, slightly less than the 17 to 19 of whole kenaf pulp. Although the brightness of control kenaf pulp was inferior to aspen kraft, pulp from white-rot fungi treated kenaf with a higher initial kappa number showed similar brightness. However, when the quantity of  $\text{ClO}_2$  used was based on 0.2 kappa factor, treated whole kenaf pulp certainly showed higher brightness than aspen pulp. This was definitely true in case of pulp from white-rot fungi treated bast having kappa number around 14, which is very similar to aspen kraft pulp, could be bleached to 86% by applying even less  $\text{ClO}_2$  in two stages.

Softwood kraft pulp (Spruce) with an initial 39 kappa number and ~45% pulp yield required about 58 kg  $\text{ClO}_2$  in two stages to bleach each ton of pulp to 75% ISO brightness, This was substantially higher than required for kenaf and aspen pulps. Indeed softwood pulp needed at least 5 stages (DEDED) to reach 88% level, whereas the brightness of the pulp from white-rot fungi treated kenaf could be raised to 86 to 88% ISO brightness level by using 3 stages (DED) or 4 stages (DEDP) bleaching. The consumption of  $\text{ClO}_2$  and NaOH for kenaf pulp was also significantly lower than required for softwood kraft (see Table 2).

The mechanical and optical properties of bleached pulp obtained from whole kenaf, bast (white-rot fungi treated and control), aspen kraft and spruce kraft are presented in Table 3. The mechanical properties of control and white rot fungi kenaf pulps were similar, but far superior to those of aspen kraft pulp and closer to softwood kraft pulp. The bast fiber was similar to softwood kraft in term of mechanical properties, but showed advantages in pulp yield, kappa number and bleachability. Bast kenaf yielded at least 4 to 5% more pulp and needed less than 50% of bleaching chemicals required by softwood kraft pulp to achieve an acceptable bleaching range. The results indicate that the bast kraft pulp was an economical substitute for softwood kraft pulp, and whole kenaf pulp could easily substitute for hardwood kraft pulp and partially substitute for softwood kraft pulp. A pulp mill based on bast kenaf would need a smaller recovery boiler and have less environmental impact.

Table 3

sample	CSF, ml	Density kg/m <sup>3</sup>	Bright- ness,%	Opacity %	Burst index, kPa. m <sup>2</sup> /g	Tear index, mN.m <sup>2</sup> / g	Tensile index, Nm/g
Bast (control) DED	465	537	78	75	5.7	16.1	68.6
Bast (control) DEDP	465	532	80	74	5.3	13.4	68.5
Bast(Ps-6074)DED	550	486	86	73	4.6	15.1	61.4
Bast(Ps-6074)DEDP	550	492	88	73.5	4.6	13.6	61.8
kenaf,cont.(0) DE	460	580	61.5	80	4.51	11.48	67.5
Kenaf,cont.(1)DED	460	585	80.9	75.7	4.59	11.96	65.5
Kenaf, cont.(2) DED	460	588	80	75	4.26	11.35	63.2
Kenaf,cont.(3)DED	460	597	78.5	75.7	4.57	11.47	62.5
Kenaf,cont.(1) DEDED	430	605	82	74	4.16	8.79	66.3
Kenaf,cont(2) DEDED	430	593	80	75	4.11	8.05	65
Kenaf,SS-3(1) DEDED	445	573	87.1	73.3	4.88	10.6	70.8
Kenaf, SS-3 (2) DEDED	445	581	85.5	74	4.75	8.8	72.1
Kenaf, SS-3(0) D	480	572	62.7	81.6	4.37	12.39	64.3
Kenaf,SS-3(1) DED	480	571	86	74.9	4.17	11.61	62.7
Kenaf,SS-3(2)DED	480	572	86.1	74.8	4.16	12.46	63.1
Kenaf,SS-3(3)DED	480	578	83.1	75.7	4.09	11.13	64.7
Aspen kraft, DED	600	-	82.5	78.1	1.93	4.36	35
Spruce kraft, DED	460	742	75.0	69.8	8.48	15.79	96

## Conclusions

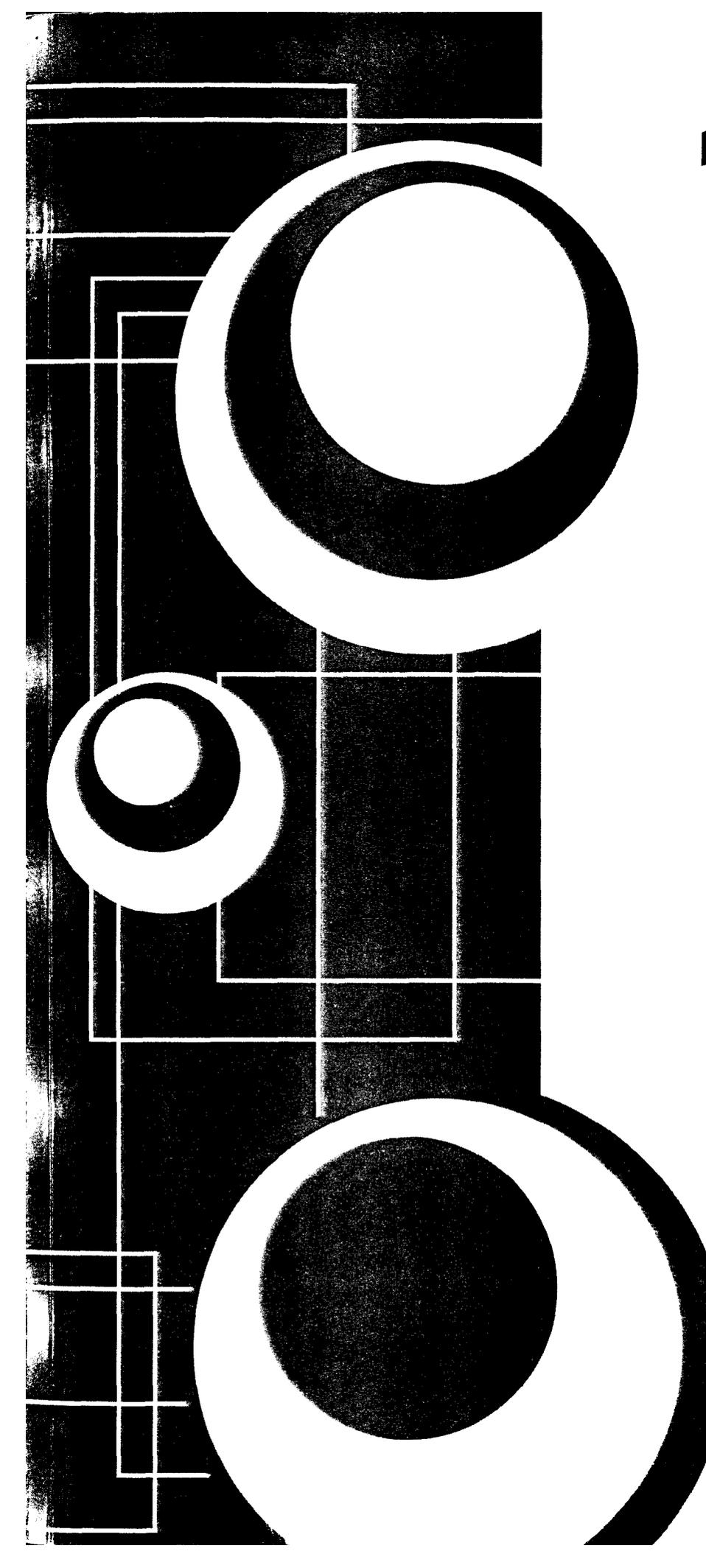
The mechanical properties of kraft pulp produced from fungi treated kenaf and control kenaf were similar. However, the response of pulp from fungi treated kenaf towards ClO<sub>2</sub> bleaching was much better than that of control kenaf. The brightness of the pulp could be raised to 86% ISO by applying DED stages, and to 88% ISO by applying DEDP stages. The control pulp could be raised to only 78 to 80% ISO under similar bleaching conditions. Bast kenaf showed yield of around 50% with 12-14 kappa number. The bast pulp required very low bleaching chemicals to raise its brightness to 86 to 88% ISO level. The bast pulp required less than half of bleaching chemicals required by softwood pulp to arrive at 75% ISO brightness for similar DED treatment. The mechanical properties of whole kenaf pulp was much superior to that of hardwood kraft pulp. The mechanical properties of bast pulp was close to that of softwood kraft pulp.

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