# MODIFIED COLD CAUSTIC PULPING OF BAGASSE

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## ABSTRACTS

*The Cold Caustic Chemi-Mechanical pulping of Bagasse has been investigated in detail considering the good pulpability of this material now available in plenty in Andhra Pradesh. The variables considered for this study were the alkali, time and temperature, for achieving pulps in high yield and quality. The best suited conditions are, soaking with 6-8% alkali at the 90°C for 1½ hours followed by a two stage refining to suit the furnish requirements. Pulps of varying qualities in the 70-85% yield range can be produced by this method to make papers for meeting specific end uses. Cold caustic pulp from Bagasse in proportions with 40-60% bamboo chemical pulp appears very promising for the manufacture of kraft and corrugating medium in the packaging industry, along with cheap grade liner boards, and wrapping varieties of paper.*

## INTRODUCTION :

It has become very essential for paper industry at this moment of acute paper famine in India, to look forward to utilising the various kinds of pulpable raw materials that it may consider potential to augment the existing supplies of the principal raw material bamboo, and hard woods by processes other than the conventional kraft pulping methods. However, the latter category, namely, most of the hard woods of Indian origin do not respond well to the alkaline pulping methods. Other than this, in India, we have only the seasonal crops like jute, sugar cane, straw and reeds which fall under the category of agricultural residue or mill wastes. Primarily, the Bagasse, left after the extraction of the recoverable sugar is utilised as a fuel in the sugar mills. If however, a part of this potentially useful fibrous raw material were available to the paper industry, this may perhaps fill up the present shortage of raw material for paper making to a considerable extent.

For example, we have in the state of Andhra Pradesh, two paper mills, producing altogether 90,000 tonnes per annum. This would require in all 2,50,000 tonnes of fibrous raw material which can be split up into 2 lakhs ton in terms of bamboo and the balance, hard woods. If we have a glance at the sugar cane production in A.P. over the last decade,[1] we would observe that there has been a 300% increase in the production of sugar cane in this period as visualised in the figure I. Nearly three hundred thousand tonnes of bagasse with 50% moisture may be available over a period of 150 days every year. The sugar industry consumes almost 93% of this bagasse as fuel for steam generation. We are left with 12,000 tonnes of bone dry bagasse that may be surplus to the sugar industry which is not enough for an economic production level. It is essential that alternative measures be taken to substitute the fuel and then release the bagasse for pulping.
We have a semichemical pulping plant in operation since a year based on hard woods from local area. In view of the possible availability of bagasse in the fresh form, we have considered the study on the chemi-mechanical pulping of bagasse as a method of producing high yield pulp of reasonable and acceptable strength properties. Considerable number of wood spieces have been investigated with the cold caustic process, such as, Eucalyptus, Sesbania Grandiflora, Jute sticks, Cochlospernum Gossipium and other mixed hard woods, in our existing plant over the last one year of operation.

Though the pulping of bagasse is not new to the Indian paper industry, 2-7, 9, 11, 13, 14 there is seldom any work done in India on the pulpability of baggasse, by the chemi-mechanical methods. However, published literature is available on the economies of pulping bagasse and its end uses in paper making[8]. It is felt that the present study will fill up the gap in the knowledge on such a method of pulping bagasse, in addition to being a source of high yield pulping to augment the present raw material supplies for making cheap grade papers like corrugating board, wrappers, and newsprint, towards making which we now use bamboo pulp to a considerable extent, which otherwise could be diverted for other special quality papers.

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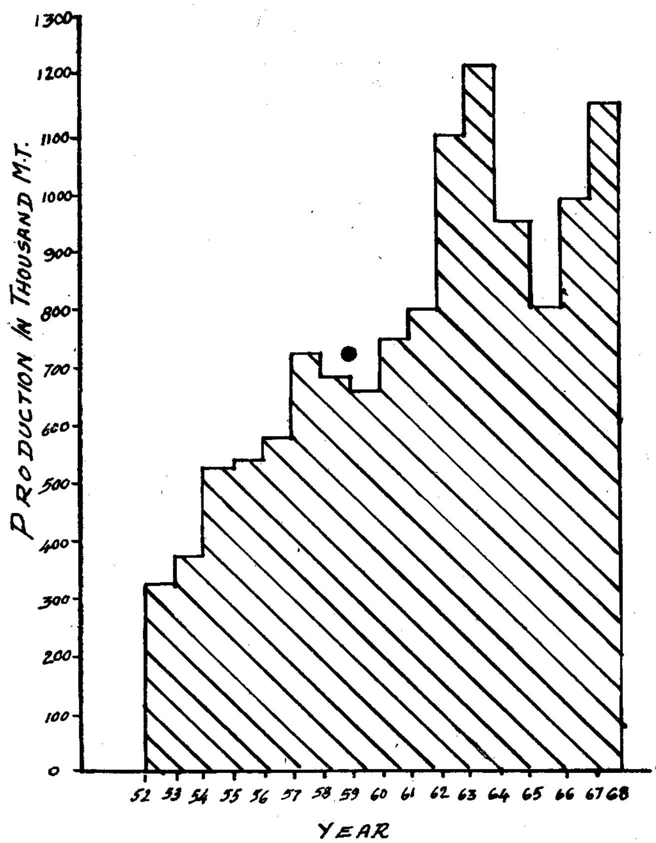


FIG-I, PRODUCTION OF SUGER CANE IN-ANDHRA PRADESH

## EXPERIMENTAL :

Nearly a tonne of bagasse was brought from the nearby sugar factory at Chagallu, for conducting the experimental study in the cold caustic pulping of bagasse.

The bagasse so collected, was pale yellow in colour, indicating reasonable deterioration over a period of four months storage. It was given a primary wash in cold water and cleaned or depithed partially, and dried before use for the experiments to follow. The useful fiber portions comprised 77.7% of the whole bagasse, pith 18.5% and water solubles were 3.8%. A typical proximate analysis of this bagasse is given in Table—I along with other fibrous raw materials like soft, and hard woods, bamboo, and an agricultural residue for comparison.

## CHEMI-MECHANICAL PULPING

The pre-steaming/prehydrolysis and chemical soaking were carried out in an electrically heated tumbling digester. The bagasse was prehydrolysed by steaming at 140°C for 15 minutes for all the runs in this investigation. A set of nearly thirty experiments were planned for the study of high yield pulping of bagasse, with variables like alkali, time and temperature.

The Table—II details all the pulping conditions considered in this study.

**TABLE I**

**PROXIMATE ANALYSIS ON DIFFERENT WOOD SPECIES**

| Sl. No. | Name of Species | Ash | Lignin | Pentosans | Holo Cellulose | Solubilities | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Ether | Alcohol Benzene | Cold water | Hot water | 1 % NaOH |
| | | % | % | % | % | % | % | % | % | % |
| 1. | White Spruce (Picea Glauca)* | 0.2 | 27.0 | 8.0 | 73.0 | 2.11 | — | 1.4 | 2.2 | 12.5 |
| 2. | Jack Pine (Pinus Banksiana)* | 0.3 | 26.7 | 9.7 | 72.0 | 2.3 | 3.7 | — | 2.9 | 11.2 |
| 3. | Western Hemlock (Tsuga Heterophyla)* | 0 3 | 27.8 | 9 2 | 68.0 | 0.8 | 1.6 | — | 0.4 | 15.1 |
| 4. | Eucalyptus Grandis** | 1.73 | 19.9 | 12.7 | 72.0 | 0.4 | 3.1 | 1.9 | 3.7 | 8.8 |
| 5. | Sesbania Grandiflora** | 1.9 | 19.2 | 15.8 | 69.9 | 0.5 | 2.7 | 3.8 | 6.3 | 18.7 |
| 6. | Bamboo (D. Sticks)** | 3.7 | 23.8 | 16.2 | 67.9 | 0.3 | 2.0 | 2.3 | 2.9 | 19.2 |
| 7. | Jute Sticks (Corchorus Capsularies)** | 0.7 | 24.4 | 18.8 | 65.8 | — | 2.9 | 3.1 | 4.2 | 24.0 |
| 8. | Wheat Straw (Triticum Satirum)** | 8.2 | 22.0 | 22.9 | 49.9 | 0.9 | 4.7 | 8.9 | 13.4 | 45.7 |
| 9. | Bagasse | 1.9 | 19.2 | 15.8 | 69.9 | 0.5 | 2.7 | 3.8 | 6.3 | 18.7 |

*Rydholm, Pulping processes p-93.
**Technical reports of APP Mills, Rajahmundry.

## TABLE II
## PULPING VARIABLES FOR CHEMI-MECHANICAL PULPING

| | |
|---|---|
| Alkali : | 5 — 10% |
| Time : | 30 minutes — 120 minutes |
| Temperature : | 50 °C — 90 °C |
| Bath ratio: | 1 : 5 |
| Moisture in chips after prehydrolysis: | 50% |

The bagasse at the end of the stipulated period of soaking in the digester was refined twice in a Sprout Waldron Disc Refiner in the Laboratory, with 40 and 7-10 thousand of an inch clearance between the plates, with the liquor. The pulp was washed free of alkali and the yield computed for each run.

### RESULTS AND DISCUSSION

The yield of Chemi-Mechanical pulps under different conditions of pulping is illustrated in Figure II. This varies linearly with time, the maximum and minimum at 90% and 63% with 5% and 10% alkali respectively. The characteristics of yield versus alkali indicates that the delignification of bagasse follows an assumed first order reaction. A similar phenonmena is exhibited in the alkali consumptions with time in the range studied illustrated in Figure-III There is enough evidence available in the literature to substantiate this assumption[7].

### EFFECT OF TEMPERATURE

In addition to the effect of time and alkali, the temperature of the soaking operation does contribute substantially towards the quality of pulp produced. This is perhaps due to the deependence of delignification rate on temperature in addition to the alkali concentration, due to diffusion, though the latter may not be rate determining. The figure IV illustrates the dependence of pulp yield on temperature with 6% alkali, at the end of soaking for 120 minutes. The pulp yield was 78.8% when the bagasse was pulped with 6% alkali for 120 minutes with the temperature dropping during the run from 90° C initially to 58°C at the end of soaking. The yield increased by 16% when pulped at 50° C under similiar conditions over that at 90°C. However, the pulp quality was comparatively poor as can be seen in Figure V. The strength properties of the pulp sheet made from a mixture of 60% bagasse Chemi-Mechanical pulp and 40% unbleached bamboo chemical pulp are illustrated in this figure. We can observe that the properties like breaking length, burst factor, and tearing factor of the pulp made at 90° C temperature, are superior to that made at 50° C temperature by 90,30 and 20 percent respectively; while the

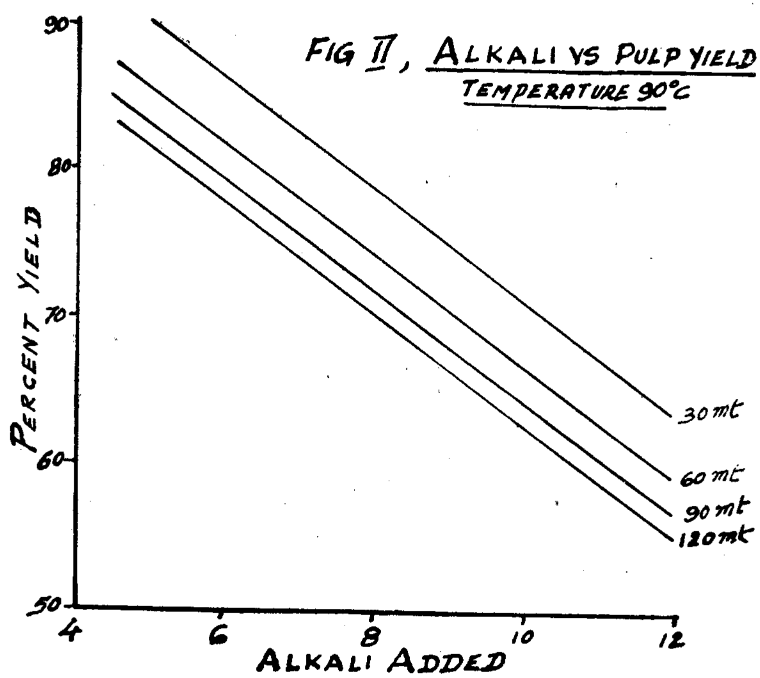

FIG II, ALKALI VS PULP YIELD

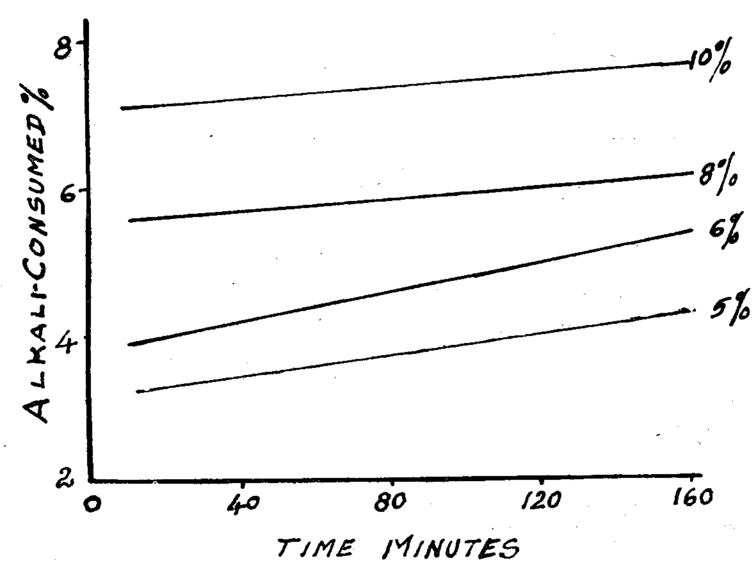

FIG-III - ALKALI CONSUMPTION VS TIME

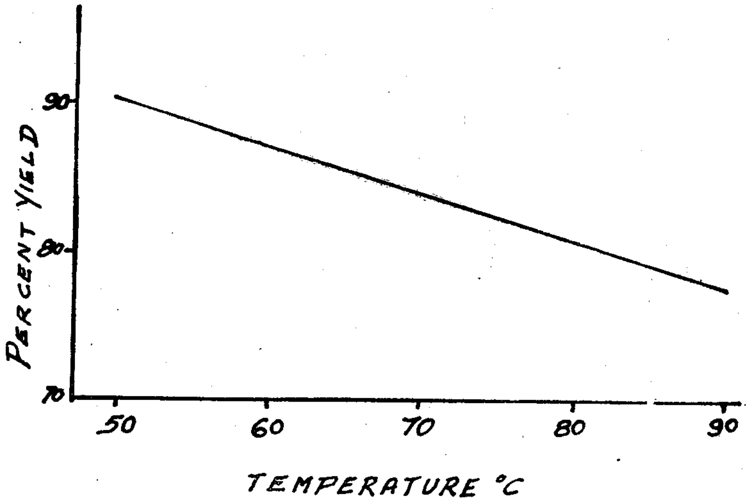


FIG-IV, EFFECT OF TEMPERATURE ON YIELD
ALKALI ADDED 6%
TIME - 2 HOURS.

folding endurance property of the pulp prepared at 90° C is far superior to that made at 50°C. It is evident from this, that the temperature plays a very major part in the pulping, keeping other parameters the same. We can also observe from figure VI that the ratio of holocellulose to lignin in the pulp rises with temperature of pulping, while hemicelluloses which are mainly composed of pentosans[12] remain constant in the pulp over the range of temperature studied. This substantiates our contention that under the conditions chosen for the Chemi-Mechanical pulping of bagasse, lignin in almost removed leaving aside the hemicelluloses and cellulose preferentially thereby contributing to high yield pulp.

## EFFECT OF ALKALI AND TIME

The strength properties of pulp produced from runs relating to the effect of alkali and time with temperature maintained[9] at 90° C are illustrated in figures VII-a and VII-b. In general, the alkali and time have a complementary effect on the strength properties, for example, to get a breaking length of 4.1 KM at 6% alkali, the time factor was 120 minutes. To achieve the same level of breaking length at 90 minutes the alkali required would be 7.25%. There is considerable improvement in the quality of pulp in respect of burst factor and the double folds, however, the same rate cannot be predicted with the tear factor. This property increases initially with time and alkali upto 90 minutes, beyond which the incremental increase in this property drops slowly. The burst factor levels off at 120 minutes soaking time with 10% alkali. However, the double folds increase is 40, 60 and 80% between 90 and 120 minutes soaking with 6, 8 and 10% alkali on bagasse respectively. Also from figure-VIII, relating the delignification rate with alkali added, it can be seen the rate of delignification preceeds faster with high alkali in the range 6-10% between 90 and 120 minutes of soaking at 90° C. If we introduce another parameter of yield in this we can conclude that for yields above 75% the best conditions of chemi-mechanical pulping would be to use 6-8% alkali over a period of 60-90 minutes at 90° C or alternatively with temperature dropping from 90° at the commencement to 60°

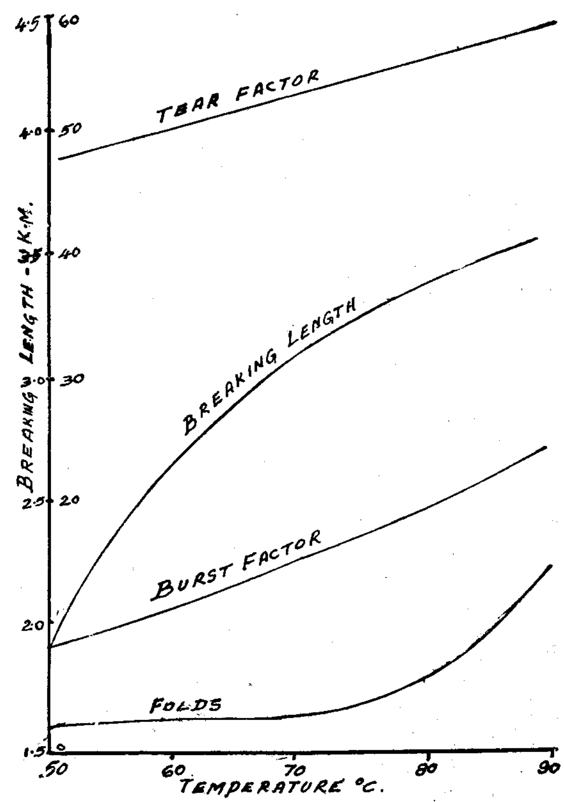


FIG V, STRENGTH PROPERTIES OF SHEETS
FROM 60% BAGASSE-40% BAMBOO
EFFECT OF TEMPERATURE ON STRENGTH PROPERTIES
ALKALI-6% TIME-2 HOURS

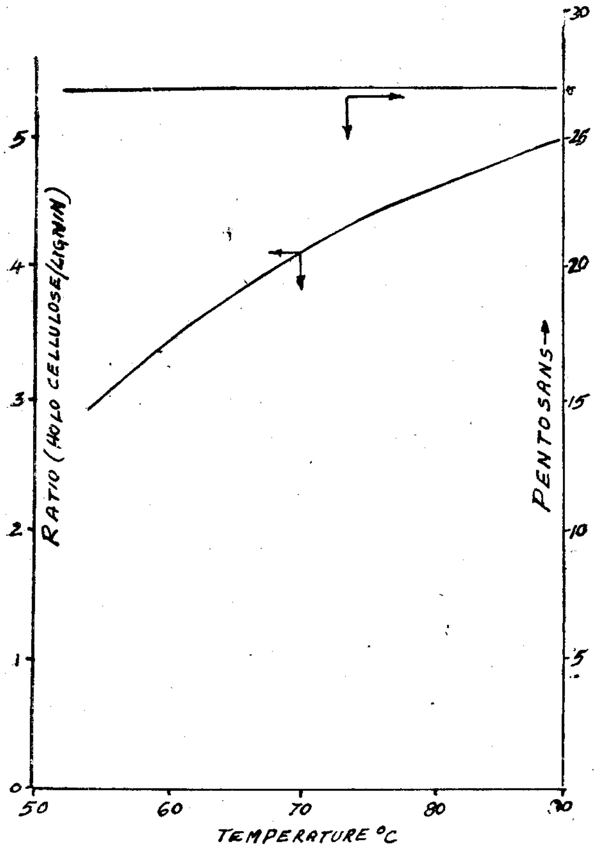


FIG-VI EFFECT OF TEMPERATURE ON-DELIGNIFICATION-

at the end of soaking operations followed by two stage hot refining in Disc Refiners.

## EFFECT OF FREENESS OF BAGASSE STOCK

For this variable, we took the bagasse pulps made with 6% alkali and 120 minutes soaking at different temperatures. They were beaten separately to different freeness ranging for 40-70° SR in a Valley beater and mixed with bamboo chemical unbleached pulp of 40° SR and hand sheets formed. The typical strength properties of a stock containing 60% chemi-mechanical bagasse pulp and 40% bamboo chemical pulp are illustrated in figures IX-a and b.

The pulp property is maximum in respect of both breaking length and tear at a bagasse pulp freeness 50° SR and temperature of pulping near 80°C. The burst factor shows an increasing trend with freeness and temperature of pulping.

## PHOTO MICROGRAPHY

A series of photo-micrographs were taken of the pulp produced under the various conditions to illustrate the effect of chemical, temperature and time on the effect of fibre liberation from the bagasse bundles. A typical photo-micrograph (Figure X) is shown as an illustration of pulping done with 6% alkali at 90°C for two hours. It can be observed that the fibres are reasonably separated and have thin walls and are ribbon like. This could be the reason that the sheets of 100% bagasse chemi-mechanical pulp are denser.

The Pulps made with 6% alkali over 120 minutes at different temperatures were fractionated in the Bauer McNett fibre classifier after the initial refining and the details are furnished in Table III.

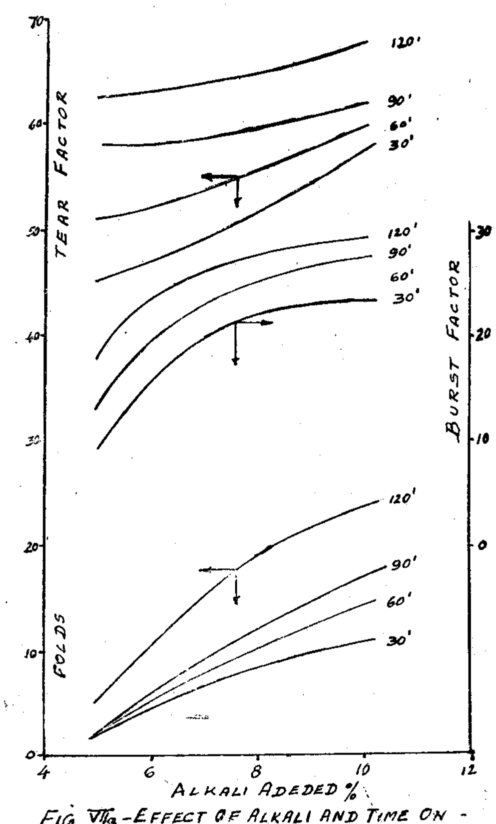


FIG VIIa -EFFECT OF ALKALI AND TIME ON -STRENGTH PROPERTIES OF CHEMI-MECHANICAL PULP FROM BAGASSE
- TEMPERATURE -90°C
60% BAGASSE PULP & 40% BAMBOO CHEMICAL -PULP

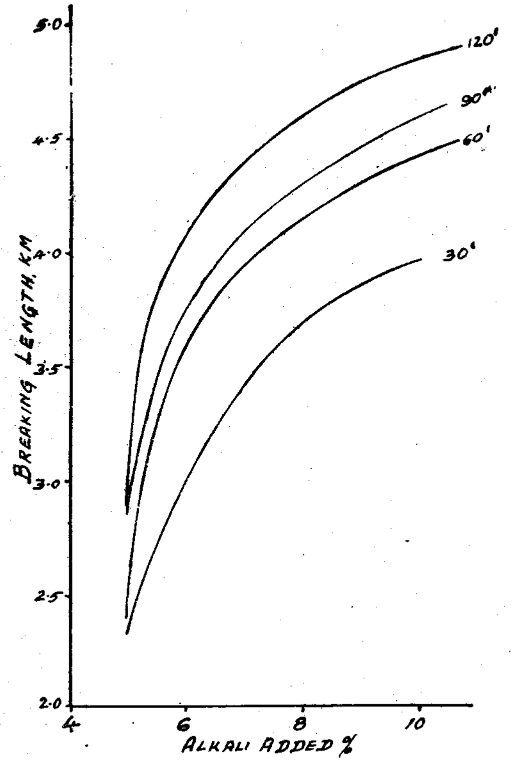


FIG-VIIIb- EFFECT OF ALKALI AND TIME ON STRENGTH PROPERTIES OF CHEMI-MECHANICAL PULP FROM BAGASSE. TEMP–90°C
60% BAGASSE PULP & 40% BAMBOO CHEMICAL-PULP.

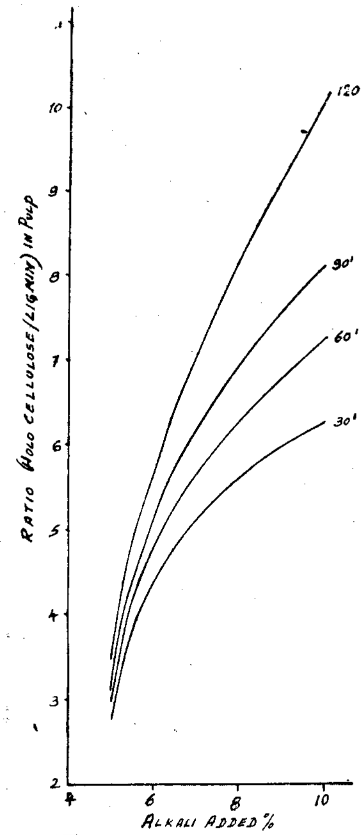


FIG VIII EFFECT OF ALKALI AND TIME ON THE DELIGNIFICATION – TEMPERATURE 90°C – ON BAGASSE COLD CAUSTIC PULPING

An attempt has been made to bleach the chemi-mechanical pulp to a medium brightness using hypochlorite followed by peroxide bleaching.

## CHEMICAL PULPING

The Bagasse was cooked by the conventional kraft method and the conditions with the properties of the pulp are illustrated in Table-IV. For comparison the properties of bamboo pulp properties are also mentioned in the table.

From the Table-IV, we observe that bagasse pulps take up less beating to develop the same freeness when compared with pulps from other raw materials such as bamboo. This could be due to high hemicellulose retained in the pulp. Fries[10] was able to make an easy beating pulp from Poplar by cooking by semichemical process under conditions such that the pulp contained a very high percentage of undegraded hemicellulose.

The fibre length of the bleached bagasse was determined by means of a binocular microscope. It is compared with pulps from Bamboo, Jute sticks and other hard wood pulps; Table V

## FUTURE WORK

We are planning to incorporate the bleaching of chemi-mechanical pulps during refining stages with lignin preservative bleaching methods. In addition our plans are under way to investigate the latency effect on these pulps which are rich in hemicelluloses and lignin compared to chemical pulps.

## CONCLUSIONS :

1. Bagasse gives pulp in high yields by chemi-mechanical pulping under conditions such as 6—8% alkali with soaking periods of 60-90 minutes at a temperature of 90°C.
2. These pulps are suitable for admixture with long fibred chemical pulp and such as bamboo pulp for end uses such as corrugating medium, cheap grade kraft liner boards, and wrapping papers.
3. The bagasse pulps take up less beating for the same freeness, when compared to bamboo chemical pulp under similar conditions.
4. The bagasse chemi-mechanical pulp exhibits maximum properties at a freeness of 50° SR when pulped at 80° C with 6-8% alkali.
5. The fibres are well separated on pulping with increasing alkali content and time.

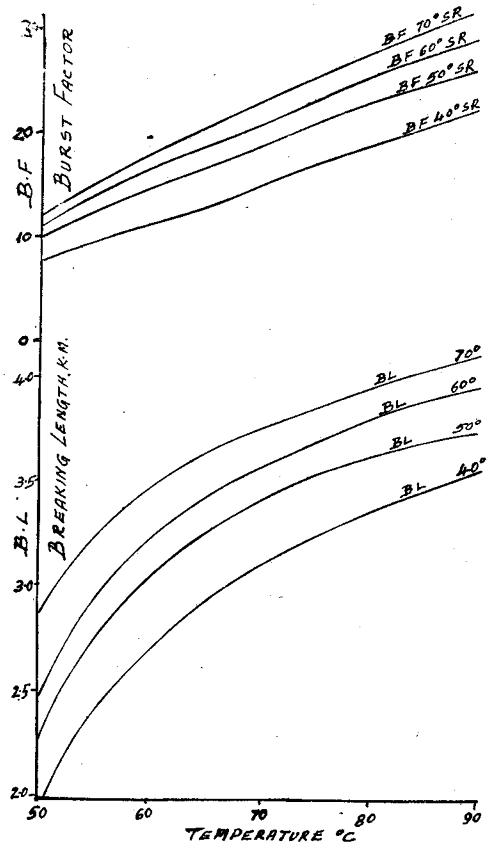


FIG IX a - EFFECT OF PULPING TEMPERATURE ON FREENESS ON STRENGTH PROPERTIES

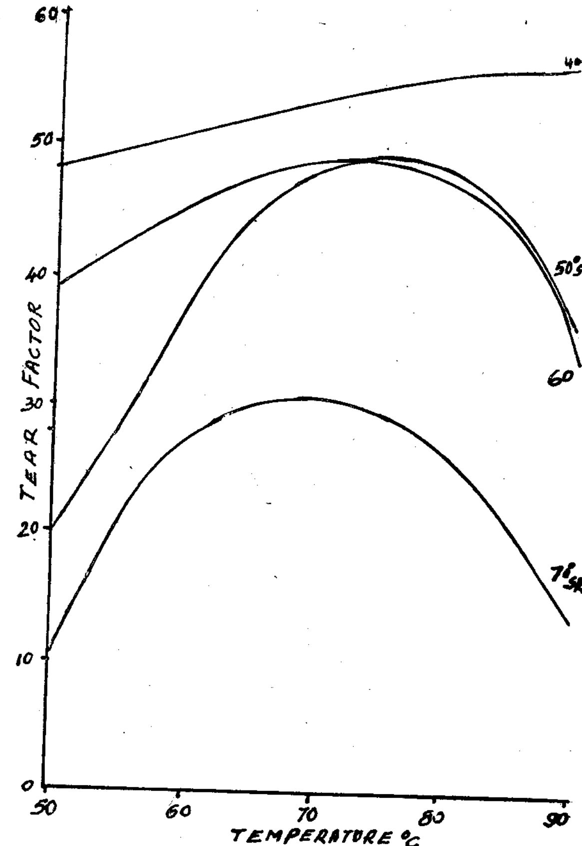


FIG IX b - EFFECT OF PULPING TEMPERATURE ON FREENESS ON STRENGTH PROPERTIES

## TABLE III

## FIBRE FRACTIONATION OF CHEMI-MECHANICAL PULP FROM BAGASSE

| Sample Identity | | B-25 | B-24 | B-23 | B-28 | B-27 |
|---|---|---|---|---|---|---|
| Temperature of Pulping | °C | 50 | 60 | 80 | 90 | Cooling |
| Initial Freeness | °SR | 17 | 35 | 34 | 26 | 25 |
| Final Freeness | °SR | 40 | 41 | 40 | 40 | 40 |
| + 28 mesh | % | 10.8 | 12.1 | 20.8 | 13.2 | 9.3 |
| − 28 + 48 mesh | % | 20.7 | 15.0 | 18.7 | 27.7 | 33.9 |
| − 48 + 65 mesh | % | 33.0 | 16.0 | 14.9 | 12.2 | 18.5 |
| − 65 +150 mesh | % | 18.1 | 22.9 | 14.4 | 19.5 | 13.9 |
| − 150 mesh | % | 17.4 | 34.0 | 31.2 | 27.4 | 24.4 |

**TABLE IV**
**KRAFT PULPING OF BAGASSE**

| | |
|---|---|
| Prehydrolysis at 140°C for 15 minutes. | |
| Active Alkali used as $Na_2O$ | 10.0 % |
| Sulphidity | 21.0 % |
| Bath ratio | 1 : 5 |
| Time to max. temperature | 60 mts. |
| Maximum temperature | 160°C |
| Time at max. temperature | 10 mts. |
| Yield | 55% |
| Permanganate/Number | 16.0 |

**STRENGTH PROPERTIES**

| | Bagasse | | Bamboo |
|---|---|---|---|
| | Unbleached | Bleached | Unbleached. |
| Bursting Strength | 1.63 | 1.2 | 2.05 |
| Burst Factor | 2 8 | 31 | 34 |
| Tensile strength | 4.7 | 6.06 | 4.85 |
| Breaking length | 5310 | 6620 | 5390 |
| Double Folds | 12 | 9 | 45 |
| Tearing Resistance | 20 | 17 | 68 |
| Tear Factor | 34 | 28 | 113 |
| Bulk | 1.69 | 1.48 | 2.08 |
| Initial Freeness | 19°SR | 26°SR | 14°SR |
| Final Freeness | 41°SR | 41°SR | 40°SR |
| Beating time | 12 mts. | 7 mts. | 33 mts. |

This is demonstrated by the progressive increase in double folds with time. The fibres have thin walls and are ribbon like.

6. The weight average fibre length of bagasse studied is 1.35 mm with maximum and minimum at 2.9 and 0.45 mm respectively.

7. It is desirable that bagasse is worked to free the same from dirt and pith to obtain a better grade pulp.

8. The chemi-mechanical pulp could be bleached to a medium brightness of 50° GE from an initial brightness of 27° GE using 15% hypo followed by peroxide bleaching with 2% sodium peroxide and 1% hydrogen peroxide, with a shrinkage of 7% during bleaching.

9. With the high yield pulping of bagasse such as the one under study the profitability would be of such a nature as to direct the bagasse for paper making from its use as fuel in sugar industry.

**TABLE V**
**FIBRE LENGTH OF BAGASSE**

| Species | Fibre Length, mm | | | |
|---|---|---|---|---|
| | Max. | Min. | Avg. | |
| Bagasse | 2.9 | 0.45 | 1.35 | * |
| Bamboo | 3.7 | 0.45 | 1.88 | * |
| Jute Sticks | 3.45 | 0.45 | 1.43 | * |
| Sesbania Grandiflora | 1.93 | 0.64 | 1.07 | * |
| Eucalyptus | 1.19 | 0.56 | 0.73 | ** |

* S.R.D. Guha, *etc. al.*, Indians Forester, Vol. 2, No. 4 April 1966 Technical
** reports of APP Mills, Rajahmundry.

## REFERENCE


1. Indian Sugar— July 1970 Page-387
2. R.C.Devgan—IPPTA, 2 No.1, 47. 1964.
3. Dr, J.C. Aggarwala *et. al.*, Group discussions IPPTA, 2, No. 1—25, 1964.
4. Dr. SRD Guha, *et. al.* Indian Pulp and Paper Vol,, 20—No. 2—August 1965.
5. Amritlal *et. al.*, IPPTA 2, No. 3 p—22, 1966.
6. Dr. N. D. Misra, *et. al.* IPPTA 2, No. 3 p.—31; 1966.
7. P. B. Chaudhuri, IPPTA—7, No. 26, 1970.
8. FAO Publication No. 6—1953, Page—48, 62.
9. S. V. Rydholm, Pulping Processes 1965, Page—309, and 416.
10. F. W. Fries—Paper Trade Journal 112, No. 21, 223—224 (1946); cf. JP Casey—Pulp and Paper Vol. II P. 628=30.
11. D. D. Hinrichs *et. al.*, Tappi, 40, 626—633—1957.
12. S. R. D. Guha *et. al.*, Indian Pulp 29, No. 5, 1964.
13. Kamyr—Technical Catalogue No. 14—1965.
14. Technical Reports of APP Mills, Rajahmundry.