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Study of Bagasse Pulps to Obtain Corrugated Medium

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STUDY OF BAGASSE PULPS TO OBTAIN CORRUGATED MEDIUM

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ABSTRACT

Bagasse was used as raw material to pulp various NSSC, Soda and Kraft liquors and evaluated as corrugating medium. A new pulping procedure with the M & K Digester was developed in order to reach maximum temperature at the shortest practical time.

It was found that a 10% Active Alkali at 5% Sulfidity and an NSSC liquor at pH 10 with 15% SO_2 on pulp gave suitable strength properties. The NSSC cook gave a higher yield but a pulp with more shives.

Keywords: Bagasse, Kraft, Soda, Neutral Sulfite Semichemical, Corrugating Medium.

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INTRODUCTION

Sociological, technological and economic progress of nations over the last 19 centuries has been so closely associated with the availability of paper, that the unending search for suitable and inexpensive fibrous raw materials throughout the world is quite understandable. Among these raw materials that are suitable for pulping are the crop residues or by-products of agriculture as well as industrial processes such as cereal grain straws and sugar cane bagasse. The use of these nonwoody fibers in the world is easy to explain by the limited or complete absence of stands of desirable pulpwoods in many of the thirdworld nations. These developing countries are concerned with the domestic manufacture of paper from indiginous raw materials such as tropical hardwood species. More often than not, such countries have deficient resources of long fiber material. Due to its difficulty and high cost, it is inconvenient to use imported long fiber pulp in the quantities required for quality grades.[6] On the average, domestically manufactured paper might require one fifth to one third of the paper volume in long fiber supplies for acceptable qualities. To some extent, quality improvements can be achieved by proper blending or substituting these domestic wood short fibers with nonwoody pulps.

The majority of these third world nations, located in tropical and subtropical geographical areas of the globe, are sugar producing zones. Sugarcane, saacharom officinarum, is a typical grass grown in these regions. Following extraction of this sugarcane for its sucrose containing juice, the fibrous portion is normally recovered.[12] It is this fibrous portion, bagasse, that has value for papermaking.

Packaging papers in these countries constitutes up to 30% of the total paper production. The great demand for satisfactory packaging papers cannot be met due to the inferior quality that local fibers present. So, these nations must import high strength kraft papers including sack bags, and corrugated board development of a stronger bagasse pulp could reduce these imports.

History

Bagasse received its first attention of consequence in the papermaking industry when it was shipped from the Isle of Martinique to France in 1844 as a fiber from which to prepare newsprint. However, it has only been since 1940 in a larger scale.[2] In 1939 successful pulp and paper mills based on bagasse were established at Paragoma, Peru; Tatio, near Tarchung Farmosa; and in the Philippines. As practical means were developed to upgrade the fiber, interest in bagasse as a papermaking fiber source intensified and its use increased. By 1964 about 25 mills were producing bagasse pulps, and these pulps were being used in machine furnishes in about 40 paper mills.[5] Today bagasse plays an important role in the production of a wide range of pulps used in practically all grades of paper.

Physical Properties

Sugarcane is a typical member of the grass family and in outward appearance closely resembles a cornstalk without ears.[3] Its botanical characteristics classifies it as a monocotyledon with a physical structure consisting of three principal components:[5]

1. The rind including the epidermis, cortex, and pericycle.
2. The vascular fiber bundles composing thin walled conducting cells accompanied by relatively thick-walled fibers with narrow lumen.

3. Ground tissue (parenchyma) or pith in which the fiber bundles are embedded randomly.

The relative proportions of these constituents vary with variety of cane, type of soil, climate conditions, length of growing season, and agronomic factors.

The rind and vascular bundles have woody characteristics and exhibit absorbancy equivalent to about five times their own weight,[7] whereas the pith portion has an absorbancy factor of about thirty. The rind carries a silicious coating, whose extent of siliceous matter is influenced by the caracter of the soil in which the cane is grown.

The fibrovascular tissue of these bagasse stalks, discounting the more open structure of the pith, has an average apparent density of .30 to .45 on od/green basis. The fibers contribute strength and rigidity to the plant. These may be classified as either having a wide or narrow lumen. Those with wide lumina occur in relatively large proportions: 48% is ribbon-like material and 46% to thick wall fibrous material.

The bagasse normally comes from the sugar mill with a moisture content of about 50%, a residual sucrose content of about 2 to 2.5% and a content of other water solubles amounting to another 2 to 2.5%. Therefore, the non-water soluble content of the bagasse (normally referred to in the sugar mill as "fiber content") amounts to approximately 45 to 46% of the moist weight of the bagasse leaving the sugar mill.[2]

Therefore as an average, the dry content of the clean cane stalk (water insoluble basis) consists of:

1. 30% pith - most of which is in the center of the stalk and is of little value for pulp.

2. 50% long strong fiber bundles from the external or rind layer.

3. 15% internal fiber bundles.

4. 5% dense non fibrous epidermis of no value for pulp.

In dimensional characteristics, bagasse fibers are similar to those of hardwoods where the average fiber length is 1.1mm and an average width of .01mm. Upon fractionation bagasse fiber yields distinctly two grades of pulp: one that can be used on producing varieties of paper which demand higher strength properties, and the other fraction can be used in paper and board where strength properties are not critical.

Chemical Properties

The same factors that contribute to differences in physical composition also account for differences in chemical composition.

> "Chemical composition of bagasse is similar to that of the deciduous woods. This composition for whole bagasse, separated fiber and pith are given on the following table from widely scattered geographical locations. Although the same varities of cane are not grown at each of the locations, the compositions of the component fiber and pith fractions are essentially the same as for the whole material at the respective location. Compared with woods, bagasse contains less lignin. Alpha-cellulose contents are lower than in coniferous woods but the pentosan contents are higher. This elevated content of hemicelluloses in the fibrous tissue favors the bonding capacity of paper webs. Cellulose from bagasse has lower tear values combined with reasonable tensile strengths. Whole bagasse has the greatest solubility in hot water and in alcohol benzene mixture. The high ash contents of the pith fraction is related to the open cells resulting from the crushing treatment in the cane mill with subsequent pickup of inorganic materials, mostly solids common to the respective geographic area."[13]

Storage

Non wood plant fibers become available during a short period of the year over which time the entire quantity of fibrous raw materials must be collected baled and stored to ensure operation of the pulp mill throughout the year. Fortunately in the case of bagasse, the problem of collection is simple as compared to other fibrous raw materials. The cost of collecting, crushing and washing the sugar cane is borne by the extraction process, and the resultant bagasse leaving the sugar mill is in excellent condition for further processing. However, since the sugar mill operation usually extends over a period of only three to six months, and since the pulp mill must operate over the entire year, it becomes necessary to store large quantities of the bagasse to insure a steady supply to the pulp mill.[14] Therefore, any plan for use of bagasse for pulp manufacture must include provision for storage during the sugar grinding season of sufficient bagasse to last until the beginning of the subsequent grinding season.

There are various storage methods practiced by the pulp companies which are chosen according to which one shows favorable economics. Factors which are considered in addition to others are losses, handling methods, preservation and recovery from storage for any given sugar mill and pulp mill location. In addition to the classical method of bailing the bagasse for storage, new methods have been developed. These new methods include wet bulk storage of the partially depithed bagasse, both with and without biological pretreatment; moist bulk storage direct from the sugar mill without any treatment; completely dry storage in dense pads, under cover after complete moist and wet depithing followed by artificial drying; and storage in dry pellets or briquettes.[7]

During storage, the bagasse fiber undergoes both physical and chemical changes. The fresh bagasse fiber has a yellow color, a slightly acidic, ph and an amount of 3% loose pith. The rest of the pith sticks to the fiber. The stored fiber instead, transforms into a clear brown fiber with a lower pH. The amount of loose pith and shives increases up to 10% and a lower quantity of fiber bundles can be observed. In addition, a darker brown color on the outside layers may be due to the contact with the atmosphere. These changes in color may also indicate an uncontrolled fermentation which produces a heterogeneity in the fiber quality that will be further detected in the process by changes in yield and chemical consumption during the digestion. A uniform bagasse color in the storage area indicates a uniform material. The increase in the loose pith of the stored bagasse is due to the influence of the fermentation process which originates a shrinkage of the pith cells and aids in loosening them. This contraction separates the pith from the fibers and opens the fiber bundles.[10] The sugar content in this stored bagasse is low, therefore, the resultant pulp does not create foaming problems.[14]

As a result of excellent progress in the development of bulk storage methods, as well as greatly improved handling techniques both in and out of storage, the cost of bagasse fiber delivered to the pulp mill has decreased appreciably. Furthermore the losses of fiber in storage as well as the degree of deterioration have both been decreased to a minimum in some cases.

Depithing

A deterrent to early efficient and successful use of sugar cane bagasse was its pith content. Therefore, pith separation from fiber is critically needed to upgrade bagasse prior to pulping. These cells have a unique facility for picking up and retaining dirt, soil and other extraneous materials that contributes to excessive demands for chemicals in the cooking and bleaching stages. Pulps containing appreciable amounts of pith are deficient in strength properties and lack the brightness and general good appearance associated with high grade printing papers. Although the pith contributes to apparent yield, the cooked pith becomes gelatinous and causes slow drainage.

Several procedures for depithing have been developed and have been proved effective and practical in laboratory and mill operations. Basically there are threemethods for depithing:

1. Dry depithing - Performed with stored bagasse.
2. Humid or moist depithing - performed with bagasse as it comes from the cane mill.
3. Wet depithing, usually conducted with bagasse coming directly from the cane mill, but may also be performed with stored bagasse.

Further description of depithing and storage methods is extensive and beyond the scope of this paper. However, the excellent progress in developing new bulk storage methods, combined with the success of the modern depithing methods, has given bagasse a great push forward toward becoming a major raw material for the manufacture of pulp, paper and board.

Pulping

Based on the chemicals employed to pulp raw materials, there is much similarity in the pulping of woods and the pulping of bagasse.[9] The physical characteristics differ sufficiently so that the manner in which the two types of materials are handled is quite different. The processes used for pulp making from this agricultural residue may be batch or continuous. However, bagasse, being an open type fibrous material, is uniquely suited for pulping through a continuous digestion system if air is vented out in order to prevent cellulose degradation. In addition, its open structure and low lignin content permits this fibrous material to be rapidly pulped with milder cooking conditions.

Bagasse is amerable to various pulping processes such as kraft or soda as well as chemimechanical methods to produce pulps in low Kappa numbers for the various paper grades. The chemical and physical properties of bagasse pulps vary with the pulping process applied. There is a wide range of types of bagasse pulps produced. These vary from the very high yield mechanical pulps to the highest quality pulps used in printing papers.[13]

Chemically and physically, bagasse reacts easily with alkaline pulping agents. The choice between soda or kraft processes for pulping depends largely upon the availability of make-up chemicals and their relative price. When unbleached pulp is used for paper making, no doubt kraft pulping is preferred due to higher yield and better strength properties.[16] The pulp properties are greatly influenced by the degree of delignification. Fibers become stiffer and have lower bonding capacity as the lignin content of the pulp increases.

Cooking agent applied, concentration and cooking time are comparable to conditions for pulping light weight hardwood species with low lignin content, and are inferior to the requirements of tropical species of high density.

Semichemical process yield pulps of comparatively inferior quality particularly with respect to brightness level of fully bleached pulp. The pulp contains a high percentage of specks and shives. This process is not satisfactory for first quality writing and printing grades.[13]

A few other processes such as De-la-Roza, Pomilios, Simon-Cusi, Villavicencio-Ayotla and other modified soda and kraft processes have been tried, which so far have not found wide commercial application.[11]

Economics

The entire economics of utilizing bagasse for the manufacture of pulp and paper, is dependent to a great extent upon the basic purchase price of the bagasse fiber delivered at the sugar mill conveyer, plus the cost of handling, bailing storing and preserving it to achieve the least possible losses. Sound and logical methods have been developed between the sugar mills and the pulp mills for establishing the basic purchase price of bagasse, based essentially on its fuel replacement value plus a small premium.[12]

It is economically desirable to remove as much pith from the bagasse at the sugar mill. This procedure results in appreciable savings in handling, storage, transportation and recovery costs. Furthermore, the purchaser pays for only the partially depithed fiber removed from the sugar mill, and the sugar mill gets some fuel value from the pith.[12]

CORRUGATED MEDIUM

The medium is the fluted paper in corrugated boxes that can provide some product protection to fragile items. It is made from a variety of sources. The majority of the medium used comes from hardwood semi-chemical pulps. However, there is an increasing trend to use 100% recycled fiber for its manufacture.

Properties of the Medium

The medium sheet is rather porous and weak. It is very receptive to moisture, since in the corrugating process, steam and heat are applied in rder to plasticize the sheet for improved fluting. There are two restrictions placed on the medium in terms of basis weight and caliper. These are:

1. Corrugating medium shall not be less than 26#/MFS
2. Corrugating medium shall not be less than .009" thick

Uniformity in caliper is important since any caliper variations can cause blisters at the corrugator.

In order to optimize the medium performance, several properties are controlled and measured. There are other tests, in addition to caliper and basis weight, that measure these properties and are routinely done. They include:

1. Float
2. Porosity
3. Edge Crush
4. Tensile Strength
5. Concora Medium Tests

The float test measures rate of water adsorption into the sheet. This test is important since moisture must be readily absorbed by the medium in order to condition it for fluting. This preconditioning operation is also important since the adhesive used is about 75% water and starch. The medium must absorb this adhesive in order to bond the various components of the corrugated board.

Porosity is the measure of resistance of a column of air by the paper. Porosity in medium is not widely understood. However, if the porosity is too high, uniform flute formation cannot be achieved.

Tensile strength is useful in wet strength properties of the paper. When conditioned with steam, the medium has to resist enough tensile strain to avoid breaking of the web.

The edge crush strength of a single sheet is mainly measured by the ring crush test. The following formula correlates ring crush test results with the edge column crush of single faced corrugated board:

$$EDD = 1.065\,(L_1 + L_2 + TU \times M) + 1.24$$

where: ECC = Edge Column Crush
L_1, L_2, M = Ring crush test results of the two liners and the medium.
TU = Take up ratio for medium which is defined as the total lineal feet of medium in a single lineal foot of combined board.

From the ECC, the compression strength of a finished corrugated box may be derived. These properties are very important to the convertor since many customers usually demand a box that performs under compression load as their primary requirement.

Finally, the Concora Medium Test, CMT, is a measure of resistance of the fluted medium to crush in the flute direction. The standard CMT value which most companies use is 60 units. When the CMT values begin to decrease, the board has less resistance to crush. Therefore, when the CMT value drops below

50 units, there is a significant detrioration in board quality.

Effect of Pulping of Medium Properties

"In processing corrugating medium on a high speed corrugator, the strength of the paper is of primary importance. A large number of factors influence the strength of the flutes in the corrugating medium, among which pulp yield plays an important role."[17]

It is generally known that many strength properties of semichemical pulps and kraft pulps such as tensile, burst, tear, etc. have a definite relationship to yield, since the lower the yield, the better is the average strength. A certain degree of disagreement appears in the literature. For example, Dahm studied NSSC and cold caustic semichemical pulps for corrugating medium in the yield range of 78.5 to 84.4% and found that the maximum obtainable CMT seems to be independent of yield in the case of cold soda and that there does not seem to be any advantage in reducing the yield of NSSC pulps below 81% as far as the level of maximum obtainable CMT values is concerned.

When dealing with high yield pulps, the number of fibers does not increase with the yield, instead, a high yield means that each fiber contains more lignin and hemicelluloses.

In semichemical pulps, the fibers are generally quite stiff. As the cooking time increases, the fibers lose their stiffness permitting the formation of more bonds. Increased bonding results in higher strength properties.

The variation of the paper properties with surface area, bonding area and sheet density and consequently with yield, implies that in the manufacture of corrugating medium, calendering should be kept at a minimum since the reduction in caliper is not accompanied by an increase in bonding. An increase in the lignin content beyond a certain level decreases the Concora value. The presence of lignin at low fluting speeds and high corrugating roll temperature will not cause cracking and breakage of the flutes. However, at normal speeds and temperatures, the increasing lignin content can be detrimental to the corrugating operation. This effect is most probably due to the ability of lignin in the pulp to soften at elevated temperatures thus minimizing the damage suffered by the fibers when shear, bending and tensile forces are applied in the operation.

Therefore, the corrugating medium behaves essentially as a thermoplastic material. The strength of the flutes in highly dependent upon the temperature attained by the medium in the corrugating operation, since upon cooling, these thermosoftening components set on and add strength to the flutes.[19]

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RAW MATERIALS

Due to the limited amount of available material, the bagasse was obtained from two different sources. The first batch, stored in New York by Elof Hansson, was imported from Mexico. Except for the pith content of 11.4%, the physical and chemical characteristics of this bagasse were unknown. The second batch was obtained from the Auburn Sugar Institute at Louisiana State University. Analysis of the bagasse done at the Sugar Institute showed the following chemical composition:

41.6%	Hemicellulose
38.5%	Cellulose
18.2%	Lignin
1.7%	Solubles

The pith content also determined at this Institute was 9.3%. This bagasse sample was fresher than the first, since the grinding period in Louisiana was ended in November, 1983.

PROCEDURE

The approach taken to pulp the bagasse was very similar to the pulping of wood. In order to ensure a representative sample of bagasse for each cook, quartering was used as the means selection. The pulps under study were pulped in the Laboratory M and K Digester. A cooking procedure using this digester was developed so that the time to reach temperature was decreased. The left digester was preheated with water to 195°C while the cooking liquor in the right digester was brought up 30°C above the actual cooking temperature. When the water was at 195°C, it was drained and the basket with the weighed bagasse was placed in the digester. Opening of the crossover valve allowed the cooking liquor to enter the left digester due to the pressure differential. The crossover valve was closed and the cooking began. Upon termination of the cook, the waste liquor was returned to the right digester which had been previously cooled down with tap water. With this method, the bagasse was subjected to quicker cooking conditions. A detailed description of this procedure can be found in the Appendix.

The working temperature (160°C) and the bagasse-to-liquor ratio (1:10 were kept constant. The bagasse was pulped as follows:

BATCH #1

Pulping Method	Active Alkali	Sulfidity	Time at Temp.(min)	Time to Temp.(min)
Soda	10%	0	15	16
Soda	14%	0	15	17
Kraft	10%	20%	15	15
Kraft	14%	20%	15	15
Kraft	10%	5%	15	16

BATCH #2

Pulping Method	% Sulfur Dioxide	pH	Time at Temp.(min)	Time to Temp.(min)
NSSC	10	10	15	17
NSSC	15	10	20	19
NSSC	30	10	30	18

After cooking, the pulps were defiberized with the one gallon Waring Blender and then passed through the 14/1000 laboratory slotted screen. The pulps were refined to 250 ml. C.S.F. with the PFI mill. Handsheets were made using the Noble and Wood Mold together with the recirculator and the suction pump. These handsheets were produced to follow the specifications of corrugated medium in basis weight and in caliper, such as 120 grams per square meter and .009 inches thick.

The sheets were conditioned at 50% RH and 72^{o}C before testing. The results performed throughout the procedure can be classified as:

I. Liquor
- A. Soda and Kraft
  - 1. White Liquor
    - a. Active Alkali
    - b. Sulfidity
  - 2. Black Liquor
    - a. Active Alkali
    - b. No Sulfidity
- B. N.S.S.C.
  - 1. Original Liquor
    - a. Combined and Free Sulfur Dioxide
    - b. pH
  - 2. Waste Liquor
    - a. pH

II. Pulp
- A. Permanganate Number
- B. Freeness
- C. Rejects
- D. Clark Classifier
- E. Yield

III. Handsheets
- A. Caliper
- B. Basis Weight

III. Handsheets (Cont.)

C. Tensile

D. Burst

E. Concora Medium Test

F. Concora Ring Crush

RESULTS

The following tables summarize the physical characteristics of the pulps produced:

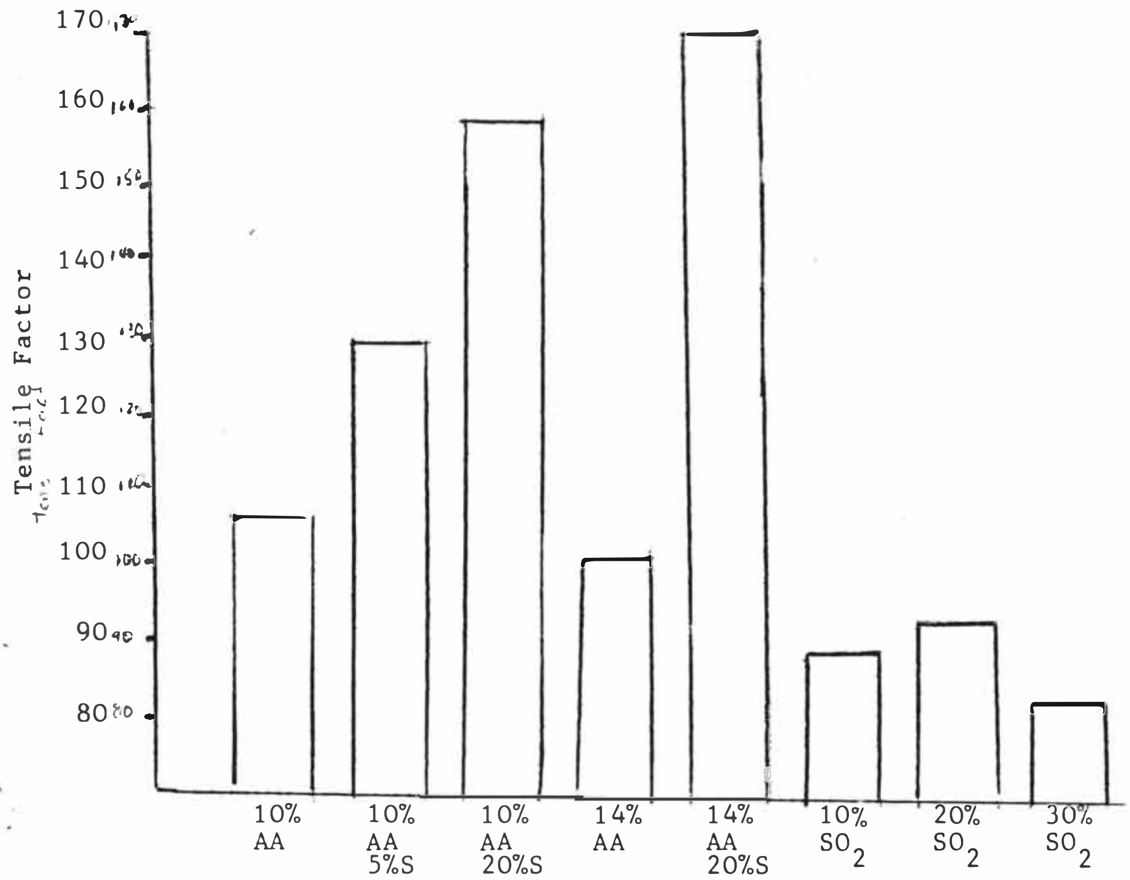
	Soda		Kraft			NSSC		
	10% AA	14% AA	10% AA 20% S	14% AA 20% S	10% SO_2 5% S	10% SO_2	15% SO_2	20% SO_2
Permanganate No.	13	12	9.6	8.7	10.3	11.0	10.8	12.0
Freeness CSF (ml)	290	287	293	285	290	292	305	295
Yield (%)	---	---	---	56%	-----	73%	-----	72%
Rejects (%)	0	0	0	0	0	1.3%	.4%	0

The very low freeness values obtained for all the cooks can cause drainage problems in papermaking from bagasse pulps. These freeness can be attributed to the pith content of the pulp and to the high fines fraction. These freeness tests were performed before any refining was done. The clark classifier shows that the bagasse pulps obtained have a higher fines content and lower long fiber fraction than any hardwood pulp. This fact may partially explain why most of the bagasse pulps have proven to have overall lower strength values than the hardwood pulps used in corrugating medium.

Mesh	Kraft (10% AA) 5% S	NSSC (15% SO_2)
15	7.5	6.8
30	26.2	27.5
45	20.7	19.3
100	13.4	15.2
Fines	32.2	31.2

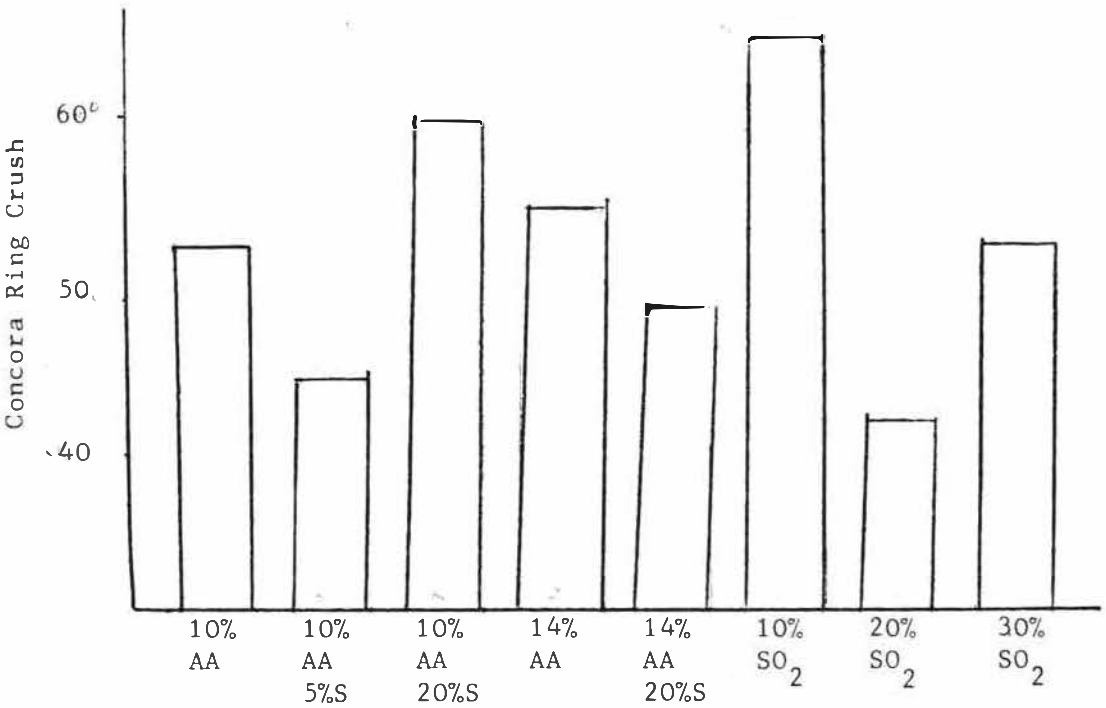
The most important tests made with the prepared pulp are the tensile, burst, Concora Medium Crush and the Concora Ring Crush. The tests describe the rheological properties which give a good indication of the pulp's final use.

At these low active alkali levels, a positive action of the sodium sulfide can be observed. Both the burst and tensile values increased as the sodium sulfide concentration increased the NSSC cooks showed the lowest strength values, especially at the 20% combined SO_2 level.



	10% AA	10% AA 5%S	10% AA 20%S	14% AA	14% AA 20%S	NSSC 10% SO_2	NSSC 10% SO_2	NSSC 10% SO_2
Burst Factor (psi)	86.5	87.5	97.3	89.7	99.2	50.3	57.6	51.4
Concora Ring Crush	56	63.2	48	47.8	55.1	58	45	46

The Concora tests showed their highest values with the 5% Sulfidity Kraft cook and the NSSC cook at 10% combined SO_2. The remaining pulps demonstrated decreasing values of Concora Medium crush and Concora Ring Crush. Kraft cooks had similar values when compared to the soda cooks. However, the NSSC pulps showed the lowest values although they had a higher lignin content as indicated by the Permanganate number. In this case, the lignin content had very little to do with the concora values since the harsher cooking conditions increased the rate of carbohydrate hydrolysis or degradation. The sulfite-bisulfite system reacted with the lignin but did not neutralize the weak organic acids formed. The lignin, instead of reacting with the cooking liquor, precipitated, and gave what appeared to be a "burnt cook".



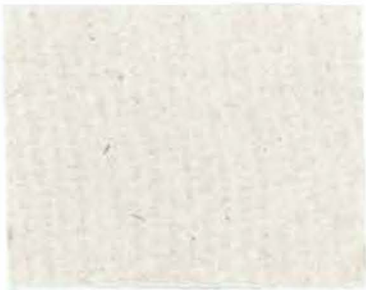
Therefore, the Kraft cook at 5% sulfidity and the NSSC cook with 10% combined Sulfur Dioxide gave CMT and CRT values that are found acceptable by most companies that produce corrugated board. The low tensile and burst values attained by the 10% combined Sulfur Dioxide, NSSC, are still adequate for fluting since the sheet is strong enough to avoid causing excessive breaking of the web.

CONCLUSIONS

The physical properties of the bagasse pulps varied with the pulping process applied. Pulp properties were greatly influenced by the degree of delignification. Fibers became stiffer and had a lower bonding capacity at the higher lignin content of the pulp.

The data collected demonstrates that the Kraft cook at 5% sulfidity and the NSSC cook with 10% combined Sulfur Dioxide gave bagasse pulps that can be used to produce corrugated medium.

As can be observed from the two samples below, the NSSC cook needs mechanical action in order to defiberize it. A further breakdown of these fibers might increase their surface areas and therefore increase the bonding to obtain a sheet with stronger physical properties. The NSSC is more suitable for corrugating medium since it gives a higher yield with admissible Concora Ring and Medium Crush values.



RECOMMENDATIONS

It would be advantageous to further study these pulps in order to find a method that would increase their freeness. Further fractionation or depithing after cooking might get rid of a large percentage of the fines and pith in order to increase their drainage rate. At this point, it would not be economically feasible to produce corrugated medium from bagasse pulps in this study since machine speeds have to be decreased.

On the other hand, the new digester procedure proved to be invaluable in the processing of these semichemical pulps. I strongly recommend this pulping method when the maximum temperature has to be reached rapidly or when the raw material does not require too much time for liquor penetration.

APPENDIX I

PULPING PROCEDURE WITH THE M & K LABORATORY DIGESTER TO YIELD SEMICHEMICAL PULPS

1. Make sure the crossover valve and the bottom drain valves are closed. Place five liters of water in the right compartment, set temperature to 195°C. Turn on the pump, the controlled heater and the continuous heater.

2. Place the calculated amount of cooking liquor in left digester. Set temperature to 30°C above cooking temperature. Turn on the ulp, and both heaters.

3. Place cover on both digesters. Have valve open and vent pipe at the respective sides of the apparstus. Tighten thumb nuts hand tight.

4. When digesters reach 100°C, close vent line valve to stop discharge.

5. When digesters reach the desired temperature, turn off all heaters.

6. In the right digester:
   - A. Crack top vent valve to relieve the pressure
   - B. Open drain valve and evacuate water.
   - C. Remove top lid and place basket with 400 g O.D. bagasse.
   - D. Close drain and vent valve, place lid and tighten thumb nuts.
   - E. Slow open the crossover valve to allow pressure to slowly push the liquor into the right digester.
   - F. When the pressure (as indicated by the gauges) in both digesters is equal, close crossover valves.

7. Turn both heaters and pump on right digester, set temperature to cooking temperature.
8. In the left digester:
   - A. Crack vent line valve to relieve pressure.
   - B. Drain remaining cooking liquor by opening bottom drain valve (usually less than 100 ml)
   - C. Pour cold water until digester has cooked down to room temperature, drain.
   - D. Put lid on, close all valves.

9. When the right digester reaches the cooking or set temperature, turn off the continuous heater and start timming cook. Record time to reach temperature.

10. Upon completion of cook, turn off heater and pumps. Open crossover valve to push liquor into other digester.

(Cont.)

11. Vent both digesters to relieve pressure.

12. Drain liquor and collect approximately ½ guart of black liquor for testing.

13. Remove top lids and basket.

14. Clean digesters.

PROCESSING THE COOKED PULP

Drain black liquor from bagasse using Buchner funnel with plastic. Place the cooked bagasse in large Waring blender and disintegrate for 30 seconds. Save approximately 3 O.D. grams of pulp to detetmine Permanganate Number. Screen the pulp through the laboratory slotted screen. Refine in the PFI mill at 100% until a 250 ml CS Freeness is obtained.

The refined pulp was made into handsheets using the Noble and Wood handsheet mold with the old of the proportionator and suction pump. A special precaution to be taken in the handsheet making is that more pulp is needed than indicated by pulp slush consistency calculations. The bagasse shows some fines are lost through the wire during the sheet making procedure.

The handsheets were made to a basis weight of 120 g/m^2 and a caliper of .009 inches. They were conditioned at 50% RH and 72^{o}F. The tests were performed on the pulp following TAPPI Standards as follows:

Caliper (T411 os76)
Basis Weight (T410 os 79)
Tensile (T404 os75)
Burst (T807 os75)
Concora Medium Crush and Concora Ring Crush (T809 os71)
Freeness (T227 os57)
Clark Classifier (T233 os75)

The liquor tests were also run according to T624 os68 for white liquor, T625 os64 for black liquor and T604 for combined and free SO_2.

The black liquor test for sulfidity could not be carried out because the suitable silver electrodes were unavailable.

Instead of running Kappa number on the pulp, the Permanganate number (T217) was used because the literature on bagasse pulping is based on the latter number. The Permanganate number is used to measure the degree of delignification in countries that use bagasse for papermaking.

APPENDIX

Liquors

	Soda and Kraft				
Active Alkali (g/l)	98.9	98.9	90.6	93.5	91.2
Sulfidity	0.0	0.0	17.8	18.3	4.9
Residual Active Alkali (g/l)	26	24	36	33	35

	NSSC		
Combined SO_2 (g/l)	9.6	16.3	27.5
Free SO_2 (g/l)	2.2	2.3	0
pH Initial	9.8	9.7	10.2
pH Final (Waste Liquor)	7.6	8.3	6.4

APPENDIX

(Cont.)

Handsheets

	Soda			Kraft		NSSC		
	10% AA	14% AA	10% AA	15% AA	10% AA	10% SO_2	20% SO_2	30% SO_2
Maximum Caliper*	11.3	10.4	12.5	13.6	11.5	10.7	11.6	12.2
Avgerage Caliper*	9.5	9.7	9.5	9.3	9.4	9.3	9.2	9.3
Minimum Caliper*	9.2	9.0	6.7	9.1	9.3	9.1	8.7	8.8
Basis Weight (g/m^2)	122 g/m^2	120 g/m^2	120g/m^2	120g/m^2	121g/m^2	120g/m^2	120g/m^2	120g/m^2

* = 1/1000 in.

The handsheets were selected so that they weightd 120g/m^2. All others were rejected and not used to testing.