CHARACTERIZATION OF SUGARCANE FIBROUS ELEMENTS

J. Fernández, O. Triana and E. Peña

Pulp and Paper Research Institute, Cuba-9, Havana, Cuba

ABSTRACT

The chemical and morphological characteristics of sugarcane fibrous element were studied. It was found that rind fibers are longer and more lignified than the rest of cane fibers; however, its flexibility ratio is greater than those of bagasse and similar to softwood fibers, so that they represent the higher sugarcane papermaking potential. New sugarmaking technologies allowing the separation of the fiber fraction from the cane stalk are reviewed. On the other hand it has been shown that by-products of sugarcane harvesting have adequate characteristics for being used in pulp and paper industry.

Key words: Sugarcane, sugarmaking, fibers, pulping.

INTRODUCTION

Sugarcane cultivation is restricted generally to a zone extending round the world at the equator and limited by approx. 30° North and South latitudes. In these areas are located a lot of developing countries having the role of making reality the possibilities that sugarcane and its by-products offer to economy diversification.

As a result of the tremendous increase in the world wide consumption of pulp and paper, there has been a trend toward greater utilization of agricultural fibers in such countries not having adequate quantities of traditional pulpwod species. At present, the utilization of bagasse as a raw material for several productions has gained a growing importance. It is used not only as fuel in the sugar mill but also as a suitable material for pulp, paper, and board manufacture, as well as animal feed by using the pith. Additionally bagasse will become a potential raw material in the production of furfural, activated carbon, and molding products. On the other hand the utilization of sugarcane residues is a promising way to assure a relative cheap source of lignocellulosic material for papermaking. It is the purpose of this paper to show a valuable information concerning the chemical and morphological characteristics of the different fiber types present in the sugarcane.
EXPERIMENTAL PROCEDURE

The sugarcanes selected for this study were manually cut from the canefield. The leaves, tops and trash were carefully separated from the stalks. After removing the epidermis, the stalks were crushed in a pilot plant with three regular sets of sugar milling rolls used for juice extraction. The separation of the hard outer rind of the crushed stalks from the soft inner tissue was made by hand.

Both these fractions as the tops and leaves were cut to about 5 cm. length and soaked overnight, treated in a model 105-A Sprout Waldron refiner equipped with 305 mm D2A-507 plates to produce the detachment of fiber bundles in a wetted process where the water acts to cushion the impact between metal and fiber avoiding the cutting action of the refiner. Mechanical separation of the pith and fiber fractions was effected through a vibrating screen with the addition of water. Chemical and biometrical properties were determined according to TAPPI standards.

RESULTS AND DISCUSSION

The sugarcane structure has widely been described in the specialized literature but here we shall particularly devote ourselves to the characteristics more relevant to the pulp and paper industry.

The cane stalk consists of two parts: the rind and the softer tissue in the interior, interspersed with fibrovascular bundles. The rind consist of two components: the epidermis and a layer of thick walled cells.

Figure 1 shows the fibers from the rind. There are basically thick walled fibers with narrow lumen, relatively long and thin walled fibers with wide lumen having a shorter length. The fibrovascular bundles consist of vessels and sieve tubes surrounded by thin walled fibers.

Figure 2 shows that most of the fibers of this component are fines, of thin wall with dull edges, forked or bifurcated.

Dr. Cusi advocated this trait of fibrovascular bundles fibers when he proposed a technology for producing newsprint from bagasse. This process is based on the theory that chemicals act more rapidly on the fibrovascular bundles than on the rind fibers due to their greater surface area and to the fact that they contain ducts which make the penetration of the chemicals into them more rapidly. A mild caustic soda digestion followed by a fiber classification yields two types of fibers that are separated and nominated "A" and "B". "A" is the most digested fibers from the central portion of the stalk and "B" is the resistant rind that remain almost raw and need further refining until it becomes pulp. These two fractions are blended again, screened and semibleached.
FIGURE 1. Fibers from the rind.

FIGURE 2. Fibers from the fibrovascular bundles.
Tamil Nadu process for newsprint also is based on the heterogeneity of bagasse fibers. Depithed bagasse is submitted separately both to a thermomechanical (TMP) and a chemical pulping (CP) process. The fine, thin walled fibers from the fibrovascular bundles and parenchyma cells are reduced to a high opacity fine fraction, meanwhile most of the resistant fibers from the rind are present in the long stiff coarse fraction after the fractionation system. This last fraction is mixed with the impregnation liquor to produce a chemimechanical pulp (CMP).

The TMP and CMP are combined and treated with peroxide into a bleaching tower. Then this high yield pulp is blended with bleached bagasse chemical pulp and hardwoods chemical pulp.

Pith is the other component of the stalk. It is composed by delicate thin walled cells grouping around and adhering both to the fibrovascular bundles and the rind fibers. This material, in fact, accentuates pulping and papermaking problems, that is why, it needs to be removed from the fiber fraction as much as possible.

In Figure 3 it can be observed that tops are composed of different kinds of fibers. There are elongated thick walled fibers like in the rind and short and fine fibers like in the green leaves, they also contain cylindrical and spherical parenchymatous cells.

The distinguished trait of sugarcane attached dead leaves is their relative great length and thin wall. As seen in Figure 4 some flexible ribbon-like fibers and nonfiber elements are also present.

The fibers from the green leaves are relatively short and fine. Figure 5 shows that they also contain very short nonfiber elements.

Bagasse is the fibrous residue remaining after the juice extraction in the sugar mill. It is composed fundamentally of three elements from the stalk, e.g. the rind, fibrovascular bundles and pith, to which some fragments of green leaves, tops, attached dead leaves and dirt must be added.

When compared with the traditional source of papermaking fibers, bagasse has the disadvantages of having a greater variety of cell types and greater percentage of nonfiber elements as seen in Figure 6.

On the other hand, in crushing cane stalk to remove juice, a lot of fibers are damaged, resulting in a bagasse of lower quality. For all these reasons, the development of non-conventional procedures in sugarmaking which do not cause fiber damage are expected to materially increase the overall fiber length and improve the strength obtainable with bagasse pulps.
FIGURE 5. Fibers from the green leaves.

FIGURE 6. Fibers from bagasse.
In this sense, two new processes have been submitted to experimentation. They are known as Separator Process and Monda Technology.

Separator Process is based on the technique of separating the hard outer rind of the sugarcane stalk from the soft pithy tissue containing the sucrose by using a machine denominated "Separator". This process can yield a wax and pith-free fiber fraction which has optimal morphological and chemical characteristics for the production of paper and board.

Monda Technology is based on the principle of separating the sugarcane stalk in its two basic components: the fibers and the pith. High efficiency techniques are applied for juice extraction in both components. The fibrous fraction so obtained is of high quality for pulping and board. It presents a low content of pith, solubles and fines.

The biometric properties of sugarcane and some wood species fibers are summarized in Table 1.

- The fibers from the rind are longer than those of hardwoods and bagasse. The fiber length of attached dead leaves and tops are of the same order, meanwhile the green leaves and fibrovascular bundles fibers present the shortest length.

- In general, the wall thickness of the fibrous portion of cane stalk and bagasse is superior to that of wood fibers, related to diameter width. This is one of the most important disadvantages of such materials due to the great stiffness of the fibers which is negative in mechanical and thermomechanical pulping because they produce a flour-like pulp and require a higher energy consumption during refining to collapse them. The best fiber from sugarcane residues correspond to the attached dead leaves. They present a relation length-to-diameter superior to wood fibers and mostly have a greater length than bagasse fibers.

Although traditionally these agricultural residues have been used as animal feed and more recently as fuel because of their calorific value, it is evident that technically they present suitable chemical and morphological properties for being used in paper production, however, more attention have to be paid on economical aspects concerning the collection, handling and storage of such materials.

The analytical data on chemical composition of sugarcane fibrous elements, bagasse, hardwood and softwood are summarized in Table 2.

- The cellulose content in fibers from the cane stalk are superior to the corresponding agricultural residues. The rind fibers cellulose content is equivalent to that of softwoods or slightly superior to that of the hardwoods.
TABLE 1. Fiber dimension of different fibrous sources.

<table>
<thead>
<tr>
<th>Fibrous sources</th>
<th>Average length (mm)</th>
<th>Average diameter (mm)</th>
<th>Length-to-diameter ratio</th>
<th>Lumen width (mm)</th>
<th>Wall width (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rind</td>
<td>1.79</td>
<td>0.0195</td>
<td>92.0</td>
<td>0.0077</td>
<td>0.0059</td>
</tr>
<tr>
<td>Fibrovascular bundles</td>
<td>0.97</td>
<td>0.0185</td>
<td>52.4</td>
<td>0.0095</td>
<td>0.0045</td>
</tr>
<tr>
<td>Attached dead leaves</td>
<td>1.55</td>
<td>0.0139</td>
<td>111.4</td>
<td>0.0066</td>
<td>0.0036</td>
</tr>
<tr>
<td>Tops</td>
<td>1.49</td>
<td>0.0150</td>
<td>99.6</td>
<td>0.0057</td>
<td>0.0046</td>
</tr>
<tr>
<td>Green leaves</td>
<td>1.15</td>
<td>0.0117</td>
<td>98.2</td>
<td>0.0047</td>
<td>0.0035</td>
</tr>
<tr>
<td>Bagasse</td>
<td>1.5</td>
<td>0.0192</td>
<td>78.1</td>
<td>0.0100</td>
<td>0.0046</td>
</tr>
<tr>
<td>Softwood (pine) (Pinus silvestris)</td>
<td>2.9</td>
<td>0.0280</td>
<td>103.6</td>
<td>0.0210</td>
<td>0.0032</td>
</tr>
<tr>
<td>Hardwood (beech) (Fagus silvatica)</td>
<td>1.5</td>
<td>0.0140</td>
<td>107.1</td>
<td>0.0074</td>
<td>0.0033</td>
</tr>
</tbody>
</table>

The pentosan content of sugarcane or bagasse is quite high compared with wood. For this reason it can be expected that pulps made from sugarcane fibers beat faster and develop greater strength than corresponding pulps containing less pentosans, but consequently the paper produced are denser and less opaque. The more lignified cells are in the rind and fibrovascular bundles, meanwhile the lower lignin contents are in green leaves and tops. The lignin content of bagasse is lower than the corresponding values for softwoods and about equal to that of the hardwoods. The agricultural residues of the cane contain more ash than the fibrous elements of the stalk. The higher ash content of the pith compared with the rind and fibrovascular bundles is associated with a greater absorption of impurities due to its higher surface area.

High amount of silica is present in attached dead leaves and green leaves. On the other hand the silica content of bagasse is superior to the corresponding values for wood. The calcium content is higher in tops than in any of fibrous elements of stalk. The higher values for magnesium content correspond to the green leaves and tops. Meanwhile the iron content is superior in tops probably due to the presence of certain
### TABLE 2. Chemical composition of sugarcane fibrous elements.

<table>
<thead>
<tr>
<th>Chemical analysis (%</th>
<th>Rind Fibrovascular bundles</th>
<th>Pith Attached dead leaves</th>
<th>Tops Green leaves</th>
<th>Bagasse Softwood (pine)</th>
<th>Hardwood (beech)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot water solubility</td>
<td>2.02</td>
<td>2.44</td>
<td>4.52</td>
<td>6.63</td>
<td>6.83</td>
</tr>
<tr>
<td>Alcohol-benzene solubility</td>
<td>1.45</td>
<td>1.29</td>
<td>1.76</td>
<td>0.61</td>
<td>1.28</td>
</tr>
<tr>
<td>1% NaOH solubility</td>
<td>23.0</td>
<td>23.16</td>
<td>30.24</td>
<td>28.29</td>
<td>36.10</td>
</tr>
<tr>
<td>Cellulose</td>
<td>50.70</td>
<td>49.11</td>
<td>47.5</td>
<td>44.95</td>
<td>43.54</td>
</tr>
<tr>
<td>Lignin</td>
<td>20.94</td>
<td>20.76</td>
<td>18.57</td>
<td>17.70</td>
<td>16.10</td>
</tr>
<tr>
<td>Pentosans</td>
<td>29.96</td>
<td>30.28</td>
<td>32.82</td>
<td>30.85</td>
<td>33.65</td>
</tr>
<tr>
<td>Ash</td>
<td>0.10</td>
<td>1.07</td>
<td>1.72</td>
<td>1.85</td>
<td>1.62</td>
</tr>
<tr>
<td>SiO₂</td>
<td>0.15</td>
<td>0.16</td>
<td>0.39</td>
<td>0.98</td>
<td>0.28</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.0125</td>
<td>0.0126</td>
<td>0.0128</td>
<td>0.008</td>
<td>0.0139</td>
</tr>
<tr>
<td>CaO</td>
<td>0.008</td>
<td>0.010</td>
<td>0.004</td>
<td>0.003</td>
<td>0.012</td>
</tr>
<tr>
<td>MgO</td>
<td>0.003</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.007</td>
</tr>
</tbody>
</table>

Pigments. The iron content for bagasse is over the corresponding values for wood. It is due to the presence of dirt derived from sugarcane harvesting methods.

### CONCLUSIONS

The rind fibers are longer and more lignified than the rest of the sugarcane fibrous elements and are characterized by a higher cell wall thickness. However, its flexibility ratio is greater than bagasse and hardwood fibers so that they represent the higher papermaking potential of the cane. A favorable contribution can be expected from sugarmaking processes allowing the separation of the fiber fraction of cane stalk in such a way that can be avoided the shortening and damages they suffer in traditional sugar milling can be avoided. Compared with the chemical composition of wood, fiber separated from bagasse is lower in lignin content in most cases than either the softwoods or hardwoods and contains more pentosans and more soluble matter in 1% NaOH.
The agricultural by-products of sugarcane harvesting, which commonly are used for animal feed and as fuel, have adequate chemical and morphological characteristic for being utilized in pulp and paper industry.

REFERENCES

Les caractéristiques chimiques et morphologiques des éléments fibreux de la canne à sucre furent étudiées. Les fibres de l'écorce sont plus longues et contiennent plus de lignine que les autres fibres de la canne; toutefois le rapport de flexibilité est plus grand que celui de la bagasse et identique aux fibres de bois mou, de sorte qu'elles représentent le plus grand potentiel de la canne à sucre pour la fabrication de papier. On a passé en revue les nouvelles technologies qui permettent la séparation de la partie fibreuse de la tige de canne. On a aussi démontré que les sous-produits de la récolte de la canne ont les caractéristiques voulues pour être utilisées en fabrication de pâte à papier.

CARACTERIZACION DE LOS ELEMENTOS FIBROSOS DE LA CAÑA DE AZUCAR

J. Fernández, O. Triana y E. Peña

Instituto de Investigaciones de la Pulpa y el Papel, "CUBA-9"
Quivicán, La Habana, Cuba

RESUMEN

Se estudiaron las características químicas y morfológicas de los elementos fibrosos de la caña de azúcar. Se encontró que las fibras de la corteza son más largas y lignificadas que el resto de las fibras de la caña; sin embargo su razón de flexibilidad es mayor que la del bagazo y similar a las fibras de madera blanda, por lo que representan el mayor potencial para la producción de papel a partir de la caña. Se revisaron las nuevas tecnologías de producción de azúcar, que permiten la separación de la fracción de fibras del tallo de la caña. Por otra parte, se ha demostrado que los subproductos de la cosecha cañera tienen características adecuadas para ser empleados en la industria de pulpa y papel.

Palabras claves: Caña de azúcar, fibras, pulpeo.