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## VARIATION OF FIBER COMPOSITION IN SUGAR CANE STALKS

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### ABSTRACT

A knowledge of the distribution of the sugar cane fiber's basic constituents—cellulose, hemicellulose, lignin—in the stalk, is necessary for a rational utilization of bagasse (principal by-product of the sugar cane industry). It is shown that concentration of these above-mentioned compounds varies with location in the stalk. An attempt is made to relate the chemical content variation of the fiber with age of the cells in the stalk.

*Keywords:* sugar cane fiber, stalk, cellulose, hemicellulose, pentosan, lignin.

### INTRODUCTION

Bagasse is the fibrous residue left when sugar cane is milled. Its principal use is as fuel for the sugar mill's furnaces. Bagasse has also been used, but less successfully as paper-making material, as a cattle feed (Biswas 1957; Knapp et al. 1957), and as a source of furfural derived from its high pentosan content. When workers investigated the use of bagasse as a raw material for chemical derivatives, they usually gave the results for ash, lignin, pentosan and cellulose contents (Knapp et al. 1957; Falcon and Rodriguez 1959; Amaral and Ramos 1959; Chatgey and Haksar 1959), but only a few papers have been written giving the method of isolation and identification of the major bagasse constituents (Guha and Pant 1964; Pathak and Srinivasan 1964; Bannerjee et al. 1960, 1961, 1964; Murphy and Richards 1968). Unfortunately, most of the workers have utilized different extraction procedures and varieties of sugar cane, and so the results they gave are not comparable.

In the search for other alternative chemical uses for sugar cane fiber, it is necessary to have a knowledge of the amounts of its major chemical constituents as well as their distribution throughout the sugar cane stalk. This is the aim of the present study.

### EXPERIMENTAL

Two varieties of sugar cane have been studied: BT 64134 (yellow) and 65966 (blue). Each variety is divided into five fractional parts: B<sub>1</sub>, B<sub>2</sub> (bottom); M<sub>3</sub>, M<sub>4</sub>

(middle); T (Top). Individual analyses of each part will indicate whether variation exists between and/or within varieties.

Approximately 500 g of ground sample were filtered under negative pressure through a büchner funnel with a fritted disc (coarse porosity). The remaining residue was washed with successive 250 ml fractions of distilled water at 50–60 C. The amount of sugar in 100 ml of each filtrate was so determined:

- a) by polarimetric method for amount of sugar greater than 1 g of sucrose per 100 ml of solution;
- b) by the colorimetric Anthrone method for amount of sugar less than 1 g per 100 ml of solution.

The filtration was stopped when the amount of sugar in the filtrate was less than 0.03 g per ml. This generally necessitates  $30 \times 250$  ml of distilled water. The insoluble residue was dried at 105 C to constant weight, then pulverized in a crushing machine, and finally sieved. All the analyses of the fiber have been performed on particles of diameter between 0.16 and 0.40 mm. Two kinds of analysis have been made: the classical elemental analysis (performed by: Service Central d'Analyse du C.N.R.S. — Vernaison — France) and analyses in triplicate of the major components described below:

#### *Extractives*

Approximately 20 g of sample was extracted for seven hours in a soxhlet with 250 ml of a 1/1 (V/V) ethanol-benzene mixture; the sample then was filtered. The filtrate was first evaporated then dried at 80 C. The alcohol-benzene insoluble residue was dried in an oven at 105 C. All the subsequent analyses were made on the alcohol-benzene insoluble residue.

#### *Lignin (Klason lignin)*

The sample was hydrolyzed in 67% sulfuric acid at 20 C for 16 hours. The sample was then diluted in 2N acid; hydrolysis was continued for 5 hours; and lignin was determined gravimetrically (Chêne and Deissenberg 1950).

#### *Pentosan*

The pentosan content was calculated from the concentration of furfural liberated after distillation of the sample in 13.5% hydrochloric acid. The furfural was successively treated by a 0.1 N bromide-bromate solution, a 40% KI solution (excess). The  $I_2$  liberated was then treated with a 0.1 N sodium thiosulfate solution and the concentration of furfural calculated.

#### *Cellulose*

The cellulose determination was made by the Kurschner and Hoffer method: Approximately 2 g of sample is treated with 100 ml of a 1:4 (V/V) nitric acid-ethanol mixture, and then raised to boiling for 1 hour. After filtration, the insoluble residue is retreated twice again using the previous process. Finally, the solid is washed with distilled water until neutrality of the sewage liquid (pH paper coloration).

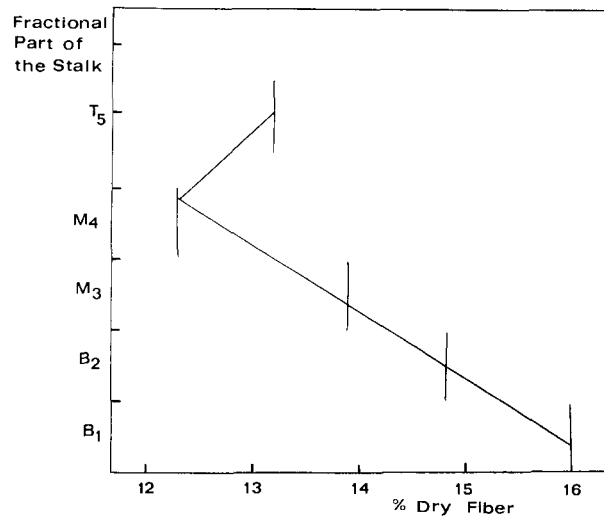


FIG. 1. Percentage (weight percent) of dry fiber in sugar cane as a function of the fractional part of the stalk.

### Ash

The ashes are obtained by incineration to constant weight of approximately 20 g of fiber in an oven at 450 C. All the components' contents are expressed on a dry matter basis.

### RESULTS AND DISCUSSION

Examination of Fig. 1 clearly indicates a decrease in the amount of fiber in the stalk between the bottom (16%), the middle (12.3%), and then a slight increase at its top (13.2%). Perhaps the greater number of nodes (richer in fiber than the inter-nodes) in the bottom and in the top of the stalk can partly explain this pattern.

The results of the elemental analysis are listed in Table 1. The percentage of hydrogen is practically the same all throughout the length of the stalk. However,

TABLE 1. Variation of the sugar cane fiber content and of the C, H and O contents in the fiber as a function of the fraction of stalk.

Sample	Sugar cane fiber content (dry basis)	Weight per cent of C, H and O in ash-free fiber			Rough fiber formula
		C	H	O	
BB <sub>1</sub> BT		47.2	6.3	46.5	CH <sub>1.60</sub> O <sub>0.74</sub>
BB <sub>2</sub> BT		47.8	6.53	45.45	CH <sub>1.64</sub> O <sub>0.715</sub>
BM <sub>4</sub> BT		47.6	6.33	46	CH <sub>1.60</sub> O <sub>0.725</sub>
BB <sub>1</sub> 69	16	48.37	6.29	45.20	CH <sub>1.56</sub> O <sub>0.70</sub>
BB <sub>2</sub> 69	14.2	47.87	6.28	45.73	CH <sub>1.58</sub> O <sub>0.72</sub>
BM <sub>3</sub> 60	13.9	47.11	6.16	46.55	CH <sub>1.57</sub> O <sub>0.74</sub>
BM <sub>4</sub> 69	12.3	47.2	6.31	46.3	CH <sub>1.60</sub> O <sub>0.736</sub>
BT69	13.2	47.77	6.24	45.89	CH <sub>1.57</sub> O <sub>0.72</sub>

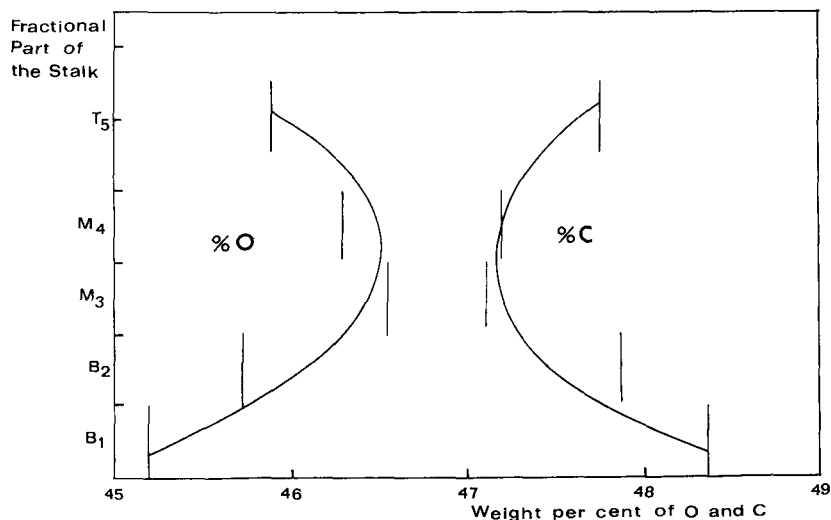


FIG. 2. Weight percent of oxygen and carbon in sugar cane fiber (dry basis) as a function of the fractional part of the stalk.

the elements carbon and oxygen vary with location in the stalk. These percentages are, respectively, minimal for carbon and maximal for oxygen in the middle part of the stalk (see Fig. 2).

#### *Chemical analyses of the fiber's components*

The amounts of fiber's components as a function of the fraction of stalk are listed in Table 2 for the two varieties of sugar cane studied. As we observe, the pattern is the same between the bottom and the top of the stalk for the two varieties:

Increase of the amount of extractives

Decrease of the percentage of lignin

Decrease of the pentosan content

Increase of the ash content

The cellulose content increases from the bottom to the middle of the stalk, then decreases up to the top.

TABLE 2. Major chemical components (by weight) of sugar cane fiber as a function of height within the stalk.

Sample	Extractives %	Lignin %	Cellulose %	Pentosan %	Ash %	Lignin
						pentosan + cellulose
BB <sub>1</sub> 69	2.7	24.5	39.5	30.5	1.4	0.35
BB <sub>2</sub> 69		23	40	28.5	1.2	0.335
BM <sub>3</sub> 69	3.1	21.9	41.9	27.2	1.6	0.317
BM <sub>3</sub> 69	3.4	22.1	41.3	24.7	1.9	0.335
BT69	3.7	22	39	23.5	3.6	0.35
BB <sub>1</sub> BT	2	25.9	36.6	33.2	1.2	0.371
BB <sub>2</sub> BT	2.3	24.7	38.3	31.2	1.2	0.355
BM <sub>4</sub> BT	2.9		39.5	28.7	1.4	

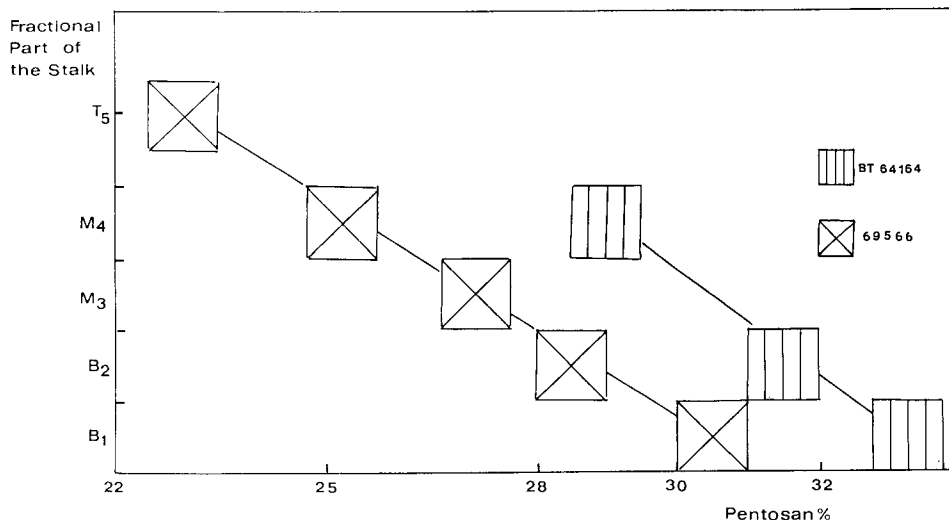


FIG. 3. Weight percent of pentosan in sugar cane fiber (dry basis) as a function of the fractional part of the stalk.

Between all the fiber's components, the highest variation in percentage is observed for pentosans (30% in the bottom, 23% in the upper part for the variety 69566, Fig. 3).

To correlate the results of the elementary analysis of the fiber (Table 1) with those obtained from the chemical analyses of the components, the following formulas were adopted: cellulose as  $(C_6H_{10}O_5)_n$ ; pentosan as  $(C_5H_8O_4)_n$ -Xylan molecule-; and for lignin:  $C_9H_{8.83}O_{2.37} (OCH)_{0.96}$ . From the above-mentioned rough formulas, the weight percent of the elements C, O, and H are respectively for each compound:

Cellulose	Pentosan	Lignin
%C = 44.46	%C = 45.47	%C = 64.8
%O = 49.37	%O = 48.47	%O = 28.86
%H = 6.17	%H = 6.06	%H = 6.34

Two observations can be made:

- 1) The hydrogen content in the three compounds being appreciably the same, the percentage of hydrogen in the fiber will be essentially constant throughout the stalk, and therefore apparently independent of the distribution of the compounds.
- 2) The lowest percentage of oxygen and the highest percentage of carbon in the fiber are located in the bottom of the stalks where the lignin (high carbon content, low oxygen content) is greatest. The lignin content decreases from the bottom to the middle of the stalk; thus values for carbon and oxygen tend to be closest at this point. Between the middle and the top part of the stalk, the percentages of C and O in the fiber deviate again. This results is probably due to the fact that the  $\frac{\text{lignin}}{\text{cellulose} + \text{pentosan}}$  ratio increases again between the middle and the top of the stalk as it is seen in Table 2.

Analysis of the fiber's components distribution as a function of the fraction of stalk permits the following comments:

The lignin content is slightly higher in the bottom than in the top of the stalk. This is probably due to the higher lignification of the mature cells which predominate in the lower part of the stalk. This relatively high lignin concentration leads to a rigidity of the cell wall with consequently a higher hardness and mechanical strength in this zone.

The cellulose content in the fiber increases gradually from the top to the middle of the stalk, then slowly decreases to the bottom. In the younger half of the stalk, this concentration of cellulose is not surprising. Indeed, during the development of sugar cane cell, the cellulose contribution increases with the successive formation of middle lamella, primary wall, and secondary wall. Hence, the increase of cellulose content between the top of the stalk (constituted of mostly young cells) and the middle part (constituted by mature cells), appears to be normal. The diminution of cellulose concentration observed in the lower half of the stalk appears to be difficult to explain.

Pentosans are the major hemicelluloses in sugar cane fiber. As is seen in Fig. 3, their concentration diminishes gradually from the bottom to the top of the stalk. Contrary to cellulose, hemicelluloses that fulfill the need for the storage of reserve food in the plant are rather located in that part of the stalk where buds will draw the food necessary for their development.

#### CONCLUSION

Chemical analysis of sugar cane bagasse leads to some original results concerning the distribution of the main constituents of fiber. Between the bottom and the top of the stalk one observed:

A decrease of lignin content.

An increase of cellulose content up to the middle then a decrease up to the top.

A decrease of the pentosan content.

For a better knowledge of bagasse and a more detailed determination of the distribution of its components across the cell wall, the present chemical analyses have to be followed by an ultrastructure study of the fiber using electron microscopy techniques.

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#### REFERENCES

- AMARAL, A., AND E. RAMOS. 1959. Perspectiva de desarrollo de los derivados de la Caña de azúcar.
- BANERJEE, B. C., S. BOSE, AND S. MUKHERJEE. 1960. The hemicelluloses from bagasse. Part 1. Nature of the sugars present. *Sharkara* 3(3):125-129.
- , S. BOSE, AND S. MUKHERJEE. 1961. Isolation of DL-Xyloketose from bagasse hemicellulose. *Science and Culture (Calcutta)* 27(10):498-499.
- , ———, AND ———. 1964. Xylan from bagasse hemicellulose. *J. Indian. Chem. Soc.* 41(5):323-329.
- BISWAS, B. 1957. Bagasse papermaking raw material. *Indian Pulp Paper* 12(7):65-69.

- CHATGEY, B. B., AND C. R. HAKSAR. 1959. Hydrolysis of sugar cane bagasse. *Vikram J. Vikram Univ* 3(1):76-79.
- CHÊNE, M., AND C. DEISSEBERG. 1950. Sur l'épuration des liqueurs résiduaire de fabrication de pâtes à papier. *Annales Inst. Polyt. de Grenoble. Numero spécial Papeterie.*
- FALCON J. E., DE LA V, AND E. R. RODRIGUEZ. 1959. Hydrolysis of bagasse US. 3, 051, 611 C1 (162-168). Aug 28, Appl. Nov 16, 1959.
- GUHA, S. R., AND P. C. PANT. 1964. Wet strength papers. *Indian Pulp Paper* 19(5):327-329.
- KNAPP, S. B., R. A. WATT, AND J. D. WETHERN. 1957. Sugar cane bagasse as a fibrous paper making material (IV). Pulping of Hawaiin bagasse. *Tappi* 40(8):595-597.
- MURPHY, P. T., AND G. N. RICHARDS. 1968. Polysaccharides of sugar cane bagasse. Pages 255-258 in H. E. Young, ed. *Proc. of the 35th Conf. Queensland Soc. of Sugar Cane Technologists.*
- PATHAK, S. R., AND V. R. SRINIVASAN. 1964. Studies on sugar cane bagasse part IV: structural features of hemicellulose A, from sugar cane bagasse fibre. *Indian J. Chem* 2(9):365-367.