Effect of Dry-off Period and Crushing and Extracting Delays on Sugarcane Quality and Productivity

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Abstract—In sugarcane production, the costs of harvesting and transporting the crop account for a large proportion of cost. To ensure sustainability of the industry, it is of vital that performance in the harvesting and transporting processes be optimized so as to reduce the cost to a minimum. These experiments were carried out at Sennar Sugar factory to show the effect of dry-off period and time lag between cutting and crushing of cane on sugarcane quality. Four dry-off period treatments were selected namely, two-, three-, four-, five- and six-week dry-off periods. The time lag was selected to be 24, 48 and 72 hours after cutting. The measured parameters were percentages of weight loss, pol, brix, purity, fiber content and sugar recovery. Analysis showed that there is high significant effect of delay in cane crushing on these parameters. From the results it can be stated that it is necessary that cane cutting, transporting and crushing periods should be kept to the minimum. Cane supply system should be highly effective to minimize losses.

Keywords—Crushing; Dry-off Period; Harvesting; Sugarcane; Transportation.

Abbreviations—Estimated Recovery Percent (ERP); International Commission for Uniform Methods for Sugar Analysis (ICUMSA); Length of the Row (LR); Number of Rows (NR); Polysaccharides (Pol); Tonne Cane per Hectare (TC/ha); Total Length of the Row (TLR); Purity (Py); Total Sugar per Hectare (TS/ha).

I. INTRODUCTION

IN the present era of economic liberalization, sugar has become an important commodity for human consumption and trade. The sugar industry in the Sudan started in the 1960`s and reached its present scale in the 1980`s [Hammad & Dawelbeit, 1]. The present strategy of the country is to expand the area under sugarcane, in order to increase sugar production and exports. Sugar industry is considered one of an organized sectors. This sector among the leading enterprise in the Sudan.

In sugarcane production, the costs of harvesting and transporting the crop account for a large proportion of cost. To ensure sustainability of the industry, it is of vital that performance in the harvesting and transporting processes be optimized so as to reduce the cost to a minimum.

Sugarcane consists of about 70-75% water, 0.5 % non-sugar, 12-14 % sugar, and I % other matters. The sugars are of two types, sucrose and reducing sugars. The percentage of reducing sugars is higher in mature cane. The sucrose content increases and reducing sugars decrease as the plant approaches maturity. Thus, only mature cane should be brought for crushing to obtain more sugar.

II. LITERATURE REVIEW

The dry-off period practice usually employed by sugarcane growers to prepare sugarcane field for harvesting [Eltahir, 2]. The accompanying mild moisture stress causes sucrose to be deposited preferentially in sugarcane stalks so that sucrose yield may be improved. The rule of thumb in the industry states that a crop should be dried-off for the time it would take pan evaporation to equal twice the available water holding capacity of the soil in which the crop is rooted [Donalson & Bezuidenhout, 3]. Despite this useful rule, cane growers often dry-off their crops excessively. To avoid such practice, the dry-off period is implemented in terms of dry-off days to prevent losses in sucrose yield. When drying-off a sugar field for harvesting the main target would be the reduction of soil moisture content to a level that permits machine trafficability, as well as improving cane quality [Ahmed, 4].

The goal of the harvest is to deliver sugarcane stalks of good quality to the mill. Quality, measured by sucrose and trash content, is reduced by damage cane and increased trash in delivered cane, and by delaying delivery [Chen, 5]. All

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operations on sugar estate are timed very carefully to obtain the maximum sugar content.

The success of the harvesting program depends to a large extent to on a well-planned dry-off period schedule. Drying-off of sugarcane fields for harvesting has not been experimentally tested throughout the history of the scheme, and what has been practiced is based on personal observations and accumulated experience of the field staff. Due to the inherent inaccuracy judgment in practice, the harvest operation may be carried out under wet conditions, which leads to machine spinning, increase in fuel consumption, slowing down of loading operation, hauling and transporting excess water, machine damage and low sugar recovery and extraction. On the other hand if the dry-off period extended beyond the optimum it may lead to over-burning, increased fiber content and reduction of cane moisture content.

Priyanka et al., [6] stated that sugarcane plant when detached from the ground lose its machinery to synthesize sucrose. Thus a well ripened crop may lose its sugar within a few days which tends to increase further due to high ambient temperature. The postharvest sugar loss is one of the most vexing problems of sugar industry and has attracted attention in the recent years.

Moisture content influences ripening of sugarcane at the maturity phase. Ripening of sugarcane involves the accumulation of sucrose in the cane stalks [Van Dellewijn, 7]. However, ripening can be more broadly defined as an increase in sucrose concentration in the cane stalks on fresh weight basis. This definition is used in almost all sugarcane producing countries, whereby the fresh weight measure of sugar content is used to describe cane quality.

Ripening occurs naturally in response to crop age and seasonal factors when the crop is accumulated adequate stem biomass and when climatic conditions favor a slowing of stem elongation, inducing mild water stress can also cause ripening [Robertson et al., 8].

Ripening can be enhanced by dry-off cane [Robertson & Donaldson, 9], reducing soil moisture content and lowering of the temperature [James, 10]. Maximum yield of sugarcane can be realized only if the crop is well ripened before harvest Elhahir [2]. To be ripe the cane stalks must first show retardation in the rate of growth. Low temperature, moderate drought and nitrogen starvation are effective ripening agents. As the growth rate declines, less of the sugar produced each day is expended in building new tissue and most of it is stored as sucrose.

Drought from natural causes, or by lengthened irrigation intervals, promotes the conversion of reducing sugar to sucrose [Humbert, 11]. As ripening proceeds, the percentage of sucrose in the stalk gradually increases while the percentage of glucose and fructose diminishes.

Moisture is considered as an extremely important factor either in natural maturity of sugarcane in the tropics or where forced ripening programs are implemented. At harvest time the cane grower is concerned with the moisture content of the millable cane since juice quality is associated with low moisture content [Humbert, 11].

Mainly as time passes the deterioration of cane occurs by heat and sun. The chemical change takes place and the sucrose inversion starts to result in inverted sugars (reducing sugars). Thus the inversion and deterioration of cane is faster in hot weather than wet and cold weather.

It is preferred that the cane should be crushed within 24 hours after cutting. If the cane is delayed it starts deterioration which leads to loss in moisture content. Deterioration also leads to inversion of sucrose and increase in reducing sugars. The increase in fiber content increases milling loss.

Sugarcane cannot be delivered to the factory as soon as it is harvested. While cutting and transporting, it comes with contact to heat till approaching the factory gate where some uncrushed marginal stock of cane is there so it is not possible to crush the cane as soon as it is cut. Due to the sun heat as the time passes cane loses its weight and sugar. It is not possible to estimate the exact quantity of sugar lost in the stale cane. But it is true that huge quantity of sugar is lost before crushing.

Delaying in transportation or crushing losses from 1 to 6 days after harvesting resulted in dry matter loss from about 1.3, to 11.5%, reduction in brix from 0.6% to 9.8%, reduction in commercial sugar content from 0.7% to 9.9%. Purity reduced from 0.03% to 0.19%. Fiber content was increased from 0.22%, to 1.11%. Glucose content increased from 1.54%, to 8.66%. It is concluded that cane should be delivered to the mill within 24 hours after harvesting [Abbasi et al., 12]. Ingale et al., [13] found that there was a reduction in weight from 7% to 10% due to evaporation after 24 to 48 hours. The fiber content increases considerably by 3.5% to 5.5% and reducing sugars increase by 0.24% to 0.29%. He concluded that the loss of weight, increase in fiber percentages and reducing sugars affects sugar recovery percentage which was decreased directly by 0.42% to 0.74% after 24 to 48 hours.

This research was conducted to verify:

a) The impact of the effect of dry-off period on the implementation of the harvesting program.
b) To determine the optimum dry-off period for the sugar fields in order to achieve the most possible profitable production.

The objectives of this work are to:

a) Determine the effect of dry-off period on sugarcane productivity.
b) Determine the effect of dry-off period on sugarcane and sugar quality.
c) Determine the effect of delaying sugarcane transportation to the mill in cane deterioration and juice quality.

This research may help field manager to better determine the optimum time to stop irrigation water to prepare sugar fields for harvesting, also it helps in better scheduling labor and machinery operating in sugarcane transportation.

III. MATERIALS AND METHODS

3.1. Equipment

Equipment used for data collection are: 50 meter measuring tape, digging hoe, cans (10cm diameter and 12cm height), polyethylene bags, card tags, drum, one inch diameter hose, 20liters plastic containers, one liter measuring cylinder, stop watch electronic balance, an oven, weighbridge and ropes.

3.2. Experimental Work

Two systems of harvesting were studied, manual and mechanical cane harvesting. The completely randomized block design was used in the experiment with five treatments (dry-off periods) and four replications under each system of harvesting. The five treatments of dry-off period were: two, three, four, five and six weeks after the last irrigation. The parameters measured were:

3.2.1. Cane Yield

The millable stalks of the two rows were harvested manually and transported as a representative effective area then weighed. The weight of cane per hectare was found as follows:

$$TC/ha = \frac{weight\ of\ millable\ cane\ harvested\ (tonne)}{Effective\ harvested\ area\ (ha)} \quad (1)$$

The effective area for manual harvesting was determined by measuring the length of the rows transported in meters, then multiplied by six (number of ridges comprising the row) and then multiplied by 1.5 (spacing between ridges), dividing the result by 10000 $m^2$to obtain the area in hectares. These steps can be illustrated as follows:

$$Effective\ area = \frac{(LR)(NR)(S)}{1000} \quad (2)$$

Where, LR is the length of the row and NR is the number of ridges and S is the space between ridges.

For mechanical harvesting, the area was calculated by multiplied by the length of ridges being reaped and transported, multiplied by 1.5 and the divided by 10000 m^2.

$$Effective\ area = \frac{(TLR)(S)}{10000} \quad (3)$$

Where, TLR is the total length of ridges being harvested.

3.2.2. Polysaccharide Content

Pol percentage is a term reflecting the degree of sweetness in the sugarcane or its juice. Pol is determined by an instrument called polarimeter. It is a cylinder containing a brism at one end and another one at the other end called the analyzer. This prism can be revolved. The analyzer is connected to a telescope containing a lens. The pol is the force of rotation of the material and is expressed in percent.

3.2.3. Estimation of Brix Percentage

This parameter was measured using the hydrometer method described by the International Commission for Uniform Methods for Sugar Analysis (ICUMSA, 1964).Brix is measured by the conventional liquid device. It is consist of a floating cylindrical tube having log thin graded extension. A metallic weight causes the tube to float vertically. The degree of immersion reflects the density of the solution or the sugar content of that solution. The degree of brix is obtained from the graded spindle.

3.2.4. Estimation of Purity Percentage

Purity is the ratio of the sucrose to the total soluble solid contents. Normally the sucrose is measured as brix and the solid materials as pol. These two measurements are exposed to error and the purity is then called an apparent purity and is given by the formula:

$$Py\% = \frac{(pol\%)(100)}{brix\%} \quad (4)$$

3.2.5. Cane Maturity

Cane maturity was found by taking the average of pol% of a bundle of ten cane stalks at the top parts and divided by the average reading of pol% of the same bundle at the bottom part (lower internodes) multiplied by hundred. This can be represented by the following equation:

$$Matt\% = \frac{(pol\%\ of\ the\ top\ part)(100)}{pol\%\ of\ the\ bottom\ part} \quad (5)$$

3.2.6. Estimation Fiber Percentage

A representative sample of crushed cane, from the previously mentioned bundle, of 100 g was taken in a cloth bag and placed in boiling water (100^0C) to remove sugar. Sugar-free sample was oven dried at 105^0C overnight and weighed repeatedly until a constant weight was obtained. The loss in weight and the final dry weight represented the moisture and the fiber contents of the cane, respectively. The fiber content of the cane and moisture content were computed as follows:

$$Fiber\ content\% = \frac{(dry\ weight\ in\ grams)(100)}{sample\ weight\ (g)} \quad (6)$$

$$Moisture\ content\% = \frac{(sample\ weight - dry\ weight)(100)}{sample\ weight\ (g)} \quad (7)$$

3.2.7. Estimated Recovery Percent (ERP)

The estimated recovery percent of sugar was calculated using the following equation, (Elhagwa 2000):

$$ERP = [pol\% - (brix\% - pol\%)(0.4)][0.74] \quad (8)$$

3.2.8. Yield of Sugar

The productivity of sugar, in tonnes per hectare was obtained by the following formula:

$$TS/ha = (TC/ha)(ERP) \quad (9)$$

Where, TS is the total sugar and TC is the total cane.

IV. RESULTS AND DISCUSSION

4.1. Effect of Dry-off Period on Cane Productivity and Quality

4.1.1. Crop Yield

The results obtained for crop yield are shown in Fig.(1). Results indicated that there were no significant differences (P=0.05) in cane yield between the different dry-off period treatments for both mechanical and manual harvesting. The shortest dry-off period gave the highest yields (15.96 and 15.29tonnes/ha.), which could be attributed to the highest level of moisture content in the crop. On the other hand, the longest dry-off period gave the lowest yields (13.65 and 13.27tonnes/ha), which could be attributed to the impact of dry conditions which led to the reduction in crop moisture content and hence crop yield.

Generally, it was observed that the yield of field reaped by the cane harvester exceeds the yield of fields manually reaped for all dry-off period treatments. This could be attributed to the fact that the cane harvested mechanically is directly transported to the factory for crushing while that harvested manually requires some time to be prepared (delayed in transportation), which results in moisture losses and hence loss in cane weight. Moreover, Fig.(1) indicates clearly that the cane yield of the mechanical and manual harvesting decreased with the increase in the length of the dry-off period.

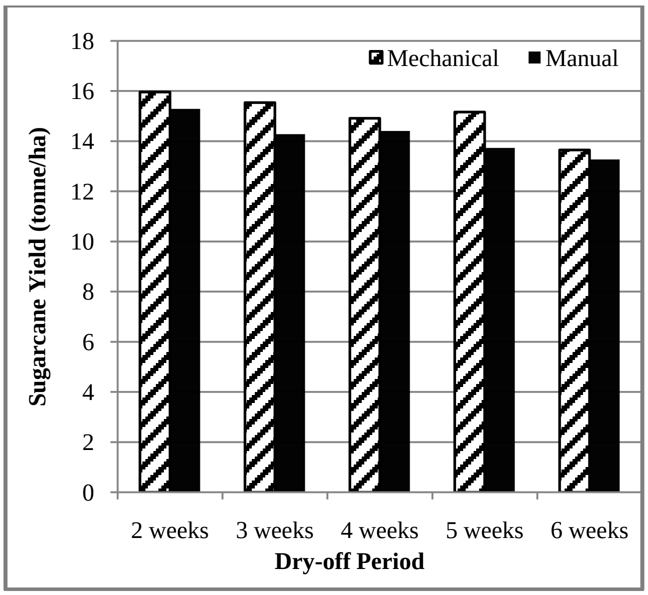

Figure 1: Effect of Dry-off Period on Sugarcane Yield

4.1.2. *Trash Content*

The results obtained for trash contents are shown in Fig. (2). The results showed that there were no significant differences (P=0.05) between treatments for both methods of harvesting. The values of trash content indicated that the highest trash content (3% and 3.3%) were obtained at the shortest dry-off period, which could be attributed to the incomplete burning of cane leaves and tops due to the high moisture content of the crop. Moreover, the mechanical and manual values indicated that the lowest trash percent (1.4 and 1.7%) were obtained at the longest period of dry-off, which could be explained by the fact that the crop was dry enough to allow most of the trash to be burned completely. However, the degree of cane burning in this case was correlated with the reduction in cane quality at the factory. Also, it was observed that the trash content for manual harvesting at all dry-off period treatments exceeded those of mechanical harvesting except in the five-week dry-off period treatments and this could be attributed to the utilization of topper and extractor fans in mechanical harvesting and the remaining of uncut tops on the lower side of each row cut manually.

4.1.3. *Maturity*

Results of cane maturity are shown in Fig. (3). Statistical analysis showed a significant difference (p=0.05) between the shortest and longest dry-off periods only. However, the lowest values of cane maturity (85.8 and 85.1%) were recorded at the two-week dry-off period for mechanical and manual harvesting, respectively, while the higher values (86.9 and 90.8%) were obtained at the longest dry-off period. Moreover, the manual column values showed that the maturity increased with the increase of dry-off period.

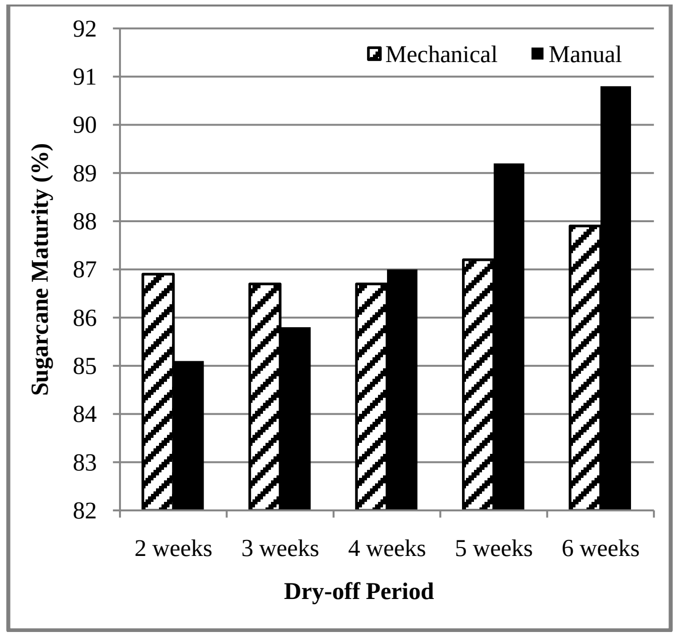

Figure 3: Effect of Dry-off Period on Sugarcane Maturity

4.1.4. *Cane Moisture Content*

The results for cane moisture content are shown in Fig. (4). Statistical analysis showed a significant difference (p=0.05) between the two-weeks and six-weeks dry-off periods treatments only. Moreover, the results revealed that the highest values of cane moisture content (65.5 and 65.7%) in both harvesting methods were obtained at the shortest dry-off period while the lowest values of crop moisture content (63.1 and 63.4%) occurred at the longest dry-off period. Generally, crop moisture content decreased with the increase of dry-off period. It is evident that the pol% and cane moisture content were inversely correlated. The results showed that the highest values of cane moisture content were obtained at the shortest dry-off period coupled with the lowest value of pol%, while the longest dry-off period resulted in the lowest value crop moisture content coupled with the highest value of pol%. However, it must be mentioned that cane with very low value of moisture content is not preferable for milling and sugar extraction.

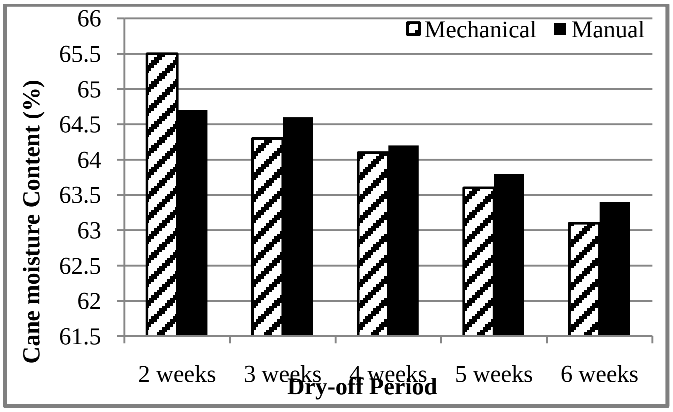

Figure 4: Effect of Dry-off Period on Cane Moisture Content

4.1.5. Polysaccharides Content (pol%)

Results of pol% are presented in Fig. (5). The statistical analysis of the results showed that there were no significant differences between the different dry-off period treatments except between the two-week and six-week dry-off periods in mechanical harvesting. However, the results revealed that the mean value of pol% was least (14%) when the sugarcane fields were harvested at the dry-off period of two weeks. On the other hand, it was observed that the longest dry-off period (six weeks) resulted in relatively higher mean values of pol% (14.6%). This could be attributed to the fact that the drought conditions at harvest forced the cane to accumulate sucrose and increased polysaccharides concentration in the cane juice due to cane moisture content reduction as indicated in Fig. (3).

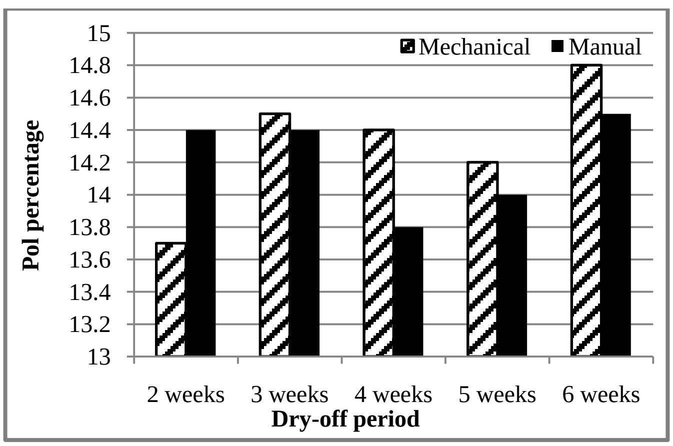

Figure 5: Effect of Dry-off Period on Pol Percentage

4.1.6. Purity

The results obtained for purity under the different dry-off period treatments are shown in Fig. (6). Statistical analysis showed a significant difference (p=0.05) between the two-week and six-week dry-off period treatments. The highest values of juice purity (92.3 and 91.5%) for mechanical and manual harvesting, respectively, were obtained at the longest dry-off period, while relatively lower values (88.3 and 88.9%) occurred at the shortest dry-off period. This could be attributed to the fact that the pol% value is higher when dry-off period is the longest.

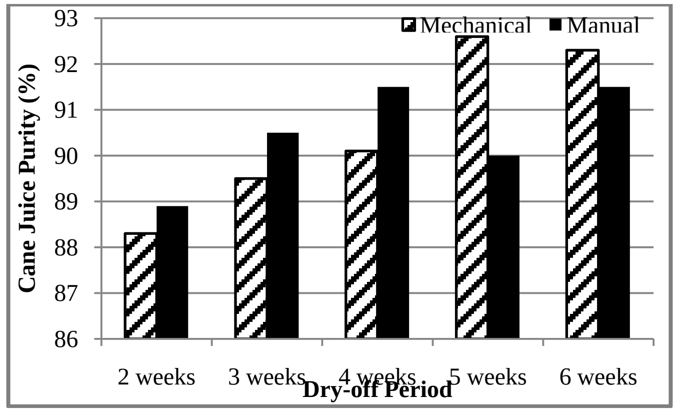

Figure 6: Effect of Dry-off Period on Cane Juice Purity

4.1.7. Fiber Content

The percentage of fiber in the cane results are shown in Fig. (7). Statistical analysis revealed a significant difference (p=0.05) between the two-week and six-week dry-off periods for mechanical harvesting only. The lowest values (18.7 and 19.0%) for mechanical and manual harvesting, respectively, were recorded at the shortest dry-off period while the highest value (19.6) was obtained from the longest dry-off period. This could be attributed to the fact that the cane moisture content will be higher in the cane subjected to the lower dry-off period. Although there were no significant differences recorded between the three-, four-, and five-week dry-off period treatments, the results showed that the values of fiber percent increased with the increase of dry-off period. This could be explained by the increase of cane maturity and reduction of cane moisture content as a result of the increase of the dry-off period.

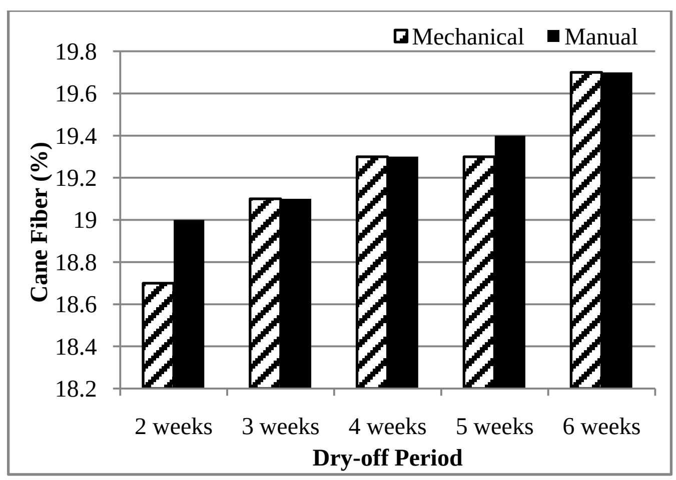

Figure 7: Effect of Dry-off Period on Cane Fiber

4.2. Effect of Crushing and Extracting Delays

4.2.1. Weight Loss

From the experiment, the stalks weight loss “mostly water” was found to be 6.5%, 15.8%, and 18.1%, after 24 hours, 48 hours and 72 hours respectively. This loss in weight is due to delayed transportation. Dehydration of the cane necessitates the addition of water to the mill to assist in juice extraction.

4.2.2. Pol Percent

The pol percent decreases through time. The reduction in pol was found to be 2.4%, 3.6% and 7.8% after 24, 48 and 72 hours respectively, while reducing sugars increased by 28.1%, 53.1% and 71.9%.

4.2.3. Brix

Delayed crushing will cause (Leconostocmesenteroides) to form the brix. Formation of the brix gives the crystals a needle-like shape which affects the marketing of the sugar. Brix was increased by 0.6%, 2.2% and 0.93%.

4.2.4. JuicePurity

The purity of the cane also deceases with time. The reduction in purity was 1.75%, 5% and 6.3% after 24, 48 and 72 hours respectively.

4.2.5. Fiber Content

The increase in fiber content was found to be 2.5%, 4.3% and 7.5%. Fiber content affects the performance of the crushers and increases the milling loss. Thus it is not profitable to crush stale cane both for farmers and millers.

4.2.6. Sugar Recovery

The above loss in weight of cane and increase in the fiber content and reducing sugars affect sugar recovery percentage which decreased by 1.1%, 3.9% and 7.4%.Statistical analysis showed highly significant effect of time lag between harvesting and crushing.

V. CONCLUSION

From the above discussion it can be stated that sugarcane is a perishable crop and must be processed into sugar quickly after harvesting. It is necessary that cane cutting, transporting and crushing periods should be kept to the minimum to reduce postharvest losses. To avoid delay some managers allocate more transporting units this practice will increase the cost because some machinery will wait for loading. So cane supply manager and his field staff play an important role in scheduling labor and machinery for avoiding such losses and reduce cost. Moreover, the optimum dry-off periods for cane harvesting could be the four-week or the five-week dry-off period, because they gave the:

(a) Second best crop yield.
(b) Second lowest trash content.
(c) Second best cane quality.

REFERENCES

[1] E.A. Hammad & M.I. Dawelbeit (2001), "Effect of Tillage and Field Conditions on Soil Physical Properties, Cane and Sugar Yields in Vertisols of Kenana Sugar Estate", *Soil and Tillage Research*, Vol. 62, Pp. 100–109.

[2] E.E. Eltahir (2002), "Sugarcane Harvesting Techniques", *National Training Center for Sugar*, Sennar, Sudan.

[3] R.A. Donalson & C.N. Bezuidenhout (2000), "Determining the Maximum Dry-off Period for Sugarcane Grown in Different Regions of South Africa", *74th Annual SASTA Congress*, South Africa.www.sasta.co.za/2000Congress/2000CongAbstractsInd.htm.

[4] E.A. Ahmed (2001), "Sugarcane Varieties", *A Working Paper Presented for the Agriculturist Training Course, National Training Center for Sugar*, Sennar, Sudan.

[5] J.C.P. Chen (1984), "Cane Sugar Handbook. A Manual for Cane Sugar Manufacturers and their Chemists", 11th Edition, *Wiley –Interscience Publications*, *John Williamson Ltd*., New York/ London.

[6] S. Priyanka, R.P. Srivastava & M.L. Sharma (2010), "Impact of Cut to Crush Delay and Biochemical Changes in Sugarcane", *Australian Journal of Crop Science*, Vol. 4, No. 9, Pp. 692–699.

[7] C. Van Dillewijn (1952), "Botany of Sugarcane", *The Chronica Botanica Department*, *Waltham Mass*, USA.

[8] M.J. Robertson, R.C. Mucho & A.W. Wood (1999), "Sugarcane Technology", *CSIRO Publishing Australian Journal of Agricultural Research*, Australia, Vol. 12, Pp. 196–202.

[9] M.J. Robertson & R.A. Donaldson (1998), "Changes in the Components of Cane Sugar Yield and Crops Research", *CSIRO Publishing Australian Journal of Agricultural Research*, Australia, Vol. 55, Pp. 201–208.

[10] G. James (1999), "The Chemical Ripening of Sugar", *CSIRO Publishing Australian Journal of Agricultural Research*, Vol. 101, Pp. 560–562.

[11] R.P. Humbert (1968), "The Growing of Sugarcane", *Elsevier Publishing Company*, Amsterdam, Holland.

[12] K.B. Abbassi, Y.J. Minhas & A.K. Bhatti (2000), "Determination of Post-Harvest Losses in Sugarcane Commercial Variety Gulabi-95 (BF-129)", *Workshop Proceedings of "Research and Development Activities on Sugarcane Crop in Pakistan"*, *Shakaraj Sugar Research Institute*, Jhang, Pakistan, *Pakistan Sugar Journal*.

[13] M.S. Ingale & A.S. Khalate (1997), "Evaporation and Inversion of Sugarcane before Crushing", *46th Annual Convention Congress*, Part 1, Agricultural Papers, India.

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