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CAUSES AND MANAGEMENT OF FIELD TO FACTORY SUCROSE LOSSES IN SOME AFRICAN SUGAR INDUSTRIES

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Abstract

Sugar recovery from crushed cane depends on the maturity and variety of cane used as well as other physiological, environmental and management factors both in the field and in the factory. Sugar production is labour intensive and in most African countries where political practice is unstable and technological acquisition lags behind; labour use at peak periods of kill to mill impedes processing rate thus accounting for great sugar losses arising from microbial activities. This review points out the various stages of sugar production from field to factory and causes of sucrose losses as well as suggests areas of improvement to stem field to factory sucrose losses.

Keywords: Sugarcane; disaccharide sucrose; maturity; variety; environmental and management factors; field and factory losses; microbial breakdown.

INTRODUCTION

The most important and economic part of the sugar cane plant is the stalk containing sucrose. The leaves assimilate carbon dioxide in the presence of solar energy to produce glucose and fructose. The final product, made up from one molecule of D-glucose and D-fructose is the disaccharide sucrose, which is chemically pure sugar (Partners, 1985). The storage of sucrose takes place in the vacuoles of cells of the cane stalk. Glucose and fructose are also needed for the growth of the sugar cane plant and, therefore, the sucrose content is relatively small in the younger upper parts of the stalk till only after the sugar cane has finished growing or has matured (Partners, 1985).

As sugar cane has the ability to store sucrose in the stalks over a period of one year or more without reaching final maturity and death, it is, therefore, the most efficient and productive crop. However, allowances have to be made for the fact that sugar cane deteriorates soon after harvest (Partners, 1985). The deterioration takes place in the form of degradation of the sucrose, loss of both glucose and fructose by respiration and also loss of moisture. Partners (1985) is also of the view that some chemical properties of the sugar cane plant have to be taken into account while addressing the problem of sucrose losses from field to factory. The high level sucrose content attained in the period of full maturity will last only for a relatively short period. Therefore the cane must be harvested within a limited period of time, which means that the harvest is not only labour - intensive, but also seasonal. Since mature cane deteriorates soon after being cut, the sugar should be extracted from the stalks as quickly as possible, a fact which, especially as regards transport of the bulky cane stalks to the mills increase the labour required during the peak period of the cane harvest.

The extraction of sugar from cane is now a highly industrialized process requiring efficient mills and, in view of the rapid deterioration of the cane after harvesting, a well-developed transport system is a necessity. Apart from these, causes of sucrose losses from filed to factory come from management practices, environmental factors, which are beyond human control and husbandry practices on the crop from plant to post harvest processes. Thus poor management of harvested sugar cane is responsible for sucrose losses from field to factory in many countries of the world (Yates 1996a). Being labour-intensive and seasonal crop, shortage of manpower for cutting and loading which are common practices in most African sugar industries, lead to overstay of harvested canes on the filed, thus causing deterioration as the result of fermentation and inversion processes by bacterial actions. Other logistic and managerial problems of cane loading cause considerable sucrose loss by protracting the kill to mill period. Kill is the pre-harvest burn or where the cane is cut green before proper maturity. These losses have affected many sugar industries else where and in Africa today, in terms of tons cane per ton sugar produced (Yates 1996a).

In the sugar cane industry, sucrose losses range from 1 to 2.5% in the factory. However, total losses, since the stage when the cane is cut till the bagging of refined sugar would be between 5 to 35% depending on the climatic conditions at the time of harvest (RASITC 2000a). This review attempts to highlight the general causes and management practices for sucrose losses from field to factory in the sugar industry with particular reference to some African countries.

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Factors affecting sucrose loses in the fields

The fundamental causes of poor quality sugar (sucrose) originate in the cane and usually poor quality sugar is generally attributed to:

Cane Variety: Bhanavase *et al.* (1995) and Nair *et al.* (1999) observed that the sucrose content of different cane varieties is not the same. For example, a cane of 15% sucrose will result in a higher extraction than one with 13%, sucrose provided that it has the same fibre and same ton cane per ton sugar (tc/ts) (RASITC, 2000a).

At Chenbere and in some African sugar industries, like South Africa and Mauritius, ripeners are used to enhance the rate and quantity of sucrose accumulation in the cane stalks and in the tops ((Mamet *et al.* 1996; RASITC 2000a; Solomon *et al.* 2001; Solomon and Li 2004).

Breeders have consciously developed high sucrose content cane varieties as the means of increasing field sucrose and thus minimizing losses ((Lo and Chen 1995). Thus in conserving and minimizing sucrose losses in the field, efforts are geared towards selecting for high sucrose canes which even when mismanaged in the field or factory operations will suffer minimal losses. Indeed, however, the fact remains that an apparent plateaux is reached whereby further increase cannot be achieved (Legendre 1995). Efforts at increasing the content of sucrose in cane varieties by researchers have further, revealed that sucrose content has a positive relationship with certain leaf characters of sugar cane particularly leaf width and area (Tyagi and Singh 1995). The selection process is, therefore, advised to target cane varieties with good leaf width and area for increased sucrose in new-bred canes. Thus, in Nigeria, the breeding unit targets canes with high sucrose content, disease and pest resistance and other traits for use by the sugar cane industry.

Climate:

Rain, high humidity and warmth accelerate the proliferation of microbial activities and therefore, the staking of cane in the field and in the factory yard, where right stock is kept. Also where harvest operations were reliable to interference by rain, sucrose was affected by rainfall preceding harvest as well as that at harvest (Yates 1983). Cane can also be damaged by frost, cyclone and drought, as is occasionally the case with some South African and Mauritian cane industries. In 1995 for example, damage of sugar cane by typhoon caused reduced sucrose production from the affected canes in Mauritius (Anon 1996a).

In Ethiopia, more than 200 ha of sugar cane fields were flooded in 1996, because the Awash River overflows its banks (Anon 1996b). Thus climate effects affect field sucrose production in African cane industries and elsewhere. However Blume (1983) reported that highest sucrose yield per hectare occurred, regardless of latitude in countries where sucrose content resulted from relatively low temperatures and precipitation.

In effect, some of these environmental factors that affect sugar cane production and eventually the quality of sucrose produced are beyond management control. For example, Moberly (1982), reported that the management of cane that had suffered severely from the effects of drought (too short to cut and handle effectively) was investigated in South Africa where it was found that sucrose yield was better when the affected cane was left standing than when it was cut back.

Fertilizers

Sucrose contents in cane are also affected by high N fertilization (Robertson et al. 1995), which results in low sucrose in the applied canes. On the other hand, high S-level-increased sucrose content of 10 and 12 month canes (Singh *et al.* 1995). Thus efficient soil and fertilizer management by African cane growers can be harnessed for the production of canes with good sucrose content as nutrient management practices are known to cause considerable variation in juice, brix, sucrose and purity % (Rakkiyappan *et al.* 2001). Lakshmi *et al.* (2003), indicated that combining early cane varieties with a nitrogen dose of 75kgha-^{1} in two equal splits wither at planting and within 30 days after planting (DAP) or at 30 and 60 DAP, depending on fertilizer availability and soil moisture influenced sucrose yield of such canes.

Cultivation

The soil is the medium on which sugar cane is grown and it harbors myriad of organisms. Thus continued cultivation activities on the soil for sugar cane production, therefore, will aid multiplication of these microorganisms, for subsequent sucrose degradation both in the field and in the factory.

Pests and Diseases

Pests and diseases such as grubs, gumming disease, red rot and others have been known to cause sucrose loss in affected canes. Other pests such as stem borers have also been implicated in the loss of sucrose of infested canes (Venuaopalarao *et al.* 1983). In Kenya, cane deterioration was attributed to a combination of poor management, uncontrolled build up of whip smut infection and ratoon stunting disease (RSD) (James, *et al.* 1995). In South Africa, sucrose losses were equally attributed to processing burnt infected cane (Paty 1981). Elsewhere, canes infected with the red rot pathogen *Colletotrichum falcatum* exhibited a decrease in juice and sucrose content (Pratap *et al.* 1994; Kumar *et al.* 1995).

Burning

Burning of cane, commonly employed by most African sugar cane industries is a practice that causes exudates from the stalks, and leads to reduced sucrose crystallization (Furlani *et al.*, 1996; Delgado and

Casanova, 2001). When cane is burnt and not cut and crushed within 48 h, sucrose losses occur due to the activities of microorganisms. Burning also increases the polysaccharide and oligosaccharide content of the cane thus reducing sucrose (Delgado and Casanova 2001). If the canes were burnt before harvesting, there is a general consensus that burnt cane deteriorates more rapidly than green canes (Yates 1996b; Delgado and Casanova 2001). Many reports have shown that the greatest loss in sugar occurs between burning and cutting (Yates 1996b). Deterioration is fast when harvest is done under high temperature, which accelerates loss of sugar as a result of formation of dextrans (Yates 1996b; RASITC, 2000c). Most of the adverse effects noted above are also attributed to lodging of canes. Apart from the normal practice of firing cane before harvest by African cane industries, intentional burning also takes place. In 1995, security forces used more than fifty tractors to torn up 500 ha of sugar cane fields in Southern Egypt to prevent their use for hiding by Muslim militias. This action caused field sucrose deterioration, as the canes could not be timely harvested and processed. (Anon. 1995). Recently, studies by Uppal (2003) in India showed that sucrose losses of burnt cane were higher than those in un-burnt cane. Effective management of cane fields, cut cane and processed cane, by African cane industries will go a long way in curtailing sucrose losses from the field to factory.

Use of Ripeners

Sucrose accumulation can be influenced in the field through cane ripening which occurs naturally when crops have accumulated adequate stem biomass and when climatic conditions favour a slowing of stem elongation (Solomon and Li 2004). Ripeners are an integral part of farm management in only few African cane industries. The Mauritian and South African sugar cane industries have employed extensive use of ripeners for field sucrose conservation in the stalks and in the tops (RASITC 2000a; Mamet *et al.* 1996; Solomon *et al.* 2001; Solomon and Li, 2004).

Ripeners are sadly not in use in Nigeria at present. It is hoped that as the cane industry grows the use of chemical ripeners for field sucrose accumulation would be adopted by the industry for good quality cane production. The non use of ripeners by most African cane industries denies them of the advantage imposed by these chemicals where growers and millers better manage harvesting schedules, thereby preventing field and factory sucrose losses.

Losses Due to Weed Interference on the Field

Cultural practices commonly employed in the cultivation of sugar cane are such that the crop is exposed to early weed competition which, if not adequately eliminated, can result in substantial sugar yield reduction (Fadayomi 1988). Although, most studies carried out on the effects of weed interference on juice quality indicates non significant differences, the quantity of cane milled is quoted to be directly proportional to sugar yield (Fadayomi and Abayomi 1988; Ndarubu *et al.* 2000; Ibrahim 1984). Thus, the quality standard on the few estates in the country put the total sugar yield to be 1/10 of total cane crushed (i.e. tc/ts =10:1). However, this ratio depends largely on the quality of cane from the field, efficiency of the milling machines and factory setup and also the climatic conditions. The ratio declined to 1/26 at NISUCO in the year 2003 due to small sized stalks and high weed contamination at harvest that was caused by poor weed management during the cropping season (Anon. 2003).

As cane fields are commonly fired before harvest on the estates in Nigeria; fields that are weedy at harvest, which often have stunted cane stalks are most inflammable and this results in large losses in total millable canes delivered to the mill (Anon. 2003).

Environmental factors responsible for sugar loses

There are certain environmental factors that affect sugar cane production, which eventually affect quality of sugar produced that are beyond management control. These challenges are well understood by plant breeders who know that cane quality is largely controlled by environmental factors. The major environmental factors, which affect cane quality, are temperature, rainfall, and moisture stress.

Temperature

Extreme temperatures, are known to affect sugar quality especially temperatures as high as 35°C – 39°C at harvest period. These temperature ranges have been found to cause wilting, decrease photosynthesis and increase in photorespiration (Yates 1996a). Sunshine hours and minimum temperatures are also possible causes of low sugar recovery in the factories. The effect of temperature in particular, was noticed in the analysis of sugar from a high-elevation equatorial factory area in Kenya (Yates 1996a). However, low temperatures (< 20°C) are important in inducing ripening.

Frost is another important environmental factor, which affect sugar quality. Although mild frost does not prevent ripening, severe frost in the range of -1 to -2°C could kill the leaves and apical meristem. However this does not reduce quality. It is advised that harvesting of canes at this period should be completed before temperature begins to rise. Very severe frost (-7°C or below) usually freezes the cells and the sugar will rapidly be hydrolyzed (Yates 1996a).

Rainfall

Rainfall adversely affects sugar quality in two ways:

Rainfall at the time of harvest will disrupt normal operations to the detriment of quality. Occasional rainfall

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Rainfall at the time of harvest will disrupt normal operations to the detriment of quality. Occasional rainfall during harvest periods will allow continued active growth of the cane and this would not permit ripening. Rainfall at the time of harvest can cause "Kill to mill" especially where cane burning is practiced. This causes discontinuities in factory operations and increase extraneous matter, which reduces sugar recovery in the factory (Yates 1996a).

These problems are common in Ethiopia, Kenya and Tanzania. Most factories, which practice pre-harvest burning of the field with mechanized harvesting and loading during wet periods, usually suffer these losses. However factories, which practice manual loading, do not experience such losses (Yates 1996a).

Moisture Stress (Dehydration Effect)

Dehydration effect on sucrose loss or sugar quality is difficult to measure precisely especially in standing canes. However, researchers in South Africa have observed that about 30% of the apparent increase in sucrose was caused by desiccation (Yates 1996a), however, this may not apply to other countries under different conditions. Dehydration effect can be detected when an increase in fibre percent cane parallels the increase in sucrose percent cane.

Abnormal delay between cutting and crushing:

Sucrose losses are principally caused through delays in cutting, and from moving and crushing cane in the factory. Such delays cause dehydration, sucrose inversion and rotting. Delayed cane, therefore, succumbs to series of deterioration activities through the activities of bacteria, fungi, yeast and other microorganisms (RASITC 2000c). This is because in acidic conditions, which would result by long delays in the field, inversion of sucrose into glucose and fructose, catalyzed by invertase would take place.

Non-Environmental Factors

These are factors that are under management control. They include: the cane variety, age of the cane at harvest, post-harvest techniques.

Cane Variety

Most sugar industries have developed varieties that are selected to maximize quality at the various stages of maturity (i.e., early maturing midseason and late). Sugar cane varieties are, therefore, bred with special emphasis on good quality milling characteristics. This includes early maturing with optimum fibre and good juice quality maintenance for longer duration in the field, resistance to post-harvest inversion and non-lodging (for mechanical harvesting) (Chiranjivi 1987). Cane varieties characterized by early tillering usually develop rapidly as weaker tillers die leaving few tillers to mature at harvest period, which maximizes the homogeneity of cane at harvest. Heterogeneous cane materials usually constitute cane stalks of different ages, and could affect sugar yield at the mill.

Age of cane at Harvest

For maximum sugar yield, sugar cane must be allowed to reach maturity before harvest. Immature canes have low sugar recovery (Yates 1996b). Yield in terms of tons of cane of unripe canes fed to the mill seriously affect sugar per hectare per month. The relative stability of the quality of cane over a wide range of ages is probably caused by a constant balance between various types of cane in the field. i.e. deteriorating mature and juvenile. Inclusion of all types of deteriorated and immature cane has reduced polarity from 14.5% to 11.4% of juice and purity from 87 to 80% (Yates 1996b).

Harvest and Post Harvest Losses

Sugar losses from harvest to post harvest processes can be quite enormous. These losses can, however, be minimized under good management. Harvest and post harvest losses result from either delay in harvesting, method of harvesting or heterogeneity of cane materials to harvest. Delay in harvesting of matured cane can cause the growth of shoots, lodging of canes, arrowing and infestation by rodents, which deteriorate cane materials before milling. Although side shoots contain some sucrose, they also contain reducing sugars and other sole impurities, which reduce recovery.

Sugar losses resulting from lodging of cane is enormous. Heavily lodged cane fields consist of heterogeneous cane materials. These include healthy mature canes, cane damaged in various ways and immature canes. The effect of lodging causes deterioration in cane materials. Two types of deterioration are known in sugar cane:

Staling: This type of sugar loss is caused by continued enzymatic activity within the plants due to inefficient photosynthesis, supplemented by the action of microorganisms. Considerable loss in sugar quality of cane stalled results in poor recovery of sucrose when time lag increases between harvest and processing. (Chiranjiva 1987). Under average conditions, about % of the original sugar available is lost per day of staling (Yates 1996b).

Souring: This is loss caused by production of compounds such as dextrans, through the action of *Leuconostoc mesenteroides* which interfere with processing. The rate of deterioration is generally influenced by harvest practices (burning or not burning, manual or mechanical; whole-stalk or chopped), the extent of disease or mechanical damage, the nature of the cane (variety and level of maturation) and The environmental conditions, (temperature and humidity) (Yates 1996b).

However efficient management skill can be used to reduce lodging in 3 ways, i.e., by breeding erect and non lodging canes (although lodging favours high cane

Closer positioning of the sprays for more effective washing.

Leakages in Sugar Drier: Leakages at the seal of the inlet of the drier was found to be source of smell and the continuous sugar loss in both Savannah Sugar Company Ltd. Numan and the Nigerian Sugar Company Bacita in Nigeria.

Some remedies were taken to forestall these losses, which are extending and centralizing the inlet screws to the sugar drier, repositioning of the hot and cold air ducts to the drier and improvement of air inlet flow to the drier.

Other African Countries

Improper Installation of Sugar Cyclone: This condition has been observed to be a cause of emission of heavy dust resulting in high sucrose loss in most sugar factories in Africa. However modification of the cyclone in some of these factories have resulted in sucrose loss reduction of 0.1% (Kaplinsky 1984).

Raw Sugar affixation and caramelization Losses

These conditions occur during the process of sugar manufacture. Raw sugar affixation involves washing the raw sugar with steam in order to purify it. However sucrose is lost in form of affixation syrup along with the impurities. Also, sugar caramelization, which is a process of sugar disintegration and dissolution in the syrup during juice evaporation as a result of uncontrolled high temperature were reported in factories in Swaziland, Malawi, Zambia and Zimbabwe (Lio'net 1995).

Generally heat destroys sucrose into polymers of coloured complexes during storage of sugar juices, syrup and massecuite leading to the formations of caramel. A similar reaction takes place on the surface of sucrose crystals in the mother liquor during process juice where there is enough water for the chemical reaction to take place as sucrose losses increase with rise in temperature (RASITC 2001d).

Maillard Reactions

Maillard type reactions in final massecuite in the continuous C-pan, the C-seed receives and C-crystalizer in Komati Mill in South Africa causes physical losses in the form of massecuite over flows, footing and carry-over of massecuite on starting up the continuous C-pan especially after long stops (Mc Master and Ravno 1975). Though the extent of this loss has not been clearly quantified, some remedial steps were taken which includes boiling of juice at lower temperatures, cooling of massecuite on stop days

Controlling of C-massecuite purity between 50 and 52 and use of sodium hydrosulphite to improve curing capacity.

Mauritius

For about 9 to 10 years ago, mechanical harvesting equipment have been used in Mauritius; to enable factories to run 24hr. day, self-powered loaders such as the Bell, Atlas is popular in Mauritius and South African sugar industries. These changes have, therefore, brought modifications in the mode of cane handling in the factory yard, thus reducing sucrose loss from cane being long on the field (RASITC 2001c).

CONCLUSIONS

In order to have maximum effect in improving quality of sugar, management efforts need to be concentrated on items, which can be controlled and expected to have a significant impact. Harvesting of cane should be done at the correct age of maturity and "kill to mill" intervals should be reduced to an absolute minimum. In industries where out grower service scheme is employed like in Nigeria, improved payment should be made to enhance good cane production and good quality sugar. Mills should also be sited closed to the field of production to reduce transport problems, as is the case with intending and emerging mills in Nigeria.

Generally, sanitation from the cutting of cane till the transport of sugar implies the necessity to follow scrupulously established sanitary measures, which are supplemented by shock spraying whenever required, and continuous application of a biocide at predetermined places. These practices definitely ensure a clean environment that limits the growth of microorganisms, thus reducing microbial sucrose losses. Such sanitary measures are being carried out by most off the African sugar industries to minimize field to factory sucrose losses.

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