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Microbes are Main Hindrance in Recovery and Quality of Sugar : Precautionary Steps to Control Losses

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ABSTRACT

The agro-based sugar industries faced financial losses due to improper planning of cane harvesting and transportation. The sugar industries have overlooked the quality of cane and time duration between cut to crush. This is because, several sugar industries are established with higher crushing capacity in a short arial distance so that, an unhealthy competition elevated between the sugar mills to meet their crushing target within a scheduled period. Hence, the harvest agencies took undue advantages to supply the post harvested stale cane with higher extraneous matter. The harvested sugar cane is very sensitive to microbial contamination and host metabolism. This activity impact quick loss of sucrose content in sugarcane from the time of harvest and also has a significant effect on sugar recovery. The recovery loss due to enzymatic and microbial interference is varied from 0.3 to 1.2% on cane. This problem of post harvest sucrose losses in sugarcane is a serious matter in cane producing countries, as it not only leads to low sugar recovery in mills but also monetary loss to growers. This loss can be reduced by adopting preventive measures by chemical, physical and biological means.

Keywords : Delay cut to crush, microbial activities, housekeeping sugar loss, sugar quality

INTRODUCTION

The time span of crushing season, capacity utilization, performance, sugar recovery and financial aspect of sugar industry is influenced by climatic condition, cane availability, sugar cane variety, cane quality, plantation and harvesting management, time duration between cut to crush, extraneous matter with cane and also deterioration of sugar by microorganisms. All sugar factories are well aware regarding unaccounted sugar loss and process problem by microorganisms due to delay in crushing and excess extraneous matter in cane. On an average, the sugar mills have lost near about 0.3 to 1.2 % sugar on cane during manual harvest, whereas the losses are higher side at the time of mechanical harvesting. The sugar losses at different stages further gets worse when crushing is extended beyond 2nd half of March and poor house-keeping practices (Solomon et al. 2001).The post-harvest delay losses mainly impacts both cane growers' and sugar mills. These losses are i) loss of moisture or tonnage and consequent loss to cane grower; loss in juice% cane which affects sugar recovery, ii) loss in recoverable sugar vis-a-vis low recovery which affect the profitability of miller and iii)production of undesirable microbial metabolites during staling which affects processing and quality of sucrose. A well-planned preventive measure with different treatment (chemical, physical and biological) from field to process would check the losses to farmers and sugar factories, such as time duration management of cut to crush is one of the controlling factors for post harvest quality in sugarcane, and biocidal, chemical, eco-friendly compounds and chemical formulation assist in minimizing the post-harvest quality losses.

Post harvested Sugar losses: Sugarcane post-harvest sucrose losses can be high or low depending on a variety of circumstances,ambient temperature, humidity,

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soluble invertase activity, cane variety, and maturity status. Cane transportation delays from the fields to the mill are normally established problems related to sucrose losses at different stages, which contribute to a significant reduction in cane weight and sugar recovery. When sugar mill processes damaged or stale canes,which create a number of challenges, such as increased viscosity due to dextran generation, formation of acetic acid, lactic acid and dextran the product of *Leuconostoc spp*. These adverse conditions impact on poor juice clarification, poor filterability, retards the evaporation rate, increase massecuite boiling times. The combination of all of these variables results lead to low recovery and poor quality sugar, resulting in significant losses for sugar mills (Solomon et al. 2001). Solomon (2001) demonstrated that there is a loss of more than one unit in terms of pol percent from harvesting to milling. Additionally, the range of quality losses caused by crushing stale canes has been discovered to be between 12 and 15 percent of sugar recovery (Figure 1).

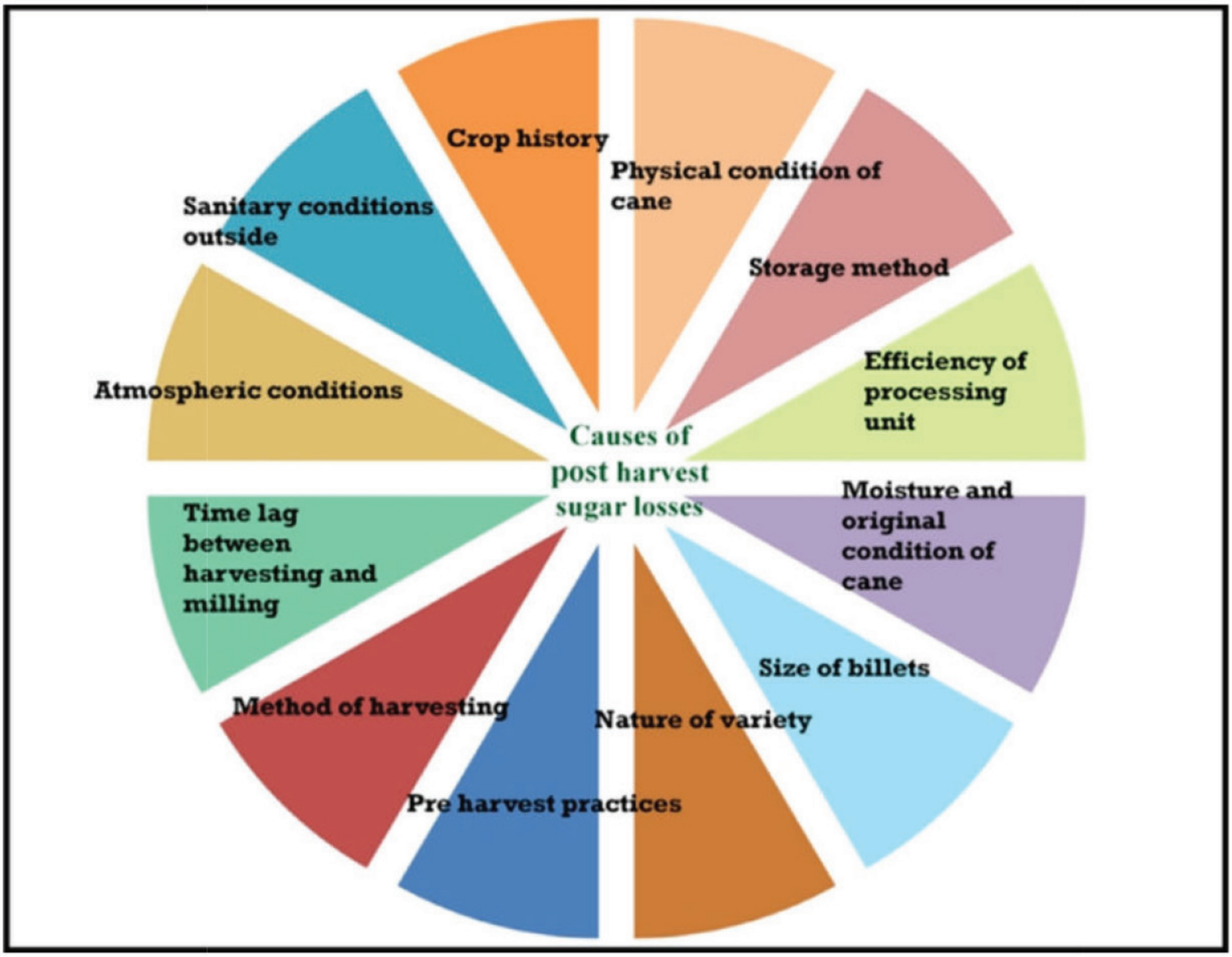

Figure 1 : Causes of post harvest sugar losses (Misra, 2022)

Socio-economic impact of post- harvest delay: Post harvest delay do not only affect financial loss to cane growers (reduction in cane weight between 7.4 to 17.0 %) but also to sugar mills due to reduction of sugar recovery by about 2.0 % (96 hours stale cane), reducing mill and boiling house capacities (Figure 2).

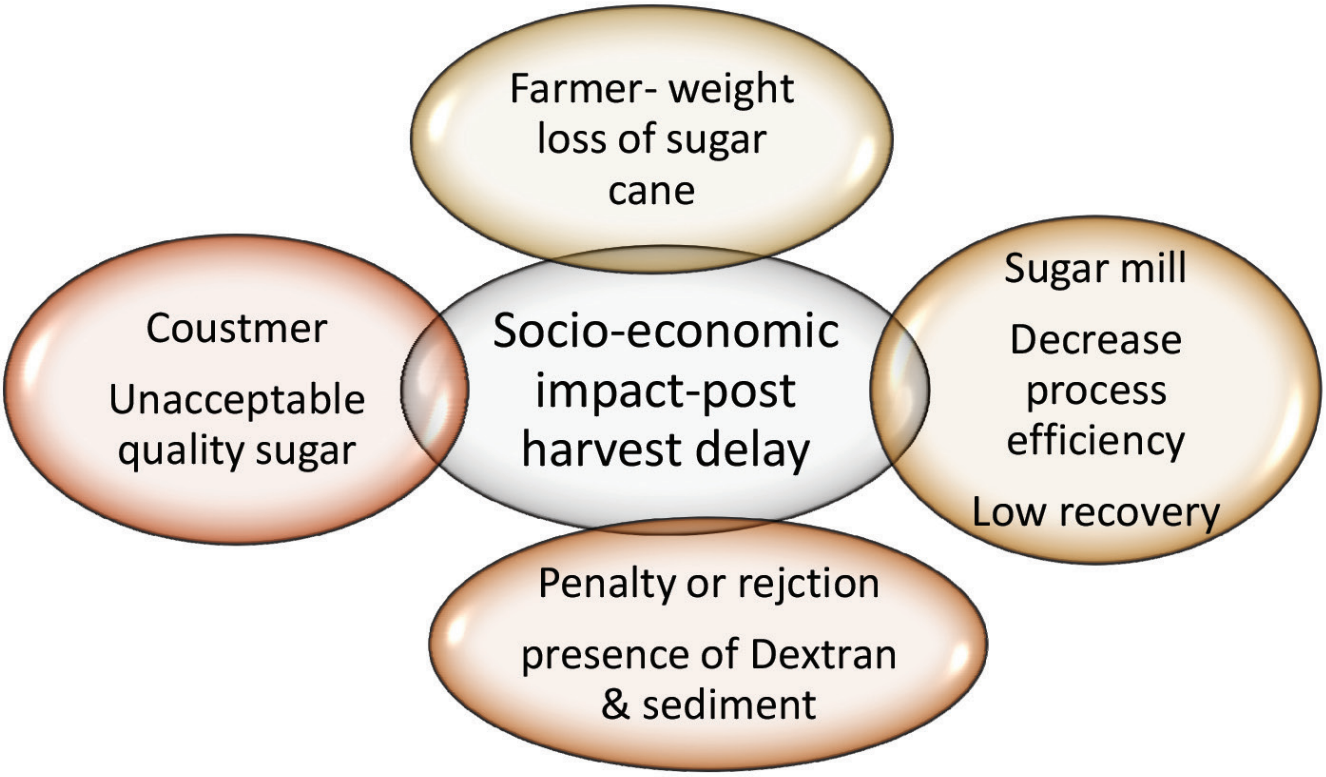

Figure 2 : Causes of post harvest sugar losses

Types of sugar losses due to post harvest delay: The degradation of sucrose in canes begins as soon as the cane is harvested. These losses become more pronounced as the time between harvesting and milling increases. These unaccounted sugar losses are categorized as :

Chemical loss: Changes in pH and temperatures, which is influenced by atmospheric condition. This loss is higher in summer season as compared to winter season.

Microbial loss: The sugar juice in the stalk is most favorable nutritive (organic and inorganic) source for growth and proliferation of microorganisms. These microbes grow at a rapid pace and forms products that deteriorate sucrose of the cane stalk. The microorganisms that adversely effects on sucrose content in harvested cane and their role in lowering the sugar recovery, thus hindering the production of final product.

Enzymatic loss: Microbial and Invertase activity, dextran synthesis, reducing sugars, and the acidic quality of juice are all bio-chemical processes that contributes to post harvest sucrose losses. Many such species of bacteria and yeasts produce enzyme invertase that splits sucrose present in cells of sugarcane stalk into glucose and fructose. This results in sucrose loss with high reducing sugar levels due to inversion, additionally some bacteria produces lactic acid and acetic acid that contributes to post harvest sucrose losses

Economical losses due to post harvest delay: According to many scientists, the harvested sugar cane reaches the sugar mill after two to three days and some times it exceeds four days. Hence forth, the quality of the cane deteriorates, the formation of undesired chemicals during cane processing (due to chemical or micro-biological activity) causes challenges in sugar processing, which impacts lower of sugar recovery and sugar quality, resulting in economic losses to sugar industries. The three main reaction pathways that results in sucrose loss are microbial, enzymatic and chemical processes on mixed juice (MJ) have indicated that 93% of sucrose deterioration is caused by microbial action, while 5.7% and 1.3% is by enzymatic and chemical processes, respectively, within the first 14 h of the deterioration process (Eggleston 2002).

Sugar recovery loss: Approximately, 4 parts of sucrose are consumed for every one part of dextran produced.

Sucrose loss in MJ (mg/kg brix) = 4 x dextran in MJ (mg/kg brix)

That means each 100 ppm increase of dextran in the juice (i.e 0.01%), resulted in the loss of 0.4 kg of sugar per ton of sugar produced without considering the industrial recovery. The purity of the final molasses increased by 1% by each 300 ppm of dextran in the syrup. It is proved that one unit rise in final molasses purity was equivalent to the loss of 0.454 kg of sugar per ton of sugar cane processed.

Sucrose losses in sugar cane billets (mechanical harvested cane): In view of crisis of manual labor for cane harvesting, the sugar mill management gradually switch over the harvesting system from manual harvesting to mechanical harvesting. The output of mechanical harvesting is more effective than manual. Whereas, the chopper harvesters have led to faster loss in quality if the time lag between harvesting to milling exceeds 24 hours. The mechanical harvesting with consequent delay in processing of billets affects factory efficiency and sugar quality in addition to reducing sugar recovery. High losses of sucrose in mechanically harvested cane and billets have been reported by many workers (Foster, 1969; Sang et al. 1986; Singh and Solomon, 2003).The reason that smaller billets are more vulnerable to microbial invasion and therefore dextran formation is prevalent because they have more cuts than the larger canes. The more cuts, the more injuries to the cane, and the cut canes are more susceptible to microbial infection. On an average CCS loss in billets is nearly 2.5 units of CCS / day in billets kept in open field conditions. The deterioration of burnt chopped cane leading to enormous difficulties in both filtration and crystallisation due to dextran formation.

Precaution to reduce post-harvest sucrose losses by mechanical harvesting:

i. The time limit between cut-to-crush should be reduced to 24 hours. That means green billets should be processed within 12–24 hours.

ii. No detention of billet loaded vehicles at cane yard.

iii. Minimize the extraneous matter with billets

iv. The sugar mills shall introduce cane payments based on CCS and percentage of extraneous matter.

v. The sugar industry shall ensure supply of fresh cane and minimize transit losses.

vi. The size of billets should be increased to minimize the exposed area of cane.

vii. In case of impending delays due to any reason, harvested cane should be sprayed with a solution of QUAT based biocide(s) and an anti-inversion compound. Such treatments have been found effective on whole cane as well as billets.

Microbial growth at mill is nothing but continuous fermentation process:

The working principle of milling train with compound imbibition & continuous fermentation are similar to each other. In a stable environment, the microorganism may be bacteria or yeast will propagate at a constant rate in a given time. The reproductivity of microorganisms indefinitely and in constant quantity, if a volume of nutrients in the proper relative concentrations is fed to the microbes in the container whereas at the same time an equivalent volume of liquid containing the microorganisms is drawn off from the propagating vessel.

Consider the volume of imbibition water entering the milling train in one hour in relation to the volume of diluted juice and bagasse passing through the entire milling train under imbibition during that hour. As this water and juice is recycled several times, the effective volume on the milling train is very large in proportion to the volume of water and undiluted juice entering the milling train, or the diluted secondary juice leaving the mills.

Microbial activity is maximum between 30-40 °C, depending on the type of micro-organism. Hence the use of hot imbibition water favours the multiplication of the microbial population.

Relatively concentrated juices slow down the reproductive rates, but the, presence of bagacillio, nullifies this retardation. Bagasse as a substrate to speed up the fermentation of *Aspergillus niger* in the fermentation of citric acid is the basis of many patents. Here the cane juice having significant amounts of phosphate is favorable for microbial population.

Micro-organisms and sugarcane: The origin of the contaminating microorganisms has been traced to the soil adhering to the sugarcane stalks and leaves. Out of these most damaging microorganism is *Leuconostoc mesenteroides* and acid producing streptomyces and actinomyces microbes are in large number in cane stalks. Upon harvesting, the cut ends of the cane stalks are open to microbial infection originating not only from the soil and surrounding plant matter, but also from the contact with contaminated cane knives. Cutting of cane is not the only mode of infection; whenever a stalk is damaged either by borer, burning or frost, it is exposed to microbial life. During sugarcane processing most of the micro-organisms which infect the cane stalks are washed off into the extracted juice; this is an excellent substrate for micro-organisms, form sugarcane juice microbes are utilizing the sucrose for growth with the concomitant excretion of their metabolic products such as acids (lactic and acetic acid), alcohols (mannitol and ethanol) and polysaccharides (levan and dextran) into the surrounding environment. *Leuconostoc spp.* are responsible for post harvest cane deterioration and that it is the produced dextran which is the 'gum' responsible for the processing problems. Hence the presence of microorganisms in a sugar factory is undesirable due to their actions. The gum/slim (high molecular weight carbohydrates) is produced from carbohydrates of deteriorated cane, polysaccharides (dextran, levan, sarkaran) produced by microorganisms. The name 'dextran' was introduced by Scheibler in 1874, when he discovered that the mysterious thickening of cane and beet sugar juices was caused by a carbohydrate of empirical formula ($C_6H_{10}O_6$) with a positive optical rotation (Scheibler, 1874). Shortly thereafter, it was suggested that Leuconostoc was responsible for slime production in sugar factories (Van Tieghem, 1878).

It is useful to remember that inadequate housekeeping and hygiene inside a factory and refinery might also result in the contamination of processing streams with microorganisms which can result in sucrose losses, gum production and related processing problems.

Effects of dextran on dugar process

Polarization: Dextran is highly dextro rotatory with specific rotation values at least three times that sucrose and hence influences sucrose determination by polarization.

In process house:

- ❖ *Lime consumption:* Is more due to fall on pH of contaminated mixed juice
- ❖ *Poor clarification:* pH maintaining at juice reaction tank is a difficult task due to contamination. It is ultimately affected on juice settling in clarifier.
- ❖ *Increase in viscosity:* Presence of dextran and starch is responsible for high viscosity in intermediate products (Mixed Juice, Clear Juice, Syrup, Massecuites and Molasses of process house.
- ❖ *Retard the rate of heat transfer:* Higher viscosity reduces the heat transfer co-efficients in juice heaters, evaporator bodies and pans.
- ❖ *Scale formation:* On heating surface of juice heaters, evaporators and pans due to slim product developed at process house.
- ❖ *Increasing boiling time of massecuite and crystal elongation:* The massecuite boiling time will be increased due to viscosity nature of feeding materials, as a result poor exhaustion. Secondly due to presence of dextran elongated crystals will be developed during massecuite boiling.
- ❖ *Poor purging at centrifugal:* High viscous massesuite along with needle shaped crystals, will reduce the purging capacity of machine and will require more wash water for disassociation of molasses from crystal surface. Thus, circulation of sugar will be increased & increase the molasses purity. Finally, it will affect the sugar quality and colour.
- ❖ *Sugar drying:* High level of dextran is reported to make it more difficult to dry & condition plantation white sugar as well as refined sugar. Dextran is also known to cause sticky soft sugars, which are difficult to pack.
- ❖ *Acid Beverage flock and sedimentation on final sugar:* The impurities like silica, starches, dextran,

gums and other polysaccharides influence the flock formation and sedimentation.

Effect of volatile fatty acid on fermentation:

- Volatile fatty acids are adversely affecting the metabolism system of yeast and prolonged the fermentation rate.
- Volatile acids in mesh reduce the yeast growth & ethanol fermentation rates
- Volatile Acids in mesh >2500ppm can reduce fermentation rate and yeast growth.
- Volatile Acids in mesh >5000ppm can reduce fermentation rate by 30-40%
- Volatile Acids in mesh >7500ppm can kill the yeast, reducing viability upto 40-50%

Some of the useful parameters to assess the juice quality of cane arriving at the factory include dextran, gum, oligosaccharides, ethanol, mannitol, reducing sugars, titrable acidity, invertase content, juice viscosity, purity drop, etc. Based on these indicators, sugar loss by microbial contamination could be assessed.

Titrable Acidity Index (TAI)

The Titrable Acidity Index (TAI) of cane juice was determined by titration using 0.1 N NaOH and phenolphthalein indicator solution. 10 ml of the diluted juice in 25 ml distilled water was placed in a conical flask with the gradual addition of 0.1 N NaOH solution until the solution turned pink.

The Titrable Acidity Index was calculated by the following formula:

TAI = (ml of 0.1 NAOH consumed*100)/brix of juice

The various formulae used for estimation of sugar losses

The formulae used for estimation of sugar losses are as under.

1. Sugar loss = 0.099 B1(C2 – C1) kg/tonnecane.(3)

Where B1 = average brix of crusher juice

C1 = g invert sugar per 100 g. dry solid in crusher juice

= (% invert sugar in crusher juice x 100)/ B1

B2 = average brix of mixed juice

C2= g invert sugar per 100 g dry solid in mixed juice

= (% invert sugar in mixcd juice x 100)/ B2

2. E. R.Q.V.– (M.J/P.J) and (L.M.J/P.J)

3. i. Using data of invert sugar:

sugar loss kg / MT cane crushed

= Rise in invert sugars from PJ to MJ X Av. brix PJ X 0.072

ii. Using acidity data:

Sugar loss kg /MT cane crushed

=Rise in acidity from PJ to MJ X Av. brix PJ X 0.0131*

The total sugar loss will be i + ii

Close monitoring to control growth and increment of microorganisms:

A. *At millingstation*

Damaged cane: Damaged cane should not be lifted for long time from both sides by cane carrier when cane is unloading.

Cane carrier bottom area: The stagnated decomposed juice is a favorable condition.

Fibriser tips: Fibriser hammer tips and both sides of fibriser are favorable conditions.

Chain links of intermediate cane and bagasse carrier: attached bagasse on chain links is highly favorable for microbial propagation.

1st mill to last mill: Accumulated prepared cane and bagasse on both sides of mills.

Drains of mill house: Stagnated diluted juice with bagasse.

Contaminated juice collecting troughs: These containers are the prime areas in the sugar mills for invasion of microorganisms particularly, multiplication of Leuconostoc sp.

Areas behind juice screens: These areas behind screens are more likely to harbor dextran producing microorganisms. Even the juice screens are major source of bacterial infection.

Dilute juice tanks: These tanks are sites of microbial contamination as they receive contaminated juices

Pipe lines and valves: Pipe lines and valves holding unlimed juice are also the sites where microbial contamination takes place.

Intermediate juice tank pump area: Stagnated and wetting condition at pump area due to leakages from pump glands and overflow from tank at the time of pump tripped.

High buffer capacity of the cane juice: The relatively high buffer capacity of the cane juice makes a great deal of acidic fermentation, consequently a very small drop in pH of the juice in its passage through the milling train can actually represent a relatively high destruction of sugars.

B. *In Process house*

Sulphited juice receiving pump area: wet condition of pump area due to gland leakage.

Sulphited juice receiving tank bottom: Deposition of sand and sludge deposited at bottom of tank.

Filtrate juice tank, muddy juice tank and their pump area: This area also favoring for microbial growth.

Rotary vacuum filter area: at the time of operation wash water and juice falling at vacuum filter area also favorable.

Syrup and molasses receiving tanks: The scum and exposing area of these tanks are favorable condition for microbial growth.

B-sugar magma mixer and C-sugar magma mixer and pump area: Generally, overhead condensate hot water is using as lubricating for curing of B massecuite and C-fore sugar curing, This condensate hot water normally contaminated due to entrainment.

All Molasses run-off tanks and pump area: Pump area is always wetting condition due to leakages from pumps.

Drains of centrifugal section: Diluted molasses and sugar solution are stagnated in drains; it is favorable to microbial growth.

Hot air blower and cold air blower area of sugar hoppers: Leakages of condensing water and falling of sugar from hopper is highly favorable area.

Actions to be taken to reduce the growth of micro-organisms:

- Better housekeeping from cane yard to sugar bagging unit.
- Cleaning surrounding the mill dead pockets, rotary juice screen outside by application of steam and hot water.
- To choose the most efficient biocides.
- A network is to be installed to distribute the biocides to the tanks. The system, which uses a specific rotating jet-head, has the advantage of being economical and guarantees distribution of the biocides over all surfaces where microorganisms are most likely to develop.
- The sugar materials residence time in the tanks is to be reduced by better flow management.
- Spray the anti-microbial chemicals at all pump area from mill to curing house.

Good housekeeping:

The presence of slime greatly accelerated the rate of sucrose loss and retarded biocide efficiency. So the regular physical cleaning or "good housekeeping" helps to reduce slime accumulation, it does not prevent but minimize the growth of microorganisms in the circulating cane juice. From cane weigh bridge to sugar godown area should be cleaned, confirm that no debris, water and liquid material is stagnating at anywhere.

Important points for better housekeeping:

- Minimimise the sugar cane falling at cane carrier area at the time cane unloading.
- Immediate collect the cane before it damaged by transport vehicles.
- Cane carrier area should be free from soil, water and foreign particles.
- Do not dump the sweeping material in cane carrier.
- Ensure the dryness of cane carrier bottom area.

- Dry cleaning at fibrizer area, bottom of mill tandem, both sides of mills and area of juice tanks.
- Do not allow water or diluted juice in the mill house drains for long time.
- The boiling house floor from clarification station to bagging station should be clean.
- Do not allow any leakages from pipe lines, tanks & pumps.
- Collect the sugar (liquid, magma and dry) immediately, which are falling from different equipment.
- Distribute the responsibility of housekeeping among the supervisors and work persons by making team.
- Maintain record regarding housekeeping.

Application of physical treatment (sanitation)

- The physical treatment is carried out by two ways, such that steam treatment & hot water treatment. This is effective only 60 % to 80%.
- *Steaming:* Steaming of cane carriers, inter carriers, mill headstocks bearing pockets and juice gutters with 40-lbs/sq.inch pressure steam twice in each shift.
- Steaming/hot water treatment should be followed surrounding the rotary juice screen.
- It must be ensured that the time of treatment at the high temperature is long enough to allow all parts to reach the correct temperature for sanitization
- *Hot water:* For hot water, typically temperatures above 80°C having minimum pressure 3 kg/cm2 and contact times of minimum 20 minutes are needed. The higher the temperature of the water, the more effective it will be, and the contact time may be reduced.

  Safety measures should be followed to avoid any accident.

Application of chemicals to harvested cane to minimize sugar loss : Several approaches involving the use of chemicals/biocides have been implemented to minimize bacterial inversion and have been successful in preventing sugar losses.

i. As per the argument of Li and Ma (2020), the utilization of chemical formulations of benzalkonium chloride and sodium metasilicate for protection harvested sugarcane against microbial invasion and restriction of sucrose losses. The implementation of this chemical formulation resulted in a notable decrease in the levels of microbial infestation, dextran, soluble acid invertase, and reducing sugars in the harvested cane. This outcome played a crucial role in changing the degradation of sucrose. As a result, enhancing the overall sugar recovery process at the milling stage.

ii. Frequent spraying of solution containing potassium permanganate (0.1% or 5 ppm) and dimethyl dicarbonate (DMDC) along with sodium meta silicate (SMS, 1%) on harvested cane had been reported to be effective in minimizing invertase activity and retaining the juice quality in the mills.

iii. Glutaraldehyde and benzalkonium chloride (1000 + 250 ppm) reduced the losses in sucrose content to 7.1% as compared to the 30.8% loss in the control, thus improving the performance by 76.9%. The application of chemicals reduced the acid invertase activity (by 60%), lowered weight loss, titrable acidity, reducing sugars content, dextran, ethanol, and ethylene production and respiration rates. The application led to the reduction in the total bacterial, fungal, *Leuconostoc,* and yeast counts by 67.92, 51.3%, 26.08, and 51.2%, respectively.

Application of chemical biocide to control microbial contamination:

Fibrizer sanitation: The Fibrrizer/ shredder is used to improve sugar extraction at mills by improving the preparation index, but this has given rise to chances of microbial infection. The fibriser hammer itself acts as a source of contamination. It has a very special requirement especially with respect to the time of action by the biocide. So that the biocide intended to be used for cane sanitation should have efficient killing ability within one minute of application.

Mill sanitation: The surrounding area of mill section is favourable condition for microbial growth. To minimise the microbial contamination chemical biocide treatment should be continuous at different places.

a) More than one biocide should be used as weekly alternate

b) Dose of biocide at Fibrisor at the rate of 3ppm on cane

c) Addition of antibiotic solution along with biocide in imbibition water at the rate of 4-5 ppm.

d) Central preparation system for dilution of biocide & that diluted biocide should be dosed at intermediate juice tanks.

e) The system of application was therefore modified as follows:

   - to the mixed juice.
   - to the 1st imbibition juice.
   - to the 2nd imbibition juice.

I. Chemical biocide should be sprayed to all point of mill section by mechanical spray machine. Minimum twice in a shift.

II. Shock dosing of biocide also required to dehydrate the microbes at an interval of 24 hours.

III. Sprinkling of formaldehyde or bleaching powder in all pump beds, juice gutters, juice retention tanks, mill beds and drainage pockets.

Boiling house sanitation: To restrict the microbial growth in boiling house, chemical biocide treatment at different places is essential

i. Antibiotic solution on hot water overhead tank.

ii. Shock/ regular dosing at filtrate juice receiving tank

iii. Spray of formaldehyde / bleaching powder/ QAC/ carbomate compound in all pump beds, juice gutters, juice retention tanks, magma mixture area, sugar melter area, molasses run off tank area and drainage pockets.

Sanitation during stoppages: considerable increase in bacterial activity occurs during stoppages and it follows that infestation of fresh juice will result in additional losses.

Benefits of biocide use as mill sanitizer.

- Improves sugar recovery by inhibiting enzyme action for the time between crushing of cane and lime neutralization
- Spillage of juice on machinery parts and nearby areas causes growth of moulds, fungi and bacteria. These biological species produce acids and cause corrosion of metal. Control by application of biocide.
- Thus, reduces maintenance and replacements costs.

Improvement in juice quality by application of a good formulation biocide on prepared cane:

- Increase in brix value of PJ and MJ.
- Increase in pol %juice of mixed juice.
- Decrease in reducing sugars from PJ to MJ.
- Reduction in dextran in PJ and MJ.
- Reduction in titrable acidity from PJ to MJ.
- Increase in purity.
- Improvement in sugar recovery % cane.

RESULTS AND CONCLUSION

The sugar industries should take a serious note on the sugar loss during post harvesting inversion, juice and intermediate products contamination by microbial activity. In our past service experience in sugar mills, authors have observed a rise in recovery by minimum of 0.2% and maximum 0.4 % by following strict control over effective mill sanitation and precise housekeeping, which is a substantial gain to the revenue.

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