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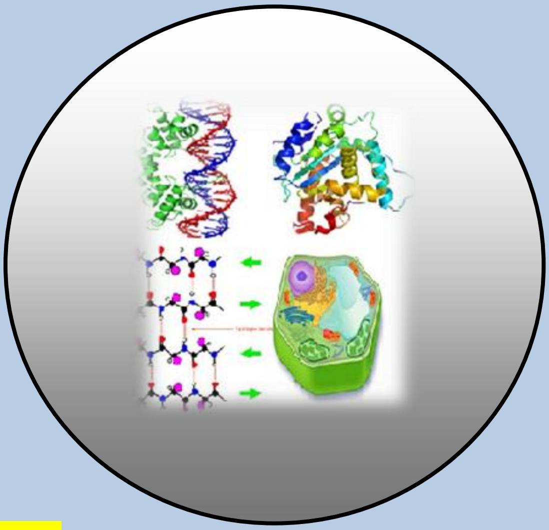

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RESEARCH PAPER

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Post-Harvest Quantity and Quality Losses of Sugarcane Crop

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ABSTRACT

Due to uncertainty of cane crop profits with increased inputs and high competence in Indian sugar industries farmers are under high acute stress. Sugarcane is a perishable commodity and must be processed into sugar quickly after it is harvested. In this review Post-harvest sucrose losses have been briefly reported from various aspects of many cane producing countries and linked with low sugar recovery and several problems during sugar processing. Biodeterioration associated with the inordinate delays between harvests to milling of sugarcane and aggravated by many intrinsic and extrinsic factors causing enormous depreciation in cane tonnage as well as sugar recovery. Besides harvest-to-mill delays, other factors such as ambient temperature, humidity, cane variety, period of storage, activities of invertase, maturity status etc. These are responsible for decline in sugar recovery. The activity of invertases and proliferation of acid, ethanol and polysaccharides (dextran) producing microbes play a crucial role in the loss in recoverable sugars in cane and milled juice. In addition to loss in sugar recovery, its adverse affects has been noticed in the sugar manufacturing process and sucrose quality. Efforts having been made to reduce loss in tonnage and sucrose using physico-chemical methods. These include spraying of water, bactericidal solution use of anti inversion and anti bacterial formulations and pre-harvest foliar and soil application of zinc and magnous compounds. An integrated mill sanitation program and simultaneous use of dextranase could further improve sugar recovery and minimize problems caused by dextran. The possibility of electrolyzed water (EW) fogging to reduce post-harvest deterioration in field and mill yard has also been explored. Some of these methods are useful and present larger options for the industry to minimize after-harvest quality losses in the field and milling tandem. Application of chemicals (1% sodium azide and picric acid) as well as (5% of neem cake and dried leaves extract) aqueous solutions sprays on harvested canes showed remarkable results in minimization of sugar losses during staling.

In the month of March, a significant response of treatment against control was recorded. Mean values showed 5% Neem leaves extract spray solution proved most effective in reducing the sugar losses and the value was statistically equal to 1% sodium azide and picric acid spray treatments. In April, the effect of sodium azide spray solution was most effective in reducing the sugar losses during staling followed by dried Neem leaves extract solution. At 120 hr in April the effect of sodium azide spray was best followed by dried Neem leaves extract spray.
Keywords Post-harvest deterioration, Acid Invertase, Dextran, Commercial Cane Sugar, Natural Biocides, Field Control and Chemicals.

INTRODUCTION

Out of total (41.7 lac ha) Sugarcane acreage in India, average half (19.4 lac ha) is cultivated in UP but it contributes only 40 percent cane production and 30 percent sugar production. Average crop production and sugar recovery of our state UP is low than any other state. Efforts are being made how to improve sugar crop production and sugar recovery through intensive and extensive researches which are being done to get better results. With present 1.6percent per year rate of increase in Indian population by 2020 it would reach 136 crore. For this challenge we have to manage extra sugar requirement in the years to come. This can be managed also by reducing post-harvest deterioration of cane by reducing cut to crush period losses. The post-harvest deterioration of sugarcane is one of the most vexing problems of sugar industry and has attracted widespread attention in the recent years. The published reports indicating loss of recoverable sugar following cane harvest began to appear towards the end of the 19th century (Stubbs 1895; Weinberg, 1903; Cross and Belile, 1914, 1915). According to these authors, Went and Geerlings from Java reported deterioration of sugarcane in 1894.Early workers emphasized the importance of time lag between harvesting and milling as well as storage environment in deterioration process Muller von Czernicki (1900) and Browne and Blouin (1907) in Java reported considerable drop in juice purity during storage of cane, however, no scientific explanation was advocated by the author .The earliest specific reference to a cane invertases role in post-harvest deterioration was made in 1907 by Browne and Blouin and later on Hall in 1913 used the term inversion to be associated with the process of cane deterioration and subsequently published another report on inversion in 1914.In 1915 Cross and Belile performed studies which established the presence of an inverting enzymes in the millable stalks and milled juice, and their they become more active during storage .These workers stated "It appeared to us possible that the inversion in the staling canes might also be due to the ferment invertases, and we therefore stored some of the juice of one of these canes with chloroform and toluene, and analyzed it after a certain time. It was found that considerable inversion had taken place as bacteria were excluded by the antiseptics added, the inversion must have been due to ferment, probably invertases present in the deteriorated cane." Guilbeau *et al* (1955,1956), noticed the phenomenon after ripening associated with the cane deterioration and advocated that increased sugar yields and profits could be gained by storing harvested cane in heaps for a period of one week or more. These workers pointed out that increased sugar content was attributed to loss in cane weight. However, in actual practice sugar content, purity of juice and tonnage showed significant decline .Somewhat similar effects were reported by Australian scientist (Egan, 1971).

A rapid decline in CCS and dextran formation in mechanically harvested burnt sugarcane crop were also reported from Taiwan (Hsia, 1972).Alexander (1973) in Puerto Rico concluded that no significant increase in recoverable sugar resulted as a delayed grinding response Many researchers reviewed the work on post-harvest biotechnology of sugar crop and highlighted the importance of loss reduction technology in improving sugar productivity.(Bruijn, 1966; Salunkhe and Desai (1988), Batta and singh,1991; Magadum and Kadam, 1996; Eggleston *et al*., 2001; Sharma *et al*, 2004, Milintawisamai *et al;* 2006; Solomon, 2000, 2002, 2004, 2006, 2009; Solomon *et al*; 1990, 1997, 1999, 2001, 2003 , 2008). The terms *stale cane* and *sour cane* are two different stages of cane deterioration after harvest. During the process of deterioration, metabolic conversion of stored sucrose takes place into less economic products (Organic acid, oligo and polysaccharides, gums, ethanol) thorough the agency of enzymes and microbes. The stale cane according to Alexander (1973)is the aging of harvested stalk which have depleted their sucrose via continuing inversion and respiration whereas sour cane is microbiological deterioration of sugarcane stalks by lactic acid bacterium *Leuconostoc mesenteroides* which converts sucrose in to organic acids of typical sour odor. However, both types of deterioration seem to operate simultaneously in cane and milled juice.

Sugarcane deterioration that detrimentally affect industrial processing is a serious economic problem for sugar industry in many cane processing countries the post-harvest sugarcane deterioration products are dependent on many factors such as method of harvesting sugarcane injury environmental conditions, variety, supply system, harvest to milling delays etc. Sugarcane management and harvesting methods also better in the prevailing supply system of raw material, cut to crush delay of 3 to 5 days is quite normal which aggravates deterioration process in the harvested cane due to inversion, respiration and formation of acids alcohol and polysaccharides producing micro-organisms. Sucrose loss in the harvested cane and milled juice through these biochemical and microbiological agents (*Leuconostoc sp*.) has detrimental effect on sugar recovery and presently a serious economic problem to sugar mills in many cane producing countries. *Leuconostoc* i*nfections is* considered as one of the main causes of factory processing difficulties when handling deteriorated sugarcane. Economically, it may not be worthwhile to process a deteriorated cane. Not only can poor cane quality impinge on profitability, It could also trigger of many processing problems and consequently factory shutdown.

There are two areas of post-harvest quality losses leading to low sugar recovery.

(a) *Primary Losses:* Sucrose inversion process following harvesting of sugarcane and subsequent delays in delivery of cane to the sugar factory.

(b) Secondary Losses: Factory losses due to inversion, dextran alcohol and acid formation in the extracted juice incident to inefficient and unhygienic processing.

Studies have conclusively proved that the cut-to-crush internal and external temperature are most important factors which determine the rate of sucrose loss through inversion, organic acids, dextran and polysaccharides formation and respiration. Hughes (1956) reported sugar losses as high as 35 percent the Hawaiian Commercial and Sugar Factory Ltd. Punnene, Maui, during the period 1929 to 1953 mainly due to staling. These losses were expected to increase up to 50 percent if the management of crop and its subsequent processing was not done on scientific lines.

Many studies have reported quality losses from delayed grinding of sugarcane crop varied from a minimum of 12 percent to as high as 50 percent of the recoverable sugar from fresh cane after it was held for 14 days (Guilbeau 1955,1956).According to Egan (1968) for normal weather conditions, some of the heaviest losses (in CCS) reported are 4 percent in dominian Republic, 5 percent in Mexico,7 percent in Argentina and 8percent in India .Studies conducted by Chiranjivi Rao (1989) have shown 2 percent loss in sugar recovery when cut-to-crush period exceeds 72 h. Burcer *et al* (2004) reported 1.5% loss in sugar/day due to delay milling .Studies under taken by Solomon *et al* (2008) in India have shown over 1.0 unit loss in pol % cane from harvest to milling stage. On an average, Indian sugar mills lose about 5 to 10 kilogram sugar per ton of cane ground. These losses further shoot up when crushing is extended in summer month. The enormous amount of sugar lost during post-harvest operations point out the futility of increasing sugar production field level if sugar is not proportionately recovered in the factory.

The field origins of dextran showed that *Leuconostoc* can enter sugarcane storage tissue before harvest when cane is physically damaged (cracks, lodging) while undamaged standing cane is free of internal contamination with Leuconostoc. Also, over burning of cane removes the protective surface wax, causing cracks in the rind and cooks the underlying storage tissue, causing stalks to collapse and juice to ooze, providing a feast for *Leuconostc. S*ound, whole stalk cane seldom shows elevated dextran content: But burned or frozen whole-stalk cane will deteriorate more rapidly (Eggleston *et al*., 2004) with the super imposed field mechanization. The organism *Leuconostoc mesenteroides* feeds on sucrose in dilute solutions in neutral or slightly acid pH at temperature under 60^{o}C and therefore grow freely on exposed sugarcane tissue, cane juice and syrups of low brix. The microorganism reproduces rapidly under anaerobic condition, for example in mud coated cane and in cane kept in large piles with little circulation of air.

Cane juice is a rich medium which contains about 15-18 percent sucrose 0.5 percent reducing sugars and adequate amount of organic nitrogen and mineral salts for microbial growth, its pH ranges from 5.0 to 5.5 making it selective for acidophilic microorganisms especially, yeasts and lactic acid bacteria. In a typical cane sugar factory, juice is extracted from the stalks by crushing them in a series or three or five roller mills. The collected juice is then limed to pH 8 and heated to boiling in the clarification process which effectively kills all vegetative cells. The time interval between crushing and clarification is approximately 15-20 minutes, but the level of microbial contamination of the juice is usually extremely high, typical viable counts being 108-10^{9} cells / ml juice. The microbial population increases tremendously if there are unscheduled stoppage and no biocides are used during milling. Nearly all microbes are eliminated during liming and sulphitation, however due to fluctuation in temperature as a result of frequent stoppage; certain thermophilic bacteria have the tendency to multiply. It has been known that a major loss of sugar occurs due to inversion of sucrose in the raw sugar cane juice and other type degradation of the juices caused by bacteria activities, enzymes and other biological factors. These losses may run from about 0.5% up to as much as 4 to 5% of the total sugar entering the factory. Of this sucrose loss, about 13% is due to chemical inversion; 25 percent is due to the activity of cell free enzymes and about 62 percent is eaten up by the microorganism present in juice and mills.

Research efforts to assess the extent of cane deterioration and contain its progress at the field and factory have met with only partial success. Some of the useful parameters to assess juice quality of cane arriving at the factory are dextran, gum oligosaccharides, ethanol, mannitol, reducing sugars, titrable acidity, invertase content, juice viscosity, purity drop, etc. Based on these indicators, quality of cane supplied to the mills could be assessed; however, sucrose loss in the harvested cane could be minimized by using methods described below.

1. There is no substitute for better communication, quick and efficient transport to minimize post-harvest losses. The harvested cane must be brought to mill and processed as quickly as possible. The factory management must ensure that fresh cane is supplied regularly and all indents should be placed according
2. The harvested cane before crushing should be made free from trash leaves and roots etc. For late-milling season (high ambient temperature), varieties with high rind hardness/fiber along with high wax content should be preferred. This will reduce considerable moisture and sugar loss from cane.
3. Soil content of cane is also one of the factors influencing not only cane deterioration but also causes process difficulties, such as cane preparation, milling, and clarification and is a source of the millions of microbes that can grow in juice.
4. It has been observed that topped cane deteriorates faster than cane with the crown of leaves attached. In case of any anticipated delay in crushing, topping should be avoided.
5. Maturity of cane is a major factor in the inversion and subsequent reduction of stored sucrose. As maturation level increases the extent of sucrose loss is minimized.
6. In order to cut down post-harvest sugar losses, it is important to identify sugarcane varieties with high sucrose content and less inclined to post-harvest inversion.
7. The transport and storage of cane also affect the process of dextran formation i.e. degree of damage from loading equipment, size and shape of container, etc Excessive mechanization viz., grab loader chains sling tend to bruise cane.
8. In case of unavoidable delay in crushing, the harvested cane should be stored in small heaps with minimum ground contact and sprinkled with a solution of bactericide and covered with a thick layer of trash.
9. The cleanliness in the cane yard is of utmost importance. The management should ensure that *first cane in should be first cane out, this* will avoid piling up of stale/deteriorated cane.
10. A study conducted by Tomer and Malik (2004) has indicated that basal application of zinc sulphate (25 $kgha^{-1}$) reduced the pace of the post harvest deterioration of sugarcane. Recent studies conducted at the Indian Institute of Sugarcane Research, Lucknow have shown that pre-harvest soil application of zinc sulphate and manganous sulphate @25kg/ha six weeks prior to harvest improved sucrose content in sugarcane and minimized post-harvest sucrose losses.
11. Post-harvest application of chemicals: Several disinfectants and chemicals have been tried in recent past but their practical use has been restricted by the availability, high cost and sometimes environmental problems. A study from Australia has shown that deterioration could be controlled by dipping stalks in formaldehyde solution.

Further studies have shown that continual spraying of the chopper blade and dipping cane stalk in bactericide did not prevent infection. Desai *et al,* (1985) noticed that spraying of harvested cane with benzoic acid (100 ppm) significantly retarded post harvest losses.

12. Combined application of anti-bacterial and anti-inversion chemicals: Solomon *et al (2006) r*eported efficacy of a few chemical formulations containing antibacterial (quaternary ammonium compounds/thiocabamates), anti-inversion chemicals (sodium metasilicate /sodium lauryl sulphate) in minimizing post-harvest sucrose losses in sugarcane. The aqueus formulation(s) are sprayed over freshly harvested cane (whole stalk and billets) following by covering the treated cane with a thick layer of dried cane leaves (trash).
13. Use of electrolyzed water (EW): The concept of electrolyzing saline to create a disinfectant is appealing because the basic materials, saline and electricity, are cheap and the end product (water) is not damaging to the environment. EW appears to work as an anti-effective agent by denaturing proteins in the membrane of single-cell organism.

PRELIMINARY WORK DONE AT THIS CENTER

Among strategies to minimize post-harvest sucrose losses in sugarcane field losses from cut to crush chemicals/natural biocides at proper place and in required doses also played an important role. A field experiment was conducted at G.F. College Agric. Farm, Shahjahanpur in spring planting season in the year 2013-14. Two bud setts of CoSe92423, a mid late maturing variety was planted in randomized block design (RBD) in three replicates. Nitrogen was given in the form of Urea @ 150kg N/ha, half basal and rest half in two equal splits before onset of mansoon. The agronomical and irrigational practices were followed as per local recommendations. Samples were harvested in the month of March and April for experimental purposes. The chemical solutions (1%) of sodium azide, picric acid and 5% solutions of neem cake extract and neem dried leaves extract were sprayed over the freshly harvested canes and was kept for 0-120 hours for Pol% at an interval of 24 hours. The sugar analysis was done by following Meade and Chen (1977) method. The data were statistically analyzed.

Table 1. Pol % cane loss in *Saccharum officinarum* (CoSe 92423) in the month of March.

	Treatments				
Staling hour	Sodium azide	Picric acid	Neem cake	Dried Neem leaves	Control
24	0.210	0.180	0.370	0.395	0.927
48	1.165	1.499	1.152	1.320	2.236
72	2.970	3.270	3.479	2.865	4.783
96	3.990	4.180	4.603	3.750	6.664
120	5.560	5.948	6.321	5.110	7.518
Mean	2.7790	3.0150	3.1850	2.6880	4.4256

S.E/C.D Hour. 0.164/0.242 Treatments 0.170/0.332

Application of chemicals (1% sodium azide and picric acid) as well as (5% of neem cake and dried leaves extract) aqueous solutions sprays on harvested canes showed remarkable results in minimization of sugar losses during staling. In the month of March, a significant response of treatment against control was recorded. Mean values showed 5% Neem leaves extract spray solution proved most effective in reducing the sugar losses and the value was statistically equal to 1% sodium azide and picric acid spray treatments (Table 1). At 120 hr. also the effect of 5% neem leaves spray solution proved most effective Neem cake was least effective (Table-1). In April, the effect of sodium azide spray solution was most effective in reducing the sugar losses during staling followed by dried Neem leaves extract solution. At 120 hr in April the effect of sodium azide spray was best followed by dried Neem leaves extract spray (Table-2). The effectiveness of several chemical compounds in respect of sugar losses in cane during staling has also been observed by Solomon et al 2006, 2007, Singh et al (2008). However, further extensive and intensive field trials are warranted with some more additional natural biocides/chemicals to confirm this fact.

Table 2. Pol % cane loss in *Saccharum officinarum* (CoSe 92423) in the month of April.

	Treatments				
Staling hour	Sodium azide	Picric acid	Neem cake	Dried Neem leaves	control
24	0.990	1.470	1.990	1.820	2.620
28	1.776	2.853	2.885	2.720	3.880
72	2.715	3.880	3.920	3.716	4.975
96	4.738	4.989	4.990	4.850	6.628
120	5.001	6.130	5.910	5.880	7.940
Mean	2.9880	3.8204	3.9390	3.7972	5.2008

S.E/C.D Hour. 0.088/0.215 Treatments 0.101/0.298

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