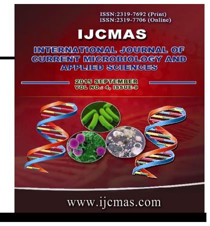

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 4 Number 9 (2015) pp. 204-218**
http://www.ijcmas.com

Original Research Article

Post Harvest Sugarcane Quality under Manual (Whole Cane) and Mechanical (Billet)Harvesting

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A B S T R A C T

Keywords

Postharvest, Sugarcane, Mechanical harvesting, Billets, Juice quality

Postharvest deterioration of cane quality due to cane staling is one of the most alarming problems of sugar industry. Sugarcane harvesting is either manual or mechanical and ultimately it is mandatory to provide harvested cane to the mil yard within shortest possible time to minimize the loss of sucrose content in the juice. In light of this, an investigation was carried out to assess the magnitude of postharvest deterioration in sugarcane variety Co 86032 under manual (whole cane) and mechanical (billets) harvesting under different environmental conditions i.e. from December 2005 to April 2006. Juice quality parameters, loss in cane weight, reducing sugars, and microbial count were studied in whole cane and billets for 2, 12, 24, 36, 48, 60 and 72 hrs. A gradual rise in percent loss in cane weight, reducing sugars and microbial count with simultaneous reduction in brix, pol, commercial cane sugar and purity percent were observed in both types of harvesting. The losses were more pronounced at 72 hrs as compared to 2 hrs of crushing in whole cane as well as in billets. Cane quality deterioration was more in billet type of harvesting as compared to manual harvesting and was extremely higher in March and April (summer) months as compared to December, January and February (winter). Juice purity was decreased by 13-15 % at 72 hrs of staling in both types of harvesting. Postharvest deterioration in sugarcane was found to be related to time lag between harvesting and milling and mainly due to staling of harvested cane up to 72 hrs in billets. Overall results suggest that, billet type harvesting causes more cane deterioration. The proper management system and improved sugarcane varieties with enhanced storage life using biotechnological tools may solve this persistent problem.

Introduction

Sugarcane is globally economically important sugar crop, however; it suffers heavy losses in recoverable sugar due to postharvest deterioration of stale cane (Solomon, 2009). Cane quality represents the main priorities in sugarcane postharvest management which is deteriorated in field, cut to crush delay, during transportation, other factors such as ambient temperature, humidity, cane variety, period of storage, activities of soluble invertases in cane, maturity status etc. (Uppal *et al.,* 2008; Solomon, 2009; Reddy *et al.*, 2014). The existing cane harvesting and supply management system in India is a serious impediment in maintaining cane quality and attaining high sugar recovery. The payments are made on the basis of estimated recoverable sugar in some countries, while in India, cane growers are paid on cane weight basis. In majority of the sugar factories, time lag between harvesting to milling of cane ranges between 3 to 10 days, which entails huge losses in recoverable sugar (sucrose) due to deterioration of harvested cane (Singh and Solomon, 2003; Solomon; 2009). Moreover, there is an increasing demand for sugar globally and to meet this challenge better management is required to minimize the losses. Therefore, for sugar industry it is a challenge to increase the sugar productivity and therefore continuous efforts have been put forth to achieve this goal. One of the major challenges faced by sugar industry is to provide harvested cane to the mil yard within shortest possible time to minimize the loss of sucrose content in the juice and avoid the deterioration with microbes. The harvesting is mainly manual however, some sugar factories in India have introduced sugarcane harvester in their operational area. Although India is over populated country, there is acute shortage of labor for cane harvesting. Contradictory, but, bitterly true, harvesting, bundling and loading of cane require lot of labors. Due to the increase in area of sugarcane cultivation and considering a high manpower requirement there is a need to mechanize the harvesting. Mechanization saves time and reduces cost; however, it becomes harmful whenever it is applied under unsuitable conditions (Ghasemnejad and Jamshidi, 2011) and often results in quality deterioration (Singh and Solomon, 2003). However, there are very scanty reports on comparative studies on postharvest sugarcane quality deterioration due to manual and mechanical harvesting in popular sugarcane varieties. Singh and Solomon, (2003) reported that mechanized harvesting and subsequent chopping (billets) of canes resulted in faster quality loss, if the time lag between harvest to crush is delayed beyond 24 hours. The mechanical harvesting with consequent delay in processing of billets could affect factory efficiency and sugar quality in addition to pulling down recovery and significant amount of postharvest sugar losses in crop harvested by chopper harvester (Singh and Solomon, 2003; Ghasemnejad and Jamshidi, 2011).

In India, crushing season normally starts from November end and continues till April or May with varying patterns of minimum and maximum temperatures (Srivastava *et al.*, 2009). The decline in sugarcane quality is high especially during late crushing period (March onwards) as compared to early crushing phase due the inversion of sucrose into monosaccharides by invertases, organic acids and dextran formation by micro-organisms such as Leuconostoc mesenteroides (Solomon *et al.*, 2006; Saxena *et al.*, 2010). Therefore, postharvest sugar loss is considered as one of the most alarming problems of sugar industry and has attracted widespread attention in the recent years (Saxena *et al.*, 2010). To date, there are extremely few published reports regarding comparative studies on postharvest deterioration of sugarcane quality under manual (whole cane) and mechanical (billet) harvesting at different crushing seasons. Overcoming postharvest sucrose loss in sugarcane is becoming an important factor and has renewed interest in breeding for increased storage potential (Varma *et al.*, 2012). Hence it is necessary to undertake studies to estimate the quality loss due to postharvest deterioration in the predominant and locally adapted commercial sugarcane varieties under manual and mechanical harvesting at different crushing seasons. Therefore, an attempt has been made to compare the effects of manual and mechanical harvesting on postharvest sugarcane quality of popularly grown sugarcane variety Co 86032 from December to April i.e. during winter and summer seasons. The magnitude of losses is evaluated and the results are compared. The data can be utilized to study and compare the postharvest losses in different sugarcane cultivars under both types of harvesting.

Materials and Methods

The experiment was conducted from December to February, 2005 (winter season – early crushing season) and April to May, 2006 (summer season – late crushing season) at sugar factory, Malegaon SSK, MS, India. Billet type mechanical harvester (CASE AUSTOFT, Australia) was used for harvesting of sugarcane. The harvester was available only at Malegaon SSK factory operational area and Co 86032 was the only variety available for crushing.

Plant material and sampling

Co 86032 is mid-late maturing and locally adapted commercial sugarcane variety in India. Canes of uniform size of Co 86032 were harvested manually (whole cane) and mechanically (billets) at farmer's field. Harvested samples were randomly selected and kept in separate bundles in three replicates and brought to the laboratory immediately after harvesting. The experiment was conducted in three replications consisting of three canes per replication. The quality assessment was performed at seven storage treatments under natural conditions from 2 hrs, 12 hrs, 24 hrs, 36 hrs, 48 hrs, 60 hrs and 72 hrs in December, January, February, March and April. Canes were immediately processed for fresh analysis (2 hrs) and the rest of the canes were stored at natural conditions. During the study daily temperature and humidity were recorded.

Loss in cane weight

Initial cane weight was measured for all the manually and mechanically harvested canes from each storage treatment. Every time the canes were weighed and final weight was measured. % loss in cane weight was calculated from initial weight and final weight using following formula:

% loss in cane weight = [(initial weight – final weight)/initial weight] X 100.

The values are presented are average of three replications.

Juice extraction

Three canes from each storage treatment used above were extracted at the interval of 2 hrs, 12 hrs, 24 hrs, 36 hrs, 48 hrs, 60 hrs and 72 hrs in a clean power operated vertical crusher. The juice was filtered through four layered muslin cloth and used for juice quality and microbial analysis.

Juice quality parameters

Brix was measured from the juice using hand Refractometer. It is the percentage of total soluble solids present in juice sample. Pol (apparent sucrose) was measured from the same juice on Saccharimeter (Schmidt + Haensch Saccharomat, NIR, W2) by Carruthers and Old Field (1962, ICUMSA) method. The commercial cane sugar (CCS) refers to the total recoverable sugar in the cane. CCS % was calculated using the following formula. CCS% or Sugar Recovery (%) = [S - (B - S)*0.4] x 0.73. Where, S= Sucrose % in juice and B= Corrected Brix (%).

Purity was calculated as Pol/Brix×100. Reducing sugars were measured from cane juice using Dinitrosalysilic acid reagent (DNSA) method (Miller, 1959). Brix%, Pol%, CCS% and Purity% were calculated for each storage treatment and the values are presented as average of three replications.

Isolation of *Leuconostoc mesenteroides*

Isolation of Leuconostoc mesenteroides was performed from the same juice from different storage treatments from each replication. Serial dilutions of cane juice from each storage treatment from each replication were plated on MRS (deMan Rogosa and Sharp) medium. One litre MRS media contained protease peptone (10 g), Yeast extract (5 g), Beef extract (10 g), dextrose (20 g), Tween 80 (1 g), ammonium citrate (2 g), sodium acetate (5 g), MgSo4 (0.1 g), MnSo4 (0.05 g) and di potassium phosphate (2 g).

The plates were incubated at 37°C for 48 hrs for counting the growth of Leuconostoc mesenteroides. The colonies were observed under microscope and compared with the standard Leuconostoc mesenteroides culture obtained from National Collection of Industrial Micro-organisms, National Chemical Laboratory, MS, India.

Statistical analysis of the data

Graphical representations and statistical parameters were performed in Microsoft office excel 2003 and GenStat 11th edition, Germany, respectively.

Results and Discussion

Effects of manual and mechanical harvesting on loss in cane weight

Effects of manual and mechanical harvesting on percent loss in cane weight due the staling of cane up to 72 hrs from December to April is depicted in tables 1, 3, 5, 7 and 9. Significantly superior % loss in cane weight was observed from 12 to 72 hrs of staling in whole cane and billets as compared to 2 hrs of staling in both the crushing seasons. It was more pronounced during late crushing season (March and April; Tables 7 and 9) as compared to early crushing season (December to February; Tables 1, 3 and 5). Peculiarly, loss in cane weight was exaggerated and it was more than 7 (whole cane) and 25 (billets) fold in March and April when compared to December at 72 hrs of staling. Nonetheless, it was 3 times higher in billets as compared to whole cane at 72 hrs of staling during late crushing season (Tables 7 and 9). These results suggest that canes started to lose their weight by drying out as soon as the summer season starts where high temperatures were recorded. It has been suggested that, the cane weight loss is mainly attributed to evaporation losses (Mahadevaiah and Dezfuly, 2013) and increased respiration (Verma *et al.*, 2012). Solomon *et al.* (1997) reported loss in cane weight between 7.14 and 15% under sub-tropical conditions and that the value could be as high as 16-18% after 120 hours of storage, during May and June. Similarly, Uppal, (2003) found the loss in cane weight was more when sugarcane harvested in April and stored for 96 hours (13%) as compared to those harvested in January (1.60%).

More loss in cane weight in mechanical harvesting can be due to the fact that harvester chops cane into smaller pieces which causes more damage to the cane tissue and this may cause fast drying up of the cane. Sing and Solomon, (2003) reported faster loss in cane weight (5.33% in billets as compared to whole cane) especially after 24 hrs in billet type of harvesting in April subjected to staling under natural field conditions for a period of one week. It has been suggested that the size of the billets was the crucial in postharvest deterioration (Wood, 1976; Ghasemnejad and Jamshidi, 2011). The loss in cane weight is very critical because in India, and other Asian countries, payment to farmers is made on a weight basis, so that a delay in supply of harvested cane to the sugar factory could lead to major economic loss to cane growers.

Effects of manual and mechanical harvesting on juice quality parameters

Data on effects of manual and mechanical harvesting on juice quality parameters due to cane staling up to 72 hrs from December 2005 to April 2006 is depicted in tables 1, 3, 5, 7 and 9. Juice quality deterioration of the harvested sugarcane is a well-known phenomenon, which involves multiple factors such as genetic makeup of the cane variety, the moisture status of cane, the climatic conditions prevalent during the period of cane harvesting, disease status of harvested cane, sanitary condition of crop, field and cane yard where harvested cane is stored etc. (Solomon 2009; Reddy, *et al.*, 2014).

Reducing sugars (%)

Reducing sugars are one of the most important juice quality parameters which could be utilized to predict the loss in commercial cane sugar when the cane is undergoing staling (Srivastava *et al.,* 2009). Gradual increase in reducing sugars was noticed from 2 hrs of staling to 72 hrs of staling in both the crushing seasons in whole cane as well as in billets (Tables 1, 3, 5, 7 and 9). It was significantly different especially after 24 hrs of storage in all the months of harvesting. As noted for loss in cane weight, reducing sugars (%) were more in billets as compared to whole cane (Tables 1, 3, 5, 7 and 9). It was highest in April in billets (3.0%) as compared to whole cane (1.04%) at 72 hrs of staling (Tables 1, 3, 5, 7and 9). The rise in reducing sugars can be attributed to enhanced activities of acid and neutral invertases due cane staling for long periods in April (Lontom *et al.*, 2008; Verma *et al.*, 2012), several other hydrolytic enzymes, and action of microorganisms which converts sucrose into reducing sugars and dextran (Suman *et al.,* 2000; Solomon, 2009). The present results are in agreement with Bhatia *et al.*, (2009) reported faster inversion of sucrose into reducing sugars during late crushing period. Amount of reducing sugars were more in billets as compared to whole cane due to the staling of up to 7 days in April (Singh and Solomon, 2003). Chopped billets provide more damaged surfaces for the entrance of microorganisms in cane tissue which further results into faster degradation of sucrose into reducing sugars, microbial polysaccharides and dextran (Singh and Solomon, 2003). Decrease in stalk length due to the chopper harvester with corresponding increased reducing sugars has been reported by Wood, (1976). As invertase plays an important role in conversion of sucrose into reducing sugars, there is good potential for molecular manipulation of the invertase genes for high sugar production via genetic modification in sugarcane. The antisense technology or gene silencing technique has been employed to reduce the hexose accumulation in potato tubers by suppressing the activity of acid invertase which leads to reduced hexose production with improved processing quality of potato tubers after long term storage (Zrenner *et al.*, 1996; Griener *et al.*, 1999).

Brix (%) and Pol (%)

Results on brix % and pol % are depicted in tables 2, 4, 6, 8 and 10. In general brix % was found to be increased in all the months of harvesting from 2 to 72 hrs of staling in whole cane as well as in billets. However, it was not significantly different in December and January (Tables 2 and 4). In February, significantly higher brix (%) was observed from 24 hrs of staling in whole cane while it was from 12 hrs of staling in billets as compared to 2 hrs of staling (Table 6). Significantly superior brix % observed from 36 hrs of staling in whole cane while it was from 12 hrs of staling in billets as compared to 2 hrs of staling in March 2006 (Table 8). However, it was significantly superior at 36 hrs of staling in both types as compared to 2 hrs of staling in April 2006 (Table 10). As brix measures total soluble solids that includes all sugars and non-sugars, the increased brix especially during late crushing period can be due to the formation of more reducing sugars and dextran. Increased in brix has been reported by Bhatia *et al.*, (2009) and Saxena et al, (2010) due to staling of cane up to several hours.

Overall, pol % was decreased; however, it was significantly decreased only in April 2006 from 12 hrs of staling (Table 10). These results indicate that, there is more inversion of sucrose especially during late crushing season due to higher temperatures. The decrease in pol % causes decrease in CCS% and thereafter purity. Sucrose percent in juice showed decreasing trend with increasing staling hours by several authors (Siddhant *et al.*, 2008; Srivastava *et al.*, 2009; Saxena *et al.*, 2010). Decline in pol % in billet type of harvesting after 72 hrs was 10.39% whereas; in whole cane this decline in Pol was 1.76% in April 2006. High losses of sucrose in billets have been reported by Singh and Solomon, 2003.

Commercial Cane Sugar (CCS) %

Inversion of sucrose by invertases, formation of organic acids, dextran by microorganisms and delay in transport of harvested cane from field to factory are largely responsible for loss of recoverable sugar (Solomon *et al.*, 2003). It has been reported that sugar recovery is known to decline under late harvest conditions and extended crushing period. Hence, it is important to study such losses in order to sustain sugar recovery (Mao *et al.*, 2006). Data on CCS% (Tables 2, 4, 6, 8 and 10) revealed that CCS % did not differ significantly in December and January (Tables 2 and 4) while in February (Table 6) it was significantly inferior only at 60 hrs and after 36 hrs of staling in whole cane and billets respectively. Significantly decreased CCS% were not observed in both whole cane and billets in March except where it was significantly inferior only after 60 hrs of staling as compared to 2 hrs of staling in whole cane (Table 8). Notably, it was significantly decreased after 24 hrs of staling over 2 hrs staling in April in both manual and mechanical harvesting (Table 10). Though, CCS% was found to be decreased in both types of harvesting, the decrease was more pronounced in April. It was 18.45% and 19.90% at 72 hrs over 2 hrs of staling in whole cane and billets respectively (Table 10). When compared with December, it was dropped by 13.50% at 72 hrs of staling in billet type where it was 11.11% in whole cane. Singh and Solomon, (2003) reported significantly higher decline in recoverable sugar in billets as compared to whole cane in April. The higher temperatures have been shown to affect juice quality and negative effects on CCS% have been recorded from

April onwards (Srivastava *et al.*, 2009). A rapid decline in CCS% during late crushing period in mechanically harvested sugarcane crop was also reported by Wood, (1976) and Singh and Solomon, (2003). Chopper harvester produces small size billets and therefore under hot, humid conditions chopped cane accelerates deterioration much faster than whole stalk cane, rate of decline in CCS% tending to increase with decrease in stalk length, while reducing sugars showed a corresponding increase (Wood, 1976; Singh and Solomon, 2003). As both type of harvesting lead to recoverable sugar loss, it can be recommended that the effects of biocides and anti-inversion chemical may help in minimizing the sucrose losses on postharvest storage of sugarcane (Solomon *et al.*, 2007).

Table.1 Effect of staling on cane weight and reducing sugars (December 2005)

Parameter	Temperature (°C)	Humidity (%)	Loss incane weight (%)		Reducing Sugars (%)	
SP			Whole cane	Billets	Whole cane	Billets
2 hrs	10.5	85	0.00	0.00	0.06	0.07
12hrs	30.7	33	0.65*	0.85*	0.07	0.08
24hrs	09.9	88	0.70*	1.17*	0.09*	0.09*
36hrs	29.9	32	1.13*	1.73*	0.11*	0.12*
48hrs	09.6	78	1.85*	2.34*	0.12*	0.12*
60hrs	28.8	46	2.24*	3.04*	0.15*	0.15*
72hrs	09.6	80	2.69*	3.74*	0.16*	0.18*
Average	--	--	1.32	1.84	0.11	0.11
SE ±	--	--	0.20	0.22	0.00	0.00
CD at 5 %	--	--	0.61	0.67	0.01	0.01

Note: - SP – Staling period, * Significantly superior / inferior over 2 hrs of staling. The values are average of three replications.

Table.2 Effect of staling on juice quality parameters (December 2005)

Parameter	Brix (%)		Apparent Pol (%)		CommercialCane Sugar (%)		Purity (%)	
SP	Whole cane	Billets	Whole cane	Billets	Whole cane	Billets	Whole cane	Billets
2 hrs	22.17	22.28	18.43	18.86	12.53	12.95	83.23	84.68
12hrs	22.58	22.97	18.72	19.15	12.71	13.04	82.95	83.38
24hrs	22.53	22.62	18.26	18.82	12.67	12.80	82.89	83.25
36hrs	22.31	22.83	18.48	18.81	12.55	12.73	82.87	82.39*
48hrs	22.84	22.89	18.79	18.87	12.70	12.77	82.28	82.45*
60hrs	22.82	22.77	18.73	18.70	12.65	12.64	82.11	82.19*
72hrs	22.69	22.58	18.39	18.55	12.33	12.53	81.08*	82.18*
Average	22.56	22.70	18.54	18.82	12.59	12.78	82.48	82.93
SE ±	0.26	0.17	0.33	0.36	2.17	1.98	0.47	0.49
CD at 5 %	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	1.41	1.47

* Significantly superior / inferior over 2 hrs of staling. The values are average of three replications

Table.3 Effect of staling on cane weight and reducing sugars (January 2006)

Parameter	Temperature (°C)	Humidity (%)	Loss incane weight (%)		Reducing Sugars (%)	
SP			Whole cane	Billets	Whole cane	Billets
2 hrs	27.8	24	0.00	0.00	0.09	0.10
12hrs	10.0	94	1.35*	1.47*	0.10	0.11
24hrs	27.7	30	1.40*	1.69*	0.12*	0.14*
36hrs	10.4	93	1.93*	2.36*	0.15*	0.17*
48hrs	27.6	23	2.08*	3.01*	0.19*	0.21*
60hrs	12.2	97	2.78*	3.49*	0.22*	0.24*
72hrs	27.4	29	3.46*	4.33*	0.25*	0.26*
Average	--	--	1.86	2.34	0.16	0.17
SE ±	--	--	0.15	0.21	0.00	0.00
CD at 5 %	--	--	0.47	0.64	0.01	0.01

Note: - SP – Staling period,* Significantly superior / inferior over 2 hrs of staling.The values are average of three replications

Table.4 Effect of staling on juice quality parameters (January 2006)

Parameter	Brix (%)		Apparent Pol (%)		CommercialCane Sugar (%)		Purity (%)	
SP	Whole cane	Billets	Whole cane	Billets	Whole cane	Billets	Whole cane	Billets
2 hrs	22.05	22.55	18.18	18.50	12.31	12.50	82.45	82.06
12hrs	22.00	22.61	18.05	18.57	12.19	12.54	82.05	82.16
24hrs	22.29	22.85	18.08	18.47	12.15	12.37	81.21*	80.87*
36hrs	22.37	23.04	18.12	18.47	12.16	12.32	81.06*	80.19*
48hrs	22.71	23.18	18.17	18.55	12.10	12.36	80.06*	80.04*
60hrs	22.52	22.96	18.01	18.39	11.99	12.25	80.02*	80.09*
72hrs	22.58	22.81	17.86	18.18	11.82	12.08	79.18*	79.73*
Average	22.36	22.86	18.07	18.45	12.10	12.35	80.86	80.74
SE ±	0.21	0.27	0.11	0.12	1.01	1.17	0.15	0.16
CD at 5 %	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.44	0.49

Note: - SP – Staling period,* Significantly superior / inferior over 2 hrs of staling, N.S:- Not Significant. The values are average of three replications

Table.5 Effect of staling on cane weight and reducing sugars (February 2006)

Parameter	Temperature (°C)	Humidity (%)	Loss incane weight (%)		Reducing Sugars (%)	
SP			Whole cane	Billets	Whole cane	Billets
2 hrs	31.3	17	0.00	0.00	0.10	0.12
12hrs	12.3	80	0.54*	0.74*	0.12	0.15
24hrs	31.0	19	1.11*	1.90*	0.20*	0.22*
36hrs	12.1	77	2.10*	2.89*	0.25*	0.27*
48hrs	30.6	20	3.52*	4.06*	0.26*	0.29*
60hrs	12.1	77	4.87*	5.62*	0.33*	0.49*
72hrs	30.4	20	7.17*	8.39*	0.46*	0.81*
Average	--	--	2.76	3.37	0.24	0.33
SE ±	--	--	0.14	0.36	0.00	0.02
CD at 5 %	--	--	0.44	1.09	0.02	0.08

Note: - SP – Staling period,* Significantly superior / inferior over 2 hrs of staling.The values are average of three replications

Table.6 Effect of staling on juice quality parameters (February 2006)

Parameter	Brix (%)		Apparent Pol (%)		CommercialCane Sugar (%)		Purity (%)	
SP	Whole cane	Billets	Whole cane	Billets	Whole cane	Billets	Whole cane	Billets
2 hrs	21.91	22.08	19.81	20.27	14.53	14.92	92.62	93.86
12hrs	22.73*	22.63	20.67	20.46	13.79	14.31	87.20*	89.62
24hrs	23.63*	23.45*	20.7	20.37	14.42	14.26	87.49*	87.25*
36hrs	23.71*	23.80*	21.24	20.2	14.43	14.06*	87.31*	85.62*
48hrs	24.42*	23.68*	21.24	20.2	14.78	13.91*	87.01*	85.37*
60hrs	24.34*	23.68*	19.91	20.06	13.42*	13.78*	81.78*	84.74*
72hrs	25.34*	24.05*	21.26	19.7	14.52	13.29*	83.88*	81.92*
Average	23.73	23.34	20.69	20.18	14.27	14.07	86.75	86.91
SE ±	0.25	0.22	0.31	0.2	0.33	0.24	1.63	1.49
CD at 5 %	0.77	0.67	0.97	0.62	1.02	0.74	5.02	4.6

Note: - SP – Staling period,* Significantly superior / inferior over 2 hrs of staling. The values are average of three replications

Table.7 Effect of staling on cane weight and biochemical parameters (March 2006)

Parameter	Temperature (°C)	Humidity (%)	Loss incane weight (%)		Reducing Sugars (%)	
SP			Whole cane	Billets	Whole cane	Billets
2 hrs	34.6	21	0.00	0.00	0.14	0.14
12hrs	21.8	79	1.06	7.45	0.12	0.39*
24hrs	33.5	25	2.58	12.33*	0.29*	0.29*
36hrs	19.8	78	4.48*	16.25*	0.58*	0.43*
48hrs	33.5	14	5.37*	19.45*	0.75*	0.82*
60hrs	16.1	86	5.95*	21.31*	0.71*	0.82*
72hrs	32.2	17	8.87*	30.01*	0.73*	1.01*
Average	--	--	4.04	15.26	0.47	0.56
SE ±	--	--	1.37	3.11	0.05	0.04
CD at 5 %	--	--	4.23	9.59	0.17	0.13

Note: - SP – Staling period,*Significantly superior / inferior over 2 hrs of staling.The values are average of three replications

Table.8 Effect of staling on juice quality parameters (March 2006)

Parameter	Brix (%)		Apparent Pol (%)		CommercialCane Sugar (%)		Purity (%)	
SP	Whole cane	Billets	Whole cane	Billets	Whole cane	Billets	Whole cane	Billets
2 hrs	19.23	19.62	18.56	18.73	13.19	13.47	94.8	94.85
12hrs	20.49*	20.07	18.29	18.3	13.16	13.46	90.56	93.32
24hrs	20.59*	20.56	18.39	18.42	12.85	12.87	88.93*	89.02
36hrs	21.15*	21.17*	18.34	18.55	12.79	12.82	86.94*	87.04*
48hrs	21.39*	21.88*	18.34	18.55	12.67	12.74	85.76*	85.05*
60hrs	21.53*	22.01*	17.97	18.48	12.24*	12.63	83.54*	83.99*
72hrs	22.47*	22.85*	18.15	18.72	12.15*	12.63	80.82*	81.99*
Average	20.98	21.17	18.29	18.54	12.72	12.95	87.34	87.89
SE ±	0.39	0.4	0.21	0.24	0.2	0.31	1.46	2.26
CD at 5 %	1.2	1.24	0.66	0.76	0.61	0.95	4.5	6.96

Note: - SP – Staling period,* Significantly superior / inferior over 2 hrs of staling. The values are average of three replications

Table.9 Effect of staling on cane weight and biochemical parameters (April 2006)

Parameter	Temperature (°C)	Humidity (%)	Loss incane weight (%)		Reducing Sugars %	
SP			Whole cane	Billets	Whole cane	Billets
2 hrs	35.7	16	0.00	0.00	0.12	0.80
12hrs	19.4	89	5.84*	10.64*	0.24	0.93
24hrs	35.3	15	6.83*	11.53*	0.62*	1.22*
36hrs	18.9	55	6.11*	18.47*	0.67*	1.51*
48hrs	35.6	15	8.18*	19.83*	0.75*	1.52*
60hrs	17.4	70	9.04*	25.80*	0.87*	2.62*
72hrs	36.7	14	9.81*	27.48*	1.04*	3.00*
Average	--	--	6.54	16.25	0.61	1.66
SE ±	--	--	1.67	0.44	0.08	0.13
CD at 5 %	--	--	5.13	1.36	0.26	0.40

Note: - SP – Staling period,* Significantly superior / inferior over 2 hrs of staling. The values are average of three replications

Table.10 Effect of staling on juice quality parameters (April 2006)

Parameter	Brix (%)		Apparent Pol (%)		CommercialCane Sugar (%)		Purity (%)	
SP	Whole cane	Billets	Whole cane	Billets	Whole cane	Billets	Whole cane	Billets
2 hrs	21.63	21.76	19.16	19.27	13.44	13.52	88.61	88.52
12hrs	21.66	21.89	18.87*	18.96*	13.13	13.16	87.09	86.61
24hrs	21.82	22.06	18.67*	18.66*	12.75*	12.80*	84.98*	84.59
36hrs	22.69*	22.78*	18.17*	18.33*	12.11*	12.24*	80.11*	80.44*
48hrs	22.73*	22.86*	17.61*	18.21*	11.52*	12.10*	77.50*	79.69*
60hrs	22.95*	23.00*	17.50*	17.52*	11.34*	11.34*	76.28*	76.17*
72hrs	23.05*	23.15*	17.17*	17.07*	10.96*	10.83*	74.49*	73.73*
Average	22.36	22.50	18.16	18.29	12.18	12.29	81.29	81.39
SE ±	0.13	0.12	0.15	0.16	0.15	0.20	0.97	1.35
CD at 5 %	0.41	0.38	0.46	0.51	0.48	0.61	3.00	4.15

Note: - SP – Staling period,* Significantly superior / inferior over 2 hrs of staling. The values are average of three replications

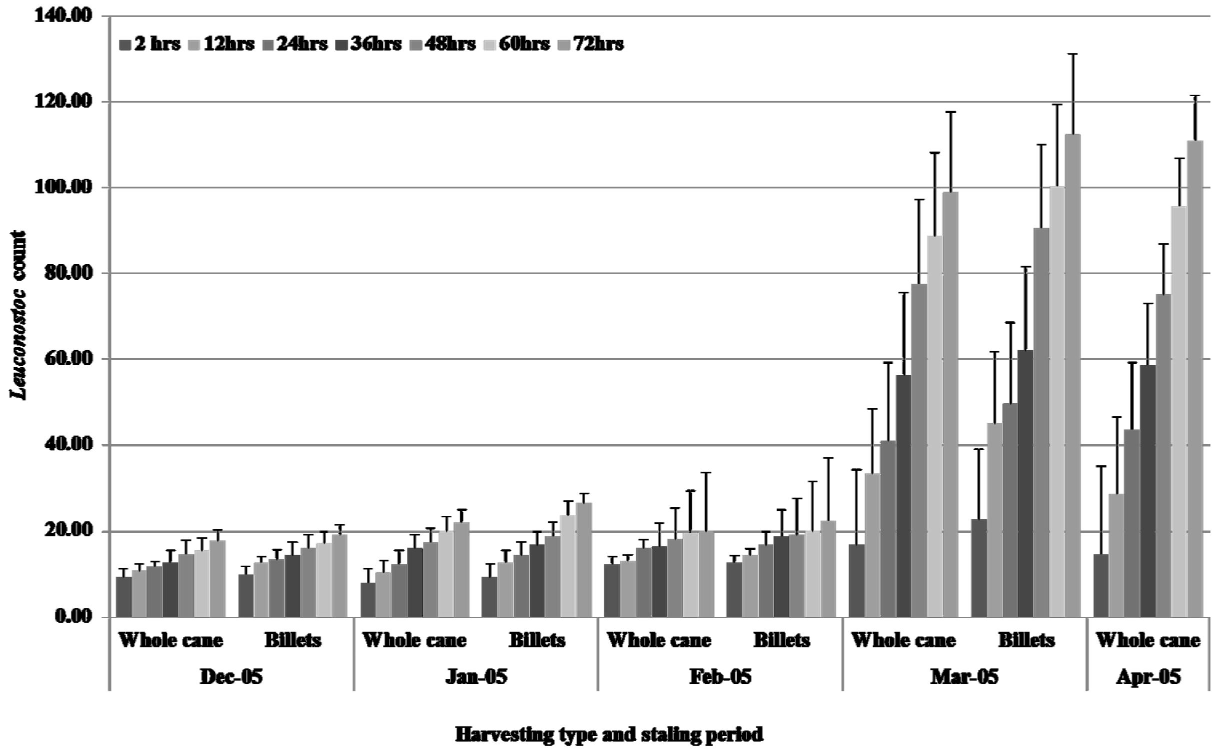

Fig. 1. Effects of manual and mechanical harvesting on microbial count (*Leuconostoc mesenteriods* L.) from December 2005 to April 2006 in Co 86032. X axis represents harvesting type and staling period while Y axis represents microbial count. Bars represent standard error from three preparations.

Purity (%)

Juice purity is the most critical factor which determines the sucrose percent in cane tissue. Loss in juice purity is mainly due the decrease in pol%, increase in reducing sugars and microbes due staling of cane up to 72 hrs causes huge sucrose loss (Singh and Solomon, 2003, Solomon, 2009). In general purity% was decreased due to staling of cane up to 72 hrs in both the crushing seasons however, it was more pronounced in March and April i.e. during late crushing season (Tables 8 and 10). The percent decreased was 14.15% (whole cane) and 16.31% (billets), 15.91% (whole cane) and 16.74% (billets) at 72 hrs of staling as compared to 2 hrs of staling in March and April respectively (Tables 2, 4, 6, 8 and 10). Steel and Trost, (2006) reported that the presence of bacteria reduces the sugar purity, which is evident in the present studies (Fig. 1). Sing and Solomon, (2003) reported that significantly higher decline in purity in billets as compared to whole cane. Under hot, humid conditions chopped cane deteriorates much faster than whole stalk cane, rate of decline in purity tending to increase with decrease in stalk length, while reducing sugars showed a corresponding increase Wood, (1976).

Further reported that, billets produced by chopper harvester, tend to accelerate deterioration under field conditions. Loss in purity can be attributed to decrease in sucrose and increase in brix as reported by Bhatia *et al.*, (2009) which is evident in the present studies. Decrease in cane quality directly affects the purity of sugarcane juice (Saxena *et al.*, 2010; Krishnakumar *et al.*, 2013).

***Leuconostoc mesenteroids* count**

Microorganisms colonizing internal parts of sugarcane thrive on stored sucrose and play an important role in postharvest losses in sugarcane quality (Suman *et al.,* 2000). The data on microbial count is depicted in figure 1. Gradual increase in Leuconostoc mesenteroids colony count was observed from December to April. Nonetheless, it was more pronounced in March and April and exaggerated in mechanically harvested cane as compared to manual harvesting (Fig. 1). It has been well documented that in harvested sugarcane and milled juice, microorganisms such as Leuconostoc sp. play an important role in cane deterioration which has detrimental effect on sugar recovery and presently a serious economic problem to sugar mills in many cane producing countries (Solomon, 2009). Leuconostoc infection is considered as one of the main causes of factory processing difficulties when handling deteriorated sugarcane. Not only can poor cane quality impinge on profitability, it could also trigger off many processing problems and consequently factory shutdown (Solomon, 2009). Therefore, decline in sugar recovery and juice purity can attributed to smaller size of billets which are more vulnerable to microbial infestation and consequently dextran formation as they have more cuts than the whole cane. It has been advocated that, sugarcane stalks contains an endophytic microbial flora viz., Acetobacter, Enterobacter, Pseudomonas, Aeromonas, Vibrio, Bacillus and lactic acid group which increased several folds during staling and also responsible for deterioration of juice quality (Solomon, 2009; Suman *et al.,* 2000).

In conclusion, the present investigation, though manually harvested cane resulted into quality deterioration, the maximum loss in cane weight, CCS%, Purity% with concomitant increase in reducing sugars and microbial count were noted under mechanically harvested cane especially during late crushing season. The losses due to mechanically harvested cane advocated more after 24 hrs of staling especially during late crushing period. Hence, during the late crushing period, if sugarcane harvested using mechanized harvester, it should be milled on priority within 24 hrs of crushing to avoid further loss in cane weight, CCS% and juice purity. It has also been reported that, sugarcane varieties plays an important role in postharvest deterioration. Therefore, cane logistics especially during late-milling phase should be organized on the basis of sugar loss profile of cane varieties (Singh and Solomon, 2003). Due to the acute shortage of labors in the near future, mechanized harvesting of sugarcane is mandatory. Whether harvested manually or mechanically, the cut to crush delay is apparent. The transport of harvested cane from farmer's field to the sugar mills is delayed due to lack of an efficient communication network (Solomon, 2009) and lack of proper post-harvest management system. Therefore, in order to minimize the losses proper management system is required. Moreover, improved sugarcane varieties with enhanced storage life using biotechnological tools may solve this persistent problem up to some extent. The presence of invertase inhibitors have been in crops like sugar beet, red beet and sweet potato (Pressey 1968) and showed to decrease hexose accumulation thereby increasing storage life and processing quality of transgenic potato tubers (Cheng *et al.,* 2007; Greiner *et al.,* 1999). Therefore, transgenic sugarcane plants expressing invertase inhibitor may eliminate the postharvest cane deterioration due to sucrose inversion.

Abbreviations: hrs – hours, CCS – Commercial cane sugar

Acknowledgements

Authors are thankful to Indian Council for Agricultural Research, New Delhi, for funding the project. Authors are also grateful to the Director, Vasantdada Sugar Institute, Pune, authorities and management of Malegaon SSK, MS, India for encouragement and facilities provided for accomplishing this work.

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