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# DIFFERENTIAL RESPONSE OF SUGARCANE VARIETIES TOWARDS POST-HARVEST STALING LOSSES

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**ABSTRACT**

Postharvest deterioration has become a topic of major concern in recent years due to faulty transport and management issues that effects appropriate cut to crush policy and ultimately sugar recovery. The quality of sugarcane juice at harvest is determined by the concentration of sucrose, which should be high and non sucrose components, which should be low. The present study was thus planned with the objective to access the effect of staling on four early and five mid-late maturing recommended varieties for commercial cultivation in Punjab, in context of the juice quality parameters viz., TSS %, Sucrose %, CCS %, purity %, extraction %, reducing Sugars %, pH and cane weight (Kg). Staling of harvested sugarcane resulted in increase in the level of average TSS of juice from 21.66 % - 26.11 %. Staling also results in gradual decline of average sucrose content (19.13 % - 13.80 %), average CCS % (12.46 % - 5.24 %), average purity % (88.51 % - 53.14 %) with a concomitant rise in the level of average reducing sugars (0.27-5.50%). A drop in mean pH (5.24 - 4.49) of the stale juice was also observed. The study indicated that CoPb 92 from early maturity group and CoPb 93 from mid-late maturity groups are promising candidate varieties possessing tolerance to post harvest deterioration as they retain maximum average sucrose % (17.9, 15.9 %) and CCS % (11.6, 8.8 %) over the staling period, respectively.

## INTRODUCTION

Sugar has become an important commodity for human consumption as well as trade in the present era of economic liberalization (Reddy and Madhuri, 2014; Praharaj *et al.*, 2016). Sugarcane is an important agro-industrial crop of the Punjab state grown in an area of about 90 thousand hectares with sugar recovery of 10.06 %. Sugarcane industry is considered as one of the organized sectors and among the countries leading economic enterprises. Sugarcane (*Saccharum spp.* hybrids) is a major source for the production of sugar in the world (Carson and Botha 2002; Lakshmanan *et al.*, 2005; Sachdeva *et al.*, 2011; Choudhary and Singh, 2016).

Sugarcane is a highly perishable crop which is reflected by their higher moisture content and respiration rate. Perishable produce thus has short storage life and needs to be processed quickly after harvest. Studies have indicated that nearly 20-30% of total sucrose synthesized by sugarcane plant is lost during various stages of raw material handling and sugar mill processing. The post harvest sucrose losses could render the entire sugar manufacturing process uneconomical if cane harvesting and supply management are not properly organised (Saxena *et al.*, 2010). The enormous amount of sucrose lost during post harvest operations point out the futility of optimizing sugarcane production for the highest at the field level and most stable sucrose yields/sugar recovery at the sugar-mills.

Postharvest deterioration of sugarcane initiates with a physical injury. Physical injury includes cutting the cane at harvest. Variety, period of storage, maturity status of the variety etc. are additional factors that effects post harvest deterioration (Uppal and Sharma, 1999; Uppal *et al.*, 2000; Solomon *et al.*, 2003; Solomon *et al.*, 2007). Postharvest deterioration has become major concern in recent years and needs management that will improve cut to crush policy and sugar recovery. The published reports indicating loss of recoverable sugar following cane harvest began to appear towards the end of the 19$^{th}$ century (Cross & Belile, 1914, 1915). Indian scientists (Magdum and Kadam, 1996; Solomon *et al.*, 1997; 2007; Solomon 2000; Siddhant *et al.*, 2008, Srivastava *et al.*, 2006, 2009) reviewed the work on post harvest deterioration of sugarcane. Their work highlighted the importance of importance of time lag between harvesting and milling as well as storage environment in deterioration process, especially in India and Asian countries.

Sucrose is synthesized in leaves and translocated through sheath to stalk where it is accumulated in cell vacuoles. Invertases are the key enzymes involved in the hydrolysis of sucrose into glucose and fructose and thus are expected to contribute to carbohydrate partitioning and to provide cells with fuel for respiration. The moment, the cane is harvested or crushed in the factory, it ceases to exist as an intact living entity capable of growth and reproduction. The invertases formerly contained therein are now totally devoid of distinct spatial and functional roles, they had performed earlier (Glasziou and Gayler 1972). However, these enzymes do remain active in the harvested cane and in the milled juice, thereby causing massive hydrolysis of sucrose. Sucrose inversion in harvested stems is always the inevitable problem during storage (Mao and Liu 2000; Saxena *et al.*, 2010).

The varieties recommended for commercial cultivation in

Punjab under different maturity groups vary in their sucrose content and yield at harvest. In order to cut down post harvest sugar losses, it is important to identify sugarcane varieties with high sucrose content with less inclination to post harvest inversion (both biochemical and microbiological).There is an ardent need to screen commercial varieties for their ability to withstand post harvest stress, especially to resist moisture loss and inversion. Therefore, the present study was planned with the objective to work out the post harvest quality profile of recommended varieties for commercial cultivation in Punjab. The paper deals with the post harvest losses of sugarcane genotypes differing in maturity behaviour, in relation to juice quality as a function of post harvest storage time.

## MATERIALS AND METHODS

The present study was conducted at the PAU, Regional Research Station, Kapurthala which represents the subtropical conditions of the country, during spring 2015-2016. Sugarcane varieties of early and mid-late maturity groups were used for the study. Varieties CoPb 92, Co 118, CoJ 85 and CoJ 64 of early maturing group and CoPb 93, CoPb 94, Co 238, CoPb 91 and CoJ 88 of mid-late maturing group, were taken to assess the post-harvest quality losses. The investigation was carried out in the months of March and April. The average maximum and minimum atmospheric temperatures and relative humidity were 28.4 and 10.6ºC; 88.4 and 43.3 in March and 37.3 and 16.6ºC; 62.0 and 21.7 in April respectively. 35 mm rainfall was recorded during this period. All the varieties were sown in randomized block design (RBD) in a plot size of 36 $m^{-2}$ having three replications with row spacing of 90 cm. Randomly selected canes of each variety were harvested, detopped, detrashed and kept in open natural field conditions in three replicates. After harvesting, canes were stored under natural field conditions for 12 days causing them to become stale. Weight of 10 canes in each replication were recorded for 12 days. Representative samples of 10 canes from each variety were selected and juice was extracted at the interval of 0, 2, 4, 6, 8, 10 and 12 days of storage in a cane crusher. The deterioration in cane quality was assessed by juice analysis following standard methods. TSS (Total Soluble Solids) / Brix was measured by hydrometry using brix spindle (0-20 and 21-30) with the method given by Meade and Chen (1977). The clarified juice was analysed with sucromat (digital automatic saccharimeter) for sucrose and purity. The results are expressed in percent sucrose in juice. Commercial Cane Sugar (CCS %) was then computed following Winter carp equation (Shukla 1991) given as

CCS % = {Sucrose % – (Brix % – Sucrose %) X 0.4} X 0.74

Where, 0.4 = multiplication factor 0.74 = crusher factor.

Reducing sugars in juice were estimated by the method of Nelson (1944). The results were expressed as percent reducing sugar in juice. Juice extraction percent was calculated by taking the cane weight and weight of juice obtained after crushing and expressed as percentage.

## RESULTS AND DISCUSSION

### Quality parameters as affected by staling period

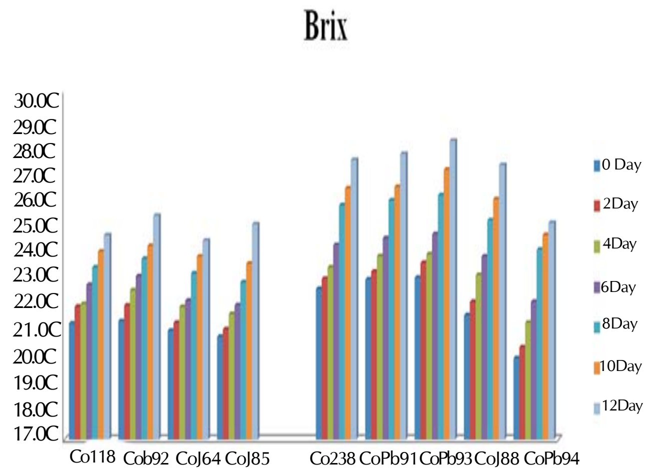
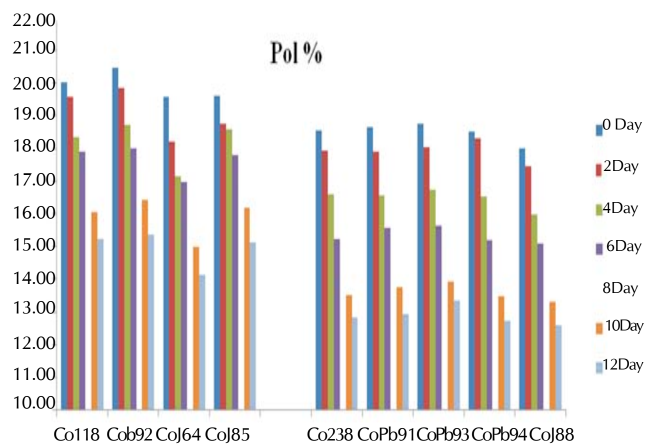



**Figure 1: Brix value as affected by Staling period**




**Figutre 2: Sucrose percent juice as affected by Staling period**

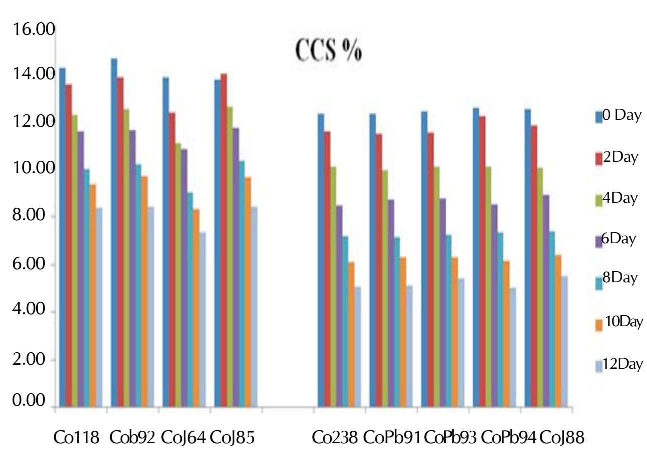



**Figure 3: Commercial Cane Sugar as affected by staling period**

Brix value reflects the percentage by weight of Total Soluble Solids (TSS) in juice. All the varieties representing the early and mid-late maturity group showed a progressive increase in percentage of TSS with increase in staling period i.e. from 0

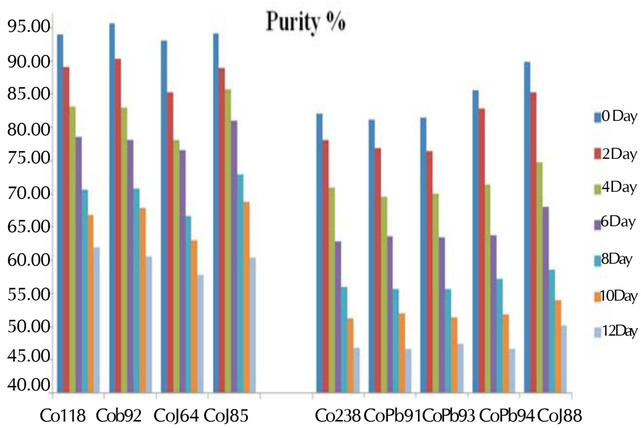



**Figure 4: Purity % as affected by Staling Period**

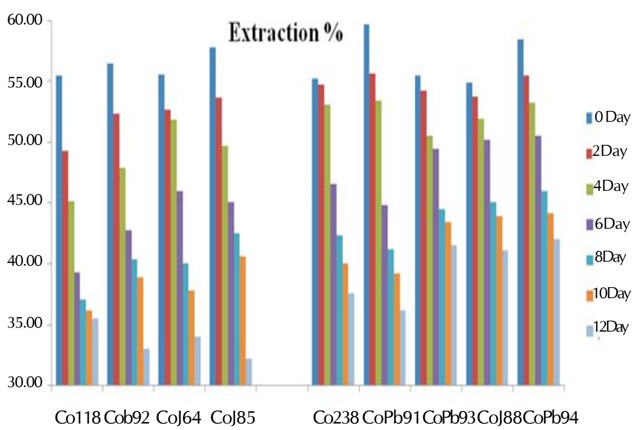



**Figure 5: Extraction % as affected by Staling Period**

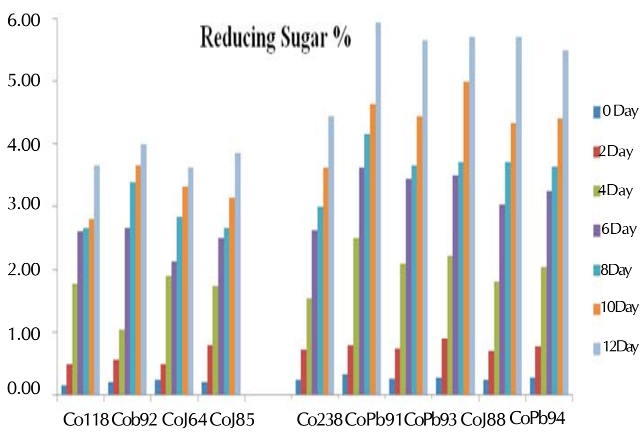



**Figure 6: Reducing Sugars as affected by Staling period**

day to 12 days (Fig. 1). Bhatia *et al*. (2009) reported gradual increase in TSS after storage of canes for twelve days regardless of the genotype or environmental conditions. Varieties under study had an average TSS of 21.66 at harvest, which gradually

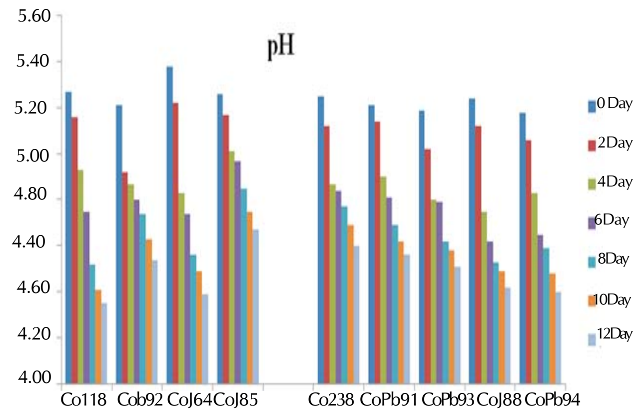



**Figure 7: pH as affected by Staling Period**

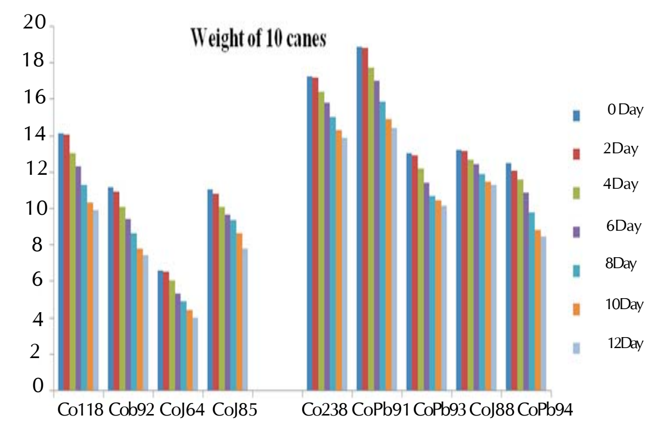



**Figure 8: Cane weight as affected by Staling Period**

increased with increasing staling period and reached to 26.11 at 12$^{th}$ day. Among the tested varieties, CoPb 92 (25.35) from early maturity group and CoPb 93 (28.14) from mid maturity group showed maximum value of TSS at 12$^{th}$ day (Maximum day of staling). The apparent increase in level of TSS in juice is the reflection of the moisture loss in the harvested canes due to high ambient temperature in the month of March and April. Higher water content in fresh cane provided an insulation effect on the cellular temperature, so on storage due to loss in moisture level this effect is diminished which results in increase in invertase activity (Batta and Singh, 1991). Inversion of sucrose results in formation of Glucose and fructose (invert sugars), thus leading to loss of recoverable sugar (Gupta *et al*., 1975).

Decreased sucrose percent juice was observed in each variety with increasing staling time (Fig. 2). Considerable rate of decrease was noticed after 6-8 days of harvest in varieties of both the maturity groups. The early maturing varieties possessed higher sucrose percent in juice in their stalk as compared to mid-late maturing varieties. CoPb 92 and CoPb 93 from their representative maturity group accumulated maximum sucrose at harvest and also retained maximum sucrose at maximum period of staling. Average Sucrose % over the studied staling period, for both the early and mid-late maturity varieties ranged from 19.13% - 13.80%. The highest mean percent juice sucrose was observed at 0 hours (19.13) but a significant decrease was observed after 4 days of staling (17.24) in all the varieties and the lowest % sucrose was observed at 12$^{th}$ day (13.80) of staling period. On the basis of overall display of the varieties on maturity group level, it may be concluded that early maturing varieties have better sucrose retention potential and possess higher storage capacity of sucrose in the sink due to less fibre content, in comparison to mid maturing varieties which have higher fibre content and less sucrose percent in their stalk. Previous authors (Siddhant *et al.*, 2008; Srivastava *et al.*, 2006, 2009; Solomon, 2009) have advocated the quality losses in staled cane juice. The biological losses such as inversion of sucrose by plant and microbial invertases, formation of organic acids and dextran by microorganisms are largely responsible for loss of recoverable sugar after harvesting of cane and its subsequent processing in mill (Solomon, 2003). The post harvest utilization of sucrose in respiration in sugarcane has also been indicated. (Bieleski, 1968). The hydrolytic enzymes present in juice get activated during storage of cane resulting in loss of quality. Thus it appears that all sugarcane genotypes are prone to quality deterioration during storage and these quality losses are relatively more at higher temperature. These losses further escalate when crushing is extended beyond March.

**Commercial Cane Sugar (CCS)** is an important trait for the industry for determination of potential quality cane. Sugar recovery in sugar mills refers to the recovery of Commercial Cane Sugar from the juice. Obviously, recovery in the sugar factories also takes into account loss and destruction of sucrose in the manufacturing process which is due to a number of factors, among which staling of cane is a major cause. The data on the effect of staling period on CCS % revealed that there was progressive decline in sugar recovery with increase in staling period as depicted in Fig. 3. Among the studied varieties from early maturity group CoPb 92 (11.59) recorded highest average CCS% over the staling period and CoPb 94 (8.96) was leading among mid maturing varieties. CoJ 64 (10.42) and CoPb 238 (8.72) recorded lowest average CCS% from their representative maturity groups indicating its high quality deterioration. On the whole, the highest average CCS % was recorded at the day of harvest *i.e.* (12.46), while the lowest CCS % was recorded on 12$^{th}$ day *i.e.* (5.24). This trend depicts the deterioration of cane quality with increase in staling period. Enhancement or increase in enzymatic activities viz: inveratses, amylases, hydrolases on storage, results in reduction in sugar recovery. Bhite *et al.*, 2007 and Solomon *et al.*, 1997 also recorded reduction in CCS% on staling.

With the storage of canes, the average purity percent of all the varieties under study, decreased from 88.51 (fresh cane) to 53.14 (stale cane). Purtity % of juice declined in all the varieties with advancement in storage period (Fig. 4). CoJ 64 (57.78) from early maturity group and CoJ 88 (46.70) from mid maturity group showed significant drop in purity % at maximum time of storage *i.e.* 12$^{th}$ day. Loss in juice purity was attributed to decrease in sucrose and increase in TSS during storage. Staling favours bacterial growth which reduces the juice purity and can be considered another reason for reduction of purity on staling.

The data on effect of staling period on extraction % was presented in Fig. 5. All the varieties showed decreased extraction % with increase of staling period from 0 to 12 days. Among the varieties, maximum extraction % was obtained at immediate harvesting (56.60 %) but goes on decreasing with increasing staling period (37.04%). The data revealed that the variety CoPb 94 (50.03) recorded the highest mean extraction % when compared to other clones but on par with CoJ 88 (48.74) whereas, the variety Co 118 (42.61 %) recorded the lowest mean extraction % over the storage period.

There was progressive increase in reducing sugar content of all the varieties with increase in staling period from 0 day to 12$^{th}$ day as mentioned in Fig. 6. Data revealed that the variety Co 118 show tolerant behaviour towards post harvest deterioration as it recorded the lowest average reducing sugar (2.03 %) over the staling period, which is due to low inversion of sucrose to reducing sugars. On the other hand, variety CoPb 91 is more prone to post harvest deterioration accumulating having highest mean reducing sugars (3.14 %) in 12 days. Reducing sugars are continuously utilized during the process of respiration and other metabolic activity. The results were in accordance with findings of Rao *et al.*, 2010. However, the mean data of reducing sugar revealed that staling behaviour of both the groups were similar. It has been drawn out that the early maturing group lost the quality relatively less as compared to the mid-late maturing group showing lower reducing sugar content in juice. The reducing sugars in juice are an important indicator of cane deterioration (Uppal and Sharma, 1997; Magdum *et al.*, 1987; Ahmad and Khan, 1988; Gaur and Desai, 1988). Studies conducted by Solomon *et al.*, (1997, 2007, 2008) have also reported higher levels of reducing sugars in juice on storage of the harvested cane.

A gradual decline in pH of the juice was also observed in all the genotypes with increase in storage period (Fig. 7). The highest average pH was observed at 0 day (5.24) while the lowest was noticed at 12$^{th}$ day (4.49). Bhatia *et al.*, 2009 reported that, with increased storage period there is gradual increase in titrable acidity with parallel decline in pH of juice. However, the effect becomes more pronounced during late crushing i.e. at high temperature. Mao and Liu (2000) also reported similar results. Among the genotypes, the highest pH was recorded in CoJ 85 (4.95) over the storage period of 12 days. The variety CoJ 88 and CoPb 94 (4.74) recorded the lowest mean pH. Since pH of sugarcane juice lies between 5.0 and 5.5, which is near optimum pH of acid invertase, so acid invertase is considered to be mainly responsible for sucrose inversion in juice (Batta and Singh, 1991)

Data on cane weight revealed that the fresh harvested canes of all the varieties recorded highest average cane weight (0 day : 13.10 ) while stale canes noticed significant reduction in weight with progressive increase in staling period (12 day : 9.71). CoPb 91 (16.83) recorded highest mean cane weight over the storage period, followed by Co 238 (15.73) and CoJ 88 (12.31) while CoJ 64 (5.40) recorded lowest average cane weight (Fig. 8). The results were in concurrence with the findings of Siddhant *et al.*, 2008. Cane weight is mainly attributed to evaporatory loss and respiratory losses (Rakkiyappan *et al.*, 2009). Besides sugar inversion post harvest delay on transit also give rise to cane weight loss due to desiccation. Previous studies inferred that harvested crop of CoJ 64 losses cane weight @ 3.0 % per day upon staling under hot weather conditions (Sharma *et al.,* 1994). Another study revealed that staleness resulted in economic loss which amount to Rs 1.5 crore per season to cane growers due to loss in cane weight (Sharma *et al.,* 2004).

These results suggest that CoPb 92 from early maturity group and CoPb 93 from Mid-late maturity groups are promising candidate varieties possessing tolerance to post harvest deterioration as they retain maximum average sucrose % (17.9, 15.9) and CCS % (11.6, 8.8) over the staling period, respectively. Since the accumulated sucrose in standing cane represents a balance between the synthesis and utilization and once the cane is harvested the plant will not manufacture new sucrose, but will only deplete it, so it is recommended that harvested cane should be crushed immediately to avoid loss in sugar recovery.

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