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RESEARCH ARTICLE

Evaluation of sugar losses in beet molasses as affected by the quality of sugar beet roots

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Abstract

This study was designed to evaluate the indices that affect the quality of sugar beet root processing in relation to sugar loss in final molasses. This quality is affected by late sugar beet root harvesting and the infestation with root rots resulted in a significant increase of the inverted sugars, K, Na and α-amino-N concentrations with detrimental consequences for processing. For this purpose, samples of sugar beet molasses and sugar beet roots were taken during the processing (from two different designs of production lines) and research fields of Delta Sugar Company during different times in the 2021 and 2022 processing seasons early season, middle season and late season (from the middle of February to late March, from early April to middle of May and from the middle of May to late June, respectively).

During the processing season, sucrose content in sugar beet roots declined significantly, while K, Na, amino N, inverted sugars and other ingredients accumulated in the beets, therefore, the quality of sugar beet roots degraded dramatically. The quality of sugar beet increased significantly from 74.8±0.024% to 83.8±0.024% during the season. Whereas the purity of sugar beet juice elevated significantly from 84.8±0.019 to 87.9±0.029% during the season. These findings revealed that there is a reversible relationship between the quality of sugar beet, the sugar losses percentage in beet molasses and the concentration of alpha-amino nitrogen, sodium and potassium in sugar beet. Therefore, the future needs of the processing industry could change the criteria of quality assessment.

Keywords: Beet processing; Sugar loss; Beet molasses; Root quality; Sugar recovery.

Introduction

Sugar beet (*Beta vulgaris L.*) is an important crop which is used for producing sugar as well as feed and organic matter for the poor soils. Sugar beet is cultivated in regions with moderate weather, in the northern hemisphere in particular, Russia, Canada and Europe as reported by De Lucchi et al. (2021). Moreover, sugar beet has been recently widely included into the Egyptian agriculture and industrial processes (Abou-Elwafa et al. 2020; Galal et al. 2022). The area planted with sugar beet and the amount of white sugar produced is growing. It has been reported that 3.3 million tonnes of sugar are consumed annually. Therefore, in Egypt, sugar beet is becoming a crucial source for sugar production (Center Sugar Crops, Ministry of Agriculture's 2021).

In Egypt, after sugar cane, sugar beet is regarded as the second sugar crop in sugar production. According to El-Hawary (1999), in recent years, sugar beet crop has played a significant role in Egypt's crop rotation as a winter crop and can be cultivated in fertile and poor soils that are saline, alkaline and calcareous. About 66% of Egyptian local requirements came from sugar beet and sugar cane regionally, while the rest (34%) is imported from overseas countries (FAO 2011). The main faced issues of beet sugar manufacture are beet roots quality deterioration and decline of sucrose which occurred due to respiration and activation of some enzymes, resulting in a decrease of physical and technological characteristics of sugar beet roots. Pavlů et al. (2017), reported that prolongation of the vegetation period in spring to 13 days increased sugar beet root yield by 10.9%. While sugar yield and quality formation are a very complicated process involving a lot of factors (Pačuta et al. 2017; Fugate and Campbell 2009), mentioned that sugar loss in beet sugar industry occurred due to three different reasons. The first one is spoilage by microorganisms which use up sugar in respiration and produced enzymes which convert sucrose to invert sugar. Meanwhile, harvesting and cleaning of sugar beet lead to root damage, which increases storage losses due to wound healing and by causing entry points for pathogens that is the main cause of beet roots deterioration (Kleuker and Hoffmann 2020).

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The second substantial source of sugar loss occurred through direct respiration of stored beet roots. The sugar loss by direct respiration was estimated at up to 0.5 pound of sugar per ton beets per day. The last source of sugar loss is the biochemical transformation of sucrose into invert sugars which inhibited crystallization and canes difficulties in beet sugar processing. Among the three approaches causing sugar loss in beets, biochemical transformation that has received the least attention. Sugar loss and also impurities are considered to be the primary goals which are directly influencing sugar extraction (Bosemark 1993). Poor beet quality results in higher needs for processing aids, enhances energy consumption and impairs white sugar quality by colour formation (van der Poel et al. 1998).

At low temperature, changes in beet quality could be kept to a minimum. Nevertheless, amino N, invert sugar and raffinose accumulated in the beets, which increases the costs of sugar manufacturing. Compositional changes during storage were consistent for the two cultivars under study, but significant differences in the concentration of the quality determining constituents of the beets occurred. Further research is necessary to examine whether genetic variability in the activity of sucrolytic or proteolytic enzymes of sugar beet exists. This could be the basis for the selection of cultivars with better storability (Kenter and Hoffmann 2009). Meanwhile, many studies have indicated the enhanced pesticides bio-degradation rate with the presence of biochars in the soil environment (Yavari et al. 2021). Therefore, there is a great demand to maintain sugar beet roots quality after harvesting by taking some chemical parameters into consideration to reduce sugar loss in molasses and to increase sugar yield. Although, recently, Alotaibi et al. (2021), have applied a soil treatment to reduce K%, Na%, and α-amino-N % and enhance sucrose content and quality index of beet root juice. However, in Egypt, there is no a specific technological process that could overcome beet roots deterioration have been commercially applied.

Therefore, the main objective of this study is to investigate the relations between quality of sugar beet roots and sugar loss in molasses. Moreover, it traces some chemical parameters such as K, Na and α-N contents in sugar beet roots that directly affect the quality of sugar beet roots with different patterns.

Materials and methods

Experimental procedures

The experiment was carried out at laboratories of Delta Sugar Company, Kafr El-Sheikh Governorate, Egypt, during the 2021 and 2022 harvest seasons, early season (from middle of February to late March), middle season (from early April to middle of May) and late season (from middle of May to late June).

Samples of healthy sugar beet roots (*Beta vulgaris L.*) and beet molasses were taken randomly from the research fields and the processes of the two production lines. The old French production line (line 1) was designed by the FCB company, while the production line 2 was recently designed by BMA company in Delta Sugar Factory. Each sample was represented as mean of five replicates during each period of the season.

Analytical methods

Determination of chemical constituents

Ash content

Ash content was determined using Muffle furnace with digital PID controller, model, CWF-11/13 max, 1100 ºC at 550 ºC according to the method of A.O.A.C (1990).

Sucrose content

Sucrose content was determined using automatic saccharimeter on a lead acetate basis according to the procedure of Delta Sugar Company (Le Docte 1977).

Reducing sugar

Reducing sugar content of beet roots samples were determined using Ofner's volumetric methods as described in A.O.A.C. (1990).

Total soluble solids (T.S.S)

Total soluble solids of fresh samples were determined using fully automatic digital refractometer, model ATR-S (04320), 0 - 95%Brix, temperature compensation 15 to 40 ºC according to procedure of Delta Sugar Company.

Alpha amino nitrogen, Sodium and potassium

Alpha amino nitrogen, Sodium and Potassium were determined using venma, Automation BV Analyzer IIG-16-12-99, 9716JP/ Groningen / Holland. Temp. 18 - 30 º C, surrounding humidity max. 70% according to Brown and Lillan (1964), the results calculated as milligram equivalents/100 g of beet roots, or by mmol/100g of beet roots.

Juice purity and beet quality

The following juice quality parameters were calculated using the following formulas according to the Delta Sugar Company procedures as described by Silin and Silina (1977) and Sapronova et al. (1979).

$$Purity = \frac{Pol\%}{T.S.S\,\%} \times 100$$

$$\text{Sugar recovery (RS\%)} = (\text{Pol} - 0.29) - 0.343(\text{K} + \text{Na}) - \alpha - \text{N}\ (0.0939)$$

$$Quality\ index\ (Qz\%) = \frac{RS\%}{Sucrose\%} \times 100$$

Where

Pol% = Sucrose%, K = Potassium, Na = Sodium, α-N = α -amin-N, SR = Sugar recovery and

T.S.S = total soluble solids.

Molasses color measurement

The molasses samples were prepared by dilution of 10 g of each sample in 200 ml of distilled water. The extracts were then filtered using filter paper or Whatman filter paper. Color absorbance (A) and transmission (T) were read on spectrophotometer at 420 nm against blank solution as described in Guo et al. (2019).

Sucrose losses in molasses%

The proportional relationship of sucrose losses in molasses was calculated according to the procedure of Delta Sugar Company by using the following equation:

Sucrose losses in molasses% = Brix% * Purity% * Yield of molasses% / 10000

pH measuring

pH was measured by using digital bench pH-meter, model pH-526/sentix – 20/AS- DIN / SIN / STH / 650 according to procedure of Delta sugar Company.

Statistical analysis

Statistical analysis was carried out using IBM SPSS version 26. Descriptive statistics such as (means and standard deviation) was calculated. Differences between the three groups (starting season, middle season and end of season) and two groups (production line 1, production line2) were assessed using Independent-Samples T test.

Results and discussion

Chemical and technological characteristics of beet juice

Sugar beet roots chemical composition is crucial to both sugar factories and sugar beet farmers. Sugars (sucrose) and non-sugar (non-sucrose) content are indications to the quality of the sugar beets where, low non-sugars and high sugars content are desirable. Therefore, in order to evaluate the quality of beet roots for sugar production and determine the sucrose losses in molasses, it is vital to evaluate the chemical and technological characteristic of beet juice. While Noghabi et al. (2011), concluded that temperature and pressure should be considered for optimization the operation conditions at the industrial scale. Chemical and technological properties of beet juice during the beet campaign (beet-processing period) are shown in Table 1. Sucrose percentage of sugar beet juice tend to range between 15.9±0.034% and 19.5±0.031% during the season of sugar beet. Similar results were reported by Abou EL-Magd et al. (2004), Asadi (2007) and Gomaa (2009), who recorded that sucrose percentage of beet juice varied from 17.5% to 19.6% which is the ideal content for sugar manufacture. Total soluble solids content of beet juice ranged from 18.8±0.041% to 21.5±0.043% as recorded in the same table. The present results are consistent with data of Zalat (1993) and Hozayen (2002), who mentioned that total soluble solids in sugar beet juice was between 15.5% and 23.6%. Comparatively, higher reducing sugar percentages were recorded a significant increase in the sugar beet juice from 0.4±0.027 to 0.6±0.023%. These data were different with those mentioned by many authors (Abou-Shady 1994), (Abd EL-Mohsen 1996) and (Gomaa 2009), who found that the percentages of reducing sugar varied from 0.3% to 1.6% (based on dry weight).

Table 1. Chemical and technological characteristic of fresh beet juice as Mean ±SD during the 2021 processing season.

Parameters	Starting of season	Middle of season	End of season	P-value
Sucrose%	15.9±0.03	19.5±0.03	16.9±0.03	<0.001**
Brix (T.S.S) %	18.8±0.04	21.4±0.03	21.5±0.04	<0.001**
Reducing sugars%	0.6±0.04	0.4±0.03	0.6±0.02	<0.001**
Ash%	0.6±0.02	0.7±0.02	0.8±0.02	<0.001**
Sucrose recovery (SR)%	13.6±0.03	16.0±0.03	13.9±0.03	<0.001**
Sucrose loss (SL)%	3.0±0.04	2.8±0.03	3.5±0.03	<0.001**
Purity%	84.8±0.02	87.9±0.03	84.9±0.02	<0.001**
Beet quality%	74.8±0.02	81.9±0.03	83.8±0.02	<0.001**
pH	6.1±0.03	6.2±0.03	5.9±0.03	<0.001**

Ash content is shown in Table 1 which is significantly increased from 0.6±0.020 to 0.8±0.021% at the end of the season in fresh sugar beet juice. The obtained results are almost consistent with Hozayen (2002) and Gomaa (2009), who found that ash content of beet juice varied between 0.5 to 0.8 %. Sucrose recovery relied on some elements such as K, Na, α-N content and sucrose. It is positively correlated with the sucrose content and negatively correlated with the sugar beet juice's Na, K, and -N contents (Mosaad et al. 2022). Sucrose recovery of sugar beet juice elevated significantly from 13.6±0.031 to 16.0±0.027% at the middle of the season during the sugar beet campaign. These results are consistent with Gomaa (2009), who reported that the recovery of sucrose (white sugar) in beet juice varied from 14.2 to 15.2 % in beet laboratory.

Data obtained in Table 1 revealed that the percentage of sucrose loss in sugar beet wastes was at the lowest level in the middle of the season (2.8±0.034%) and tend to increase to 3.5±0.028% at the end of season. The elevation of sucrose loss percentage occurred due to sugar losses increasing in beet pulp, in the filter cake and in the final molasses. Therefore, it is recommended to compare analysis between factory laboratory and beet laboratory to find out the consequences of a short storage (few hours) duration and long storage (more than 24 hours) duration on sugar losses. These results are consistent with findings mentioned by Gomaa (2009), who recorded that the percentages of sucrose losses varied from 3.1 to 4.1 % in beet juice. It could be concluded that by decreasing the sucrose losses, the amount of white sugar produced increased. The ratio of sucrose to total solids as a percentage is defined as the purity of sugar beet juice.

The results in Table 1 show that the beet juice purity enhanced significantly from 84.8±0.019 to 87.9±0.029 %. To illustrate, the main goal of the sugar factory is to separate non-sugar from sugar to improve the beet juice purity to produce high purity beet juice. Furthermore, increasing the purity of beet juice would accelerate and improve beet sugar production. These results were in the same line with Asadi (2007), who mentioned that the beet juice purity usually varied from 85 to 88% in a standard washed beet (beet without peeling).

Data in Table 1 revealed that the beet quality relied on the maturity degree of sugar beet roots as reported by El-Sheikh et al. (2009). Therefore, the beet quality decreased by alkaline (K and Na content) and nitrogen content arising, during first and last days of seasons of the factory's operation. Consequently, it showed a significant increase from 74.8±0.024% at the first of season and increased to 81.9±0.025% at the middle of season then decrease to 83.8±0.024% at the end of season.

It is clear to notice that the change of beet quality values and the change of reducing sugar percentages throughout the processing season are in an inverse relationship. Moreover, the best beet roots quality values were recorded in the middle of the season as it was the lowest values of reducing sugars. These findings are consistent also with those recorded by Gomaa (2009), who reported that the beet quality varied from 78.6 to 83.0% during the campaign of the beet processing. The result in Table 1 showed the pH values of sugar beet juice which were from 5.9±0.031 to 6.2±0.025 during the beet campaign. These data were lower than those reported by Gomaa (2009), who found that the pH of sugar beet juice ranged from 6.5 to 6.7.

Table 2. Chemical and physical characteristic of beet molasses as Mean±SD during the 2021 processing season.

Parameters	Starting of season			Middle of season			End of season		
	Line (1)	Line (2)	T-test	Line (1)	Line (2)	T-test	Line (1)	Line (2)	T-test
Brix%	78.4±0.02	79.1±0.14	4.7	80.3±0.02	80.1±0.01	9.0	79.8±0.01	78.3±0.02	71.5
Purity%	60.4±0.01	61.4±0.01	68.0	59.6±0.01	59.7±0.01	8.4	61.8±0.01	61.8±0.01	7.6
Reducing sugar%	0.2 ±0.01	0.2±0.01	8.7	0.5±0.01	0.3±0.01	9.8	0.8±0.01	0.6±0.01	19.5
Color (MAU) at 420 nm	28197.2±2.24	40171.7±1.39	4548.7	31566.8±1.92	43121.8±2.20	3962.8	33180.4±0.81	44998.6±1.42	7225.1
Specific gravity	1.4±0.02	1.4±0.01	0.4	1.4±0.01	1.4±0.01	1.9	1.4±0.01	1.4±0.01	1.2
pH	7.7±0.02	8.3±0.01	26.7	7.5±0.01	8.7±0.01	94.3	7.9±0.01	8.2±0.01	24.0

Initially the term molasses referred specifically to the final effluent obtained from preparation of sucrose by repeated evaporation, crystallization and centrifugation of juices from sugar cane and sugar beets. Today, several types of molasses are recognized according to the Association of American Feed Control Officials (AAFCO 1982) and Jamir et al. (2021), as cane molasses, starch molasses and beet molasses.

Beet molasses is the runoff syrup from the final stage of crystallization, usually contains about 50% sugar and 80% dry substances (Brix). It is the most valuable by product of the sugar factories (Moosavi and Karbassi 2010). Table 2 compared chemical and physical characteristics of beet molasses from the two production lines during the 2021 processing season. The result in Table 2 reflects the following indication; the brix of beet molasses ranged insignificantly from 78.42±0.021to 80.3±0.021% in the production line (1) and (2), respectively. The purity of molasses ranged from 59.58±0.014to 61.8±0.007 % during all periods of season. An insignificant increase occurred in reducing sugar content at the end of the season 0.8±0.012% for production line (1) and low value 0.6±0.008% in the production line (2). The results in Table 2 reveal that the color for production line (1) ranged from 28197.2±2.235 to 33180.4± 0.806 MAU. Higher values of color were recorded in the production line (2) ranged from 40171.7±1.391 to 44998.6±1.424 MAU. These results agreed with Asadi (2007), who reported that the color of molasses ranged from 40000 to 70000 MAU. Meanwhile, Rahimi et al. (2018), found that by decreasing pH degree, color intensity increased. The specific gravity of molasses in normal value is about 1.4±0.2. Also pH of beet molasses increased from 7.5±0.007 to 8.7±0.011 insignificantly. These results are consistent with those reported by AL-Tantawy (2012), who demonstrated the following results for analysis of beet molasses in Delta Sugar Company: the purity is ranged from 59.5 to 61.92%, the color is 28267 to 51630 MAU, the specific gravity is 1.4% and the pH is 8 to 9.5. These results were carried out in different periods of campaign

Table 3. Relation between sugar beet quality and the sugar loss% in the final molasses and the changes in K%, Na% and α- amino-N% (Mean±SD) in the production lines 1 and 2 during the 2021 processing season after 3 days of beet harvest.

Parameter	Starting of season			Middle of season			End of season		
	Line (1)	Line (2)	T-test	Line (1)	Line (2)	T-test	Line (1)	Line (2)	T-test
Sugar%	15.5±0.01	16.1±0.02	26.4	19.1±0.99	18.8±0.02	0.8	17.7±0.01	16.9±0.01	47.2
K%	6.5±0.01	6.0±0.03	18.7	6.1±0.01	5.8±0.01	17.4	6.7±0.02	6.3±0.01	18.1
Na%	2.9±0.01	2.4±0.02	31.2	2.6±0.01	2.1±0.02	21.2	3.8±0.02	3.5±0.02	12.0
α-amino-N%	3.8±0.01	3.7±0.02	4.3	3.3±0.02	3.2±0.02	4.1	4.2±0.02	3.5±0.01	29.1
Quality%	75.0±0.02	78.1±0.01	141.2	81.2±0.02	82.6±0.02	61.9	75.9±0.02	76.3±0.17	2.2
Sugar loss%	2.6±0.02	2.5±0.02	3.2	2.5±0.01	2.4±0.02	2.2	3.1±0.01	3.0±0.03	3.9

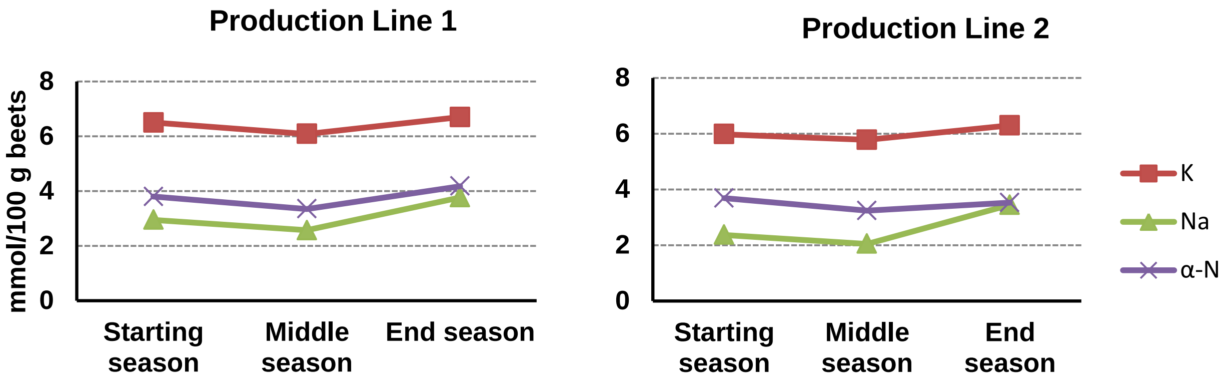

Figure 1. K%, Na% and α-amino-N% during the 2020 and 2021 processing seasons in the production lines 1 and 2.

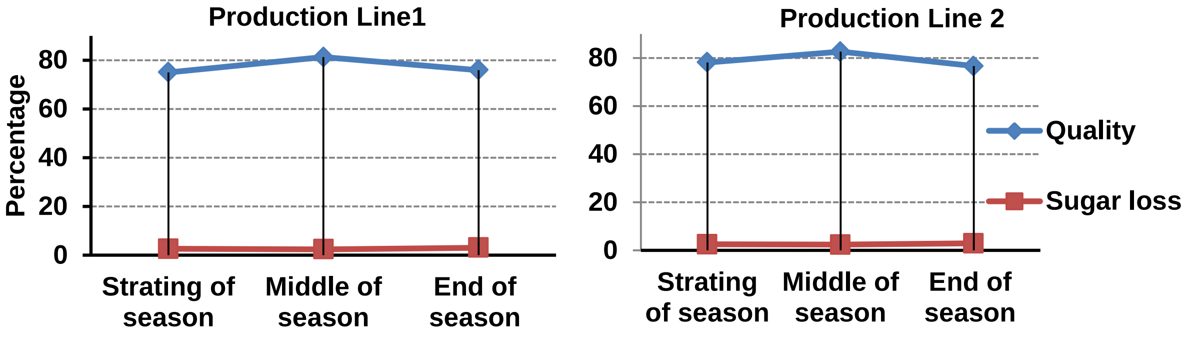

Figure 2. Changes in sugar beet roots quality and sugar loss in molasses% during the 2020 and 2021 processing seasons in the production lines 1 and 2.

It is well known that the quality of molasses depends on the nature of its sugar beet. In sugar technology, sugars in molasses are considered as sugar loss. Decreasing the sugar loss value in molasses is one of the most important goals of sugar factory because it increases profitability. Therefore, the easiest way to evaluate the performance of sugar factory is molasses purity. The lower the molasses purity, the less sugar is left in molasses, at the same amount of molasses production. Thus, credit that sugar beet factory can get.

Data in Table 3 indicates the relation between sugar beet quality and sugar loss percentages in final molasses in the production line (1) and (2) during the 2021 processing season after (3 days) from beet harvest during different periods of season. From Table 3, the obtained results showed that the sucrose content in sugar beet roots ranged from 15.6±1.1 to 19.1±1.3 % after (3 days) from beet harvest i.e., fresh beet. The results are in agreement with Gomaa (2009), who reported that sucrose content in sugar beet in the most cultivars is ranged from 17.3 to 19.3% directly after harvest. The data in Table 3 and Figure 1 demonstrated that as alpha amino nitrogen, sodium and potassium content increased at the end of season so that, the quality of sugar beet decreased and consequently the amount of sugar loss in final molasses increased and vice versa. As shown in Table 3 the quality of sugar beet decreased from 81.2±2.9 and 82.6±3.8% in the middle of season to 75.9±2.4 and 76.6±2.3% at the end of season in both production lines (1) and (2) respectively. Figure 2 showed the differences in sugar loss in relation to beet roots quality during the whole season. At the middle of the season, sugar loss was at the lowest level then decreased insignificantly at the middle of the season in both production lines. This might happen due to the insignificant reduction in K, Na and α-N levels that occurred in the middle of the season (Hoffmann 2010). Consequently, the sugar loss in molasses increased from 2.5±0.4 and 2.4±0.6% in the middle of season to 3.1±0.5 and 3.0±0.2% at the end of season in both production lines (1) and (2) respectively, during different periods of beet season and after (3 days) from mature beet harvest. Also it could be noticed that there is a reversible relationship between the quality of sugar beet, the sugar losses in molasses and the concentration of alpha amino nitrogen, sodium and potassium content in sugar beet. These results are confirmed by AL-Tantawy (2012), who demonstrated that as alpha amino nitrogen, sodium and potassium content increase in sugar beet, the quality of sugar beet decrease and consequently the amount of sugar lost in final molasses increase. This reversible relationship reflects some characters of the produced molasses.

Table 4. Determination of sugar losses in the final molasses as a percentage of beet in relation to beet quality%, sucrose%, K%, Na% and α- amino-N% at the start of the 2021 processing season for 8 days in sequence from sugar beet harvest.

Day	Beet quality%	Sucrose%	K%	Na%	α-amino-N%	Sugar loss%	P-value
1	75.9±0.03	15.8±0.02	6.1±0.03	3.1±0.03	3.9±0.03	2.5±0.03	<0.001**
2	76.1±0.03	15.5±0.04	6.0±0.03	2.9±0.03	3.7±0.03	2.6±0.04	<0.001**
3	75.5±0.02	15.7±0.03	6.3±0.03	3.1±0.03	3.8±0.03	2.6±0.02	<0.001**
4	75.3±0.02	15.5±0.02	6.6±0.02	2.7±0.02	3.7±0.03	2.7±0.02	<0.001**
5	76.9±0.09	16.0±0.03	6.0±0.02	3.0±0.03	3.5±0.03	2.7±0.02	<0.001**
6	78.2±0.02	16.6±0.03	5.9±0.02	2.8±0.03	3.6±0.03	2.8±0.03	<0.001**
7	77.5±0.02	16.7±0.03	6.1±0.02	2.9±0.03	4.0±0.02	2.9±0.03	<0.001**
8	77.6±0.02	16.8±0.03	6.2±0.03	3.0±0.03	4.0±0.05	3.1±0.02	<0.001**
Mean	76.6±0.03	16.1±0.03	6.1±0.03	3.0±0.03	3.8±0.03	2.8±0.03	<0.001**

Data in Table 4 showed that in the starting of processing season after 8 days from beet harvest there is a reversible relationship between the quality of sugar beet and sugar loss in molasses. A significant increase has been recorded after 8 days of alpha amino nitrogen 3.8±0.029, sodium 3.0±0.028and potassium 6.1±0.025 mmol/100g beets leads to reduce the sugar beet quality to 76.6±0.032% significantly. Consequently, the average of sucrose losses in final molasses % of beet was increased to 2.8±0.026% in both production lines. These results are very close to those reported by Al-Barbari (2017), who found that in the starting of beet season the sucrose content of sugar beet juice was 16.6 and 17.0%, beet quality with low values was 74.9 and 78.8%.

Table 5. Determination of sugar losses in the final molasses as a percentage of beet in relation to beet quality%, sucrose%, K%, Na% and α- amino-N% at the middle of the 2021 processing season for 8 days in sequence after sugar beet harvest (Mean±SD).

Day	Beet quality%	Sucrose%	K%	Na%	α-amino-N%	Sugar loss%	P-value
1	80.7±0.03	18.4±0.03	5.9±0.022	2.7±0.03	3.5±0.03	2.7±0.02	<0.001**
2	81.3±0.03	18.5±0.03	5.8±0.03	2.6±0.02	3.3±0.03	2.6±0.03	<0.001**
3	82.8±0.03	19.0±0.03	5.8±0.02	2.0±0.03	3.4±0.02	2.6±0.03	<0.001**
4	82.7±0.02	19.1±0.02	5.9±0.01	1.9±0.02	3.4±0.03	2.4±0.03	<0.001**
5	82.3±0.02	19.1±0.04	6.1±0.03	2.1±0.02	3.3±0.01	2.5±0.04	<0.001**
6	82.5±0.03	19.2±0.03	5.9±0.02	2.1±0.03	3.3±0.03	2.6±0.03	<0.001**
7	82.8±0.03	19.2±.02	5.7±0.03	2.2±0.03	3.5±0.03	2.7±0.03	<0.001**
8	84.0±0.03	19.5±0.03	5.5±0.02	1.9±0.03	3.1±0.05	2.4±0.02	<0.001**
Mean	82.4±0.03	19.0±0.03	5.8±0.02	2.2±0.03	3.3±0.03	2.6±0.03	<0.001**

Data in Table 5 also confirms the facts that at the middle of processing season after 8 days from beet harvest there is a reversible relationship between the quality of sugar beet and the sugar loss percentage in molasses.

Data in Table 5 indicated that at the middle of the season, the mean of sucrose content of sugar beet juice increased to 19.0±0.028 significantly.

Moreover, by increasing the quality of sugar beet to 82.4±0.028%, the sucrose loss percentage in final molasses recorded a significant decrease to 2.6±0.027% in both production lines.

These results also are very close to those reported by Al-Barbari (2017), who found that, at the middle of the season, the sucrose content of sugar beet juice elevated to 20.0 and 20.0%, while the beet quality increased to 84.1 and 86.0%.

Table 6. Determination of sugar losses in the final molasses as a percentage of beet in relation to beet quality%, sucrose%, K%, Na% and α- amino-N% at the end of the 2021 processing season for 8 days in sequence after sugar beet harvest (Mean±SD).

Day	Beet quality%	Sucrose%	K%	Na%	α-amino-N%	Sugar loss%	P-value
1	80.7±0.02	18.8±0.03	6.0±0.03	2.8±0.03	3.4±0.03	2.9±0.03	<0.001**
2	80.1±0.06	18.2±0.03	6.0±0.03	2.8±0.03	3.6±0.03	2.9±0.02	<0.001**
3	80.3±0.02	18.3±0.03	5.9±0.03	2.8±0.03	3.5±0.03	2.9±0.03	<0.001**
4	79.1±0.03	17.7±0.03	5.9±0.03	3.0±0.03	3.4±0.03	3.1±0.03	<0.001**
5	78.4±0.03	16.9±0.03	5.9±0.03	3.0±0.03	3.5±0.03	3.1±0.05	<0.001**
6	76.9±0.02	16.8±0.02	6.0±0.03	3.5±0.03	3.5±0.03	3.2±0.03	<0.001**
7	76.6±0.02	16.5±0.02	6.1±0.04	3.4±0.03	3.5±0.03	3.2±0.03	<0.001**
8	73.7±0.03	15.7±0.02	6.4±0.03	3.8±0.03	4.1±0.03	3.7±0.03	<0.001**
Mean	78.2±0.03	17.4±0.03	6.0±0.03	3.1±0.03	3.6±0.03	3.1±0.03	<0.001**

Results obtained in Table 6 demonstrated the change of some chemical parameters at the end of processing season and after 8 days of beet harvest. This is crucial time because all farmers harvest beets to allow for timely preparation of the land multi-cropping. Sugar beet roots stored directly in atmospheric air which leads beet roots to be exposed to high temperatures. In this case, alpha amino nitrogen, sodium and potassium content will increase significantly in sugar beet leads to a significant decrease in beet roots quality index.

Consequently, the mean of sugar loss in final molasses was increased to high values in both production lines. Results in Table 6 revealed that by a significant increase of alpha amino nitrogen, sodium and potassium (3.6±0.028, 3.1±0.029 and 6.0±0.031mmol/100 g beets, respectively) in sugar beet leads to decrease the beet quality to 78.2±0.027% significantly. These results are confirmed by Asadi (2007), who mentioned that the molasses is sold as a by-product of the factory; the amount sugar loss in molasses is considered as the largest loss about 80% of unrecoverable sugar which ends up in molasses.

Conclusions

It could be concluded that accelerating the sugar production process leads to minimise changes in beet quality. However, the beets accumulated amino N, invert sugar, K, and Na, which raises the cost of sugar production. Moreover, significant differences occurred in the concentration of components that affect the beet roots quality. Further research is needed to evaluate the impact of storage temperature on sugar beet quality changes, with a focus on non-sucrose compounds that limit sugar recovery. For long stored beet roots, a quality assessment based on K, Na, amino N and inverted sugars appears to be insufficient. Furthermore, processing conditions that are minimizing the effect of these impurities have been investigated enough yet.

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