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(Original Article)

Monitoring Invertase Activity and its Impact on Sugar Beet Roots (*Beta vulgaris* L.) During Extended Storage Under Controlled Conditions

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Abstract

Sugar beet factories employ long-term storage of sugar beet roots to extend the processing campaign in Egypt. Changes in the chemical composition of sugar beet roots during storage, driven by invertase enzyme activity, impact the crystallization process in sugar production. This study aimed to monitor invertase activity in sugar beet roots harvested at 180, 195 and, 210 days of cultivation, applying different storage conditions for 1, 10, 20, and 30 days. Additionally, the study explored the influence of invertase activity on reducing sugars content in sugar beet roots. Results indicated that covered storage conditions exhibited the lowest invertase activity compared to open air and room storage conditions. Moreover, reducing sugars content was affected by invertase enzyme activity. Storage conditions displayed the lowest inverted sugars content across all tested sugar beet root varieties. Thus, the study suggests that long-term storage with covered conditions is suitable for extending the processing campaign, emphasizing the importance of considering inverted sugars concentration.

***Keywords**: Sugar beet (Beta vulgaris L.), Invertase enzyme, Sucrose, Reducing sugars, storage, Controlled conditions.*

Introduction

Sugar beetroots (*Beta vulgaris* L.) are typically stored from harvest until processing. Because of respiration, wound healing, and pathogen infestation, sugar beetroot roots lose sugar during storage, and the quality of processing deteriorates (Fasahat *et al*., 2018). The length of the storage time and the amount of roots that are required to be stored will grow along with the need for extending the processing campaigns in sugar plants (Madritsch *et al*., 2020). Extending storage periods raises the possibility of increased reducing sugars and quality degradation. During storage, the sucrose is cleaved, mainly by sucrose synthase, and inverted sugars (glucose + fructose) accumulate in the roots as a function of time and temperature. Inverted sugars have negative processing effects because they lower the alkalinity of the fluids and cause color development (Vasantha *et al*., 2021).

Therefore, to lower the fixed expenses of sugar manufacture, the sugar producers are thinking about extending the processing campaign. In the future, the

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number of beets stored will rise and the storage duration will also be prolonged. The quality of beetroot has a major impact on how efficiently sugar is manufactured (Kenter and Hoffmann, 2009). Also, it is important to ensure adequate ventilation to prevent the buildup of carbon dioxide and other gases that can harm the roots. Ventilation holes can be created in the covering or by ensuring gaps between the pile and the covering (English, 2023).

High concentrations of sucrose and low amounts of non-sucrose compounds that prevent the recovery of white sugar are characteristics of good processing quality. The amount of sucrose lost to molasses is increased by soluble non-sugars like potassium, sodium, and nitrogenous compounds including amino acids, betaine, and nitrate that are unable to be eliminated from the factory juices during purification. The quality of white sugar is lowered when amino acids react with inverted sugar to generate color (Mohamed *et al*., 2023). Moreover, Kenter and Hoffmann (2009) reported that the decomposition of glutamine and inverted sugar (glucose + fructose) produces acids, which lower pH. Juices with low reserves of alkalinity must have soda added, which raises costs and boosts the amount of sugar lost in molasses.

Moreover, negative effects of inverted sugars can be a problem in sugar manufacture because inverted sugar is less stable than sucrose and can lead to problems with crystallization and storage. Also, reducing sugars can caramelize at high temperatures, leading to the formation of dark brown compounds that can affect the color and flavor of sugar products. While the Maillard reaction can lead to the formation of undesirable compounds that can affect the quality of sugar yield. Reducing sugars can also affect different stages of sugar manufacture. During the extraction of sugar from sugarcane or sugar beets, reducing sugars can be extracted along with sucrose. This can lead to problems with inversion and caramelization. Reducing sugars can react with other compounds in the juice to form impurities that can make it difficult to clarify the juice. During evaporation, reducing sugars can concentrate and lead to problems with crystallization. Reducing sugars can interfere with the formation of sucrose crystals which directly affects sugar recovery (El-Geddawy *et al*., 2023).

Furthermore, other enzymatic reactions cause additional non-sucrose compounds to accumulate in the beetroot. According to Hoffmann *et al*. (2021), for economical beet processing, quality losses should be minimized. Many studies have been conducted on how beetroot quality varies whether stored in commercial heaps or field clamps. However, changes in reducing sugars in relation to invertase enzyme fluctuation in the clamps are not predictable and vary considerably. This makes it difficult to identify significant differences between treatments in storage clamps in the field (El-Geddawy and Abd El-Rahman, 2019). Therefore, the amount of sugar that may be recovered decreases as a result of the beets' changing chemical composition during storage. Thus, invertase enzyme and reducing sugars during long-term storage have not been studied under controlled conditions. In the present study, the storage conditions were therefore standardized to assess the effect of invertase enzyme activity, reducing sugars and the storage period. The aim was to quantify the effect of storage duration and invertase enzyme activity on quality changes of sugar beet with special emphasis on reducing sugars that impair sugar recovery.

Materials and Methods

Four varieties of sugar beet roots Pleno, Top, Kawemira and Cerses Poly were harvested at different dates (180, 195, and 210 days after planting). Then, sugar beet roots were stored for 1, 10, 20, and 30 days by covering, open-air and room storage conditions. Invertase enzyme activity and reducing sugars content in sugar beet roots were determined after 1, 10, 20, and 30 days of storing for each variety. Each sample was displayed as the mean of five replicates for each storing condition.

Determination of invertase activity

Invertase enzyme activity determination was conducted according to Pavlinova *et al*. (2002) as follows:

Invertase extraction

A sample of 100 ml of acetate buffer was mixed with 40 gm of minced sugar beet by blender for 5 min. The supernatant was filtered under cooling (10 ºC) with filter paper.

Preparation of substrate

A sample of 6.5 gram of sucrose was dissolved in acetate buffer pH 4.5 and completed to 100 ml using the acetate buffer.

Determination of invertase activity

Invertase activity was determined using the following procedure of Bergmayer (1974). A sample of 3 ml enzyme acetate was added to 6 ml of the substrate and incubated for 30 min. at 25ºC in water bath. The reaction was stopped by heat treatment (100 ºC for 3 min.). The same mixture without incubation was used as a blank.

Preparation of acetate buffer

Sodium acetate solution: For a 0.1 M solution, dissolve 8.42 grams of sodium acetate in 1 liter of water. Acetic acid solution: For a 0.1 M solution, dilute 10 ml of glacial acetic acid with 90 ml of distilled water. Mix the sodium acetate and acetic acid solutions: Slowly add the acetic acid solution to the sodium acetate solution while stirring continuously. Monitor the pH using a pH meter or pH test strips.

Standard curve of glucose

Glucose solution prepared (50 ml) by dissolving 9.008 gm glucose (anhydrous) in distilled water to 100 ml (stock solution).

Standard solution of (0.6 nm): prepared by diluting 10 ml of stock solution in 1000 ml distilled water.

A standard curve for glucose was constructed using 10 to 70 mg glucose per ml.

The absorbance was developed and measured at wavelength of 620 nm and it was plotted against the corresponding concentration of sugar to obtain the standard curve calculation:

$$\text{Units/mg} = \frac{\text{Micromoles sucrose liberated}}{\text{mg enzyme in reaction mixture} \times 3\text{ min.}}$$

Reducing sugar determination

According to A.O.A.C. (1990), reducing sugar content of samples of sugar beet roots was assessed using Ofner's volumetric techniques.

Statistical analysis

In order to conduct the statistical analysis, IBM SPSS version 26 was used. Calculated descriptive statistics include means and standard deviation. The Independent-Samples T test was used to evaluate differences between the four groups (Pleno, Top, Kawemira and Cerses Poly varieties) and the three groups (covering, open-air and room storage conditions).

Results and Discussion

The effect of different storage conditions on changes in invertase activity of sugar beet roots has been studied at different cultivation periods. The results are presented in Table (1) and Fig. (1a, 1c and 1e). The results revealed that the invertase activity of four varieties Pleno, Top, Kawemira and Cerses Poly increased significantly during storage period (30 days).

However, the invertase activity was 0.426±0.07, 0.394 ±0.03and 0.309±0.01 unit/mg in Pleno, 0.348±0.06, 0.317±0.06 and 0.391±0.03 unit/mg in Top, 0.526±0.09, 0.479±0.03 and 0.456±0.08 unit/mg in Kewamira and 0.567±0.11, 0.471±0.06, 0.410±0.01 unit/mg in Ceres Poly, at harvesting dates of 180, 195and 210; respectively, similar results were recorded by Kusstatscher *et al*., (2019) while storing in clamps. Thus, invertase activity in Ceres Poly was much higher than that in Kawemira, Pleno and Top varieties were harvested at 180 days. The results showed that invertase activity in Kewamira was higher than that recorded with Ceres Poly, Pleno and Top varieties at harvesting dates of 195 and 210 days.

Under covering storage conditions (Table 1) Pleno variety recorded the highest value of invertase activity at all harvesting dates; meanwhile, Kawemira variety recorded the lowest value. On the other hand, in open-air storage, Pleno variety had the highest value of invertase activity at all harvesting activity at all harvesting dates, although Top variety recorded the lowest value in invertase activity.

On the contrary, in the room storage, Pleno variety had the highest value of invertase activity on most of the harvesting dates, while top variety recorded the lowest value on all harvesting dates. These results were in agreement with those reported by Ferweez *et al*. (2018). As a result, the increase in invertase activity was followed by an increase in reducing sugars very closely.

The sucrose content of sugar beet roots declined after harvesting as a result of sucrose conversion to reducing sugars and oligosaccharides. At storage temperatures above 5 ºC, reducing sugars (glucose and fructose) accumulate, alternatively, at temperatures below 5ºC both raffinose and reducing sugars accumulate Lafta *et al*., (2020). Reducing sugars content of the roots did not change during 30 days of storage at 2ºC, however, it doubled at 21ºC. IRS *et al*., (2013) concluded that at 5ºC day the reduced sugars content increased in the last 50 days of storage.

The data reflected that there were differences among the four varieties and different storage conditions and periods of storage. The same records of invertase activity during storage were observed in the four varieties; however, the increase may be explained by the decrease in the sucrose content Hoffmann (2010).

In this connection, it should be recalled here that Giaquinta (1979) mentioned that the sucrose is hydrolyzed by cell wall acid invertase and resulting hexases are activity accumulated into storage parenchyma and resynthesized to sucrose phosphate synthatase. Moreover, Misra *et al*. (2023) confirmed the same trend in sugarcane.

It could be observed that covering storage condition was the best treatment of storage that reduced invertase activity sharply. Meanwhile, room storage condition was the next best and storage in open-air increased invertase activity. The present results of invertase activity are in agreement with those of Jammer *et al*. (2020) who found that the invertase enzyme activity of sugar beet roots was stimulated during storage. The stimulation of the invertase activity which was detected in this study (Figure 1a, 1c, 1e) during storage was correlated very closely with the increase in reducing sugars during the same periods (Table 1). Amjad *et al*. (2019) reported that the stimulation in the invertase followed the increase in reducing sugar were closely.

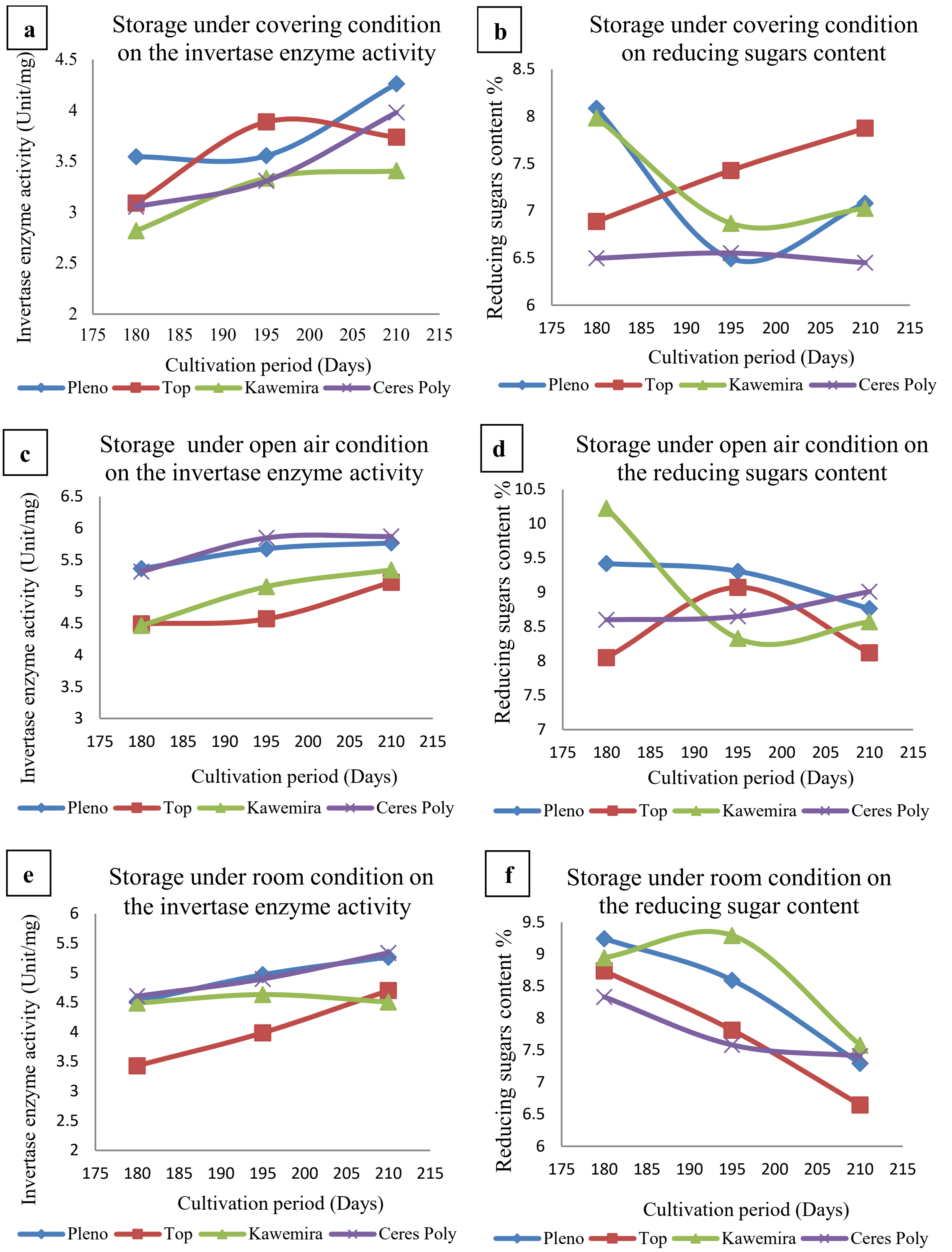

Figure 1. Effect of storage conditions on the invertase enzyme activity (Unit/mg) [a, c and e] and reducing sugars content [b, d and f] of four sugar beet varieties for different storage and cultivation periods under controlled conditions.

Table 1. Effect of storage conditions on the invertase enzyme activity (Unit/mg) of four sugar beet varieties for different storage and cultivation periods under controlled conditions.

Cultivation period in days	Storage period in days	Invertase enzyme activity (Unit/mg) Beet varieties				P-value
		Pleno	Top	Kawemira	Ceres Poly	
Covering storage						
180	1	0.425±0.07	0.348±0.06	0.526±0.09	0.567±0.11	<0001**
	10	2.249±0.98	1.399±0.73	0.812±0.12	0.904±0.71	<0001**
	20	5.1871.89	4.344±2.03	3.666±1.23	4.128±1.60	<0001**
	30	6.315±2.02	6.269±1.98	6.269±1.09	6.627±2.02	<0001**
Mean	-	3.544	3.09	2.818	3.054	-
195	1	0.394±0.03	0.317±0.06	0.479±0.03	0.471±0.06	<0001**
	10	2.187±0.98	1.561±0.79	1.901±1.01	1.677±1.99	<0001**
	20	5.527±2.01	6.777±2.05	3.968±1.97	4.885±1.58	<0001**
	30	6.106±1.93	6.887±1.85	6.99±2.01	6.191±2.05	<0001**
Mean	-	3.553	3.885	3.334	3.306	-
210	1	0.309±0.01	0.391±0.03	0.456±0.08	0.410±0.01	<0001**
	10	3.367±1.06	1.623±0.20	2.072±0.93	2.458±0.84	<0001**
	20	6.33±1.57	5.658±1.12	4.877±1.16	5.976±1.29	<0001**
	30	7.034±2.08	7.366±2.18	6.207±2.01	7.073±3.01	<0001**
Mean	-	4.260	3.737	3.406	3.979	-
Open-air storage						
180	1	0.425±0.07	0.348±0.06	0.526±0.09	0.557±0.1	<0001**
	10	4.506±0.93	3.223±1.05	3.231±1.11	3.842±1.07	<0001**
	20	7.088±2.68	6.431±2.10	6.246±2.07	7.08±2.19	<0001**
	30	9.430±3.06	7.969±2.91	7.866±2.89	9.778±3.92	<0001**
Mean	-	5.362	4.492	4.467	5.316	-
195	1	0.394±0.03	0.317±0.06	0.479±0.03	0.471±0.06	<0001**
	10	4.599±1.26	3.231±1.11	3.149±1.07	5.109±2.01	<0001**
	20	7.652±2.03	6.223±2.09	6.794±2.27	7.784±2.81	<0001**
	30	10.066±3.81	8.510±3.06	9.895±3.91	10.025±3.98	<0001**
Mean	-	5.677	4.570	5.079	5.847	-
210	1	0.309±0.01	0.301±0.03	0.468±0.08	0.410±0.01	<0001**
	10	4.638±0.98	4.12±0.91	3.501±0.83	4.429±0.95	<0001**
	20	7.691±1.86	6.505±1.3	7.366±1.69	8.200±2.04	<0001**
	30	10.435±2.41	9.670±2.29	10.049±2.18	10.443±2.51	<0001**
Mean	-	5.768	5.149	5.343	5.870	-
Room storage						
180	1	0.425±0.07	0.348±0.06	0.526±0.09	0.557±0.1	<0001**
	10	3.958±1.03	0.788±0.10	2.819±1.02	3.331±1.05	<0001**
	20	6.316±1.95	5.55±1.07	5.99±1.84	6.315±1.87	<0001**
	30	7.361±2.15	7.042±2.08	8.626±2.53	8.124±2.76	<0001**
Mean	-	4.515	3.432	4.490	4.606	-
195	1	0.394±0.03	0.317±0.06	0.479±0.03	0.471±0.06	<0001**
	10	3.231±0.94	2.110±0.89	2.520±1.08	3.478±1.34	<0001**
	20	7.361±2.29	5.558±1.01	6.903±1.85	6.730±1.97	<0001**
	30	8.889±2.72	7.969±2.90	8.633±2.91	8.912±2.82	<0001**
Mean	-	4.968	3.988	4.633	4.897	-
210	1	0.309±0.01	0.301±0.03	0.468±0.08	0.410±0.01	<0001**
	10	4.004±1.05	3.177±0.91	3.285±0.97	3.942±0.89	<0001**
	20	7.088±2.74	6.431±1.58	6.671±1.89	7.413±2.05	<0001**
	30	9.67±3.79	8.897±2.49	7.621±1.83	9.592±3.04	<0001**
Mean	-	5.267	4.701	4.508	5.339	-

*Each sample was represented as a mean ± SD of five replicates.

Reducing sugar content

Studying the effect of different storage conditions and harvest dates on changes in reducing sugars content of sugar beet roots of four sugar beet roots varieties was estimated. Reducing sugars content was assessed as it is considered an indication of the proper storage conditions. The results reflected that the reduced sugar content of root of four varieties increased significantly during storage period (Table 2) and (Figure 1b, 1d and 1f).

Under all three storage conditions, Pleno variety recorded the highest value of reducing content percentage (2.39±0.79, 2.481±0.94 and 2.51±0.80%, respectively) after 10, 20, and 30 days of storage, whereas Ceres Poly variety recorded the lowest value in reducing sugar content percentage at all harvested dates and after 10, 20, 30 days of storage. There were differences between the four varieties between the different storage conditions and periods of storage. The same trend was observed when reducing sugars content increased during storage in all four varieties. The present results of reducing sugars are in agreement with Al-Zubi *et al*. (2016). Meanwhile, freshly cut discs of beet contained large amounts of sucrose and usually litter glucose and fructose. However, increasing the storage temperature from 5 to 15 ºC almost doubled the daily sugar losses from low impact harvested and normally harvested sugar beet as also shown by Kenter *et al*. (2006). Furthermore, Huijbregts *et al.* (2013) reported that the inverted sugars of beet at harvest increased from 0.73 mg/ml to 1.14 mg/ml after 140 days of storage at 2 ºC and 21ºC for 30 days and 5ºC for 110 days and 160 days. The sucrose content of sugar beet roots declines after harvest as a result of sucrose conversion to reducing sugars (glucose and fructose) and accumulates at temperature below 5ºC both raffinose and reducing sugars. Whereas Majumdar *et al.* (2022) also found that reducing sugars content of the roots did not change during 30 days of storage at 2 ºC, however, they were doubled at 21 ºC.

At 5ºC the reducing sugar content increased rapidly in the last 50 days of storage. Kleuker and Hoffmann (2020) reported that the inverted sugars in sugar beet roots were significantly increased as the result of mechanical operations. The increase to invert sugars in sugar beet roots during storage may not only be the result of mechanical damage, but it also may be the result of the metabolic action. Furthermore, Varga *et al*. (2021) reported that the respiration rates also were significant higher in roots that were harvested mechanically.

Mold highlighted the reduction in sugar formation in the roots. After eliminating mold and sprouting, the variety temperature relationship was found to be crucial in lowering sugar accumulation. When there was no mold present, the reduction of sugar rose greater at higher temperatures (3 vs 10 ºC) storage (Mohamed *et al*., 2017).

Table 2. Effect of storage conditions on reducing sugars content of four sugar beet varieties cultivated four different periods under controlled conditions.

Cultivation period in days	Storage periods in days	Reducing sugars content percentage				P-value
		Sugar Beet varieties				
		Pleno	Top	Kawemira	Ceres Poly	
Covering storage condition						
180	1	2.39±0.79	1.82±0.61	1.99±0.72	2.22±0.54	<0001**
	10	6.47±1.67	5.02±1.19	6.38±1.83	4.37±1.01	<0001**
	20	11.03±3.04	10.17±2.75	10.94±2.39	8.67±1.93	<0001**
	30	12.45±3.61	10.54±2.63	12.63±3.85	10.73±2.83	<0001**
Mean	-	8.085	6.887	7.985	6.497	-
195	1	2.481±0.94	1.72±0.18	2.65±0.89	1.88±0.49	<0001**
	10	3.82±1.07	4.68±1.28	4.96±1.37	4.79±1.07	<0001**
	20	8.23±1.84	9.6±2.06	9.99±2.16	8.94±1.92	<0001**
	30	11.49±3.39	14.31±3.51	9.87±2.31	10.6±2.64	<0001**
Mean	-	6.492	7.427	6.867	6.552	-
210	1	2.51±0.80	2.62±0.84	3.08±0.99	2.26±0.47	<0001**
	10	6.17±1.94	6.53±1.69	6.60±1.91	4.41±1.15	<0001**
	20	9.43±2.28	11.07±3.36	9.26±2.01	8.86±1.82	<0001**
	30	10.23±2.47	11.28±3.23	9.16±2.19	10.27±2.94	<0001**
Mean	-	7.08	7.875	7.025	6.45	-
Open-air storage condition						
180	1	2.39±0.79	1.82±0.61	1.99±0.72	2.22±0.54	<0001**
	10	8.68±1.91	6.92±1.73	7.72±2.02	6.33±1.92	<0001**
	20	11.82±3.60	11.40±3.01	14.83±3.95	12.52±3.29	<0001**
	30	14.79±4.01	12.06±3.82	16.36±4.19	13.33±4.01	<0001**
Mean	-	9.42	8.05	10.225	8.60	-
195	1	2.481±0.94	1.72±0.18	2.65±0.89	1.88±0.49	<0001**
	10	6.65±1.79	7.83±2.09	7.30±2.13	6.44±1.57	<0001**
	20	13.31±3.82	12.67±3.17	12.77±3.57	12.02±3.31	<0001**
	30	14.79±3.99	14.07±3.93	10.6±3.02	14.26±3.78	<0001**
Mean	-	9.308	9.073	8.330	8.650	-
210	1	2.51±0.80	2.62±0.84	3.08±0.99	2.26±0.47	<0001**
	10	9.8±2.87	8.85±2.89	7.32±2.26	7.09±2.31	<0001**
	20	11.35±3.01	10.59±2.56	10.98±2.77	11.79±3.22	<0001**
	30	11.39±2.79	10.42±2.18	12.9±3.65	14.9±3.14	<0001**
Mean	-	8.762	8.12	8.57	9.01	-
Store room condition						
180	1	2.39±0.79	1.82±0.61	1.99±0.72	2.22±0.54	<0001**
	10	7.96±2.16	7.27±2.74	4.78±1.95	6.14±2.16	<0001**
	20	11.86±3.55	11.94±3.61	12.55±3.18	11.44±3.41	<0001**
	30	14.76±3.74	13.92±3.52	16.46±4.12	13.53±3.91	<0001**
Mean	-	9.242	8.737	8.945	8.332	-
195	1	2.481±0.94	1.72±0.18	2.65±0.89	1.88±0.49	<0001**
	10	6.72±2.31	6.74±2.38	6.88±2.51	5.48±2.19	<0001**
	20	12.34±3.02	10.91±2.71	13.7±3.91	10.83±2.65	<0001**
	30	12.84±3.08	11.89±3.53	13.94±3.95	12.14±2.89	<0001**
Mean	-	8.595	7.815	9.292	7.582	-
210	1	2.51±0.80	2.62±0.84	3.08±0.99	2.26±0.47	<0001**
	10	6.54±2.41	4.63±1.87	6.77±1.88	5.93±1.61	<0001**
	20	9.96±2.69	8.97±2.09	9.94±2.65	9.93±2.88	<0001**
	30	10.17±3.06	10.37±3.17	10.53±3.21	11.52±3.59	<0001**
Mean	-	7.295	6.647	7.580	7.410	-

*Each sample was represented as a mean ± SD of five replicates.

On the other hand, Wyse and Dexter (1971) stored beet roots at three temperatures; 4.5, 7.5 and 12.8 ºC for up to 145 days. In the first 70 days of storage, there was no significant change in reducing sugar content at the three temperatures. Beet roots stored at 12.8º C began to sprout after 70 days and the reducing sugars increased. Beet stored at 4.5 ºC and 7.2ºC remained to excellent conditions with neither mold nor sprouting and the increase in reducing sugars was corresponding small.

Sakr *et al*. (2013) studied the effect of storage conditions and vernalization treatment on reducing sugars, the noticed that inverted sugars in sugar beet roots increased significantly due to the different storage conditions. Moreover, Mohamed *et al*. (2017) reported that the reducing sugars of roots were significantly increased. Also, they reported that an increase from 0.35% to 6.84% in reducing sugars in roots of two varieties during storage conditions.

Conclusions

Extending sugar beet roots storage after harvesting has been investigated in this investigation and depicted that covering storage condition had the lowest invertase activity. In addition to the activity of sucrose hydrolyses enzymes, reducing sugars content increased. Moreover, sugar beet roots harvesting after 180 days of cultivation displayed the lowest values of invertase enzyme activity and reducing sugars content. Therefore, it is recommended to apply covering storage condition for sugar beet roots harvested after 180 days of cultivation and stored for 10 days to prevent the negative impact of invertase enzyme and reducing sugars. Further studies are needed to investigate the effect of temperature of sugar beet roots storage on the invertase enzyme activity and inverted sugars.

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مراقبة نشـــاط الإنفرتيز وتأثيره على جذور بنجر الســكر (*Beta vulgaris* L.) أثناء التخزين الممتد تحت ظروف محكومة

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الملخص

تسـتخدم مصـانع بنجر السـكر التخزين طويل المدى لجذور بنجر السكر لزيادة مدة تشـغيل مصـانع السـكر في مصـر. أثناء تخزين جذور بنجر السـكر تحدث بعض التغيرات في التركيب الكيميائي للجذور نتيجة نشـاط إنزيم الانفرتيز الذي يؤثر على عملية التبلور في صـناعة السـكر. ولذلك، تم تصـميم هذه الدراسـة لتتبع نشـاط الانفرتيز لجذور بنجر السـكر التي تم حصـادها بعد 180، 195، 210 يوما من الزراعة وتطبيق ظروف تخزين مختلفة لمدة 1، 10، 20، 30 يوما.

علاوة على ذلك، تم التحقق من محتوى السـكريات المختزلة في جذور بنجر السـكر كمنتج نهائي لنشاط إنزيم الإنفرتيز. أظهرت النتائج التي تم الحصـول عليها أن ظروف التخزين بالتغطية كانت لها أقل قيمة في نشاط إنزيم الإنفرتيز مقارنة بظروف التخزين في الهواء الطلق وفي الغرفة. علاوة على ذلك، أظهر تقليل محتوى السـكريات المتأثر بنشـاط إنزيم الإنفرتيز وظروف التخزين بالتغطية أقل محتوى من السكريات المحولة كذلك في جميع أصناف جذور بنجر السكر المختبرة. وبالتالي كشـفت الدراسـة الحالية أن التخزين طويل الأمد مناسـب لإطالة الحملة باسـتخدام ظروف التخزين المغطاة. ومع ذلك، ينبغي أيضا أن يؤخذ في الاعتبار تركيز السكريات المحولة.