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QUALITY CHANGES IN SUGAR BEET (*BETA VULGARIS* L.) ROOTS DURING STORAGE PERIOD IN PILES

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Abstract

Root transportation or remaining in fields or trucks for many days before manufacturing is considered one of the main problems that leads to the deterioration of root quality, and caused a great loss for the farmer and government. Because of the importance of this issue, a study was conducted during 2007 and 2008 seasons at winter time (15th of Jan) at Al Ghab Agriculture Research Center, General Commission for Scientific Agricultural Research (GCSAR), Syria, to determine the effect of some agricultural treatments (varieties), and environment conditions on the quality traits, water content of sugar beet during 1-10 days after harvest. Also to estimate correlation coefficient between post harvest period and the quality traits and water content. Four recommended sugar beet varieties were used, tow monogerm i.e. Rizor and Sherif, and tow multigerm i.e. Hospoly and Kronos. Randomized Completely Block Design (RCBD) was used with four replicates. The results showed that prolonging storage period of the harvested roots leads to high and gradual increment in the total soluble solids (brix %), from the first day to the last day of the studied storage period. The percent of increment for all varieties in brix% was 42.98%. Also the results clarified low sugar percent, and water content, which were 46 and 21.25 %, respectively. The reduction in juice purity % ranged from 76.08% in the first day to 67.23% in the last day for all varieties. The coefficient of correlation (r) exhibited a positive correlation between brix % and sucrose % , and a negative correlation between brix % and purity %, and also a negative correlation between water content and both brix and sucrose percentages.

Key words: Sugar beet, storage period, piles, Syria

Introduction

Sugar beet, internationally is considered the second source of sugar, and represents 40% of the total sugar production in the world, while sugar cane is considered the first source of sugar and represents 60% of the total sugar production. Sugar beet is the main and only source of sugar in Syria (AL Jbawi et al., 2015). The main area for growing sugar beet in Syria is in Al Ghab, the total area is about 6 thousand hectares, which produced 316855 tons of roots, while the yield is 49.5 ton. ha^{-1} (The Ministry of Agriculture and Agrarian Reform, 2013).

After harvest, most of the beets is stored in piles, during which respiration, rotting, and physical deterioration decrease extractable sucrose (Campbell and Klotz, 2006; Campbell et al., 2008; Al-Abdallah et al., 2010). Because of that the ultimate goal of the sugar industry constantly strives to attain is to store sugar beets for long periods of time with a minimum of weight and sugar loss. The problems arising out of such storage will vary somewhat from area to area, but in general they are the same, at least to the agriculturist who is charged with the responsibility of delivering about as many beets to the factory as were paid for (Al-Abdallah et al., 2010, 2011). Under European conditions, long-term storage is only reasonable at low temperature with beets which are protected against frost (Jaggard et al., 1997; Kenterand Hoffmann, 2006; Kenter et al., 2006). At low temperature, changes in beet quality could be kept to a minimum. Nevertheless, amino N, invert sugar and raffinose accumulated in the beet, which increases the costs of sugar manufacturing.

Storage conditions are important factors affecting the losses of technological value of beets (Miyamoto et al., 1989; Bzowska-Bakalarz, 1991; Al-Abdalla, 2010). Besides crop management and environmental conditions during the growing season also affect subsequent storage losses (Smith and Ruppel, 1971; Bugbee, 1993; Wiltshire and Cobb, 2000).

Changes in root characteristics are closely related to the loss of tissue turgor (Chelemskij and Eroszeenko, 1972; Vukov, 1977). Also loss of moisture and thus turgor drop and increase of the degree of wilting, changes processing properties of the crop as well as the strength parameters of the root (Vukov, 1977; Trzebinski, 1984). Sugar loss represents a substantial decrease in revenue for the sugar industry, and even small reductions in storage losses can have significant economic impact, when multiplied over the volume of roots processed and the time in storage.

Having in mind diversity of the new varieties of sugar beets introduced to Syria, diversified conditions of production (fertilization, agro-technology, soil), as well as time and conditions of storage after harvesting, a study to define the effect of some selected factors on the root resistance to static loading was carried out. Learning about the effect of those factors shall enable to define the optimum conditions for harvesting and storage of the tested varieties as well as to determine some operational parameters of machines in the course of harvesting and further processing. The aim of the present study was to quantify changes in the quality of beet during storage in piles in the field, in order to assess whether this is an appropriate to prolong the processing campaign.

Materials and Methods

The experiment was carried out at Agricultural Research Center, (GCSAR), Al Ghab, Syria, during 2007/2008 and 2008/2009 seasons. The study included four varieties, the source of those genotypes were clarified in Table (1).

Table 1: The source of sugar beet varieties

Genotype	Germity	Source
Rizor	monogerm	Belgium
Sherif	monogerm	Belgium
Hospoly	multigerm	Netherland
Kronos	multigerm	Netherland

Source: Sugar Beet Department (GCSAR)

Beets were grown on the plantation with row spacing of 50 cm and 20 cm plant spacing in rows. The recommended plant density of sugar beet in Syria is 100 000 plant.ha^{-1} (50 X 20) (Al Jbawi et al., 2009). The plot size was 32 m^2, number of rows was 8 rows, row length was 8 m, 4 m was the width. The soil classifies as sandy clayed, low content of organic matters, high nitrogen and phosphorous contents, and good content of potassium, because of that no nitrogen, potassium, and phosphorous fertilizers addition. The previous crop was wheat. The crop was harvested after 210 days after sowing. The temperatures during August at harvest reached 37°C (Table 2).

Table 2: Temperatures distribution during 2007/2008 and 2008/2009 seasons

Season	2007/2008		2008/2009	
Month	**Max. Temperature °C**	**Min. Temperature °C**	**Max. Temperature °C**	**Min. Temperature °C**
January	10.80	-1.20	10.00	1.10
February	14.47	3.36	14.50	6.30
March	22.60	9.11	18.00	7.10
April	26.56	11.29	24.00	9.00
May	28.60	12.20	29.70	11.60
June	34.50	17.40	36.10	18.23
July	36.30	19.80	36.50	23.60
August	37.50	22.10	37.40	20.60
September	33.40	17.90	32.90	18.30

Source: Meteorology Station in Al Ghab

After harvest the root samples were washed, marked and stored in plastic produce bags for storage in one place in natural conditions, at the average temperature of 37oC (Table 1). However, temperature changes in the piles are not predictable and vary considerably at

different depths of the pile (Jaggard et al., 1997). The storage period from harvest to the final measurement was 10 days.

Studied traits

Sucrose was determined polarimetrically (McGinnis, 1982). Juice purity was calculated using the procedures described by Dexter et al. (1967). Sucrose concentrations for the samples obtained were expressed on a fresh weight basis. Subsample of brie 50 g dried in a vacuum oven at 85℃ to constant weight to calculate water content.

Experiment design and statistical analysis

Randomized Completely Block Design (RCBD) was used with four replicates, to analyze the source of variations (ANOVA), and the interaction. The statistical program GenStat.V. 12 was used for each season and the combined analysis also (Gomez and Gomez, 1984). Least significant difference was used at 5% level of probability.

Results and discussion

The effect of postharvest on the quality traits:

Total Soluble Solids % (Brix%):

The differences between varieties in terms of this trait (Table 3) were significant ($P \leq 0.05$) in most days after harvest during both seasons, Hospoly variety gave the highest brix% values (29.88, and 29.69) in the first and second seasons, respectively. The monogerm varieties were deteriorated less compared to multigerm varieties according to this trait, they gave less values.

The statistical analysis of one or two seasons shows that prolonging postharvest period of beet roots in the fields leads to an increase in brix% significantly; these results are accompany with Kenter and Hoffmann, (2008) who stated that storage conditions in piles had negative consequences of accumulation of nonsucrose substances. The highest value was achieved in the last day of storage 36.16%, and 35.27% for the first and second seasons respectively. The loss percentage was 40% in the first season, and 46% in the second season. The results are in a link with Smith and Ruppel, 1971; Bugbee, 1993; Wiltshire and Cobb, 2000, who concluded that the environmental affect subsequent storage losses.

Table 3: The effect of postharvest on brix% of four sugar beet varieties during 2007 and 2008 seasons

Days after harvest	Season 2007					Season 2008					Grand mean
	Monogerm		Multigerm		Mean	Monogerm		Multigerm		Mean	
	Rizor	Sherif	Hospoly	Kronos		Rizor	Sherif	Hospoly	Kronos		
1***	20.72^{b}	21.20^{ab}	21.68^{ab}	22.59^{a}	**21.55^{g}**	18.28^{b}	19.93^{a}	20.52^{a}	20.06^{a}	**19.70^{f}**	**20.62^{g}**
2**	22.82	22.52	23.33	23.61	**23.07^{f}**	22.01^{c}	21.24^{bc}	24.09^{a}	22.56^{b}	**22.48^{e}**	**22.77^{f}**
3**	25.17	24.94	25.53	25.38	**25.26^{e}**	22.82^{b}	22.15^{b}	24.49^{a}	23.43^{ab}	**23.22^{e}**	**24.24^{e}**
4**	25.05	25.47	26.67	25.81	**25.75^{e}**	31.04^{ab}	28.91^{b}	31.35^{a}	30.47^{ab}	**30.44^{cd}**	**28.10^{d}**
5***	27.59^{b}	26.28^{c}	28.83^{a}	26.02^{c}	**27.18^{d}**	28.26^{b}	29.93^{ab}	31.92^{a}	28.53^{ab}	**29.66^{cd}**	**28.42^{d}**
6**	31.00	29.92	31.46	30.67	**30.76^{c}**	28.04^{b}	29.89^{ab}	30.57^{a}	29.54^{ab}	**29.51^{d}**	**30.14^{c}**
7*	30.32^{b}	30.17^{b}	31.90^{ab}	33.17^{a}	**31.39^{c}**	30.69	29.84	33.13	28.81	**30.62^{c}**	**31.00^{c}**
8	33.23	30.48	32.95	34.12	**32.70^{b}**	32.84	32.69	35.22	33.04	**33.45^{b}**	**33.07^{b}**
9*	36.27^{ab}	34.64^{b}	37.51^{a}	37.75^{a}	**36.54^{a}**	32.69	35.79	35.90	36.70	**35.27^{a}**	**35.91^{a}**
10*	35.45^{b}	35.63^{b}	39.93^{a}	33.63^{b}	**36.16^{a}**	-	-	-	-	**-**	**-**
Mean	**28.76^{ab}**	**28.13^{b}**	**29.98^{a}**	**29.28^{ab}**	**29.04**	**27.41b**	**27.82b**	**29.69a**	**28.13b**	**28.26**	**28.25**

***Significant differences between varieties in2007 season at 5% level of probability.**

****Significant differences between varieties in 2008 season at 5% level of probability.**

*****Significant differences between varieties in 2007 and 2008 seasons at 5% level of probability.**

Sucrose %:

The results in Table (4) shows that the differences between varieties were not significant in most days after harvest during both seasons, Kronos variety surpassed the all varieties in the first and season (21.68) according to sucrose%, but the differences between varieties was not significant in the second season.

The combined analysis of the two seasons shows that prolonging postharvest period of beet roots leads to an increase in sucrose% significantly ($P \leq 0.05$); the highest value was achieved in the last day of storage 24.45%, and 21.60% for the first and second seasons respectively. The increment percentage was 36% in the first season, and 30% in the second season. This increase in sucrose% because of the reduction in water content as a result of high temperature during storage period (Table 2). Because of that, this increment is not a good indicator, this reduction in water content of the roots make them lose their refreshment and affect negatively sugar extraction during manufacturing in sugar factories. During storage sugar concentration is reported to decline by around 0.02% per day (Jaggard et al., 1997). The increment in clamp temperature improve the respiratory losses thereby root damage (Wiltshire and Cobb, 2000). The high temperatures hydrolyses sucrose to give the reducing sugars, glucose and fructose, which are then used in respiration (Wiltshire and Cobb, 2000). Respiration rate is highly and predictably correlated with sucrose loss (Youssif, and Abou El-Magd, 2004; Kenter and Hoffmann, 2008).

Table 4: The effect of postharvest on sucrose% of four sugar beet varieties during 2007 and 2008 seasons

Days after harvest	Season 2007					Season 2008					Grand mean
	Monogerm		Multigerm		Mean	Monogerm		Multigerm		Mean	
	Rizor	Sherif	Hospoly	Kronos		Rizor	Sherif	Hospoly	Kronos		
1***	15.43^{b}	15.42^{b}	16.87^{ab}	17.22^{a}	**16.24^{i}**	14.34^{b}	14.77^{b}	15.28^{ab}	16.12^{a}	**15.13^{d}**	**15.68^{f}**
2	17.45	17.46	17.47	17.68	**17.52^{h}**	16.26	15.80	15.80	16.37	**16.06^{c}**	**16.79^{e}**
3	17.55	18.33	18.85	18.85	**18.40^{g}**	15.70	16.59	15.87	15.67	**15.96^{c}**	**17.18^{e}**
4	17.13	14.79	16.44	17.71	**16.52^{i}**	21.29	20.96	21.84	20.77	**21.22^{a}**	**18.87^{d}**
5***	18.42^{c}	19.40^{ab}	20.55^{a}	19.75^{ab}	**19.53^{f}**	20.76^{b}	21.54^{ab}	22.90^{a}	20.97^{b}	**21.54^{a}**	**20.54^{c}**
6*	19.51^{b}	21.64^{a}	21.77^{a}	22.43^{a}	**21.34^{d}**	20.29	21.02	21.34	19.87	**20.63^{b}**	**20.98^{c}**
7*	21.00^{a}	20.70^{ab}	18.53^{b}	21.03^{a}	**20.32^{e}**	21.22	19.93	20.85	20.47	**20.62^{b}**	**20.47^{c}**
8	24.24	21.17	23.77	22.77	**22.99^{c}**	21.16	20.40	21.83	21.67	**21.27^{a}**	**22.13b**
9*	24.71^{b}	23.90^{b}	26.83^{a}	25.71^{ab}	**25.29^{a}**	21.07	21.09	22.16	22.07	**21.60^{a}**	**23.44^{a}**
10*	23.67^{b}	23.40^{b}	24.63^{ab}	25.16^{a}	**24.45^{b}**	-	-	-	-	-	-
Mean	**19.91^{b}**	**19.62^{b}**	**20.57^{ab}**	**21.68^{a}**	**20.45**	**19.12**	**19.12**	**19.76**	**19.33**	**19.33**	**19.56**

***Significant differences between varieties in 2007 season at 5% level of probability.**

****Significant differences between varieties in 2008 season at 5% level of probability.**

*****Significant differences between varieties in 2007 and 2008 seasons at 5% level of probability.**

purity %:

Table (5) shows no significant differences according to purity% between varieties in most days after harvest during both seasons, Kronos variety gave the highest value in the first season (71.61), but in the second season the variety Rizor gave the highest value (70.40%).

The combined analysis shows that prolonging postharvest period of beet roots leads to reduction in purity% significantly ($P \leq 0.05$). The reduction percentage was 3% in the first season, and 20% in the second season. This decrease in purity% because of the increase in brix%, because the correlation between those two traits is negative (Table 7).

Table 5: The effect of postharvest on purity% of four sugar beet varieties during 2007 and 2008 seasons

Days after harvest	Season 2007					Season 2008					Grand mean
	Monogerm		Multigerm		Mean	Monogerm		Multigerm		Mean	
	Rizor	Sherif	Hospoly	Kronos		Rizor	Sherif	Hospoly	Kronos		
1	74.47	72.74	77.81	76.23	**75.31^{a}**	78.45	74.11	74.46	80.36	**76.84^{a}**	**76.08a**
2	76.47	77.53	74.88	74.88	**75.94^{a}**	73.88	74.39	65.59	72.56	**71.60^{b}**	**73.77ab**
3**	69.73	73.50	73.83	74.27	**72.83^{b}**	68.80^{ab}	74.90^{a}	64.80^{b}	66.88^{b}	**68.84^{c}**	**70.84c**
4	68.38	58.07	61.64	68.62	**64.18^{f}**	68.59	72.50	69.67	68.17	**69.73^{c}**	**66.95d**
5	66.76^{b}	73.82^{a}	71.28^{ab}	75.90^{a}	**71.94b^{c}**	73.46	71.97	71.74	73.50	**72.67^{b}**	**72.30bc**
6*	62.94^{b}	72.33^{a}	69.20^{a}	73.13^{a}	**69.40d^{e}**	72.36	70.32	69.81	67.26	**69.94^{c}**	**69.67c**
7*	69.26^{a}	68.61^{a}	58.09^{b}	63.40^{ab}	**64.84^{f}**	69.14	66.79	62.93	71.05	**67.48^{c}**	**66.16d**
8	72.95	69.46	72.14	66.74	**70.32^{cd}**	64.43	62.40	61.98	65.59	**63.60^{d}**	**66.96d**
9	68.13	69.00	71.53	68.11	**69.19^{de}**	64.45	58.93	61.73	60.14	**61.31^{d}**	**65.25d**
10*	66.77^{b}	65.67^{bc}	61.68^{c}	74.81^{a}	**73.53^{e}**	-	-	-	-	-	-
Mean	**69.59**	**70.07**	**69.21**	**71.61**	**70.75**	**70.40**	**69.59**	**66.97**	**69.50**	**69.11**	**69.78**

***Significant differences between varieties in 2007 season at 5% level of probability.**
****Significant differences between varieties in 2008 season at 5% level of probability.**
*****Significant differences between varieties in 2007 and 2008 seasons at 5% level of probability.**

Water content (%):

Loss of moisture increases the degree of wilting and changes processing properties of the crop (Vukov, 1977; Trzebinski, 1984). The results in Table (6) shows that the differences between varieties were significant (P≤0.05) in most days after harvest during both seasons, Sherif variety gave the highest value in the first and season (71.25), but in the second season the variety Rizor achieved the highest value (69.98%).

The statistical analysis of one or two seasons shows that prolonging postharvest period of beet roots leads to reduction in water content % significantly (P≤0.05). The reduction percentage was 20.24% in the first season, and 19.97% in the second season. This decrease in water content% because of high temperature during storage period (Table 2). Kenter and Hoffmann, 2008 confirmed that the storage duration and temperature have large significant on the changes of beet quality and water content.

Table 6: The effect of postharvest on water content% of four sugar beet varieties during 2007 and 2008 seasons

Days after harvest	Season 2007					Season 2008					Grand mean
	Monogerm		Multigerm		Mean	Monogerm		Multigerm		Mean	
	Rizor	Sherif	Hospoly	Kronos		Rizor	Sherif	Hospoly	Kronos		
1*	75.86^{b}	76.28^{a}	75.01^{ab}	73.83^{b}	**75.24^{c}**	77.80	77.00	77.16	76.91	**77.22^{a}**	**76.23b**
2**	75.85	76.70	76.84	76.75	**76.53^{b}**	76.49^{a}	74.08^{a}	74.07^{ab}	73.94^{b}	**74.64^{b}**	**75.59b**
3	76.18	75.29	72.60	74.53	**74.65^{c}**	75.47	73.29	73.29	73.01	**73.76^{bc}**	**74.21c**
4*	72.50^{b}	77.26^{a}	76.83^{ab}	76.09^{b}	**75.67^{bc}**	69.18	66.70	67.78	66.86	**67.63^{d}**	**71.65d**
5*	83.02^{ab}	82.65b	85.80^{a}	83.27^{ab}	**83.69^{a}**	74.65	71.56	74.07	73.11	**73.35^{c}**	**78.52a**
6**	64.18	70.32	67.47	64.07	**66.51^{d}**	66.35^{b}	68.82^{a}	68.46^{ab}	67.70^{ab}	**67.83^{d}**	**67.17e**
7***	65.65^{a}	65.65^{a}	65.43^{b}	65.92^{a}	**65.66^{d}**	63.38^{b}	64.55^{b}	65.09^{a}	61.58^{b}	**63.65^{e}**	**64.66f**
8*	62.45^{a}	64.79^{a}	62.03^{b}	60.58^{b}	**62.46^{e}**	64.89	64.59	64.01	62.37	**63.97^{e}**	**63.21g**
9*	60.69^{ab}	61.08^{a}	59.05^{ab}	58.78^{b}	**59.90^{f}**	61.64	63.10	61.32	61.14	**61.80^{f}**	**60.85h**
10*	59.31^{a}	62.50^{a}	58.34^{b}	59.96^{a}	**60.02^{f}**	-	-	-	-	-	-
Mean	**69.57^{b}**	**71.25^{a}**	**69.94^{ab}**	**69.38^{c}**	**70.03**	**69.98^{a}**	**69.30^{b}**	**69.47^{ab}**	**68.51^{b}**	**69.32**	**70.23**

***Significant differences between varieties in 2007 season at 5% level of probability.**
****Significant differences between varieties in 2008 season at 5% level of probability.**
*****Significant differences between varieties in 2007 and 2008 seasons at 5% level of probability.**

Correlation between quality traits and water content in sugar beet root after harvest:
The results in Table (7) exhibited a positive and significant correlation between brix% and sucrose% (r=0.86*). Also a negative correlation was noticed between brix% and purity%, (r=-0.43), when prolonging the time of storage after harvest. It was noticed a negative correlation between water content and both brix% and sucrose% (r=-0.79, -0.71), respectively.

Table 7: Correlation between quality traits and water content after harvest

Traits	Water content %	Brix%	Sucrose%	Purity%
Water content %	0.01			
Brix%	-0.79	0.01		
Sucrose%	-0.71	0.86*	0.01	
Purity%	0.26	-0.43	0.08	0.01

Conclusion

Prolonging storage period of the harvested roots leads to high and gradual increment in the total soluble solids (brix %), from the first day to the last day of the studied period. Also the results clarified low sugar percent, and juice purity % at the end of storage period as compared with the first day. The percent of decrement in water content was 21.25 % for the all varieties. The coefficient of correlation (r) exhibited a positive correlation between brix % and sucrose % , and a negative correlation between brix % and purity %, and also a negative correlation between water content and both brix and sucrose percentages.

Poor beet quality results in higher needs for processing aids, enhances energy consumption and impairs white sugar quality by color formation (Van der Poel et al., 1998), and it is crucial to optimize the storage conditions to prevent heating of the piles with the negative consequences of accumulation of non sucrose substances.

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.

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