Efficacy of wilting degree on physiochemical traits and sugar processing parameters of sugar beet roots postharvest

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ABSTRACT: Under Egypt conditions sugar beet roots are processed in factories during the period from the first week of February to mid of June every year. Whenever, wilting of beet roots carried out at high temperature and low humidity for any cause, which are prevailing during the period from the end of April to Mid of June. So, this work was carried out at laboratories of Delta Sugar Company, Kafr El-Sheikh Governorate, Egypt, as well as Food Science and Technology Department, Faculty of Agriculture, New Valley Branch, Assuit University during 2016 and 2017 working seasons for eight days. Experiment was replicated four times during the period from 25th April to 6th June to identify the influencing of wilting degree (the loss% in moisture content of beet roots) postharvest on physiochemical traits, impurities content and processing efficiency parameters of sugar beet roots.

The obtained results revealed that wilting degree of beet root had a significant effect on physical properties of sugar beet juice expressed as total soluble solids %(TSS%), pH value, bulk density (kg/m3) and color of raw juice (Icumsa units); impurities content of sugar beet,i.e. α-N, K and Na(millieq./100g), and chemical composition of sugar beet roots, i.e. pol %, reducing sugars% and dextran content as well as processing efficiency parameters of sugar beet roots, i.e. juice purity%, sucrose recovery %, sugar losses% in waste, quality index of beet roots and weight losses % of beet roots.

We hope that the above-mentioned results in this work would help understand the changes which take place in sugar beet roots postharvest caused by the wilting, which cause significant economic losses in sugar production and to know the practices that reduce sugar loss during processing. Here, we demonstrate that all sugar beet growers and the processors' benefit directly when postharvest losses are minimized. The increase in wilting degree of beet roots affects negatively sugar extraction during manufacturing in sugar factories.

Keywords: Sugar beet, wilting degree, sugar recovery, quality index and alpha amino nitrogen.

1- INTRODUCTION

Sugar beet plays a prominent role in sugar production in Egypt. There is an intention in the policy of the Egyptian government to expand the cultivation of sugar beet, consequently, the number of beet factories is increasing. The importance of sugar beet to agriculture is not only confined to sugar production but also for its secondary products (Badawy, 1992). Beet cultivars were imported mostly from Europe. Sugar beet is facing some problems with respect to climate and variety of sugar beet related to postharvest like weight losses, rotting and staleness leading to declined sugar recovery. It is desirable that beet roots should have a high pol%, on its own, but pol% of beet roots is an incomplete quality criterion. In addition, beet sugar production reached 57% of the local sugar production (2.3 million tons) in 2016 (CCSC, 2017) .

A harvested beet root continues to live by respiration and consumption of its sugar which is considered sugar loss (Asadi, 2007). Its respiration is important to maintain life. It is subject also to microbiological attack. Sugar loss begins on the first day postharvest and rapidly increases. Wilt of root meaning, relating to moisture loss under various conditions of temperature and relative humidity and the respiration and sugar losses associated with such dehydration. Beet roots become weak, shrinkage and begin to bend towards the ground and also affects their appearance, texture and quality. Therefore the water loss as a result of roots wilting will result in weight losses. The weight loss of roots vary in different conditions of temperature, relative humidity as well as size and shape of beet roots or exhibition surface.

Wilting degree (the loss moisture content of beet root postharvest) which takes place as a result of the delaying in transporting and processing of beets causes a rapid qualitative deterioration and high quantitative losses (Davis, 1982). Postharvest, sugar beet roots outdoors at temperature above 7ºC, rotting can become an appreciable factor and the final result can be complete loss as reported by Ishikuri et al. (1992). Prolonged period of sugar beets postharvest and before processing requires to be healthy and clean to minimize sugar losses due to extraneous conditions related to internal damage, still, a considerable part of such losses could be due to intercellular conversion of sucrose to glucose and fructose. The enzyme responsible for sucrose splitting is invertase, Sakalo and Tyltu (1997).

There is little information on the impact of wilting degree on physiochemical traits and impurities contents of beet roots. Dehydration or wilting of beet roots begins immediately postharvest and generally increases with the delaying duration than manufacturing of sugar beet in sugar factories. The increase in wilting degree of beet roots means the reduction in water content of beet roots make them lose their refreshment and affect negatively sugar extraction at manufacturing in sugar factories. So, the objective of the present investigation was carried out to identify the influencing of wilting degree (the loss moisture content of beet root) postharvest on physiochemical traits, impurities content and processing efficiency parameters of sugar beet roots.

2- MATERIALS AND METHODS

The trail was carried out at laboratories of Delta Sugar Company, Kafr El-Sheikh Governorate, Egypt, as well as Food Science and Technology Department, Faculty of Agriculture, New Valley Branch, Assuit University at 2016 and 2017 working seasons for eight days and replicated four times during the period from 25th April to 6th June. The samples of sugar beet roots (*Beta vulgaris* L.) of different working cultivars (Top, Pleno, Farida, Raspoly, Tribel, Maribo, marcopoly and kawimera) were taken from the research fields of Delta Sugar Company to identify the influencing of wilting degree (the loss moisture content of beet root for any cause) postharvest on physiochemical properties, impurities contents and processing efficiency parameters of sugar beet roots. The experimental design was a randomized complete block with four replicates and five treatments. The research site was selected because it was usually represented the largest Factory of beet sugar production in Egypt. Samples of beet roots (about 30 kg beet roots) were taken at random from the studied different wilting degrees as follow:

1- 0 % or No wilt (at harvest or control).
2- 4.88% or Slight wilting (at 2 days postharvest) .

3- 8.61% or Moderate wilting (at 4 days postharvest).
4- 14.14% or High wilting (at 6 days postharvest).
5- 18.41% or very high wilting (at 8 days postharvest).

On the harvest day (after 195 days from sowing date), a samples of approximately 30 kgs were obtained from the healthy vegetative homogenous beet roots of sugar beet in four replicated times. The sample of each treatment was topped, cleaned and thoroughly mixed into a pile. Aerobic atmosphere conditions were temperature from 27.5–33.5°C and relative humidity from 77–85% as in Dutton and Huijbregts (2006); Campbell et al. (2008) and Hassan et al. (2011).

2-1- Wilting degree of beet root was calculated as follow:

Wilting degree of beet root = the moisture% of beet root at harvest - the moisture% of beet root at the studied period X 100/The moisture% of beet root at harvest.

2-2- Determination of physiochemical traits and processing efficiency parameters at the studied wilting ratios:

Samples of beet roots (about 0.5 ton of beet roots) of the above-mentioned different working cultivars were taken at random and divided separately into five categories, each containing about 100 kg of roots. Four categories of roots were used for determination of the changes in the weight and the other category was used for determination of the changes in the chemical composition of beet roots. Samples of roots at the different wilting ratios, i.e. 0, 4.88, 8.61, 14.14 and 18.41% were sent to the laboratory for analysis. Samples of beet roots were cleaned with running tap water, dried. Each sample was grated separately with grater into cassettes and mixed thoroughly to determine the physiochemical traits of beet roots as follow:

2-3-1- Physical traits of beet roots:

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, according to procedure of Delta sugar Company according to Cooke and Scott (1993).

2-3-1-1- pH measuring: pH value of beet samples measuring by using digital bench pH-meter, model pH-526/sentix–20/AS- DIN / SIN / STH / 650 according to procedure of Delta sugar Company as described in A.O.A.C. (2005).

2-3-1-2- Bulk density of beet samples was determined by kg/m^3 according to procedure of Delta sugar Company as described in A.O.A.C. (2005).

2-3-1-3 Color of raw juice of beet samples was measuring by spectrophotometer at 420 nm as Icumsa units according to procedure of Delta sugar Company as described in A.O.A.C. (2005).

2-3-2- Chemical composition of beet roots:

Moisture content: The moisture content was determined by drying samples to constant weight at in aluminum weighing dishes at 105ºC for 24h, using the air oven-drying method according to A.O.A.C. (2005).

Sucrose content: Sucrose content was determined using automatic saccharimeter on a lead acetate basis according to procedure of Delta Sugar Company, as described in Le Docte (1977) and Cooke and Scott (1993).

Reducing sugars: Reducing sugars content of beet roots samples were determined using Fehling volumetric methods as described in A.O.A.C. (2005)

Dextran content (ppm): Dextran in fresh and stored samples was determined according to procedure of Roberts (1983) and Dutton and Huijbregts (2006).

2-4- Impurities content of beet roots:

Alpha amino nitrogen, Sodium and potassium contents/ 100 g beet:

Alpha amino nitrogen, sodium and potassium contents were determined using venma Automation BV Analyzer IIG-16-12-99, 9716JP/ Groningen / Holland. Temp. 18-30ºC, surrounding humidity max. 70% according to Brown and Lillan (1964) and Dutton and Huijbregts (2006), the results were calculated as milli equivalents / 100 g beet.

2-5- The processing efficiency parameters of sugar beet:

Purity = (sucrose%.100)/ (T.S.S %)

Quality index= (SR.100)/pol.

SR= (pol-0.29) – 0.343(k+Na) - α N (0.0939)

Where:

Pol% = Sucrose %, K = Potassium, Na = Sodium, α-N = Alpha-amino nitrogen,

SR% = Sugar recovery% and TSS% = total soluble solids%

Sugar losses in wastes (SL): Sugar losses in wastes percentage were determined according to the procedure of Delta Sugar Company using the following equation:

$$SL = 0.343\left(K + Na\right) + \alpha .\, N\,(0.094) + 0.29$$

The procedures according to Delta Sugar Company described by Silin and Silina (1977) and Sapronova et al. (1979); Dutton and Huijbregts (2006) and Hassan et al. (2011).

Mass or weight losses in beet roots: The mass loss was determined of the specific samples for each group by using electrical balance LHW –120×0.02 kg, model HW according to procedure of Delta sugar Company as in Dutton and Huijbregts (2006) and Campbell, et al. (2008).

2-6- Statistical analysis:

Collected data were subjected to the proper analysis of variance (ANOVA). The proper statistical of all data was carried out according to lined by Gomez & Gomez (1984). Homogeneity of variance and differences among treatments were evaluated by the least significant difference test (LSD) at 5%. The results were as averages of four times during the period from 25th April to 6th June and average of 2016 and 2017 seasons.

3- RESULTS AND DISCUSSION

3-1- Normal physiochemical parameters of beet roots during working season:

Sugar beet roots composition (the raw material of the beet sugar factory) is important to both the sugar beet farmer and the factory. Determination of sugar (sucrose) and non-sugar (non-sucrose) contents in beet roots define quality of beet roots, where, high sugar and low non-sugar contents are desirable. So it is important to evaluate the physiochemical properties of beet roots in order to evaluate the quality of different fresh sugar beet roots for sugar production. The results recorded in Table (1). summarized normal physio-chemical parameters averages of sugar beet roots during working season of beet roots processing without wilting degree of beet roots postharvest. The present results are in agreement with the findings of by Gomaa (2009).

Table (1): Physiochemical properties average of different fresh sugar beet roots during processing working season in for the studied different cultivars.

Parameters	*Average working seasons of 2016 and 2017
Moisture content %	77.82 ± 0.47
Total soluble solids (T.S.S) %	21.23 ± 0.74
Sucrose (pol) %	18.23 ± 0.51
Reducing sugar%	0.13 ± 0.07
α-N nitrogen (milliequ./100g beet)	1.81 ± 0.19
Sodium (milliequ./100g beet)	1.93 ± 0.23
Potassium (milliequ./100g beet)	6.07 ± 0.48
Dextran content (ppm)	79.33 ± 3.52

* Each value was an average of ten determinations ±SD.

3-2- Effect of wilting degree on physical properties of beet roots:

Data in Table (2) clarified that wilting degree of sugar beet roots stored for 8 days in open air during the beet campaign (beet-processing period) had a significant effect on physical properties of sugar beet juice expressed as total soluble solids% (TSS%), pH value, Bulk density (kg/m3) and Color of raw juice (Icumsa units). The increase in wilting degree of beet roots from 0.0 or no wilt to slight wilting, moderate wilting, high wilting and very high wilting led to increasing in TSS% of beet root by 10.08, 18.22, 32.09 and 36.99%, bulk density (kg/m^3) of beet roots increased by 1.49, 2.24, 4.26 and 10.38% and color of extracted raw juice (Icumsa units) increased by 17.29, 25.99, 29.64 and 32.07 of the control value, respectively. This result might be attributed to the gradually decrease in moisture content of beet roots with increasing wilting degree of beet roots as the processing days delayed from zero time (at harvest) up to 8 days. The obtained results are in general acceptance with those recorded by Al.Jbawi & Al.Zubi (2016) and El.Hefnawy (2016). They reported that sugar beet roots are considerable perishable materials to wilting because of its high moisture content (75.00%).

Table (2): Effect of wilting degree on physical properties averages of fresh beet roots stored for 8 days in open air.

Wilting degree	TSS%*	pH value	Bulk density (kg/m3)	Color of raw juice (Icumsa units)
No wilt (at harvest)	21.63	6.60	671.30	20525.33
Slight wilting	23.81	6.73	681.33	24074.67
Moderate wilting	25.57	6.49	687.33	25860.00
High wilting	28.57	6.38	692.00	266080.00
Very high wilting	29.63	6.31	697.00	27106.67
Overall mean	25.83	6.50	697.00	24834.93
F value	**	**	**	**
LSD 0.05	0.93	0.07	5.54	1660.30

TSS**%*=** Total soluble solids %

3-3- Effect of wilting degree on chemical composition of beet roots:

Table (3) pointed out that wilting degree of beet root had a significant effect on components average of chemical composition of sugar beet root, i.e. pol%, reducing sugars% and dextran content. There was a gradual decrease in pol% (on DWB) by 12.86, 19.90, 26.50 and 35% of the control value with increasing wilting degree of beet roots from no wilt to slight wilting, moderate wilting, high wilting and very high wilting, respectively. However, this increase in wilting degree of beet roots led to increasing in the dextran content of beet root by 22.27, 36.14, 52.94 and 93.28% of the control value, respectively. Wilting degree of beet roots postharvest is associated with a loss of sucrose or pol% and overall root quality. This decrease in pol% (on DWB) of beet roots with increasing wilting degree of beet roots might be attributed to respiration process, which represents 70-80% of the sucrose or pol losses that take place postharvest. The increase in dextran content of beet roots postharvest might be attributed to the microbiology activity. The increase in wilting degree of beet roots reduces water content of beet roots and makes them lose their refreshment and affect negatively sugar extraction during manufacturing in sugar factories. These results are in correspondence with the findings of Abou EL-Magd and Nariman (2004); Asadi (2007); Gomaa (2009); Al.Jbawi & Al.Zubi (2016) and El.Hefnawy (2016). They revealed that sugar loss of sugar beet postharvest represents a substantial decrease in revenue for sugar industry and can have a significant economic impact.

In the light of the results obtained from this study, there was adversely relationship between wilting degree of beet roots and processing efficiency parameters of sugar beet roots.

Table (3): Effect of wilting degree on chemical composition averages of fresh beet roots stored for 8 days in open air.

Wilting degree	Moisture %	Pol %*	Reducing sugars %	Dextran (ppm)
No wilt (at harvest)	**77.82**	**82.35**	**0.13**	**79.33**
Slight wilting	74.02	72.97	0.24	97.00
Moderate wilting	71.12	68.68	0.08	108.00
High wilting	66.82	65.10	0.06	121.33
Very high wilting	63.49	61.00	0.05	153.33
Overall mean	70.65	70.02	0.11	111.80
F value	**	**	**	**
LSD 0.05	0.71	5.54		16.48

Pol %* calculated as dry weight basis (DWB)

3-4- Effect of wilting degree on impurities content of beet roots:

The results of impurities content of beet root, i.e. alpha amino nitrogen (α-N), potassium (K) and sodium (Na) contents are presented in Table (4) .It could be noted that wilting degree exhibited a significant effect on impurities content of sugar beet roots. There were a gradual increase in α-N content of beet roots by 38.12, 49.17, 56.35 and 62.43%; K content of beet roots increased by 1.32, 4.28, 6.26 and 7.43%,and Na content of beet roots increased by 16.06, 23.32, 31.09 and 40.93% of the control value with increasing wilting degree of beet roots from no wilt to slight wilting, moderate wilting, high wilting and very high wilting, respectively. This increase might be attributed to the gradually increase in dry matter content of beet roots with increasing wilting degree of beet roots as the processing days delayed from zero wilt (at harvest) up to 8 days. Technical knowledge of the impurities contents of beet roots is important in processing of sugar beet roots because it had a highly deteriorate effect on juice purification and sugar crystallization (Draycott, 2006). These results are in the same line with those of Asadi (2007). He indicated that there was a negative relationship between the impurities content of beet roots and recoverable sugar yield produced from sugar beet. These impurities increase the loss of sucrose to molasses and impede crystallization of sugar.

Table (4): Effect of wilting degree on impurities content of fresh beet roots stored for 8 days in open air.

Wilting degree	**α amino nitrogen content ***	**Potassium content***	**Sodium content***
No wilt (at harvest)	1.81	6.07	1.93
Slight wilting	2.50	6.15	2.24
Moderate wilting	2.70	6.33	2.38
High wilting	2.83	6.45	2.53
Very high wilting	2.94	6.54	2.72
Overall mean	2.55	6.31	2.36
F value	**	**	**
LSD 0.05	0.46	0.36	0.21

***Determined as milliequavalent / 100 g beet**

3-5- Effect of wilting degree on processing efficiency parameters average of beet roots:

Weight loss of beet roots was expressed as a percentage of the root's weight at the beginning of the experiment. It could be scored from results in Table (5) that wilting degree exhibited a significant effect on processing efficiency parameters of sugar beet roots, i.e. juice purity%, sucrose recovery%, sugar losses% in waste, quality index of beet roots and weight losses% of beet roots. There was a gradual decrease in juice purity% of beet roots by 7.99, 11.99, 13.59 and 14.21%. Sucrose recovery% of beet roots decreased by 4.91, 11.35, 20.54 and 36.29%. Quality index of beet roots decreased by 4.15, 5.29, 11.17 and 17.96% of the control value, while, sugar losses% of beet roots increased by 12.56, 16.87, 20.05 and 25.28% of the control value with increasing wilting degree of beet roots from no wilt to slight wilting, moderate wilting, high wilting and very high wilting, respectively. This decrease in juice purity%, sucrose recovery% and quality index of beet roots might be attributed to the gradually decrease in pol% or sucrose content of beet roots (dry weight basis). It depends entirely on respiration to supply the energy when increasing wilting degree. The gradually increase in sugar losses% in waste and weight losses% of beet roots might be attributed to the gradually decrease in pol% or sucrose content of beet roots with increasing wilting degree of beet roots. Weight loss of beet roots was mainly due to a decrease in root water content. These data are in agree with those obtained by Ferweez et al. (2006); Abbas and Fugate (2009); Dewdar et al. (2015); Al.Jbawi & Al.Zubi (2016) and El.Hefnawy (2016). They exhibited that this decrease might be due to some natural vital functions such as respiration and sprout formation. Here too, they reported that respiration rate declined in response to low levels of water loss. Respiration is the primary cause of postharvest sucrose loss in sugar beet roots.

Table (5): Effect of wilting degree on processing efficiency parameters average of fresh beet roots stored for 8 days in open air.

Wilting degree	Juice purity%	Sucrose recovery%*	Sugar losses% in waste	Beet quality index	Weight losses% in beet roots
No wilt (at harvest)	85.82	67.89	3.20	82.38	0.00
Slight wilting	79.47	64.71	3.65	79.10	12.56
Moderate wilting	76.63	60.97	4.03	78.24	16.87
High wilting	75.55	56.32	4.37	74.10	20.05
Very high wilting	75.14	49.81	5.02	69.84	25.28
Overall mean	78.52	59.94	4.06	76.73	14.95
F value	**	**	**	**	**
LSD 0.05	3.94	4.48	0.13	2.28	1.60

* Sucrose recovery% of pol % of sugar beet roots on dry weight basis (DWB).

We hope that the above-mentioned results in this work would help sugar beet growers and the processors' to understand the changes which take place in the physiochemical properties and processing efficiency parameters of sugar beet roots postharvest caused by the wilting. It has the potential to cause significant economic losses in sugar production. Wilting is common in postharvest sugar beet roots and is known to increase sugar loss postharvest. Unknown, however, is the proportion of wilting-associated sugar loss that is attributable to elevations in respiration rate, since sugar is lost not only to respiration, but also to conversion to other carbohydrates and to storage rots and diseases. The increase in wilting degree of beet roots make them lose their refreshment and affect negatively sugar extraction during manufacturing in sugar factories. Here, we demonstrate that wilting might be associated with an increase in root respiration. All sugar beet growers and the processors benefit directly when postharvest losses are minimized. It is not advisable wilting of beet roots postharvest before the processing, in order to prevent the dislike changes and damage in pol content and weight of sugar beet roots.

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تأثير درجة ذبول جذور بنجر السكر بعد الحصاد على خصائصه الفيزيوكيميائية ومعايير كفاءة تصنيع السكر

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الملخص: تعامل جذور بنجر السكر تحت الظروف المصرية فى المصانع خلال الفترة من الأسبوع الأول من شهر فبراير إلى منتصف شهر يونيو، ويحدث ذبول لجذور بنجر السكر بعد الحصاد عند درجات الحرارة العالية والرطوبة النسبية المنخفضة أثناء الفترة من نهاية شهر ابريل إلى منتصف شهر يونيو، لذا أجري هذا البحث فى معامل أبحاث شركة الدلتا للسكر بكفر الشيخ وقسم علوم وتكنولوجيا الأغذية بكلية الزراعة بالوادي الجديد – جامعة أسيوط أثناء موسم ٢٠١٧ لمدة ثمانية أيام وكرر ذلك أربع مرات لمعرفة تأثير درجة ذبول جذور بنجر السكر (نسبة الفقد لنسبة رطوبة جذور بنجر السكر) بعد الحصاد على الصفات الفيزوكيميائية وكميات الشوائب ومؤشرات كفاءة تصنيع جذور بنجر السكر.

أوضحت النتائج المتحصل عليها الآتى:

١- حقق مستوى درجة ذبول جذور بنجر السكر تأثيراً معنوياً على الصفات الطبيعية للمادة الخام لتصنيع السكر (جذور البنجر) كنسبة المواد الصلبة الذائبة الكلية وقيمة الرقم الهيدروجينى ولون العصير الخام (وحدة اكوميسا).

٢- وجد أن لمستوى درجة ذبول جذور بنجر السكر تأثير معنوي على التركيب الكيميائى للمادة الخام لتصنيع السكر (جذور البنجر) كنسبة الحلاوة ونسبة السكريات المختزلة الكلية وكمية الدكستران (جزء فى المليون).

٣- أحدث مستوى درجة ذبول جذور بنجر السكر تأثيراً معنوياً على كميات الشوائب (كميات ألفا أمينونيتروجين، الصوديوم والبوتاسيوم ملمكافئات /١٠٠ جم بنجر) الموجودة فى المادة الخام لتصنيع السكر (جذور البنجر).

٤- أحدث مستوى درجة ذبول جذور بنجر السكر تأثيراً معنوياً على معايير كفاءة تصنيع السكر كنسبة السكر القابل للاستخراج ونسبة السكر المفقود فى المولاس ومعامل جودة المادة الخام ونسبة فاقد الوزن لجذور البنجر.

٥- نأمل أن تساعد النتائج فى فهم التغيرات التي تحدث لجذور بنجر السكر بعد الحصاد التي تحدث بسبب الذبول والتي ينتج عنها فاقد اقتصادى في إنتاج السكر ولمعرفة الممارسات التي تخفض فاقد السكر فى المولاس، ونوضح أن جميع مزارعي ومصنعي بنجر السكر يستفيدون مباشرة عندما يكون ذبول جذور البنجر عند الحد الأدنى، والزيادة في درجة الذبول لجذور البنجر تعني فقدانها طزاجتها وجودتها وتؤثر سلباً على استخلاص السكر أثناء التصنيع في مصانع السكر.