Chemical and Technological Characteristics of Fresh Roots of Four Sugar Beet Varieties Harvested at different Periods

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Abstract: The present investigation was carried out with an objective to understand the biochemical and technological changes that occurred in sugar beet roots of four commercial sugar beet varieties under different harvesting at different periods. For this study, four varieties of sugar beet were selected: Pleno, Top, Kawemira, and Ceres poly (P3) with high yield of roots as well as high sugar content. Moisture and ash contents were 75.66 to 81.52% and 2.34 to 3.97%; respectively, at different harvest periods. Total nitrogen content ranged between 0.65 and 2%. TSS ranged between 17.20 and 23.90%. Sucrose content of four varieties ranged between 12.40 and 19.50%.While, white sucrose percentage ranged between 8.76% and 16.35%. The purity of sugar beet roots juice of four varieties harvested at three periods ranged between 68.13% and 81.58%. Quality of fresh sugar beet roots was ranged between 70.65 and 84.58%. This investigation showed the sugar beet manufacturing at 210 days gives the lowest percentage of nitrogen substance, thus sugar percentage increased in comparison with early periods.

Keywords: *Beta vulgaris* L.; sucrose content; TSS; total nitrogen; sugar recovery; sugar losses and purity.

INTRODUCTION

Sugar beet (*Beta vulgaris* L.) is one of the most important crops, not only to produce sugar but also another major source to produce feed and organic materials used to increase soil fertility. Sugar beet is grown in a temperate climate region as, in the northern hemisphere, such as Europe, Canada and Russia. Sugar beet has been introduced recently in agricultural and industrial activities in Egypt. However, the area planted with sugar beets and produced white sugars is increased. The annual consumption of sugar is 2.6 million tons. Thus, sugar beet became the growing source of sugar production in the Arab Republic of Egypt (Center Sugar Crops Center, Ministry of Agriculture, 2012). Which is around 80% of sugar cane is produced and the remaining 20% is derived from sugar beet (FAO, 2009). Europe is the leading sugar manufacturer, focused mainly in the processing of sugar beet, which accounts for almost 80% of the world's sugar beet manufacturing (Řezbová *et al*., 2013).

Forward to sugar cane, sugar beet is listed second most significant in Egypt with an average manufacturing of 50 tons / hectare (FAO, 2011). Recently, in Egyptian crop rotation, sugar beet crop has been a significant place as a winter crop not only in rich soil, but also in bad, saline, alkaline and calcareous soils. About 66% of our local requirements came from sugar beet and sugar cane regionally, while the remainder (34%) is imported from overseas nations (FAO, 2011).

Sugar yield and quality formation are a very complicated process involving a lot of factors (Pačuta *et al*., 2017; 2018). Pavlů *et al.* (2017) reported that prolongation of the vegetation period in spring to 13 days increased sugar beet root yield by 10.9%.

Sugar beet is a plant that takes two years to complete its life cycle, the first year of development, the root (the portion that contains sucrose) and leaves. While in the second year, flowers produce beets that produce seeds, which are planted in the spring, and sugar beets are harvested in late autumn or early winter. Typically, sugar beets take six to eight months to grow and are ready for processing in a sugar factory. In the last century, industries grew exponentially. World sugar production increased from about 10 million tons to 181 million tons from 2008/2009 to 2018/2019 (USDA, 2019; Statista, 2019).

During the 2019/2020 season, refined sugar production is expected to increase by about 14% to 2.74 million tons, compared to the 2018/2017 estimated of 2.40 million tons. Of these total projections, 1.5 million tons of sugar beet will be produced, while 1.2 million tons will be sourced from sugarcane. With the creation of a new online processing facility and farmers' expansion of cultivated areas to meet increase demand, beet sugar production in 2019/2020 is expected to increase by 195,000 tons, to 1.5 million tons. This is up 15% from 1.3 million tons in the previous marketing year (USDA, 2019).

The objective of this work was studying chemical and technological characteristics of fresh roots of four sugar beet varieties harvested at different periods.

MATERIALS AND METHODS

Materials:

Sugar beet (*Beta vulgaris* L.) cultivars, pleno, Top, Kawemira, Ceres poly (P3), Ras poly Tribel, Maribo Maroc poly, Despres poly N, Kaweferma and supra poly were obtained for the preliminary investigation during 2017/2018 from the fields of experiments at sakha Research station Kafr El-Sheikh Governorates Egypt. Four sugar beet varieties were chosen to carry out for the analysis after harvesting on 180, 195 and 210 days.

Methods of Analysis:

Chemical composition:

The moisture, ash and fiber content were determined according to the procedure described in the AOAC (2012). Ash determination was carried out not more the 55°C with about 2gm sample. Total nitrogen

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was determined by Micro-Kjeldahl apparatus according to methods by AOAC (2012).

TSS in the fresh roots was determined by hand refractometer using Carl Zeiss Jena DDR783295 (A.O.A.C, 2012). Sucrose percentage was determined using Saccharometer on a lead basis according to the procedure of Delta sugar company (Le Docte, 1977).

Total sugars (non-reducing and reducing sugars) were determined in accordance with the method outlined in the AOAC (2012).

Alpha amino nitrogen, sodium and potassium they were determined according to the procedure of Delta sugar Co. using Autoanalyzer type ZIG venma, Automation BV Analyzer IIG-16-12-99, 9716JP/ Groningen / Holland. Temp. 18 - 30º C, surrounding humidity max. 70% according to Brown and Lillan (1964). The results calculated as milli-equivalents/100gm beet.

Determination of technological characteristics:

Sugar recovery (SR) (White sugar):

Sugar recovery percentage (SR%) was determined according to the procedure of Delta sugar company described by Silin and Silina (1977) and Sapronova *et al.* (1979) using the following equation:

$$SR = pol - 0.29 - 0.343\,(K+Na) - \alpha.N \times 0.0939$$

Where:

pol = sucrose %; K= Potassium, Na = Sodium; α.N = Alpha amino nitrogen

Sugar losses in wastes:

Sugar losses (D) in wastes percentage and purity were determined according to the procedure of Delta sugar company described by Silin and Silina (1977) and Sapronova *et al.* (1979) using the following equations:

$$\mathbf{D = 0.343\,(K+Na) + \alpha.N\,(0.094 + 0.179)}$$

$$\text{Purity} = \frac{Sucrose\%}{Soluble\ solids\ \%} \times 100$$

RESULTS AND DISCUSSION

The gross chemical composition of sugar beet roots is given in Table (1).

Moisture and ash content:

Moisture content of different varieties ranged between 75.66and 81.52% at different harvest periods. Similar results were recorded by Ferweez *et al.* (2006) and Gomaa (2009). The ash contents ranged between 2.34% and 3.97% in roots of sugar beet. The results obtained are in agreement with those reported by Alfaig *et al*. (2011).

Total fiber content:

Sugar beet contained relatively low content of fiber. Total fibers content ranged between 2.0and 6.0% in the roots of the four varieties at different harvest periods. The results obtained are in agreement with those reported by Seadh *et al.* (2013). While, Mousa (1990) reported that fiber content was ranged from 0.38 to 0.91 % at harvest.

Total nitrogen content:

Total nitrogen content ranged between 0.65and 2% in the roots of four varieties at different harvest periods. The present results are in a good agreement with the findings of Hoffmann *et al.* (2009).

Total soluble solids (TSS) and Sucrose percentage:

The TSS ranged between 17.20 and 23.90%. Sucrose percentage of four varieties ranged between 12.40and 19.50%, similar results were recorded by El-Sharnouby *et al.* (1999). Michalska-Klimczak *et al.* (2019) and Alfaig *et al*. (2011) found that sucrose percentage was ranged from 16to 18.6% and 10.93 to 13.24%; respectively. While, the present results are in agreement with the findings of Abido *et al.* (2015).

Total sugars and reducing sugars:

The total sugars of sugars beet of the four varieties studied contained considerably high value of the sugars, *i.e.* 14.36 to 22.04%. The results are in a good agreement with the findings of Hashemi *et al.* (2014). Joshi *et al*. (2006) found that the total sugars and reducing sugars content of sugars beet was 14.00to35.13% and 0.244 to 0.724, respectively in roots in different varieties. Lower reducing sugar value were observed in the roots of four varieties harvest at three periods at they ranged between 0.16 and 0.71%. The present results are in agreed with finding of Masri and Hamza (2015). Meanwhile, Strochalska *et al.* (2014) found that the invert sugar in crown, slice and roots was 0.72, 0.71and 0.23%; respectively.

Alpha amino nitrogen, sodium and potassium content:

Alpha amino nitrogen, sodium and potassium content of the roots of four varieties harvest at three periods at they ranged between 0.38 to 2.20, 1.49 to 3.65 and 5.15 to 6.70 milli equivalent/ 100g beet. These results are similar to those found by AL-Tantawy (2012). Michalska-Klimczak *et al.* (2019) found that α-amino nitrogen, sodium and potassium content in years 2012–2014 were ranged between 1.15 to 3.35, 0.22 to 0.39 and 3.61 to 4.15 (mmol/100g), respectively.

Table (1): Chemical composition of fresh sugar beet varieties investigated at different harvesting periods

	Chemical composition	Pleno			Top			Kawemira			Ceres poly (P3)		
	Harvesting periods (days)	180	195	210	180	195	210	180	195	210	180	195	210
1	**Moisture**	80.78	78.22	76.16	81.38	76.15	75.98	80.92	77.00	77.06	81.52	77.16	75.66
2	**Ash%**	3.70	3.49	2.34	3.97	3.42	2.62	3.66	3.21	2.89	3.90	3.03	2.62
3	**Total fiber%**	3.00	5.00	4.00	2.00	5.00	4.00	3.00	6.00	4.00	3.00	2.00	6.00
4	**Total N%[(a)]**	1.95	1.55	0.75	1.75	1.25	0.70	1.90	1.60	0.75	2.00	1.56	0.65
5	**TSS%[(b)]**	19.20	21.40	23.00	17.20	22.00	23.90	18.10	22.60	21.90	18.20	22.30	23.60
6	**Sucrose**	14.66	16.00	18.31	12.86	17.08	19.50	13.72	16.31	16.38	12.40	18.06	19.06
7	**Total sugars**	16.87	17.85	19.94	14.97	18.95	22.04	15.61	18.35	18.37	14.36	19.58	20.42
8	**R. sugars[(c)]**	0.16	0.54	0.60	0.34	0.41	0.63	0.38	0.61	0.71	0.41	0.43	0.55
9	**α-amino N[(d)]**	0.38	1.95	2.00	1.68	1.09	0.89	1.66	1.53	1.20	2.20	2.00	1.90
10	**Na**	2.24	2.86	2.65	2.43	2.39	1.49	3.07	2.72	2.83	3.65	2.50	1.67
11	**K**	5.55	6.42	6.70	6.20	6.36	6.62	5.47	5.15	5.85	5.48	5.26	5.35

(a): Total nitrogen, (b): Total soluble solids (TSS), (c): Reducing sugars, (d): α-amino nitrogen milli equivalents/100gm beet.

Technological characteristics of fresh roots of four sugar beet varieties harvested at different periods:

Table (2) showed that the technological characteristics of fresh roots of four varieties of sugar beet which have been grown at different times. White sucrose or sucrose recovery (SR) of four varieties harvested at three periods ranged between 8.76and 16.35% similar results were recorded by Al-Barbari *et al.* (2014a) and Al-Barbari *et al.* (2014b) who found that SR was ranged from 14.31 and 15.96%. Sucrose recovery depended on some factors such as sucrose, K and α-N content. It has positive correlation with sucrose content and negative correlation with Na, K and α-N content of sugar beet juice. These findings are in agreement with Gomaa (2009) who reported that SR of beet juice ranged from 14.19 to 15.16 % in beet laboratory.

Table (2): Technological characteristics of fresh roots of four sugar beet varieties harvested at different periods

	T. Charac[a]	Pleno			Top			Kawemira			Ceres poly (P3)		
	Harvesting periods	180	195	210	180	195	210	180	195	210	180	195	210
1	**SR[b]**	11.42	12.34	14.63	9.45	13.69	16.35	10.36	12.84	13.00	8.76	14.84	16.12
2	**SL[c]**	3.18	3.66	3.68	3.41	3.39	3.15	3.36	3.47	3.38	3.64	3.14	2.88
3	**Purity%**	76.04	74.78	79.60	74.76	77.63	81.58	75.80	72.16	74.79	68.13	80.71	80.50
4	**Quality**	77.90	77.13	79.90	73.48	80.15	83.85	75.51	78.72	79.37	70.65	82.17	84.58

(a): Technological characteristics. (b): Sucrose recovery. (c): Sucrose loss

Sucrose loss value in wastes of four varieties harvested at three periods ranged between 2.88 and 3.62%. Generally, the percentage of sucrose loss in wastes within the ranged of 2.80 and 3.68% as reported by Salami and Saadat (2013). These findings are agreement with results reported by Gomaa (2009) that the losses of sucrose in wastes were ranged from 3.06 to 4.12 % in the beet juice. From data in Table (2), it could be said that by decrease the losses of sucrose in wastes, the sugar produced as white sugar increase.

The data illustrated in Table (2) showed that the purity of sugar beet roots juice of four varieties harvested at three periods ranged between 68.13 and 81.58%. These results are like those found by Joshi *et al*. (2006) and Alfaig *et al*. (2011) were ranged from 65.483 to 73.030 and 78.59 to 82.45 %; respectively at harvest. It can be said that; the main aim of the sugar factory is to separate non-sugar from sugar to improve the beet juice purity to the extent that sugar with 100% purity is produced. Also, by increase the purity of beet juice would make sugar beet processing much faster and easier. These results were supported by Asadi (2007) who mentioned that the purity of beet juice usually ranged between 85 to 88% in atypical washed beet (beet without tare). From Table (2) it can be recognized very clearly that the beet quality depends on the case of beet roots, healthy or injured. So, that the beet quality decrease in the case of arising alkaline (K and Na content) and nitrogen content. The results are similar with those reported by Gomaa (2009) who found that the quality of beet ranged from 78.63 to 82.95% during the period of the beet processing.

Quality of fresh sugar beet roots of four sugar beet varieties harvested at different periods was ranged between 70.65 and 84.58%. The results are similar with those reported by Zaki *et al.* (2014) who found that the quality of beet ranged from 77.63 to 80.15%. The tabulated data in Table (2) demonstrated that, as α-amino nitrogen, sodium and potassium content increase in sugar beet the quality of sugar beet decrease and consequently the amount of sugar lost increase and vice versa. The quality of sugar beet increased from 70.65 to 84.58 % during different periods of root of four varieties at different harvest periods studied. Also, it could notice that, there is a reversible relationship between the quality of sugar beet, the sugar losses % on beet in molasses and the concentration of alpha amine nitrogen, sodium and potassium content in sugar beet. These results are confirmed by AL-Tantawy (2012) who demonstrated that as alpha amine nitrogen, sodium and potassium content increase in sugar beet the quality of sugar beet decrease and consequently the amount of sugar lost in molasses increase.

CONCLUSION

From obtained data in this study, it can be concluded that in order to manufacture sugar beet just after harvesting to reduce sugar losses during manufacturing and to prevent the inversion of sucrose to glucose and fructose. This investigation showed the sugar beet manufacturing at210 days gives the lowest percentage of nitrogen substance, thus sugar percentage increased in comparison with early periods.

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الخصائص الكيميائية والتكنولوجية لجذور أربعة أنواع من بنجر السكر التي يتم حصادها في مواعيد مختلفة

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تم إجراء البحث الحالي بهدف فهم التغيرات الكيميائية الحيوية والتكنولوجية التي تحدث في جذور بنجر السكر لأربعة أصناف تجارية فى مواعيد حصاد مختلفة. لإجراء هذه الدراسة، تم اختيار أربعة أنواع من بنجر السكر وهى: Pleno و Top و Kawemira و Ceres poly (P3) ذات إنتاجية عالية من الجذور ونسبة عالية من السكر. تراوحت نسبة الرطوبة والرماد في هذه الأنواع من ٧٥.٦٦ إلى ٨١.٥٢ ٪ ومن ٢.٣٤ إلى ٣.٩٧ ٪. على التوالي في مواعيد الحصاد المختلفة. تراوح إجمالي محتوى النيتروجين بين ٠.٦٥و ٢٪، وتراوحت TSS بين ١٧.٢٠ و ٢٣.٩٠ ٪. تراوحت نسبة السكروز في الأربعة أصناف بين ١٢.٤٠ و ١٩.٥٠ ٪. بينما تراوحت نسبة السكروز الأبيض بين ٨.٧٦ و ١٦.٣٥٪. تراوحت نقاوة عصير جذور بنجر السكر للأربعة أصناف التي حصدت في ثلاثة مواعيد مختلفة بين ٦٨.١٣ و ٨١.٥٨ ٪. أما جودة جذور بنجر السكر الطازج فقد تراوحت بين ٧٠.٦٥ و ٨٤.٥٨٪. أظهر هذا البحث أن تصنيع بنجر السكر عند ٢١٠ يومًا يعطي أقل نسبة من مادة النيتروجين، وبالتالي تزداد نسبة السكر مقارنة بالفترات المبكرة.