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Optimal Timing of the Sugar Beet Juice Season as an Intelligent Adaptation Strategy to Climate Change in Egypt

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Abstract

Agricultural production, especially beet sugar production, is expected to face climate change-induced challenges, which require adaptation using innovative techniques and strategies. Therefore, this work was conducted in the rural area of Abnoub, Asyut governorate, Egypt, during the 2020–2021 working season and in laboratories of Delta Sugar Company, Kafr El-Sheikh governorate, as well as in laboratories of Food Science and Technology Department, Faculty of Agriculture, New Valley University, Egypt. The aim of this study was to investigate the effects of juicing season timing on quantitative and qualitative indices of beetroot. The obtained results indicated that juice season timing exhibited a significant effect on quantitative indices of beetroots, including root yield, gross sugar, recoverable sugar, and sugar loss (t/ha) as well as qualitative indices of beetroots, including total soluble solids, purity, sugar recovery, sugar loss% to molasses, non-sucrose substances, quality index, moisture, pol, total sugars, reducing sugars, total nitrogen content, total lipids, marc, ash%, impurities: α-amino N, and Na content. The early juice season, beginning in mid-February, proved to be the best time for sugar beet manufacturing and can be suggested as smart sugar manufacturing in Egypt to combat climate change. However, under the study conditions, the timing of the late juice season in mid-June is unfavorable for sugar manufacturing.

Keywords: sugar beet, pol %, juice season timing, climate change.

1. Introduction

Sugar beet, a sucrose-rich crop, is known for its multivarious uses in the industrial field. It competes well with the sugarcane crop for sugar production. Sugar beet is cultivated in Europe and to a very lesser extent in Asia and North America. Sugar beet production is conditioned much more by climatic factors than some of the other agricultural plants (Bisbis et al., 2018). In general, in climate change research, trade-offs are discussed as a form of inter-relationship between adaptation and mitigation or as conflicts between different environmental, social, and economic goals. Although food security is likely to be less dependent on the climate, induced uncertainty (substantial fluctuations) in food production may result from elevated temperatures in the future. Some studies indicate that climate change will result in an increased mean temperature in many regions of the globe. Agriculture and rural areas will be more affected by climate change (Maho & Skenderasi, 2020; Mall, et al. 2021). Therefore, this work aimed to investigate changes in quantitative and qualitative indices of sugar beet caused by climate changes such as temperature and global radiation related to juice season timing as a smart sugar manufacturing strategy to contend with climate changes in Egypt.

2. Materials and Methods

This study was conducted on a farm in Abnoub rural area, Asyut governorate, as well as laboratories of Delta Sugar Company, Kafr El-Sheikh governorate, and laboratories of Food Sci. & Techno., Department of Fac. Agric., New Valley Univ., Egypt, during the 2020-2021 working season. To evaluate the effects of juice season timing on quantitative and qualitative indices of beetroot. Three of the four juice season timings were studied as follows: 1-Juice season begins in mid-February 2-Juice season medium begins in mid-April, and the 3-Juice season ends in mid-June. The Kawamera cultivar of sugar beet was sown and treated according to the traditional agricultural practices of the region. A sugar beet (*Beta vulgaris* L.) genotype was selected according to its high technical quality and productivity. The experiment was conducted as a randomized complete block design (RCBD) with four replications.

2.1. Sampling

At harvesting time, at age of 195 days from sowing, a random sample of twenty healthy plants per treatment or timing was harvested. Plants were separated into storage roots and leaves. Samples (clean beetroots) were transported immediately to the laboratory where the roots were washed to remove the soil particles. The weather conditions of Abnoub rural area, Asyut Governorate, Egypt at the studied juice season timings, temperatures °C average, are shown in Table (1).

Table 1: Mean temperature during the studied juice season timings during the working season of 2020–2021.

Temperature	Manufacturing season timings		
	Mid- February 2021 (Juice season starting)	Mid-April 2021 (Juice season medium)	Mid- June 2021 (Juice season end)
Minimum	10.00	16.00	24.00
Maximum	23.00	34.00	36.00
Mean	11.50	25.00	30.00

Source: Asyut Metrological Station, Asyut Governorate, Egypt.

Table 2. Effect of juice season timing on productivity indices (ton/ha) of sugar beet.

Yield indices	**Juice season timings**					
	Season starting*	Season medium*	Season end*	Mean	F value	LSD at 5%
Fresh roots	66.06 [c]	70.75 [b]	76.71 [a]	71.51	**	1.08
Gross sugar	11.86 [a]	11.61 [b]	10.37 [c]	11.28	**	0.24
Recoverable sugar	10.05 [a]	9.47 [b]	8.76 [c]	9.43	**	0.22
Sugar loss	1.81 [b]	2.14 [a]	1.60 [c]	1.85	**	0.04

* **Season starting** = Mid-February, Season medium = Mid-April, Season end=Mid-June. Notes: Values in the same row with different superscripts are significantly different ($p < 0.05$). Values in Table are means of ten replicates.

These results are consistent with findings reported by **Chloupek *et al*., (2004)**; **Hoffmann *et al*., (2009); Supit *et al.*, (2010)** and **Olesen *et al.*, (2011).** In this respect, **Wiréhn, (2018); Maho & Skenderasi (2020) and Bastaubayeva *et al.*, (2022)** demonstrated that there was a characteristically close negative correlation between root yield and sugar content. A warmer climate is also anticipated to increase insect and virus infestations as well as opportunities for new pests and insects to establish themselves. The climate changes described, i.e., rising temperatures and length of sunshine hours were therefore favorable for sugar beet growth.

3. 2. Changes in qualitative indices of sugar beet

Quality starts with good management of the crop so that the quality at harvest is excellent. Egypt, having a special climate in each area, has suitable land to produce various strategic crops, illustrating the diverse types of climates in the territory. The technological value of sugar beet (*Beta vulgaris* L.) is complex of biological, physical, and chemical parameters of the root which determines the positive effects of processing on the effectiveness of white sugar gain (**Ayyogari, *et al*., 2014, Baryga & Połeć 2016**).

3. 2.1. Changes in physical quality indices of sugar beet

As shown in Table 3, the timing of the juice season had a significant effect on the physical quality indices of beets, namely total soluble solids (TSS)%, purity%, SR%, sugar loss % to molasses (SLM%), NSS%, and quality index (QZ) of sugar beet. It was concluded that early juice season timing in mid-February recorded the highest values (20.38, 88.14, 15.22, and 84.74%) of TSS%, purity%, SR%, and QZ as well as the lowest values (2.74 and 2.42%) of SLM and NSS% in beetroots, respectively. This result might be attributed to the fact that early juice season timing in mid-February, at an average temperature of about 10–23°C, achieve proper growth of sugar beet and helps sugar accumulation and reduces the respiration rate of beetroots, while late juice season timing at mid-June, temperatures of about 30.0 °C, might retard sugar accumulation and increase the respiration rate of beetroots. Consequently, this led to the increase in TSS%, purity%, SR%, and QZ of beetroots for early juice season timing in mid-February. There was a positive correlation between pol% and both TSS%, purity%, SR%, and QZ and, reversely, with SLM and NSS% of beets. On the other hand, the lowest values (18.45, 80.15, 11.43, and 77.28%) of TSS%, purity%, SR%, and QZ as well as the highest values (3.36 and 4.94%) of SLM and NSS% in beetroots were scored for late juice season timing at mid-June, respectively.

Table 3. Effect of juice season periods on physical indices of sugar beet.

Physical indices	**Manufacturing season timings**				
	Season starting*	Season medium*	Season end*	Mean	F value	LSD at 5%
TSS%	20.38 [a]	19.75 [b]	18.45 [c]	19.52	**	0.22
Purity %	88.14 [a]	83.12 [b]	80.15 [c]	83.80	**	1.19
SR%	15.22 [a]	13.39 [b]	11.43 [c]	13.35	**	0.15
Sugar loss %	2.74 [c]	3.02 [b]	3.36 [a]	3.04	**	0.03
NSS%	2.42 [c]	3.33 [b]	4.94 [a]	3.56	**	0.27
Quality Index	84.74 [a]	81.57 [b]	77.28 [c]	81.20	**	0.35

* Season starting=**Mid-February, Season medium=Mid-April, Season end = Mid-June. TSS%= total soluble solids, NSS%= Non-sucrose substances%. Notes: Values in the same row with different superscripts are significantly different ($p < 0.05$). Values in the Table are the mean of ten replicates.**

This agrees with the results of **Chloupek, *et al*., (2004); Olesen *et al*., (2011); Hozayn, *et al*., (2013) and Aminzadeh, *et al*., (2014). In the same subject, Wiréhn, (2018); Bisbis, *et al.* (2018); Al Jbawi, (2020). and Maho & Skenderasi (2020)** clarified that physical quality indices of sugar beet roots in different regions may vary due to differences in their ability to benefit from the environmental factors that enable them to adapt and achieve better quality parameters.

3.2.2. Changes in chemical indices of sugar beet

Sugar factories require beetroots with high concentrations of sucrose and low concentrations of molassigenic substances to maximize the amount of extractable sugar. The results given in Table 4 show that juice season timing had a significant effect on chemical indices of beetroots (moisture, pol, total sugars, reducing sugars, total N, total lipids, marc, and ash%). Early juice season timing in mid-February contained the highest values of pol% and total sugars% (70.37 and 74.25% DWB), as well as the lowest values of moisture, reducing sugars, total N, total lipids, marc, and ash% (74.48, 0.12, 3.91, 1.42, 14.82, and 3.08% DWB), respectively. This result might be due to the greatest intensity of sugar accumulation in beetroots being at early juice season timing in mid-February, a temperature of less than 20 ^{o}C (13.50–16.50 ^{o}C) compared with the other studied juice season timings. As a result, the other chemical indices of beetroot (such as marc%, total N, and total lipids%, among others) are the lowest. Late juice season timing (mid-June) had the lowest pol and total sugars% values (63.54 and 67.28% DWB), as well as the highest moisture%, reducing sugars%, total N%, total lipids%, marc%, and ash% values (78.73, 0.20, 5.41, 1.71, 17.77, and 4.80% DWB), respectively. This might be due to the respiration requirements of beetroots for the late juice season timing at mid-June, which requires a temperature of about 30 ^{o}C (24-36 ^{o}C), double for every 10 ^{o}C temperature increase. For this reason, sugar beets are planted only if the grower has a contract for processing. **Trebbi and McGrath (2004); Hozayn *et al.* (2013); Awad-Allah (2017); Gobarah *et al.* (2019) and Alami *et al.* (2021)** all reached similar conclusions. They indicated that sugar beet, a sucrose-rich crop, and the moisture content of beetroots are used as a harvest indicator for sugar beet due to its direct correlation with sugar content, a key quality component depending on the environment. They pointed out that a limited amount of inverted sugar content in roots indicates the stabilization of this simple sugar in the cell vacuole. The technical control of the sugar factory is to insure the best practical results; to what extent of the losses in the factory and to help to evaluate these losses as well as to one period work and to be comparable with those of the other periods.

Table 4. Effect of manufacturing season timings on chemical indices (%) of sugar beet (db).

Chemical indices	**Manufacturing season timings**					
	Season starting*	Season medium*	Season end*	Mean	F value	LSD at 5%
Moisture %	74.48 [C]	75.54 [b]	78.73 [a]	76.25	**	0.22
Pol %	70.37 [a]	67.12 [b]	63.54 [c]	67.01	**	0.20
Reducing sugars%	0.12 [C]	0.16 [b]	0.20 [a]	0.16	**	0.02
Total sugars %	74.25 [c]	71.12 [b]	67.28 [c]	70.88	**	0.21
Total Nitrogen%	3.91 [c]	4.76 [b]	5.41 [a]	4.69	**	0.11
Total Lipids%	1.42 [C]	1.56 [b]	1.71 [a]	1.56	**	0.08
Marc %	14.82 [C]	16.90 [b]	17.77 [a]	16.49	**	0.14
Ash %	3.08 [C]	4.19 [b]	4.80 [a]	4.03	**	0.08
α- Amino N* **	1.67 [C]	2.01 [b]	2.30 [a]	1.99	**	0.06
K * **	4.82	5.35	5.76	5.31	Ns	-
Na * **	1.86 [C]	2.08 [b]	2.23 [a]	2.06	**	0.08

* Season starting=**Mid-February, Season medium=Mid-April, Season end = Mid-June. TSS%= total soluble solids, NSS%= Non-sucrose substances%. Notes: Values in the same row with different superscripts are significantly different ($p < 0.05$). Values in the Table are the mean of ten replicates.**

3.3. Changes in impurities parameters or molassigenic quality of sugar beet (wb)

Data obtained in Table 4 clearly show that juice season timing had a significant effect on impurity parameters of beetroots (α-amino N and Na contents), except that the K content of beetroot was not significant. Early juice season timing in mid-February had the lowest values (1.67, 4.82, and 1.86 milliequivalent/100 g) of α–amino N, K, and Na content, respectively. This might be due to the early juice season starting in mid-February containing the lowest value of NSS% (Table, 3), where there was a positive relationship between NSS content and impurity parameters of beetroots (contents of α-amino N, K, and Na). Typically, sodium, potassium salts, and amino nitrogen compounds together represent about 80% of the total non-sugars. Conversely, the late juice season timing at mid-June contained the highest values (1.99, 5.76, and 2.23 mill equivalent/100 g) of α–amino N, K, and Na content, respectively. This agrees with the results of **Trebbi & McGrath (2004) and Hozayn, *et al.*, (2013).** In addition**, Curcic, *et al.*, (2018), and Mekdad *et al*. (2021)** reported that the various impurities of beetroots, i.e., all soluble extract components other than sucrose, have different degrees of negative influence on the ability to recover the sucrose presented in the beetroot juice, which hampers the crystallization of sugar. The maximum sucrose yield per unit of cultivated area can be obtained by processing juices with high sucrose content, high purity, and as low a percentage of non-sugars as possible, which cause processing difficulties in sugar manufacturing. In general, good management of juice season timing for the sugar industry is critical for utilizing the optimal juice season timing as smart climate agriculture in the face of climate change in Egypt and maximizing the amount of extractable sugar. Based on the analysis of climatic factors in the manufacturing of sugar beet and agro-climatic conditions for sugar beet cultivation according to favorable and unfavorable juice season timings in different months of the study region, they are as follows. It can be concluded from the results that the early juice season starting in mid-February timing is the best time for manufacturing sugar beet under the study conditions because it achieved the highest values of SR% (15.22%), QZ (84.74%), and pol% (70.37%), followed by juice season medium timing at mid-April, but late juice season timing at mid-June is unfavorable for manufacturing and reflecting Egypt's climate.

Conclusion

The obtained results may help farmers, to choose the appropriate harvest time, i.e., in February and April when beets and their corresponding liquor qualities have superiority. The chemical composition of sugar beet is the most important parameter affecting its processing. Sugar factories require beet with high concentrations of sucrose and low concentrations of molassigenic substances to maximize the amount of extractable sugar.

Abbreviations

TSS% = Total soluble solids,
NSS% = Non-sucrose substances%.
Ns = No significant difference
DWB%=Dry weight basis%.
WWB%= Wet weight basis.
SR% = Sugar recovery%,
SLM% = Sugar loss % to molasses
QZ = Quality index
AOAC = Association of Official Analytical Chemists.

Conflicts of Interest

This manuscript has no conflicts of interest.

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الموعد الامثل لبدء موسم عصير بنجر السكر، كاستراتيجية تكييف ذكية للتغيرات المناخية فى مصر

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يواجه الإنتاج الزراعي بشكل عام وإنتاج سكر البنجر بوجه خاص تحديات ناجمة عن التغير المناخى تتطلب استخدام تقنيات حديثة كاستراتيجية ذكية للتكيف مع التغيرات المناخية. لذلك تمت هذة الدراسة في مركز ابنوب بمحافظة أسيوط، مصر خلال موسم عمل 2020-2021، معامل شركة الدلتا للسكر، محافظة كفر الشيخ ومعامل قسم علوم وتكنولوجيا الأغذية بكلية الزراعة– جامعة الوادي الجديد، مصر لدراسة تأثير موعد موسم العصير على المؤشرات الكمية والنوعية لجذور بنجر السكر.

أشارت النتائج **أن** موعد بدء موسم العصير له تأثيرًا معنويًا على المؤشرات الكمية مثل ناتج الجذور، ناتج إجمالي السكر، ناتج السكر القابل للاستخراج ، وناتج فقد السكر (طن/ هكتار)، ايضا على المؤشرات الجودة الطبيعية لجذور البنجر مثل نسب المواد الصلبة الذائبة الكلية ، النقاوة ، استخراج السكر ، السكر المفقود فى المولاس، المواد غير السكروز و معامل الجودة، كذلك على المؤشرات الجودة الكيميائية مثل نسب الرطوبة، الحلاوة ، السكريات المختزلة ، السكريات الكلية ، النيتروجين الكلى، الليبيدات الكلية و الرماد و ايضا على مؤشرات الشوائب مثل الالفا امينو نيتروجين و الصوديوم اما البوتاسيوم كان غير معنوى.

بناء على ذلك وجد أن موعد موسم العصير المبكر (منتصف فبراير) هو الموعد الأفضل لتصنيع بنجر السكر كاستراتيجية ذكية لمواجهة التغيرات المناخية في مصر، لأنها حققت أعلى قيم فى نسبة استخراج السكر (15.22٪)، معامل الجودة (84.74 %)، درجة الحلاوة (70.37 % وزن جاف) وناتج السكر القابل للاستخراج (10.05 طن / هكتار) ومتبوعًا بموعد منتصف موسم العصير (منتصف أبريل)، لكن الموعد المتأخر لموسم العصير الى منتصف شهر يونيو يكون غير مناسب تحت ظروف الدراسة.