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Evaluation of physicochemical properties and purity indices of sugar beet syrup according to different irrigation conditions

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ABSTRACT

The present study was conducted to evaluate the physicochemical properties and purity indices of sugar beet syrup under different irrigation conditions. This study was conducted by implementing six different irrigation treatments including different combinations of row spacing and irrigation interval (full and every other). Harvested sugar beet samples were analyzed to determine physicochemical parameters including potassium, sodium, harmful nitrogen, alkalinity, sugar percentage, syrup purity and sugar in molasses. The results showed that treatments with row spacing of 50 to 60 cm and every other irrigation (I4) provided the highest syrup purity (83–85%) and sugar percentage (13–14%) ($p<0.05$), while the amounts of potassium, sodium and harmful nitrogen were also within acceptable ranges in these treatments. Significant differences were observed between treatments for syrup purity and sugar percentage indices ($p<0.05$), but parameters such as potassium and alkalinity did not differ significantly in some treatments ($p<0.05$). The findings of this study indicate that optimal irrigation management and selection of appropriate planting line spacing can improve the quality of sugar beet syrup in addition to increasing water use efficiency. These results can be used as a practical guide to determine effective irrigation treatments in similar climatic conditions.

1- Introduction

Agricultural production is influenced by numerous factors, including water, soil, plant nutrition, light, plant density, and technical knowledge [1]. In arid and semi-arid countries like Iran, the primary limitation on agricultural production is access to water resources, while other factors such as human labor, machinery, and soil are not considered restrictive [2]. Therefore, optimizing water consumption and increasing its productivity per unit area, especially for crops like sugar beet which are highly sensitive to water stress, is of particular importance [3, 4].

Sugar beet, as the main source of sugar and raw material for the food industry, is significant not only for its quantitative yield but also for the quality of its syrup and the percentage of extractable sugar [5]. The physicochemical properties of sugar beet juice, including sugar percentage, impurity indices, extractable sugar percentage, and sugar in molasses, can be influenced by cultivation conditions, the amount and method of irrigation, and plant density [6, 7]. These indices are directly related to the final product quality and associated food industry processes, and changes in them can have a significant impact on the efficiency and quality of sugar products and their derivatives [4, 8].

Previous studies have shown that alternate furrow irrigation, in addition to reducing water consumption, can maintain sugar yield and product quality [9, 10]. Naseri et al. (2020), citing Sepaskhah and Kheradnam (1977), reported that alternate furrow irrigation was able to reduce water consumption by up to 40%, while no significant decrease in extractable sugar was observed [7, 8]. Talaghani et al. (2024) reported that in addition to the amount of irrigation, row arrangement and plant density play a crucial role in light use efficiency and plant growth. Increasing plant density up to an optimal level can increase the sugar percentage and syrup quality, but excessive density leads to reduced light interception by each plant and a decrease in dry matter production [9].

The density and arrangement of sugar beet plants not only affect plant growth and solar radiation efficiency but also directly impact the quality and amount of extractable sugar and other physicochemical properties of the syrup [4]. Research has shown that a square-like arrangement of plants with a spacing of 30×30 cm can provide balanced and optimal growth conditions, but in practice, limitations such as field management, irrigation, and mechanized harvesting prevent the full use of this spacing. In this regard, new planting methods, including cultivating two rows of sugar beet on one ridge with uneven spacing between the lines, in addition to allowing for optimal density, create better compatibility with farm mechanization equipment. This method, while maintaining the quantitative and qualitative quality of the product, can improve important food industry indices such as extractable sugar percentage, juice purity, and reduction of impurities [1, 4, 10].

International studies also indicate that plant density and row spacing have a significant impact on crop yield [9-11]. Similar studies have reported the highest aerial part weight and sugar yield at a density of 50,000 plants per hectare with row spacings of 40–50 cm [11]. It has also been shown that high densities above 85,000 plants per hectare lead to increased competition among plants and higher sugar yield [12]. Furthermore, they have introduced the ideal density for sugar beet as approximately 100,000 to 105,000 plants per hectare and have emphasized that increasing density, coupled with proper nutrient management, can enhance crop yield and quality [13].

From the perspective of sugar industry technology, the quality of sugar beet juice and its physicochemical indices are of special importance [14], as these parameters determine the efficiency of the sugar extraction process, juice purity, the amount of sugar in molasses, and ultimately, the quality of sugar products and industrial derivatives. Changes in irrigation conditions and planting arrangements can alter the ratio of sugar to impurities and other physicochemical properties of the syrup, thereby directly affecting the efficiency of sugar production and other food product processes [15, 16]. Furthermore, understanding the sensitive growth stages of sugar beet to water deficit helps in precise planning for applying controlled stress. Studies have shown that the period from four to three weeks after germination until the root-filling stage is the most sensitive growth stage of sugar beet to water stress, and applying appropriate management during this period can both reduce water consumption and maintain product quality [17-19].

Accordingly, the present study was conducted with the aim of evaluating the effects of different irrigation conditions (full and alternate) and different planting arrangements on the physicochemical properties and purity indices of sugar beet juice. The results of this research can serve as a practical guide for optimizing water consumption, increasing production efficiency, and enhancing the quality of sugar products in the food and agricultural industries.

2- Materials and Methods

2-1. Sample Preparation and Measurement of Juice Quality Attributes

After harvest, sugar beet root samples were randomly selected from each experimental plot and transferred to the laboratory. First, the roots were thoroughly washed to remove soil and foreign materials. Then, for juice extraction, the samples were cut into small pieces (thin rings). The raw juice was extracted through a hot diffusion process; this involved placing the beet pieces in contact with hot water to transfer sugar and soluble substances into the water. The resulting juice was clarified using standard chemical agents (such as lead acetate or calcium chloride and glucose) to remove suspended matter and trash, yielding a clear sample suitable for subsequent analyses. All measurements were performed on this clarified juice.

2-2. Parameter Measurement Methods

2-2-1. Pol (POL)

To measure Pol, which indicates the amount of pure sucrose, a polarimeter was used. First, the clarified juice was placed in a standard tube of a specific length (usually 10 or 20 cm). The tube was then placed inside the polarimeter, and the angle of rotation of polarized light by the sugar solution was measured at the standard temperature of 20°C. The device was calibrated before measurements using a standard sucrose solution of known concentration. This method is based on the GS1-9 standard of the International Commission for Uniform Methods of Sugar Analysis (ICUMSA) [20].

2-2-2. Potassium (K) and Sodium (Na)

The concentration of these ions was determined using a flame photometer. For this purpose, a calibration curve for each ion was first prepared using standard solutions of known concentrations of potassium and sodium. The juice sample was then diluted to a specific ratio and injected into the device. The sample was atomized in a gas flame, and the K and Na ions emitted light of specific wavelengths. The intensity of this light was measured by a detector, and the exact concentration of each ion in the original sample was calculated using the calibration curve [21].

2-2-3. Harmful Nitrogen (N)

Harmful nitrogen (mainly including amino acids and amides) was measured using the ninhydrin colorimetric method. In this method, a specified amount of juice was mixed with the ninhydrin reagent, and the resulting mixture was placed in a water bath for a set time (e.g., 15 minutes) to complete the reaction and develop a distinct purple-blue color. After cooling, the color intensity was read using a spectrophotometer at a wavelength of 570 nm. The concentration of harmful nitrogen was determined by comparing the absorbance of the samples with a calibration curve prepared using a standard amino acid (e.g., leucine) [22].

2-2-4. Alkalinity (ALC)

The alkalinity of the juice, representing the sum of alkaline cations (mainly K and Na), was measured via acid-base titration. A specified amount of clarified juice (e.g., 10 ml) was placed in an Erlenmeyer flask, and a few drops of phenolphthalein indicator were added. The solution was then slowly titrated with standard sulfuric acid (H_2SO_4) until the endpoint (when the faint pink color completely disappeared) was reached. The volume of acid used was calculated as milliequivalents per 100 grams of sugar and reported as alkalinity [22].

2-2-5. Sugar Percentage (SUGAR) and Juice Purity (Purity)

These two parameters are computational. First, Brix (the total soluble solids in the juice) was measured using a refractometer based on light refraction. Then, with the values of Pol and Brix, the juice purity was calculated using the following formula:

`Juice Purity (%) = (Pol / Brix) × 100`

The extractable sugar percentage was also calculated using standard empirical factory formulas that consider Pol, purity, and impurities [20].

2-2-6. Molasses Sugar (MS)

This index is a prediction of the amount of sucrose that will be transferred to molasses during the factory process and is not directly measured. Its value was calculated using standard empirical formulas based on the obtained qualitative data (such as juice purity, alkalinity, and harmful nitrogen). These formulas model the relationship between impurities and the sugar remaining in molasses [23].

2-3. Data Analysis

The experiment was conducted as a split-plot in time design with details on the number of years, treatments, and replications. The data from the experiment were subjected to a combined analysis of variance, and the comparison of means was performed using Duncan's multiple range test at the 5% probability level.

Table 1. Characteristics of the experimental treatments based on the planting arrangement and irrigation method

Irrigation method	Planting arrangement and spacing	Treatment
Full (irrigation of all furrows at each turn)	Single row, row spacing 60 cm	**I1**
One-in-between	Single row, row spacing 60 cm	**I2**
Full (irrigation of all furrows at each turn)	Single row, row spacing 50 cm	**I3**
One-in-between	Single row, row spacing 50 cm	**I4**
One-sided (irrigation from one side of the ridge)	Double row on a ridge (total spacing 100 cm)	**I5**
One-sided (irrigation from one side of the ridge)	Double row on a ridge (total spacing 90 cm)	**I6**

3-Results and Discussion

The results of the combined analysis of variance for the qualitative data over the two years of the experiment (Table 2) showed that the "year" factor had a significant effect on most of the studied traits. This factor was significant at the 1% level for Pol, potassium, sodium, harmful nitrogen, juice purity, and molasses sugar, indicating climatic variations between the two years of the experiment. However, the effect of year on alkalinity and sugar percentage was not significant.

The main factor of the study, namely "irrigation and planting arrangements," had a highly significant effect ($p < 0.01$) on the concentration of potassium, sodium, harmful nitrogen, alkalinity, juice purity, and molasses sugar, and was also significant at the 5% level for sugar percentage. A noteworthy point was that the effect of the treatments on Pol, which represents the initial sucrose concentration in the root, was not statistically significant. This finding indicates that although the applied treatments could not alter the fundamental sucrose concentration, they significantly affected the level of impurities and the calculated qualitative juice indices that are vital for the sugar industry.

Table 2. Analysis of variance of qualitative results of samples

Analysis of variance								
MS	Purity	SUGAR	ALC	N	Na	K	POL	df

									Source of Variation
3.37^{ns}	89.44^{ns}	0.15^{ns}	0.056^{ns}	8.11	8.13	2.89	4.95	1	Year
0.05	4.26	0.87	0.15	0.37	0.21	0.86	0.57	6	Year × Treatment
0.47	16.56	1.37	0.62	2.90	0.74	0.82	0.19^{ns}	5	Treatment
0.04	2.36	0.34	0.19	0.42	0.15	0.57	0.22	30	Error
7.36	1.84	4.23	17.25	18.41	18.54	4.49	2.85		CV
2.72	83.45	13.81	2.5	3.52	2.09	5.72	16.53		Mean

Significant at the 5% level Significant at the 1% level n.s Not significant

3-1. Pol (POL)

Based on the results of the analysis of variance, the effect of different irrigation and planting arrangement treatments on the Pol or sucrose concentration of sugar beet juice was not statistically significant ($p > 0.05$). This indicates that irrigation management and changing the planting spacing in this study could not significantly affect the amount of sugar stored in the root.

Table 2. Comparison of Means of Samples Under Different Treatments

Treatment	POL (°)	K (g/kg)	Na (g/kg)	N (g/kg)	ALC (%)	SUGAR	Syrup purity	MS
I1	16.56 (ns)	6.11 a	2.59 a	4.41 a	2.32 ab	13.45 ns	81.08b	3.11 a
I2	16.61 (ns)	5.71 b	2.31 ab	3.61 abc	2.45 ab	13.82 ns	83.04ab	2.80 b
I3	16.34 (ns)	5.51 bc	2.08 ab	3.01 c	2.71 ab	13.74 ns	84.03a	2.60 bc
I4	16.35 (ns)	5.27 c	1.88 b	2.88 c	2.81 a	13.92 ns	85.07a	2.44 c
I5	16.74 (ns)	5.65 b	1.79 b	3.17 bc	2.67 ab	14.19 ns	84.59a	2.56 bc
I6	16.74 (ns)	6.05 a	1.90 b	4.01 ab	2.07 b	13.73 ns	82.89ab	2.82 b

Values with the same letter (a, b, c, etc.) in each column are not significantly different (comparison test).ns = not significant.

3-2. Potassium (K)

The experimental treatments had a highly significant effect ($p < 0.01$) on the potassium concentration of the juice. Comparison of the means showed that the highest amount of potassium (6.11 g/kg) was observed in treatment I1 (60 cm spacing and full irrigation), and the lowest (5.27 g/kg) was observed in treatment I4 (50 cm spacing and alternate irrigation) (Figure 1). This reduction in potassium concentration in treatment I4 could contribute to improving juice purity.

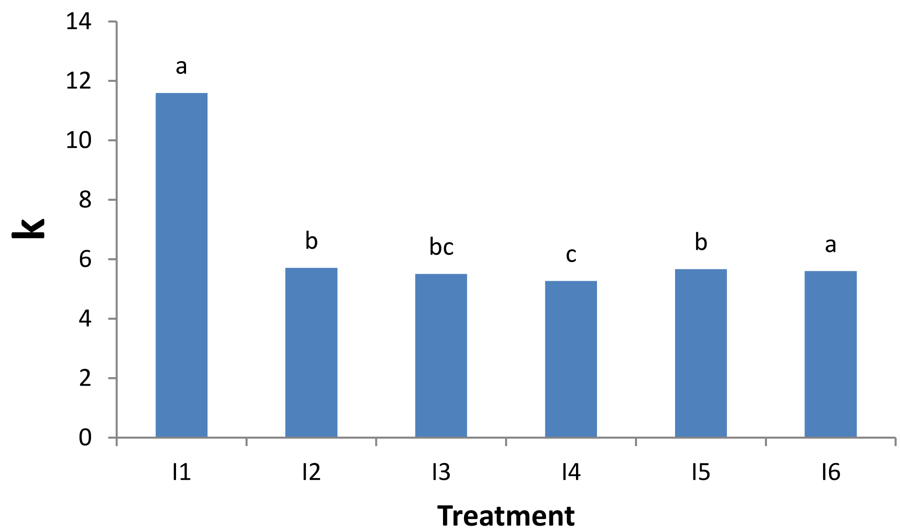

Figure 1. Comparison of the average potassium of the treatments

3-3. Sodium (Na)

The sodium concentration of the juice was also significantly affected by the treatments ($p < 0.01$). The highest level of sodium (2.59 g/kg) belonged to treatment I1, while the lowest amount (1.88 g/kg) was recorded in treatment I4 (Figure 2). This pattern was similar to the results for potassium and indicates that treatment I4 was more effective in reducing this important impurity.

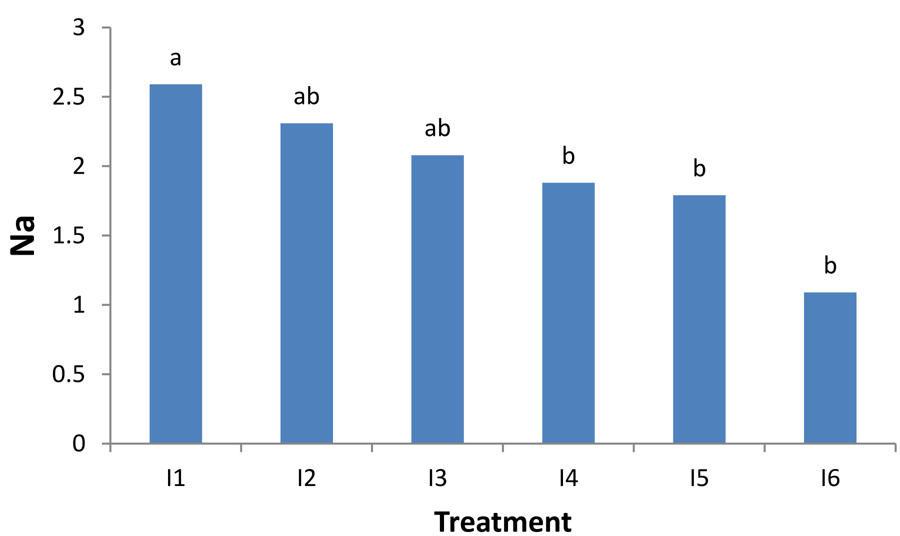

Figure 2. Comparison of the average Sodium of the treatments

The results of this research indicated that treatment I4 (50 cm row spacing and alternate irrigation) was associated with the significantly lowest concentrations of both potassium and sodium in the sugar beet juice. This finding is consistent with previous research that emphasizes the impact of growth resource management on juice quality. For example, Manzour et al. (2023), in their study on optimizing sugarcane quality under stress conditions, showed that proper management of water and nutrition can significantly reduce mineral impurities. Furthermore, the study by Moghaddam et al. (2021), which addressed the combined application of potassium and zinc, demonstrated that the balance of nutrients and growth conditions plays a key role in determining impurity concentrations. The reduction in the concentration of these two ions in treatment I4 indicates that the combination of denser planting spacing and alternate irrigation is an effective strategy for controlling the uptake of these impurities.

From a physiological perspective, this phenomenon can be attributed to two main factors: controlled water stress and root competition. Alternate furrow irrigation creates wet and dry cycles in the soil [24, 25]. During the dry periods, water uptake by the roots is reduced, and consequently, the passive transport of highly soluble and mobile ions like potassium (K+) and sodium (Na+) into the plant is severely restricted [18, 26]. Under these conditions, the plant manages nutrient uptake more selectively and actively [27]. On the other hand, a 50 cm row spacing increases plant density and competition among roots for water and nutrient resources. This competition forces the root system to develop more efficiently and absorb nutrients more targetedly, resulting in reduced excessive uptake of non-essential or harmful ions.

The industrial importance of this finding is significant. Potassium and sodium are known as "main impurities" in the sugar industry [28, 29]. These ions combine with sucrose during the sugar extraction process, leading to an increase in "molasses purity" [30, 31]. The higher the molasses purity, the more sucrose remains in the molasses and is removed from the extraction process. Therefore, reducing the concentration of K and Na in the raw juice directly leads to increased factory efficiency, reduced energy consumption in the purification stages, and, ultimately, higher production of white sugar per ton of beet [32]. This aligns perfectly with the goals of sugar supply chain optimization proposed by Najafi et al. (2021) and introduces treatment I4 as a sustainable agricultural solution for enhancing the industrial quality of the product.

3-4 Harmful Nitrogen (N)

The treatments had a significant effect on harmful nitrogen concentration at the 1% level. The results indicated that treatment I6 (double-row cultivation on ridges with 90 cm spacing) had the highest harmful nitrogen content (4.01 g/kg), whereas treatment I4 showed the lowest value (2.88 meq/L), demonstrating the best performance in reducing non-sucrose nitrogen compounds (Figure 3).

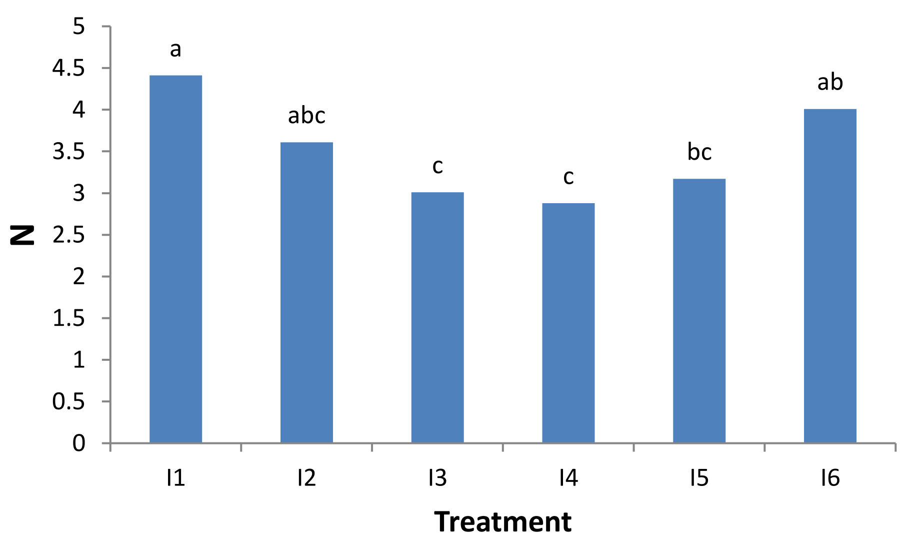

Figure 3. Comparison of the average Nitrogen harmful.of the treatments

3-5. Alkalinity (ALC)

Juice alkalinity, which represents the sum of alkaline cations, was significantly affected by the treatments ($p < 0.05$). The highest alkalinity (2.07%) was observed in treatment I6, while the lowest (2.81%) was found in treatment I4 (Figure 4), which once again emphasizes the superiority of treatment I4 in reducing mineral impurities.

Based on the results, the lowest levels of harmful nitrogen and alkalinity were also observed in treatment I4, while treatment I6 (double-row planting on a ridge with 90 cm spacing) had the highest values for these two indices. These results are consistent with research that emphasizes the impact of agronomic management on nitrogenous impurities [17, 33, 34]. Talaghani et al. (2024) specifically showed that different nitrogen levels and irrigation conditions significantly affect the amount of harmful nitrogen impurities in sugar beet. The findings indicate that even with a constant fertilization rate, irrigation method and planting arrangement can act as powerful tools for managing the uptake and accumulation of these compounds. Furthermore, Kazet Korbat et al. (2018), in their investigation of sugar by-product contaminants, highlighted the importance of monitoring nitrogenous compounds, and our results confirm the necessity of managing them in the field.

The explanation for this phenomenon is similar to that for potassium and sodium, but with key differences. Harmful nitrogen mainly consists of amino acids and amides, which are products of nitrogen metabolism in the plant [35]. Under mild water stress conditions caused by alternate irrigation, the plant's vegetative growth slows slightly, and the absorbed nitrogen, instead of being converted into structural proteins, is directed towards the synthesis of protective compounds and accumulates as free amino acids [36, 37]. However, it seems that in treatment I4, the stress level was controlled enough that the plant could utilize these compounds in its metabolic cycle and prevent their excessive accumulation [38]. In contrast, treatment I6, with a high density of 110,000 plants per hectare, likely experienced a different type of stress condition due to intense competition, leading to protein breakdown and an increase in harmful nitrogen levels in the root. Alkalinity is also directly related to the concentration of alkaline cations (K^+ and Na^+), and its reduction in treatment I4 is a direct result of the decrease in these ions.

The industrial importance of reducing harmful nitrogen and alkalinity is even greater than that of reducing potassium and sodium. Harmful nitrogen severely stimulates unwanted reactions during the sugar extraction process [19, 39]; these compounds react with reducing sugars (Maillard reaction), causing juice darkening and increasing the color of the final product [39]. Additionally, during the carbonation stage, harmful nitrogen reacts with lime, increasing lime consumption [40], which in turn raises operational costs [41, 42]. Therefore, by reducing these two indices, treatment I4 not only improves the quality of the raw juice but also reduces processing costs and contributes to the production of sugar with better color and higher purity. This demonstrates the high potential of farm management to achieve sustainability and efficiency goals in the sugar industry.

3-6. Sugar Percentage (SUGAR)

The extractable sugar percentage was significantly affected by the treatments ($p < 0.05$). Based on the results, the highest sugar percentage (14.19%) was obtained in treatment I5 (double-row planting on a ridge with 100 cm spacing), while the lowest value (13.45%) belonged to treatment I2 (60 cm spacing and alternate irrigation) (Figure 5).

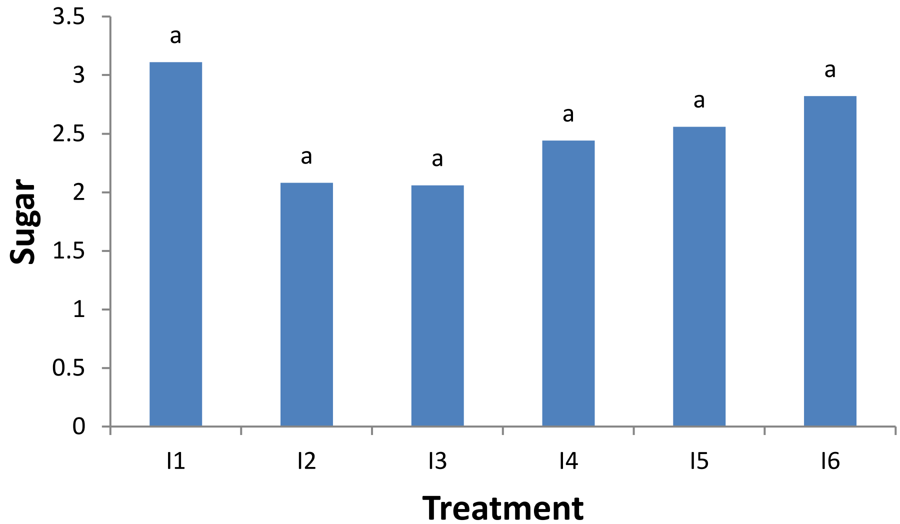

Figure 5. Comparison of the average Sugar of the treatments

3-7. Juice Purity (Purity)

Juice purity, as one of the most important qualitative indices, showed a highly significant response ($p < 0.01$) to the treatments. The highest purity (85.07%) was achieved in treatment I4, which was statistically in the superior group. Treatments I3 and I5 also had high purity (84.03% and 84.59%, respectively), while the lowest purity (81.08%) belonged to treatment I1 (Figure 6).

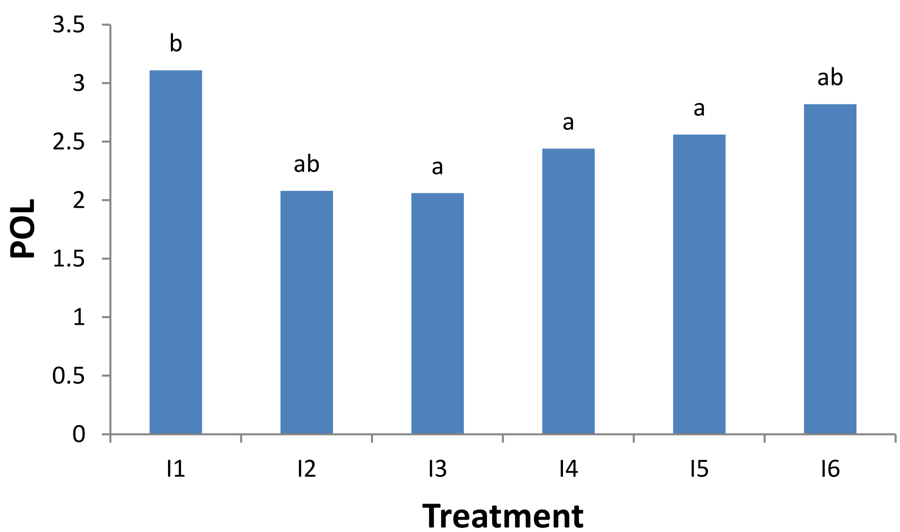

Figure 6. Comparison of the average POL of the treatments

3-8. Molasses Sugar (MS)

The predicted amount of sugar remaining in molasses (MS) was also highly significantly affected by the treatments ($p < 0.01$). The most desirable result (the lowest amount of sugar in molasses) was achieved in treatment I4 with a value of 2.44% (Figure 7), indicating higher sugar extraction efficiency in this treatment. In contrast, treatment I1, with 3.11% sugar in molasses, predicted the highest amount of sugar loss to molasses.

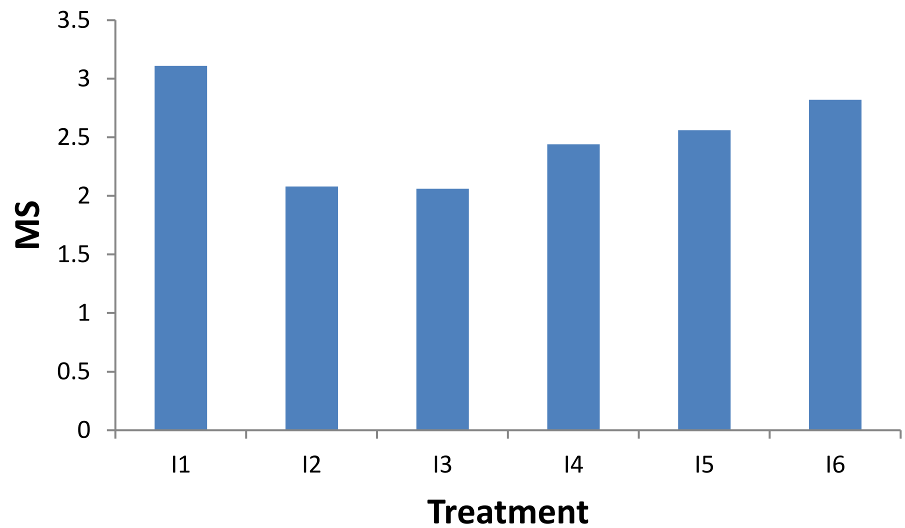

Figure 7. Comparison of the average MS of the treatments

The most important finding of this research was the highly significant effect of the treatments on juice purity; treatment I4 had the highest quality with a purity of 85.07%, while treatment I1 had the lowest quality with a purity of 81.08%. These results are perfectly aligned with the ultimate goal of qualitative research in the sugar industry. Zakidizaji et al. (2021) used purity as one of the most important indices for predicting sugarcane juice quality [3] and showed that this criterion is directly related to the quality of refined sugar. Furthermore, Dagbeh et al. (2020) emphasized the importance of value creation from by-products like molasses [1], and reducing the sugar present in molasses (MS) directly contributes to this goal. Our finding of the lowest MS in treatment I4 (2.44%) compared to I1 (3.11%) demonstrates the success of this treatment in increasing sugar extraction efficiency.

The analysis of these results is the cumulative effect of all previous changes. Since the analysis of variance showed that Pol or the initial sucrose concentration was not affected by the treatments, the significant increase in purity in treatment I4 is solely due to the reduction of non-sugars. By successfully reducing the concentration of potassium, sodium, harmful nitrogen, and alkalinity, the ratio of sucrose to the total soluble solids (Brix) in the juice increased, which is the very definition of higher purity. The main reason for the superiority of I4 can be attributed to the greater reduction of mineral impurities (K and Na). In other words, treatment I4 succeeded in producing a "cleaner juice." The molasses sugar (MS) index is also a computational index that is inversely related to purity; the higher the purity, the less sucrose is trapped by impurities and enters the molasses stream [19, 43].

The industrial importance of these indices is undeniable. Juice purity is the primary criterion for the purchase and pricing of sugar beets by factories and the main determinant of the overall efficiency of the sugar production process [44]. A 4% increase in purity (from 81% to 85%) means producing several tons more sugar on an industrial scale, without needing to increase the cultivated area or root yield. This directly impacts the factory's profitability and the efficiency of the entire supply chain, as emphasized by Najafi et al. (2021) and Namdari et al. (2024) [4]. Therefore, treatment I4 is not only a solution for saving water consumption but also a smart agricultural strategy for enhancing the quantitative and qualitative quality of the product and optimizing the entire sugar production system.

3-9. Conclusion

This research was conducted to evaluate the simultaneous effects of irrigation conditions and planting arrangements on the physicochemical properties and purity indices of sugar beet juice. The key finding of this research indicates that although the fundamental sucrose concentration (Pol) did not change significantly under different treatments, the strategic management of irrigation and planting density had a profound impact on the juice's impurity profile and, consequently, its industrial quality. Specifically, the combination of 50 cm row spacing with alternate irrigation (treatment I4) was identified as the superior strategy. This approach effectively prevented the accumulation of key non-sugar impurities, namely potassium, sodium, and nitrogenous compounds. From the perspective of food industry technology and processing, this finding is extremely important. The significant reduction of these impurities directly led to a meaningful increase in juice purity (up to 85.07%) and a simultaneous decrease in the predicted sugar in molasses (down to 2.44%). This indicates that treatment I4 provides a higher-quality raw material for sugar factories, requiring less intensive processing, lower consumption of chemicals (like lime), and ultimately, increased overall efficiency and yield of refined sugar. These results are fully consistent with the goals of sugar supply chain optimization and enhancing the quality of final products. The significance of these findings extends beyond immediate quality indices and presents a practical model for sustainable development in sugar beet cultivation. Treatment I4 is a dual-purpose solution that simultaneously addresses the critical challenge of water scarcity by reducing water consumption volume by approximately 40% while producing a product with higher industrial value. This achievement is an evidence-based and practical recommendation for producers in arid and semi-arid regions, such as the Khoy area, who are seeking to increase economic efficiency under water crisis conditions. Ultimately, this study demonstrates that precise water management, when combined with optimal planting geometry, is not only a tool for maintaining yield but also a critical lever for enhancing the intrinsic quality of sugar beet and creating a bridge between agricultural performance and industrial excellence in the food industry sector.

Data Availability

The data used to support the finding of this study are available from the corresponding author upon request.

Conflict Of Interest

The authors have no conflicts interest to report.

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مقاله علمی_پژوهشی

ارزیابی ویژگی‌های فیزیکوشیمیایی و شاخص‌های خلوص شربت چغندرقند در شرایط مختلف آبیاری

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چکیده

پژوهش حاضر با هدف ارزیابی ویژگی‌های فیزیکوشیمیایی و شاخص‌های خلوص شربت چغندرقند تحت شرایط مختلف آبیاری انجام شد. این مطالعه با اجرای شش تیمار آبیاری متفاوت شامل ترکیب‌های مختلف فاصله خطوط کاشت و دور آبیاری (کامل و یک در میان) انجام گرفت. نمونه‌های چغندرقند برداشت شده برای تعیین پارامترهای فیزیکوشیمیایی شامل میزان پتاسیم، سدیم، ازت مضر، قلیاییت، درصد شکر، خلوص شربت و قند موجود در ملاس مورد تجزیه و تحلیل قرار گرفتند. نتایج نشان داد که تیمارهای دارای فاصله خطوط ۵۰ تا ۶۰ سانتی‌متر و آبیاری یک در میان (I4) بیشترین میزان خلوص شربت (۸۳–۸۵٪) و درصد شکر (۱۳–۱۴٪) را ارائه نمودند ($p<0/05$)، در حالی که مقادیر پتاسیم، سدیم و ازت مضر نیز در این تیمارها در محدوده قابل قبول قرار داشتند. تفاوت‌های معنی‌دار بین تیمارها برای شاخص‌های خلوص شربت و درصد شکر مشاهده شد ($p<0/05$)، اما پارامترهایی مانند پتاسیم و قلیاییت در برخی تیمارها تفاوت معناداری نداشتند ($p>0/05$). یافته‌های این تحقیق نشان می‌دهد که مدیریت بهینه آبیاری و انتخاب فاصله مناسب خطوط کاشت می‌تواند علاوه بر افزایش کارایی مصرف آب، کیفیت شربت چغندرقند را نیز بهبود بخشد. این نتایج می‌تواند به عنوان راهنمایی عملی برای تعیین تیمارهای آبیاری مؤثر در شرایط اقلیمی مشابه مورد استفاده قرار گیرد.