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# Influence of Sugar Beet Nitrogen Content on Quality and Efficiency of Sugar Extraction

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## ABSTRACT

The present study highlights on the effect of over nitrogen content on beet sugar quality, sugar content, alkalinity, impurity value, raffinose formation, chemical impurities especially (Na) ions and the loss of sugar in molasses. The results showed that nitrogen content must be done in the way that causes a high productivity of roots with a high content of sucrose and pureness percentages with low levels of vegetarian growth levels. Also, the acceptable values of α-amino N, K and Na in roots for processing must be about 150, 140 and 700 -1000 mg $100g^{-1}$ sugar, respectively. One of the greatest effects is the increment the loss of sugars to molasses rate as a result of the increment of sucrose solubility hence decrement in crystallization. Therefore, this study recommends not to overuse nitrogen fertilization because the increase of the nitrogen inside the roots inhibits the processes of crystallization process hence, decreasing the quality of sugar extraction process.

**Keyword:** Nitrogen content - non-sugar impurities- root yield - sucrose content – sugar beet.

## INTRODUCTION

Beat (*beta vulgaris L.*), which is considered a temperate crop, then it was spread in subtropical countries and it is able to successfully grown via the winter time. It contributes about 21.8% of world sugar. Numerous ecological and agronomical agents effect on sugar beet yield and quality. Nitrogen considered as one of the greatest effective nutrients in sugar beet harvest, determining the productivity of white sugar. Moderate N fertilization encourages the growth level of shoots instead of the growth of roots and the accumulation of sucrose. While, the excessive N addition is responsible for high α-amino N and very high Na concentrations in sugar beet roots. Adding nitrogen in a limited level may cause a constricted in the vegetarian growth levels, minimal in the yield of the fresh roots with a high content of sucrose and pureness of juice. Nitrogen content may be lead to lose in the juice alkalinity hence, decreasing its thermostability, increasing molasse lose and decreasing the quality of white sugars via forming melanoidines colors (Martın-Olmedo, 2001).The presences of great percentages of nitrogen in the soil enhance the vegetarian growth levels and increment the fresh weight of roots; however, decrease the roots technological quality parameters. The optimum nitrogen inputs in sugar beet and thus the efficacy of N using is sufficiently influenced by the annual variation of weather (De Koeijer *et al*., 2003).

Researches has shown that the optimal nitrogen dose, which may produce maximum yield and best root quality parameters (sucrose, K, Na, α-amino N concentrations) under Egyptian conditions is 75-80 kg/fad of nitrogen (Shrivastava, 2006 and Anonymous, 2013). During the processing of sugar beets, one of the most important raw substance technological parameter is deleterious nitrogen.

Sugar beets soluble nitrogen substances, which cannot be removed via purification of juice, may be lead to increment the thickness of juice and reduce the recovery rate of sugar. The main factor determining sugar beet yield as well as its technological quality is fertilization. Sodium and potassium in the roots of sugar beet are also the major molassigenic agent causing an increment in losses of sugar rate. However, the prior studies revealed that, Na and K percentages into the roots of sugar beet were influenced mostly with the location and the year of cultivation and not only with fertilizing even while Na and K fertilization was used. The acceptable roots on a commercial range for processing stage must have a concentration of K in the range of 0.7 to 1%. Na absorbance may be useful for the growth of sugar beet when the soil contains a lower Na concentration than 25 mg /100g soil. In addition, At semi-arid zones, like the Mediterranean, especially beneath irrigation systems, Na+ percentages (50-100 mm) may have a negative influence on the growth and quality parameters (Milford *et al*., 2000, Mahn & Hoffmann, 2001 and Francis, 2006). Accordingly, the aim of sugar beet processors world-wide is to produce pure sugar, at least expense, from the roots which they have purchased and which represent their major manufacturing cost.

This work was aimed to assessment the influence of nitrogen content on the quantitative (the weight of fresh beets and the yield of sugar) and qualitative (K, sucrose content, α-amino N and Na) of sugar beets cultivated under Egyptian climate.

## MATERIALS AND METHODS

**1. Materials**

The delivered heterogeneous well- topped beet which have been performed through the working season 2016, in Delta Sugar Company, Elhamoul Mill, Kafr-Elsheikh Governorate, Egypt were used in this study.

**2. Methods**

**1. Chemical analysis**

The extracted juice was analyzed daily for sugar polarity, sodium, potassium, α-amino nitrogen, apparent and true sucrose, invert sugar and raffinose. The campaign is divided into 8 periods, and each consists of 10 days. Total soluble solids (TSS) of beet juice were determined by using a fully automatic digital refractometer, model RX-5000 (ATAGO Co., LTD). Apparent purity percentage (%) was determined as a ratio between sucrose % and TSS% of roots according to a reported method of Carruthers and Oldfield (1960).

The concentrations of sucrose, potassium, sodium and α -amino nitrogen were determined from automatically homogenized beet brei, prepared by means of the mechanical saws and analyzed by an automatic beet laboratory system (clarified by aluminum sulphate for each section by an automatic beet laboratory system (Venema Groningen, NL) using Venema Analyzer III G. Sucrose content was determined polarimrtrically according to ICUMSA (1994).

Potassium and sodium were determined by flame-photometry (Minilyser. Fa. Venema) according to ICUMSA (1994) and α- amino nitrogen was determined by the fluorometric OPA-method (Burba and Georgi, 1976). True sucrose, Raffinose and inverted sugar contents were determined as described by Asadi (2007) according to the following equations:

**% True sucrose = (0.512 DP- IP/0.839)**

**% Raffinose = (0.33 DP + IP/1.563)**

**Where:**

**DP is the direct polarization and IP is the invert polarization.**

**%Invert sugar= (ml thiosulfate Blank – ml thiosulfate sample – 0.2)/g Sample×10**

Impurity value (IV) was determined based on the formula of Carruthers and Oldfield (1962) and the formula of Carruthers and Oldfield (1961) respectively.

**Impurity value (mg/100 g sugar) = (2.5K + 3.5Na + 10 αN)**

**Where: Na, K and α-N were expressed as mg /100 g of sugar.**

Quality index %, sugar losses in molasses %, total sugar losses %, Alkalinity coefficient % and sugar recovery % were determined according to reference of Reinefeld *et al.* (1974). These parameters were used to estimate the following equations:

**Quality index = 100 [100 – (D/Pol)]**

**Sugar loss in molasses % = 0.343 (K+ Na) + 0.094 (α -amino N) - 0.31**

**Total sugar losses %( D) = 0.343 (K+Na) + 0.094 (α -amino N) + 0.29**

**Alkalinity coefficient (AC) % = (K+ Na) / (α -amino N)**

**Theoretical sugar recovery % = Pol - 0. 29- 0.343(K+ Na) - 0.094 (α -amino N)**

**where,**

**K + Na is sum of potassium and sodium concentration in beet (mmol /100g in beet fresh matter), α-N is α-amino-N concentration in beet (mmol /100g in beet fresh matter), Pol is sucrose concentration (% in beet fresh matter) and D is total sugar loss % .**

**2. Statistical analysis**

Data collected for yield and quality of sugar beet were subjected to the statistical analysis according to Steel and Torrie (1980) and all means were compared at least significant differences (LSD) at 5% & 1 % levels of probability.

## RESULTS AND DISCUSSION

**1. Egyptian sugar beet quality parameters**

Beet quality is a complex process that is influenced by many factors. The technical quality of beets is essential for the economical production of sugar. Particularly, this relied on the beetroot chemical composition. It considered as an important factor to assess the chemical quality of beet and their quality of sugar productivity (Tawfik *et al*., 2010).

Regarding to the attained results shown in Table (1) the highest K contents in beets roots was 6.47 mmol /100 g beet in period 1. On the other hand, the lowest values of 6.13 mmol/100 g beet was observed in period 5 during the working season 2016, with over all mean of 6.24 mmol/100 g beets.

**Table 1. Effect of major chemical components of sugar beet roots on the alkalinity coefficient.**

| Period No. | Cation and anion content in(mmol /100 g beet ) | | | Sugar polarity(%) | Alkalinity Coefficient (AC) |
|---|---|---|---|---|---|
| | W ( k) | W (Na) | W (α-N) | | |
| 1 | 6.47 | 3.10 | 3.54 | 18.25 | 2.73 |
| 2 | 6.20 | 2.76 | 3.92 | 18.30 | 2.31 |
| 3 | 6.20 | 2.49 | 3.76 | 18.62 | 2.35 |
| 4 | 6.16 | 2.26 | 3.26 | 18.83 | 2.60 |
| 5 | 6.13 | 2.15 | 3.63 | 18.70 | 2.28 |
| 6 | 6.19 | 2.14 | 3.34 | 18.97 | 2.51 |
| 7 | 6.22 | 2.33 | 3.91 | 18.60 | 2.20 |
| 8 | 6.39 | 2.65 | 4.16 | 18.88 | 2.18 |
| A.v | 6.24 | 2.49 | 3.69 | 18.64 | 2.40 |
| L.S.D 5% | 0.12 | 0.10 | 0.28 | 0.19 | 0.12 |
| L.S.D 1% | 0.16 | 0.13 | 0.37 | 0.26 | 0.16 |

**Each period represented ten days and every day referred a mean of seven hundred replicates.**

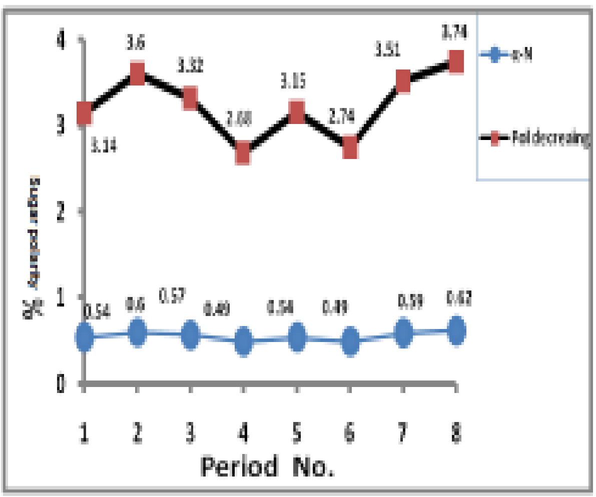


**Fig. 1. Effect of Egyptian sugar beet α- amino nitrogen on the sugar polarity during different periods.**

These results are in accordance with those reported by Milford *et al*. (2000)., who referred that the acceptable roots on a commercial range for processing stage must have a concentration of K in the range of 0.7 to 1%. Similar results are in line with recorded by Ferweez *et al.* (2006), who stated that the delaying of crop delivery to factory had a significant effect on pol %, alpha amino nitrogen, Na, K contents and sugar loss %.

From the results recorded in Table (1), it could be noticed that, maximum value of sodium content was 3.10 in period 1, while minimum value was 2.14 mmol/100 g beet in period 6. The overall mean was 2.49 mmol/100 g beets. The increase of Na content may be due to the high loss of moisture during storage. Such finding coincide those reported by Maslaris and Tsialtas (2005), who stated that the soils in semi-arid zones may contain high levels of Na. For this reason, the growth of sugar beets could be repressed by the excess levels of Na in soils or roots.

The data in Table (1) show that the highest α-amino-N contents in roots (4.16 mmol /100g) were noticed in period 8 and the lowest value (3.26 mmol/100g observed in period 4. Moreover, the overall mean was 3.69 mmol/100 g. the bets will be acceptable if there content of α-amino-N were not higher than 2.14 and2.86 mmol/100 g root for mineral and organic soils. Europabio (2003) stated that the non-sucrose components most relevant for technical quality of sugar beet are potassium, sodium and alpha-amino nitrogen. On the other hand, Darrin *et al.* (2008) reported that there is a general tendency to increase the percentage of nitrogen on dry matter basis in sugar beet roots by prolonging the storage period.

**2. Effect of α- amino nitrogen of Egyptian sugar beet on the sugar polarity.**

Regarding to the attained results shown in Table (2) and Figure 2 the overall mean of α-amino nitrogen during the working season 2016 was 3.69 mmol/100 g beets which leads to a decrease in the beet sugar polarity by about 3.24 %. These results are in accordance with literature Dutton and Bowler (1984), who stated a decrement in sugar content of beets (0.8%) as a function to the increment to of 100 mg amino nitrogen /100g. to achieve the highest yield they proposed that the main target should be to set an upper limit of 150 and 200 mg N/100 g sugar for mineral and organic soils, respectively.

**Table 2. Effect of α - amino nitrogen of sugar beet roots on the sugar content.**

| Period No. | Cation and anion content in (mg % sugar ) | | | Sugar polarity (%) | Max.( α-N) (mg % sugar) | Increasing of (α-N) (mg % sugar) | Polarity decreasing(%) |
|---|---|---|---|---|---|---|---|
| | W(k) | W(Na) | W(α-N) | | | | |
| 1 | 1382 | 391 | 543 | 18.25 | 150 | 393 | 3.14 |
| 2 | 1322 | 347 | 600 | 18.30 | 150 | 450 | 3.60 |
| 3 | 1299 | 308 | 566 | 18.62 | 150 | 416 | 3.32 |
| 4 | 1275 | 276 | 485 | 18.83 | 150 | 335 | 2.68 |
| 5 | 1279 | 264 | 544 | 18.70 | 150 | 394 | 3.15 |
| 6 | 1273 | 260 | 492 | 18.97 | 150 | 342 | 2.74 |
| 7 | 1305 | 288 | 588 | 18.60 | 150 | 438 | 3.51 |
| 8 | 1319 | 323 | 618 | 18.88 | 150 | 468 | 3.74 |
| A.v | 1307 | 307 | 554 | 18.64 | 150 | 404 | 3.24 |
| L.S.D 5% | 25.89 | 13.11 | 42.87 | 0.19 | - | - | 0.34 |
| L.S.D 1% | 34.37 | 17.41 | 56.91 | 0.26 | - | - | 0.46 |

**Each period represented ten days and every day referred a mean of seven hundred replicates.**

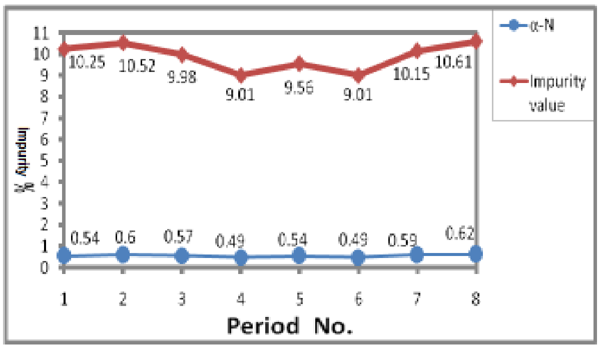


**Fig. 2. Effect of Egyptian sugar beet sucrose and major non sugar components on the impurity value**

The data shown in Table (3) revealed a highly significant difference for raffinose content among the eight periods during the 2016 campaign. Maximum raffinose content (0.58%) was noticed in period 8 and minimum value 0.36% in period 5 with an average of 0.45%. These results are in agreement with those confirmed by some authors Martin *et al.* (2001), who reported that during storage, raffinose concentrations change with the magnitude and direction of change dependent on storage conditions. Such finding agreement with the results reported by Abdel-Rahman (2007) and Darrin *et al.* (2008), where raffinose was found to impact negatively the sugar beet processing by decreasing extractable sucrose yield and altering sucrose crystal morphology which reduces filtration rates and slows processing. Moreover, raffinose has the characteristics of a prebiotic, similar to other non-digestible oligosaccharides such as fructo-oligosaccharides and galacto-oligosaccharides.

**Table 3. Effect of α - amino nitrogen on the raffinose content.**

| Period No. | Cation and anion content in (mmol /100 g beet ) | | | Sugar polarity (%) | Alkalinity Coefficient (AC) |
|---|---|---|---|---|---|
| | W ( k) | W (Na) | W (α-N) | | |
| 1 | 6.47 | 3.10 | 3.54 | 18.25 | 2.73 |
| 2 | 6.20 | 2.76 | 3.92 | 18.30 | 2.31 |
| 3 | 6.20 | 2.49 | 3.76 | 18.62 | 2.35 |
| 4 | 6.16 | 2.26 | 3.26 | 18.83 | 2.60 |
| 5 | 6.13 | 2.15 | 3.63 | 18.70 | 2.28 |
| 6 | 6.19 | 2.14 | 3.34 | 18.97 | 2.51 |
| 7 | 6.22 | 2.33 | 3.91 | 18.60 | 2.20 |
| 8 | 6.39 | 2.65 | 4.16 | 18.88 | 2.18 |
| A.v | 6.24 | 2.49 | 3.69 | 18.64 | 2.40 |
| L.S.D 5% | 0.12 | 0.10 | 0.28 | 0.19 | 0.12 |
| L.S.D 1% | 0.16 | 0.13 | 0.37 | 0.26 | 0.16 |

**Each period represented ten days and every day referred a mean of seven hundred replicates.**

**4. Effect of sugar beet sucrose and major non sugar components on the impurity value.**

The results shown in Table (4) and Figure (2) summarize the average values of sucrose and major non–sugar components of the Egyptian sugar beet. The results indicate that the impurity value gave high significant differences along the eight periods during the working season2016. Impurity value ranged from 9.01 to 10.61 with an average of 9.89 mg % sugar overall the working season. The elevation in the impurity value largely reflects increasing the concentration of the amino compounds caused by excessive uptake of nitrate late in the season. These results are in agreement with those of Kenter and Hoffmann (2006) and Seadh *et al*. (2007), who stated that due to the increased level of nitrogen fertilizers, the sucrose content decreases gradually in the root due to the reduction of sucrose and the exact percentage of proteins and nitrogen in non-sucrose substances, such as amino acids. Moreover, the fact is that increased nitrogen levels increase the ability to keep water in the roots of the tap, and vice versa, the percentage of fresh sugar cane is also reduced.

**Table 4. Effect of α-amino nitrogen of sugar beet roots on the impurity value.**

| Period No. | Cation and anion content in (mg % sugar | | | Sugar polarity (%) | Impurity value (mg % sugar) |
|---|---|---|---|---|---|
| | W ( k) | W (Na) | W (α-N) | | |
| 1 | 1382 | 391 | 543 | 18.25 | 10.25 |
| 2 | 1322 | 347 | 600 | 18.30 | 10.52 |
| 3 | 1299 | 308 | 566 | 18.62 | 9.98 |
| 4 | 1275 | 276 | 485 | 18.83 | 9.01 |
| 5 | 1279 | 264 | 544 | 18.70 | 9.56 |
| 6 | 1273 | 260 | 492 | 18.97 | 9.01 |
| 7 | 1305 | 288 | 588 | 18.60 | 10.15 |
| 8 | 1319 | 323 | 618 | 18.88 | 10.61 |
| A.v | 1307 | 307 | 554 | 18.64 | 9.89 |
| L.S.D 5% | 25.89 | 13.11 | 42.87 | 0.19 | 0.42 |
| L.S.D 1% | 34.37 | 17.41 | 56.91 | 0.26 | 0.56 |

**Each period represented ten days and every day referred a mean of seven hundred replicates.**

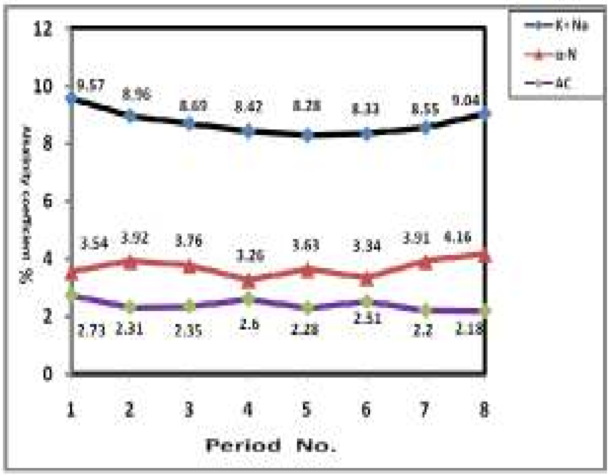


**Fig. 3. Effect of Egyptian sugar beet sucrose and major non- sugar components on alkalinity coefficient (AC).**

Data from Table (4) and Figure (3) postulate the average chemical analysis sucrose and major non–sugar components of the Egyptian heterogeneous sugar beet materials. The results indicate that the alkalinity coefficient gave high significant differences along the eight periods during the working season 2016. Alkalinity coefficient values ranged from 2.18 to 2.73 with an average of 2.40 overall the season. Similar results are recorded by Van der Poe *et al*. (1998) who confirmed that The N components betaine, amino acids and amides lead to alkalinity losses in the juices, an increase in molasses sugar and a decrease in the quality of the crystalline sugar due to color formation (melanoides).

The data in Table (5) revealed a gradual increase in beet quality was noticed along the eight periods during 2016 campaign. Maximum Beet quality (81.75%) was seen in period 6, while the minimum (78.60%) observed in period 1 with an overall mean of 80.51 %. These results are close to those reported by Seadh *et al*. (2007).

These components interfere with the crystallization process, which causes a greater proportion of the sugars to be recovered as molasses with a reduction in refined sugar. Moreover, Abdel-Rahman (2007) and Malbaša *et al.* (2008) reported that these nitrogenous compounds affect the industrial purification of sucrose and contributes to the actual sugar so they affect the quality of sugar beet. The concentration of sucrose slightly increased at 8 °C because of dehydration. At 20°C sucrose percentage decreased due to high respiration loss at elevated temperature. The concentration of amino- N, invert sugar and raffinose increased.

The most sugar losses in sugar factories resulted from the sugar in molasses, which is not crystallized. It is estimated by the major non-sugar components in the beet. It is also important for stability of juice in the factory that the content of alpha-amino-N would be maintained low in relation to that of K and Na ions (Abo-Shady *et al*., 2010). Reducing sugars are undesirable because they break down during processing to yield organic acids, which in turn affect juice pH and subsequent processing requirements, with molassigenic consequences. In the same way, Dutton and Huijbregts (2006) found that molasses purity is affected by both the quality of the sugar beet and the factory's equipments. So, it is difficult to give an absolute definition for exhausted molasses.

**Table 5. Effect of chemical impurities on the loss of sugar in molasses and beet quality.**

| Period No. | Cation and anion content in (mmol /100 g beet ) | | | Sugar polarity (%) | Predicted sucrose losses in molasses % on beet ($m_{MS}$), total losses and quality index according to the Reinefeld assessment formula % on beet based on beet analysis | | |
|---|---|---|---|---|---|---|---|
| | W ( k) | W (Na) | W (α-N) | | Molasse loss ( % on beet ) | Total loss ( % on beet ) | Quality Index (%) |
| 1 | 6.47 | 3.10 | 3.54 | 18.25 | 3.30 | 3.90 | 78.60 |
| 2 | 6.20 | 2.76 | 3.92 | 18.30 | 3.13 | 3.73 | 79.59 |
| 3 | 6.20 | 2.49 | 3.76 | 18.62 | 3.03 | 3.63 | 80.53 |
| 4 | 6.16 | 2.26 | 3.26 | 18.83 | 2.88 | 3.48 | 81.49 |
| 5 | 6.13 | 2.15 | 3.63 | 18.70 | 2.87 | 3.47 | 81.44 |
| 6 | 6.19 | 2.14 | 3.34 | 18.97 | 2.86 | 3.46 | 81.75 |
| 7 | 6.22 | 2.33 | 3.91 | 18.60 | 2.99 | 3.59 | 80.70 |
| 8 | 6.39 | 2.65 | 4.16 | 18.88 | 3.18 | 3.78 | 79.97 |
| A.v | 6.24 | 2.49 | 3.69 | 18.64 | 3.03 | 3.63 | 80.51 |
| L.S.D 5% | 0.12 | 0.10 | 0.28 | 0.19 | 0.06 | 0.06 | 0.39 |
| L.S.D 1% | 0.16 | 0.13 | 0.37 | 0.26 | 0.08 | 0.08 | 0.52 |

**Each period represented ten days and every day referred a mean of seven hundred replicates.**

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## تأثير اضافة الأسمدة النيتروجينية على ناتج السكر ومحتوى المواد غير السكرية لمحصول بنجر السكر تحت الظروف المصرية

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**[1]شركة الدلتا للسكر**

**[2]معهد بحوث المحاصيل السكرية- مركز البحوث الزراعية-الجيزة**

سلط هذا البحث الضوء على تأثير المحتوي النيتروجيني في الجذورعلى جودة بنجر السكر، ومحتوى السكر، والقلوية، الرافينوز، والشوائب الكيميائية خاصة (أيونات الصوديوم) وفقدان السكر في المولاس. ومن ناحية أخرى، فإن هذه الدراسة توصي بأن يتم إدارة عملية التسميد الأزوتي لبنجر السكر لإنتاج جذور مرتفعة التركيز في السكروز ومستويات النقاء مع الحد الأدنى من النمو الأعلى. ونظرا للإضافات المفرطة من التسميد النيتروجيني في المناطق المزروعة شمال مصر التي تتركز فيها مصانع البنجر في ارتفاع تركيزات النيتروجين بسبب خلط المياه المروية مع مياه الصرف، فإن قيم الألفا- أمينو نيتروجين، N و K في الجذور سجلت حوالي ٥٥٠، ٣١٠ و ١٣٠٠ ملجم / ١٠٠ جرام من السكر، على التوالي. في حين أن القيم المقبولة للمعالجة كانت ١٥٠ و ١٤٠ و ٧٠٠ -١٠٠٠ ملغ ١٠٠ جم - ١ سكر، على التوالي. ويمكن أن يعزى التأثير السلبي للمواد غير السكرية أثناء المعالجة إلى عدة تأثيرات. أهم واحد هو زيادة فقدان السكر في المولاس عن طريق زيادة ذوبان السكروز وبالتالي تقليل التبلور وتسمى هذه الخاصية من هذه المواد Melassigenity. لذا توصي هذه الدراسة بعدم الإفراط في التسميد الأزوتي لما يترتب عليه من مشكلات في جودة عمليات إستخلاص السكر حيث أن زيادة الأزوت داخل الجذور يعيق عمليات البلورة.