Research article

Distribution of nitrogen compounds in important sections of sugar beets

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Abstract: *In literature the beet is often described as consisting of the following technologically important sections: crown, root and tail. The aim of the study was to determine the distribution of nitrogen compounds in the technologically important beet sections of untopped sugar beets with particular emphasis on the content of nitrate and nitrite. The Finezja sugar beet variety had been collected from the clamps in one of the Polish sugar factories in October during 2013/2014 campaign. The untopped sugar beets were divided into three sections: crown, root and tail. The content of total amount of nitrogen, proteinaceous nitrogen, α-amino nitrogen, the sum of the amide and ammonia nitrogen, nitrates and nitrite in these sections were determined. Although the crown of the sugar beet represented only 14.7% of it mass, this section contained on average 30% of the total quantity of α-amino acids as well as amide and ammonia nitrogen. This section contained approximately 77% of the total quantity of nitrate and 88% of nitrite. Untopped sugar beets would introduce much higher amounts of nitrogen compounds in comparison to topped raw material.*

Keywords: *sugar beet, topping, nitrate, nitrite, α-amino acids, amides.*

Introduction

Efficiency of the sugar production process depends mainly on the raw material quality. The forms of nitrogen present in the sugar beet can be divided into proteinaceous and soluble nitrogen. The main and most important components of the soluble nitrogen compounds which negatively affect the sugar production process are free amino acids, amide, ammonium, nitrates and nitrites [1-3]. The content of these substances in sugar beets depends mainly on nitrogen fertilizer rates, weather conditions throughout the development of the beet and the employed agricultural practice [4, 5].

The content of soluble nitrogen in sugar beet is several times higher in the crown than in the root. This depends mainly on the presence of leaf material in the crown area remaining after topping [5]. Hence it is of particular importance to carry out the process of topping correctly and accurately. Correct topping can mean different things for individual companies. However in the central Europe the objective is to cut sugar beets below the crown because this section includes green leaf stalks. The tops and crowns of the beet are of low quality compared to the main root and therefore most factories do not want to pay for these parts. While in some regions of North America where adverse climatic conditions occour, a much smaller topping cut is required in order to decrease sugar losses during prolonged storage [6].

To reduce production costs sugar factories must receive the raw material of good quality. The actual mass of beet is determined in the tarehouse. Therefore each delivery of beets is sampled for an analysis providing the tare and the sugar content of the beets. The tare includes mass of beet tops, leaves, stones, soil and other foreign bodies [7].

Different methods are used in tarehouses to determine the top tare of delivered beets. Some companies use only visual examination of the beet samples. But the most common approach is to cut off the tops of sugar beet and transfer them to tare. The tops of beets are thereby not included for the determination of quality parameters of received beets [6]. In most of the terahause the topping of beets is performed manually by seasonal workers. The work is difficult, require high concentration and may be inaccurate. To replace manual topping different vision system have been investigated, based on shape [8] or colour [7].

The most important component of the sugar beet is sucrose, while the various nitrogen compounds in varying degrees adversely affect the sugar yield, white sugar quality and quality of molasses and beet pulp. Due to difficulties in analysis, only amino nitrogen is taken into account for quality assessment of sugar beet in the routine of a factory.

The proteinaceous substances pass, in small amounts, from beets into the raw juice during the extraction process and are removed almost entirely during the purification process. Therefore these nitrogen compounds pose little problem for the technological process [9]. About 95% of the free amino acids and amides go from the sugar beets into the raw juice during the extraction process due to the small particle size. A part of amino acids react with invert sugar in the *Maillard* reaction resulting in the formation of melanoidins [10,11]. High concentrations of amides and ammonia cause a decrease of alkalinity which leads to the inversion of sucrose [12]. Furthermore the pH value is corrected in the factory by caustic soda addition which increases the loss of sucrose in molasses and production cost [6].

Nitrates are taken up from soil by the fibrous root system to the leaves where there they are partly reduced to nitrites and finally to hydroxylamine and ammonia [5]. The nitrate content in sugar beets is very variable and depends mainly on nitrogen fertilizer rates and climatic conditions during growth, whereas the nitrite content in sugar beets is found in small quantities [1]. The activity of thermophilic bacteria, which are capable of reducing nitrate to nitrite, can cause an increase in the nitrite content during storage of the beets or during the extraction process. This can influence the nitrite content in the extractor and finally the nitrite content in molasses which is undesirable because excessive levels of nitrite adversely affect animal health [13]. Molasses and beet pulp are only temporarily excluded from the list of products subjected to the limit [9].

A high proportion of untopped beets increases the beet amount but, on the other hand, it makes sugar processing more difficult and expensive because it substantially increases the content of nonsugar substances including the soluble nitrogen. Moreover, the upper part of the crown, particularly if it includes remnants of leaf stalks, has worse mechanical properties than the root, and this hinders processing [6]. So far, the concentration of α-amino nitrogen and the total content of soluble nitrogen in different section of sugar beet were determined [14]. In the literature, there is little data available on the undesirable levels of nitrate and nitrite in sugar beets.

The aim of this study was to determine the distribution of nitrogen compounds in important sugar beet sections of untopped sugar beets with particular emphasis on the content of nitrates and nitrites, with regard to the technical quality for processing.

Experimental

Materials and methods

The material for these investigations were untopped fresh beets (roots with petiols and leaf stalks). The Finezja sugar beet variety had been collected from the clamps in one of the Polish sugar factories in October during 2013/2014 campaign. In total 46 samples of untopped sugar beet were analyzed.

The sugar beets were washed by hand and according to technological quality were then divided into three sections: crown, root and tail. Following this, the individual parts of beets were milled to obtain beet brei. In the above sections of beet the content of total amount of nitrogen, proteinaceous nitrogen, α-amino nitrogen, the sum of the amide and ammonia nitrogen, nitrates and nitrite were determined.

For the determination of dry matter, sugar beet brei was dried at 105°C until constant weight [15]. The concentration of sucrose and α-amino nitrogen was determined from beet brei clarified by aluminium sulphate. The concentration of sucrose was analyzed polarimetrically according to ICUMSA GS6-1 (1994) method. The α-amino nitrogen (free amino acids) content was determined by the fluorometric method in accordance with the ICUMSA GS6-5 (2007) method [16]. The sum of the amide and ammonia nitrogen, total amount of nitrogen and proteinaceous nitrogen were determined in accordance with the analytical techniques used to control the technology process in sugar factories [15]. For the determination of nitrate and nitrite, the sugar beet brei was diluted with distilled water (18 MW) and the resulting solution was filtered through membrane filters with a pore diameter of 0.45 µm. The content of nitrate and nitrite were determined using an ion chromatograph DIONEX ICS-3000 with a conductivity detector [17].

The boxplot presents the distribution of the value. ANOVA analysis was conducted using STATISTICA software system, with level of confidence $p<0.05$. The Tukey test was used to evaluate differences between the results of the contents of nitrogen compounds in the individual sections of sugar beet.

Results and Discussion

The sugar beets were divided into three parts: crown, root and tail. The content of total amount of nitrogen, proteinaceous nitrogen, α-amino nitrogen, the sum of the amide and ammonia nitrogen, nitrates and nitrite, sucrose and dry matter in the above parts of sugar beets were determined. The weight of the technologically important parts of sugar beets are presented in Table 1.

Table 1. The characteristics of the important sections of sugar beet

The individual parts of sugar beet	Crown	Root	Tail
weight of the individual parts of sugar beet, g	173.3 ± 51.9	963.8 ± 146.6	38.6 ± 6.4
percentages of the various parts of beet, %	14.7 ± 4.4	82.0 ± 12.5	3.3 ± 0.5

There were no statistically significant differences in the dry matter concentration between the sugar beet sections. The average content of dry matter in crown, root and tail was respectively amounted to 26.33, 25.54 and 25.16%. The content of sucrose in crown was statistically significant lower than in root and tail. The average content of sucrose in crown, root and tail was respectively 14.15, 18.15 and 16.67% (Fig. 1).

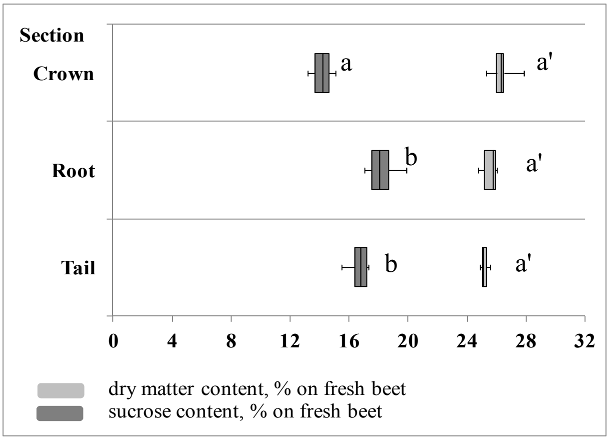

Figure 1. The content of sucrose and dry matter in different morphological sections of sugar beet. The same letter on the graph indicates a lack of statistical differences between the results in particular section of sugar beet

The reduction of nitrate via nitrite to ammonia takes place inside the leave system. Therefore some amounts of nitrate and nitrite can be found in the petiole. Frenzel investigated the content of nitrate in beet throughout the entire of 2014/2015 campaign. The content of nitrate fluctuated from 80-120 mg/100 g Sugar. For the first two month (September and October) the content of nitrate remained on the lower level of approx. 80 mg/100 g sugar [18].

Mahn et al. reported only a small increase of nitrate in the upper part of the sugar beet (in crown) [5], while our studies have shown a statistically significant increase of nitrate content in the crown, in comparison to the root. In the crown the content of nitrate ranged between 160 and 230 mg/100 g of sugar and in the root was from 25 to 43 mg/100 g of sugar (Fig. 2). This may be due to the fact that, in contrast to the research carried out by Mahn et al. [5], in our study crown contained petiols and leaf stalks. The wide range of variation of nitrate content in crown is due to the fact that the beets contained a different quantity of leaf stalks.

In most of the root samples the nitrite was not detected. The concentration of nitrite in the root samples which contained this compound varied from 1.5 to 3.0 mg/100 g of sugar. The all crown samples contained nitrite ant its content fluctuated in wide range, from 32 to 50 mg/100 g of sugar. In the tail, the nitrite was not detected.

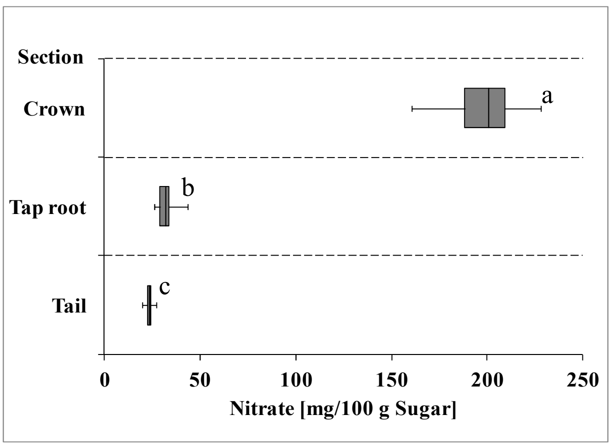

Figure 2. The content of nitrate in different morphological sections of sugar beet. The same letter on the graph indicates a lack of statistical differences between the results in particular section of sugar beet

The average content of α-amino nitrogen was more than two times higher in the crown than in the root and tail. The content of α-amino nitrogen in crown fluctuated in a wide range, from 68 to 87 mg/100 g of beet (Fig 3). Mahn et al. reported that the α-amino nitrogen content in the upper part of the beet was three times higher than in the root [5]. The average content of α-amino nitrogen in root and tail amounted to 33 and 38 mg/100 g beet. Zahradnicek et al. reported higher amount of α-amino nitrogen in crown, about 85-90 mg/100 g of beet, and in root, where the content of α-amino nitrogen varied from 45 to 70 mg/100 g of beet. The tail also contained higher amount of α-amino nitrogen, on average 60 mg/100 g of beet, similar to our research [19-21].

The average content of amide and ammonia nitrogen was also more than two times higher in the crown than in the root. In contrast, there were no statistically significant differences between the content of these compounds in root and tail (Fig. 3). The crown contained amide and ammonia nitrogen at the level of 40 mg/100 g of beet, while root and tail contained on average 18 mg/100 g of beet. Van der Poel et al. has collected data which showed that the content of amide and ammonia nitrogen in root was varied and was in the range from 5 to 41 mg/100 g beet [6].

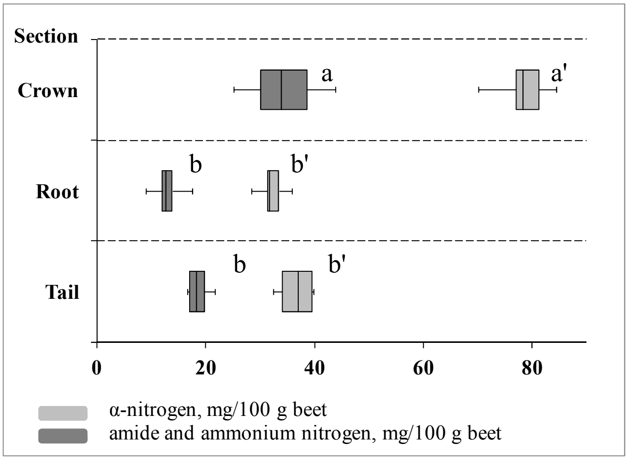

Figure 3. The content of α-amino nitrogen and amide and ammonia nitrogen in different morphological sections of sugar beet. The same letter on the graph indicates a lack of statistical differences between the results in particular section of sugar beet

The content of proteinaceous nitrogen and total nitrogen in the root and tail was approx. two times lower than in the crown (Fig. 4). The content of total nitrogen in crown fluctuated in a wide range, from 1200 to 1620 mg/100 g of dry matter. The average content amounted to 1520 mg/100 g of dry matter. Svachula and Vratny also reported the similar content of total nitrogen in crown, at about 1460 mg/100 g of dry matter [22]. In our study, the root and tail contained the total nitrogen at the level 750 and 850 mg/100 g of dry matter, respectively. The root contained the total amount of nitrogen at the level of 750 mg/100 g dry matter, while in tail was on average 850 mg/100 g of dry matter. Svachula and Vratny in these study also demonstrated very similar content of total nitrogen in this parts of beets. The content of total nitrogen in root varied from 610 to 720 mg/100 g dry matter, while in the tail amounted on average 860 mg/100 g of dry matter [22].

The content of proteinaceous nitrogen in crown fluctuated in a wide range, from 570 to 890 mg/100 g of dry matter. There was no statistically significant difference between the content of proteinaceous nitrogen in root and tail. The average content of proteinaceous nitrogen amounted to 450 and 390 mg/100 g dry matter, respectively in root and tail (Fig. 4).

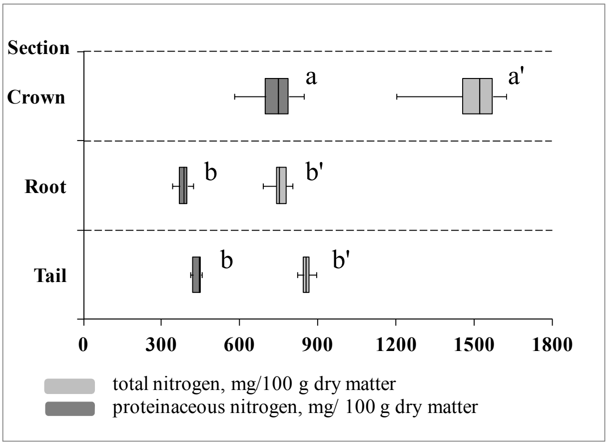

Figure 4. The content of total and proteinaceous nitrogen in different morphological sections of sugar beet. The same letter on the graph indicates a lack of statistical differences between the results in particular section of sugar beet

In the calculation of the percentage of individual forms of nitrogen in the individual parts of the beets, the weight ratio of separate parts of the beet has been taken in account (Table 2).

Table 2. The percentage of nitrogen compounds present in technologically important sections of sugar beet

Forms of nitrogen present in sugar beet	The percentage of individual forms of nitrogen in the following parts of the beet [%]		
	Crown	Tap root	Tail
total nitrogen	26.7±1.9	70.4 ± 3.7	2.9 ± 0.1
proteinaceous nitrogen	25.8 ± 2.2	71.2 ± 4.0	2.9 ± 0.1
α-amino nitrogen	29.1 ± 2.1	68.0 ± 4.2	2.9 ± 0.1
amide and ammonium nitrogen	28.0 ± 2.4	69.6 ± 6.5	2.4 ± 0.1
nitrate	77.2 ± 6.0	22.2 ± 3.0	0.6 ± 0.1
nitrite	88.0±3.8	12.0±4.1	nd*

*nd – not detected

Although the crown of the sugar beet represented only 14.7% of its mass, this section contained 29.1% of the total quantity of α-amino acids as well as nearly 28.0 % of the total quantity of amide and ammonia nitrogen. Particular attention should be paid to the amount of nitrates and nitrites in the crown, the contents of which amounted to 77.2% and 88.0% of the total quantity, respectively. The tail, which represented only 3.3 % of the total mass of the sugar beet, has a small part in bringing different forms of nitrogen compounds into the process.

Conclusion

The concentration of the nitrogen compounds in the upper section of sugar beet mainly depends on the presence of leaf material. Untopped sugar beets introduce much higher amounts of nitrate and nitrite in comparison to topped raw material. The beet tops (crown) and leaves are relevant criterion for the evaluation of the content of nitrate and nitrite.

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