COMPONENTS OF HARMFUL NITROGEN IN SUGAR BEET – INFLUENCE OF VARIETY AND ENVIRONMENT

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ABSTRACT

The total soluble nitrogen in sugar beet impairs sugar recovery during processing and is therefore called harmful nitrogen. It consists of amino N, betaine, nitrate and the non-identified residual N. For quality assessment in Germany, only amino N is determined as a representative of all soluble nitrogen compounds. The aim of the project was to study the effect of variety and environment on the components of harmful nitrogen and the relationship to each other. For the study beet brei samples from variety trials with 42 varieties at 15 sites in 2000 and 2001 were analysed.

For total soluble N, amino N and betaine the effect of environment was higher than the effect of variety. Furthermore, interactions between environment and variety became evident. The data show a close correlation between the concentration of total soluble N and amino N, although the slope was not identical for all varieties. The proportion of amino N on total soluble N increased with increasing amino N concentration, irrespective of whether the amino N concentration was increased due to the influence of variety or environment. The proportion of betaine decreased with increasing proportion of amino N, since betaine showed not as much response to environmental factors as amino N. This clearly demonstrated that the proportion of these fractions on total soluble N varied and thus it cannot be judged as constant, neither among different varieties nor for one variety in different environments.

ABRÉGÉ - COMPOSANTS DE L'AZOTE NUISIBLE DANS LES BETTERAVES SUCRIÈRES - INFLUENCE DE LA VARIÉTÉ ET DE L'ENVIRONNEMENT

L'azote total soluble présent dans les betteraves sucrières gêne l'extraction du sucre en usine, raison pour laquelle on le désigne azote nuisible. Il se compose d'azote aminé, de bétaïne, de nitrate et d'azote non identifié. Dans le cadre, en Allemagne, de l'évaluation de la qualité, on ne détermine que l'azote aminé en tant que représentant de tous les composants solubles de l'azote. Le présent projet avait pour but de saisir l'effet de la variété et de l'environnement sur les composants de l'azote nuisible, et les relations de ces composants entre eux. Les analyses ont fait appel à des échantillons de râpure de betteraves issues d'essais de variétés de 42 variétés sur 15 sites, ceci en 2000 et 2001.

L'effet de l'environnement s'est avéré plus important que l'effet de la variété sur l'azote total, l'azote aminé et la bétaïne. En outre, des interactions entre l'environnement et la variété ont été constantées. Les résultats montrent une étroite corrélation entre la teneur en azote total soluble et en azote aminé, bien que la pente de la courbe ne soit pas identique pour toutes les variétés. La part d'azote aminé dans l'azote total soluble augmente au fur et à mesure que la teneur en azote aminé augmente, indépendamment de ce que la teneur en azote aminé soit accrue par l'environnement ou la variété. La teneur en bétaïne diminue comme l'augmentation de la part d'azote aminé vu que la bétaïne ne réagit pas dans les mêmes proportions que l'azote aminé aux variations environnementales. Ceci montre nettement que la part de ces fractions varie dans l'azote total soluble et qu'elle ne peut pas être considérée comme constante ni à travers les variétés, ni dans une même variété exposée à des environnements différents.

KURZFASSUNG - KOMPONENTEN DES SCHÄDLICHEN STICKSTOFFS IN ZUCKERRÜBEN – EINFLUSS VON SORTE UND UMWELT

Der lösliche Gesamtstickstoff in Zuckerrüben behindert die Zuckergewinnung in der Fabrik und wird daher als Schädlicher Stickstoff bezeichnet. Er setzt sich zusammen aus Amino-N, Betain, Nitrat und dem nicht identifizierten N. Für die Qualitätsbewertung wird in Deutschland nur der Amino-N als Repräsentant für alle löslichen Stickstoffkomponenten bestimmt. Ziel des Projektes war es, den Effekt von Sorte und Umwelt auf die Komponenten des Schädlichen Stickstoffs und deren Verhältnis zueinander zu erfassen. Für die Untersuchungen wurden Breiproben aus Sortenversuchen mit 42 Sorten an 15 Standorten in 2000 und 2001 analysiert.

Für löslichen Gesamt-N, Amino-N und Betain war der Effekt der Umwelt größer als der Sorteneffekt. Ferner gab es Wechselwirkungen zwischen Umwelt und Sorte. Die Ergebnisse zeigen eine enge Korrelation zwischen dem Gehalt an löslichem Gesamt-N und Amino-N, obwohl die Steigung nicht identisch für alle Sorten war. Der Anteil Amino-N am löslichen Gesamt-N stieg mit steigendem Amino-N-Gehalt an, unabhängig davon, ob der Amino-N-Gehalt durch den Einfluss der Umwelt oder der Sorte erhöht war. Der Anteil Betain sank mit steigendem Amino-N Anteil, da Betain nicht im gleichen Ausmaß auf Umweltänderungen reagierte wie Amino-N. Dies zeigt deutlich, dass der Anteil dieser Fraktionen am löslichen Gesamt-N variiert und nicht als konstant angesehen werden kann, weder zwischen Sorten noch für eine Sorte in unterschiedlichen Umwelten.

INTRODUCTION

Soluble N components from the beet, which cannot be eliminated during juice purification and therefore accumulate in the thick juice, are the main non sucrose substances, which adversely affect sugar recovery. 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 colour formation (melanoides) (VAN DER POEL et al. 1998). Total soluble nitrogen in thick juice, which is defined as total N minus protein N, is therefore called "harmful nitrogen". There is a close correlation between the harmful N found in thick juice and the total soluble N determined in beet brei at delivery to a factory (BURBA 1996).

In Germany only potassium, sodium and amino N are determined for quality analysis of sugar beet. Thereby it is assumed, that these components are representative for the effect of all compounds which adversely affect sugar recovery. Since for quality assessment the Braunschweiger formula (BUCHHOLZ et al. 1995) is used instead of the Reinefeld formula (REINEFELD et al. 1974), the amino N concentration in the beet has a higher importance for beet quality than several years ago.

The breeding progress was very high in the past years, so that the amino N content of the new sugar beet varieties has decreased considerably. Today it is only about half of the content which it was 20 years ago (HOFFMANN & MÄRLÄNDER 2002). However, for these varieties only the amino N content is determined, but no other components of harmful N.

The objectives of our study were to describe the relationship between amino N and total soluble N in order to find out, whether the composition of total soluble N has changed compared to the past. Furthermore differences among varieties in the composition of total soluble N were studied.

MATERIAL AND METHODS

For the study brei samples were taken from the official variety trials at 22 locations all over Germany in the years 2000 and 2001. These locations were representative for the sugar beet growing areas in Germany. The varieties were chosen according to their amino N concentration, so that a broad range of different qualities were obtained.

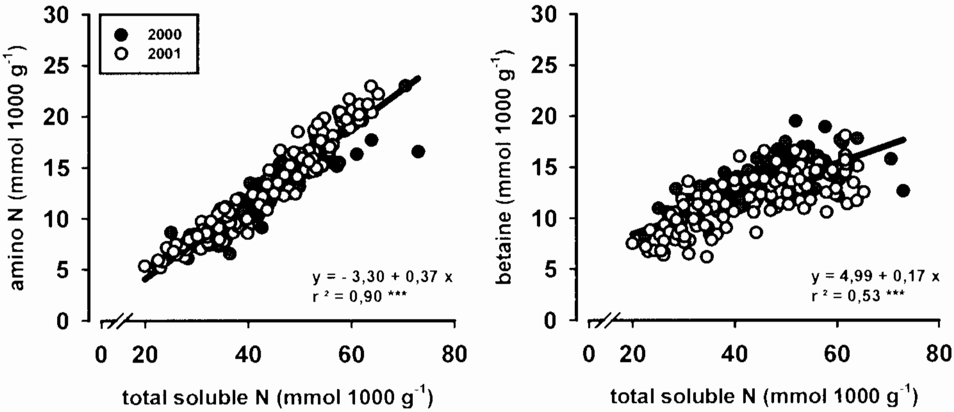
The beet brei clarified with aluminium sulphate solution (ICUMSA 1994) was analysed for N components. α-amino N was determined with the fluorometric OPA-method (BURBA & GEORGI 1975, 1976). Results were corrected with the regression according to GLATTKOWSKI & MÄRLÄNDER (1994) to the blue number value (STANEK & PAVLAS 1934, KUBADINOW & WIENINGER 1972), which was used for the calculation of standard molasses loss (BUCHHOLZ et al. 1995). Total soluble N was determined by dry combustion with a gas chromatographic method, betaine by the colorimetric method according to STOREY & WYN JONES (1977). Nitrate was determined with an ion-selective electrode (MILHAM et al. 1970), whereas rest N was calculated from the difference between total soluble N minus amino N minus betaine minus nitrate.

RESULTS AND DISCUSSION

The total soluble N content varied between 20 and 80 mmol per kg beet, the amino N content between 5 and 25 mmol per kg beet (Fig. 1 left). There was a very close relationship between the amino N and the total soluble N content with a r^2 of 0.90. With increasing total N the amino N content also increased with a slope of 0.37. But, at an amino N content of 9 mmol per kg beet one could either find 22 or 42 mmol total N per kg beet, which is almost twice as high. That means, there were also deviations from this close relationship, which could be attributed to either variety or site.

The same relationship is shown for betaine (Fig 1 right). The betaine content varied between 5 and 20 mmol per kg beet. It was thereby on a similar level as the amino N content. But the relationship between betaine and total N was not as close as for amino N, the r^2 was much lower compared to amino N. Furthermore, the betaine content did not increase as much as the amino N with increasing total N, the slope was only 0.17.

Fig. 1: Relationship between amino N and total soluble N in sugar beet, 42 varieties, 15 sites, 2000/01



For nitrate, there was no close correlation to total N, in tendency it increased with increasing total N. Surprisingly, rest N also had a close relationship to total N. It seems as if the variation of the various N components have compensated each other.

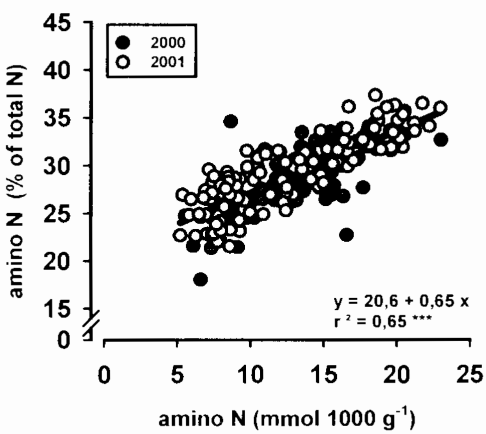
In summary, it can be concluded that amino N is still the best representative for total soluble N compared to the other components, although there were cases, in which the relationship between amino N and total soluble N was not very close.

On average of 42 varieties at 15 sites in 2000 and 2001 amino N was about 30 % of the total soluble N in beet. Compared to former studies (BURBA 1996) it had decreased from 40 % to 30 %, so that it was even a smaller part of the total N than in former times. That may partly be due to the fact, that in particular the amino N is increased with high N supply. Therefore, with low N supply, amino N decreases. The N recommendation and N application practices have changed in the past decade, so that this decrease in amino N may additionally be attributed to changes in agricultural practice, not only to changes in genotype. Both effects cannot be distinguished.

Betaine was 30 % of total soluble N similar as amino N, nitrate was 5 %. The biggest part of the total soluble N was rest N with 36 %. For given conditions (environment, variety), however, the composition may differ quite substantially from that average.

Amino N is the component of total N, which is most important for quality assessment and should therefore reliably represent harmful nitrogen. For the estimation of the harmful nitrogen it is assumed, that amino N is a constant percentage of total soluble N. But the percentage of amino N differed for varieties and for one variety at different sites: dependent on the N supply of a site the amino N content changed and thereby the percentage of amino N (Fig. 2). That means, that amino N was not a constant percentage of total N, but the percentage increased with the content.

Fig. 2: Effect of amino N concentration on percentage amino N of total N in sugar beet, 42 varieties, 15 sites, 2000/01



The various components of harmful nitrogen did not change independently. In particular amino N and betaine seemed to be related. Varieties with 25 % amino N had about 35 % betaine, whereas varieties with 35 % amino N had only 20 % betaine of total N. In conclusion, it seems as if a low amino N percentage is always compensated by a higher betaine percentage, independent whether the low amino N is attributed to the effect of variety or environment, in particular N supply.

CONCLUSION

In summary it can be concluded, that the composition of harmful nitrogen is not constant among varieties. For the quality assessment of sugar beet in Germany, amino N is the only N fraction analysed, since it has the closest correlation to total soluble N. However, amino N is not a constant percentage of total soluble N, and it is lower than reported from the past. With further breeding progress and decrease in the amount of N fertiliser applied to sugar beet the percentage amino N will further decrease, so that the total soluble N will be represented by a decreasing part.

In future the quality of sugar beet might be more reliably estimated by taking further N components into account apart from solely amino N, which is only a minor part of the total N. But in practice there are a few problems to solve: there are still no analytical methods for the analysis of other components in the routine of a sugar factory, although there are efforts to adapt a NIRS method for the determination of total soluble N in beet (BURBA et al. 2001). Once there are methods available, a new basis for quality evaluation is required, that means, a new formula for quality assessment must be developed.

REFERENCES

1. BUCHHOLZ, K., MÄRLÄNDER, B., PUKE, H., GLATTKOWSKI, H. & THIELECKE, K. 1995: Neubewertung des technischen Wertes von Zuckerrüben. *Zuckerind.* 120, 113-121.

2. BURBA, M. 1996: Der Schädliche Stickstoff als Kriterium der Rübenqualität. Zuckerind. 121, 165-173.

3. BURBA, M. & GEORGI, B. 1975/76: Die fluorometrische Bestimmung der Aminosäuren in Zuckerrüben und Zuckerfabriksprodukten mit Fluoreszamin und o-Phthalaldehyd. *Zuckerind.* 26, 322-329.

4. BURBA, M., HUIJBREGTS, T. & HILSCHER, E. 2001: Zur Bestimmung des löslichen Gesamt-Stickstoffs in Zuckerrüben mit Nah-Infrarot-Spektrometrie. *Zuckerind.* 126, 367-375.

5. GLATTKOWSKI, H. & MÄRLÄNDER, B. 1994: Zur Frage der Beeinflußbarkeit von Ertrag und Qualität beim Anbau von Zuckerrüben durch pflanzenbauliche Maßnahmen. Teil 1: Ertragsparameter und Melassebildner. *Zuckerind.* 119, 570-575.

6. HOFFMANN, C. & MÄRLÄNDER, B. 2002: Züchterischer Fortschritt in Ertrag und technischer Qualität von Zuckerrüben. *Zuckerind.* 127, 6, 425-29.

7. ICUMSA Method GS6-3 (1994): The determination of the polarisation of sugar beet by the macerator or cold aqueous digestion method using aluminium sulphate as clarifying agent – Official Methods Book, Colney, Norwich, 1-3.

8. KUBADINOW, N., WIENINGER, L., 1972. Bestimmung des -Aminostickstoffs in Zuckerrüben und Betriebssäften der Zuckerproduktion. *Zucker* 25, 43-47.

9. MILHAM, P J., AWAD, A. S., PAULL, R. E., BULL, J. H., 1970. Analysis of plants, soils and waters for nitrate by using an ion-selective electrode. *Analyst* 95, 751-757.

10. POEL, P.W. VAN DER, SCHIWECK, H & SCHWARTZ, T. 1998: Sugar Technology. Beet and Cane Manufacture. Verlag Dr. Albert Bartens KG – Berlin 1998.

11. REINEFELD, E., EMMERICH, A., BAUMGARTEN, G., WINNER, C. & BEIß, U. 1974: Zur Voraussage des Melassezuckers aus Rübenanalysen. *Zucker* 27; 2-15.

12. STANEK, V., PAVLAS, P., 1934. Über eine schnelle, informative Methode zur Bestimmung des schädlichen Stickstoffes, der Amide und der Aminosäuren in der Rübe. *Zuckerind. Cech-slov. Rep.* 59, 129-142.

13. STOREY, R. & WYN JONES, R.G. 1977: Quaternary ammonium compounds in plants in relation to salt resistance. *Phytochemistry* 16, 447-453.

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