TECHNICAL QUALITY ASSESSMENT OF SUGAR BEET IN EUROPE

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ABSTRACT

Sugar content is the most important parameter in the assessment of the technical quality of sugar beet. However, the percentage of sugar that can be gained as granulated sugar during processing is influenced by several compounds in the beet. These compounds are characterised by melassigenic properties and/or influence the alkalinity of the extracted juice.

The most important melassigenic compounds are: amino nitrogen compounds, pyroglutamate, betaine, lactate (from reducing sugars), chloride, nitrate and sulphate. The accompanying cations mainly are potassium and sodium.

The alkalinity is negatively affected by amino nitrogen compounds (by splitting of ammonia), reducing sugars (by conversion to acids) and magnesium and calcium (by precipitation).

Phosphate, oxalate, citrate, sulphate and malate have a positive effect on the alkalinity by precipitating with calcium ions.

To estimate the amount of non-extractable sugar, several formulas have been developed in Europe. To allow the assessment of the internal quality on a large scale at reasonable analytical costs, these formulas contain only a few parameters. Most formulas are based on the quantity of potassium, sodium and α-amino nitrogen. Some also take into account the amount of reducing sugars in the beet.

Examples are given of formulas used in Europe and of the effects of these formulas on the losses calculated.

ABRÉGÉ - L'ÉVALUATION DE LA QUALITÉ TECHNOLOGIQUE DE LA BETTERAVE SUCRIÈRE EN EUROPE

Le taux de sucre est le paramètre le plus important dans l'évaluation technique de la qualité de la betterave sucrière. Néanmoins le pourcentage de sucre à extraire comme sucre granulé est déterminer dans le processus par plusieurs composants.

Ces composants ont été caractérisés par les pouvoirs mélassigènes et leur effet sur l'alcalinité du jus extrait. Les composants mélassigènes le plus important sont: les composants d'azote α-aminés, le pyrrolidonate, betaine, lactate (des

sucres réduits), chlorure, nitrate et sulfate. Les cations principaux à les accompagner sont le potassium et le sodium.

L' alcalinité est négativement corrélé avec ces composants α-amino-azotés (par le décomposition de l'ammoniaque), les sucres réduite (par la conversion vers les acides), le magnésium et le calcium (par précipitation). Phosphate, oxalate, citrate, sulfate et malate ont un effet positif sur l'alcalinité par leur précipitation avec les ions de calcium.

Pour estimer le taux de sucre non extractif , plusieurs formules de calcul ont été développées en Europe. Pour permettre une évaluation de la qualité interne sur une grande échelle, ainsi que contre les frais analytiques raisonnables, ces formules contiennent que quelques paramètres. La plupart de formules a été basée sur les teneurs en potassium, sodium et l'azote α-aminé. Quelques formules contiennent également le teneur en sucres réduite de la betterave.

Exemples ont été donnés pour les formules utilisés en Europe et leurs effets sur les pertes calculées.

KURFASSUNG - BEWERTUNG DER TECHNISCHEN QUALITÄT VON ZUCKERRÜBEN IN EUROPA

Der wichtigste Parameter für die Bewertung der technische Qualität von Zuckerrüben ist der Zuckergehalt. Allerdings ist der Anteil Zucker, der als kristalliner Zucker bei der Verarbeitung gewonnen werden kann, von zahlreichen Inhaltsstoffen in Rübe beeinflusst. Diese Inhaltsstoffe sind charakterisiert durch ihre melassogenen Eigenschaften und/oder dem Einfluss auf die Alkalität der extrahierten Säfte. Die wichtigsten melassogenen Komponenten sind: Amino-N, Pyrrolidoncarbonsäure, Betain, Lactat (aus reduzierenden Zuckern), Chlorid, Nitrat und Sulfat. Die begleitenden Kationen sind meistens Kalium und Natrium.

Die Alkalität wird negativ beeinflusst vom Amino-N (durch Freisetzung von Ammoniak), reduzierende Zucker (durch Umwandlung in Säuren) und Magnesium und Calcium (durch Ausfällung). Phosphat, Oxalat, Citrat, Sulfat und Malat haben positive Effekte auf die Alkalität dadurch, dass sie mit Calciumionen ausfallen.

Um die Menge an nicht extrahierbarem Zucker abzuschätzen, wurden verschiedene Formel in Europa entwickelt. Um die Bewertung der inneren Qualität im großen Maßstab zu vernünftigen Analysekosten zu ermöglichen, enthalten diese Formeln nur wenige Parameter. Die meisten Formeln basieren auf dem Gehalt an Kalium, Natrium und Amino-N. Einige Formeln beziehen darüber hinaus auch den Gehalt an reduzierenden Zuckern in der Rübe ein. Anhand einiger Beispiele werden Formeln, die in Europa angewendet werden, und die Auswirkung auf die errechneten Verluste dargestellt.

INTRODUCTION

The technical quality of sugar beet depends on their composition. Sugar content is the most important parameter in the assessment of the technical quality of sugar beet. However, the percentage of sugar that can be gained as granulated sugar during processing is influenced by several compounds in the beet. These compounds are characterised by melassigenic properties and/or influence the alkalinity of the extracted juice (HUNGERFORD, E.H. & MCGINNIS, R.A. 1982; Oltmann, W. *et al.*,1984). Beside that, some compounds are involved in unwanted formation of colours during processing (CLARKE, M.A. *et al.*,1989). Also the structure of the beet may be important in relation to beet damage (resulting in beet and sugar losses) and slicing properties (DRATH, L. *et al.*,1984). However, physical properties are not taken into account for the assessment of the technical quality.

BEET COMPOSITION

The overall chemical composition of sugar beet in Europe is given in Table 1 (IIRB-STUDY GROUP, 1996; BOHN, K.,1998; BURBA, M. *et al.*, 2001). The composition may vary considerably due to differences in growing conditions (weather, soil, fertilization, pests and diseases) and variety.

See Table 1: *Overall chemical composition of topped sugar beet in Europe*

MELASSIGENIC PROPERTIES, ALKALINITY AND COLOUR FORMATION

Several compounds have melassigenic properties and/or influence the alkalinity of the extracted juice. The most important melassigenic compounds are: amino nitrogen compounds, pyroglutamate (PGA), betaine, lactate, chloride, nitrate and sulphate. PGA is formed during processing from glutamine and glutamate. Lactate is a degradation product from reducing sugars. The accompanying cations mainly are potassium and sodium. Figure 1 shows the melassigenic contributions for these compounds, based on average composition and melassigenic coefficients (DEVILLERS, P. *et al.*,1984; IIRB-STUDY GROUP, 1996).

Figure 1: *Contribution of different beet compounds to molasses sugar (Sm)*

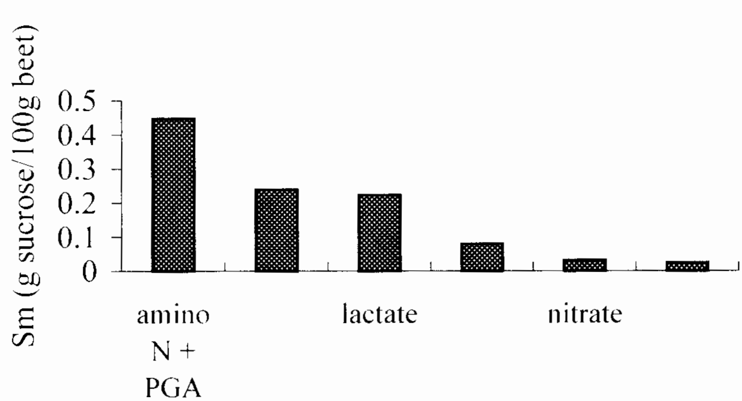
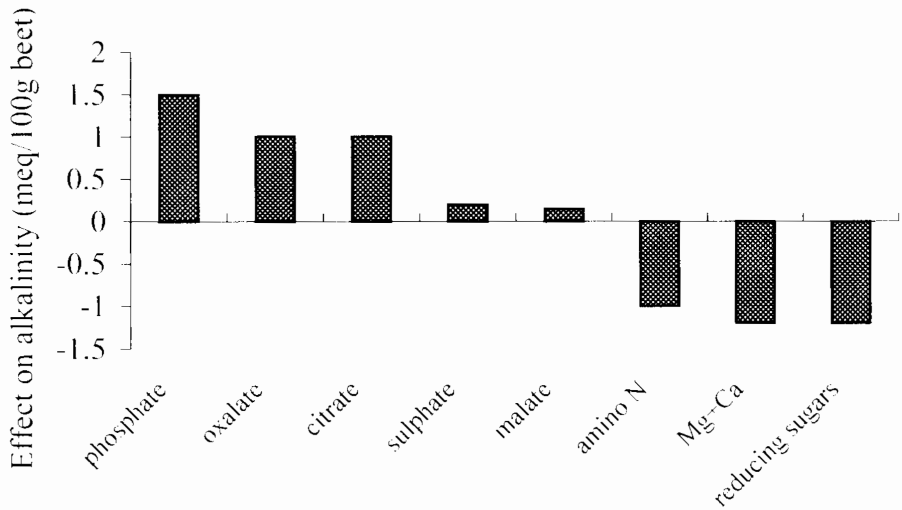


Table 1: *Overall chemical composition of topped sugar beet in Europe*

Compound		Content (g/100g)	
Water		76	
Water-insoluble compounds (marc)		4	
	pectic substances		2
	cellulose		1
	hemicellulose		1
	proteins		0.1
	lignin		0.1
	saponins		0.1
Water-soluble compounds			
Sucrose		17	
Proteins		0.4	
α-Amino nitrogen		0.25	
	glutamine		0.1
	asparagine		0.02
	glutamic acid		0.02
	aspartic acid		0.02
Betaine		0.2	
Cations		0.3	
	potassium		0.2
	sodium		0.02
	magnesium		0.01
	calcium		0.003
Anions		0.3	
	phosphate		0.08
	citrate		0.08
	oxalate		0.05
	sulphate		0.02
	nitrate		0.02
	chloride		0.01
	malate		0.01
	lactate		0.01
	acetate		0.01
Pectic substances		0.1	
Saponins		0.1	
Glucose		0.1	
Fructose		0.05	
Raffinose		0.05	
Galactose		0.01	

The alkalinity is negatively affected by amino nitrogen compounds (by splitting of ammonia), reducing sugars (by conversion to acids) and magnesium and calcium (by precipitation). Phosphate, oxalate, citrate, sulphate and malate have a positive effect on the alkalinity by precipitating with calcium ions. The effects of these beet compounds on alkalinity are shown in figure 2 (IIRB STUDYGROUP 1996; HUIJBREGTS, A.W.M., 1996).

Figure 2: Effect of beet compounds on alkalinity during processing



Soda or lime has to be added if the alkalinity is insufficient. Conversely, acids have to be added if the alkalinity is too high. These additions increase the melassigenic properties of the juice.

Colour formation during beet processing may have several origins (CLARKE, M. A. *et al.*,1989), reducing sugars always being an important factor (DE BRUIJN, J. M., 1999). This is an extra reason why the amount of reducing sugars in the beet should be as low as possible.

FORMULAS USED IN EUROPE FOR QUALITY ASSESSEMENT

To estimate the amount of non-extractable sugar, several formulas have been developed in Europe to calculate the molasses sugar (Devillers, 1988; Buchholz, K. *et al.*,1995; Pollach, G. *et al.*,1996; Huijbregts, T. 1999). To allow the assessment of the internal quality on a large scale at reasonable analytical costs, these formulas contain only a few parameters. Most formulas are based on the quantity of potassium, sodium and α-amino nitrogen. Some also take into account the amount of reducing sugars in the beet.

In 1927 already it was published that 1 mmol of potassium and sodium corresponds with 1 mmol of sugar in the molasses (DEDEK, J. 1927). Because 1 mmol sugar is 0.342 gram this means that the percentage molasses sugar was 0.342 times the concentration of potassium+sodium, expressed as mmol per 100 g beet. Since 1927 numerous formulas have been introduced, based on sugar factory data, laboratory experiments and theoretical considerations.

Some of the formulas that have been developed in Europe for the estimation of the molasses sugar (Sm) during the last 15 years are given below.

1988 France: $Sm = 0.14 \times (K+Na) + 0{,}25 \times \alpha N + 0.50$

$Sm = 0.14 \times (K+Na) + 0{,}25 \times \alpha N + 3.3 \times G + 0.3$

1995 Germany: $Sm = 0.12 \times (K+Na) + 0{,}24 \times \alpha N + 0.48$

1996 Austria: $Sm = 0.11 \times K + 0.09 \times Na + 0{,}30 \times \alpha N + 0.46$

$Sm = 0.11 \times K + 0.09 \times Na + 0{,}30 \times \alpha N + 0.35 \times RS + 0.27$

1998 Netherlands: $Sm = 0.342 \times (K+Na)$, if $K+Na-\alpha N \geq 3.5$

$Sm = 0.142 \times (K+Na) + 0{,}2 \times \alpha N + 0.7$, if $K+Na-\alpha N < 3.5$

Sm is expressed as % sugar on beet. K, Na and αN (α-amino nitrogen) are expressed as mmol/100g beet. G is glucose, expressed as % on beet. RS is reducing sugar, expressed as mmol/100g beet.

The German formula is called the "New Brunswick Formula". In the literature the analytical date of the beet samples with diverging quality, used to develop this formula, are available (Buchholz, *et al.*,1995). Figure 3 shows the Sm values for these beet samples calculated with the four formulas.

For the Austrian formula the ratio between potassium and sodium is assumed to be 10:1, because only the potassium+sodium data have been published. Reducing sugars are not taken into account, because these data were not available.

In general the effect of the different formulas on the molasses sugar estimated are similar. Only the Dutch formula showed large deviations for some samples. These are samples with sufficient alkalinity and relatively high potassium+ sodium levels.

*See **Figure 3:** Calculated molasses sugar with different formulas for beet samples used to develop the "New Brunswick Formula"*

The contribution of glucose in the French formula and reducing sugars in the Austrian formula is illustrated in table 2 for low, medium and relatively high concentrations of glucose and fructose.

Figure 3: Calculated molasses sugar with different formulas for beet samples used to develop the "New Brunswick Formula"

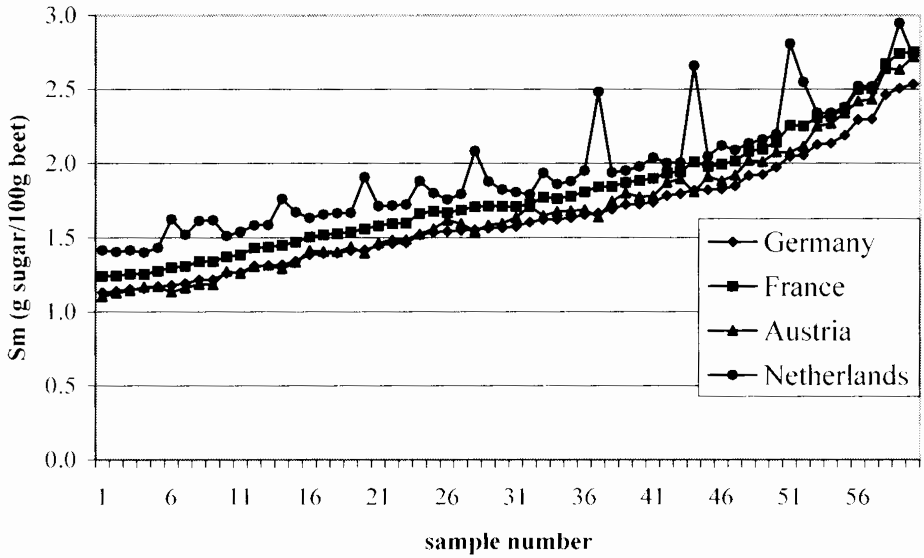


Table 2: Melassigenic effect (Δ Sm) of glucose and fructose on molasses sugar calculated by the French and Austrian formula, compared with the same formulas using a constant for the contribution of reducing sugars

Concentration (g/100g beet)		Δ Sm (g sugar/100g beet)	
glucose	fructose	French	Austrian
0.03	0.02	-0.1	-0.09
0.07	0.03	+0.03	0
0.2	0.1	+0.46	+0,39

The calculated differences between low and high concentrations of reducing sugar show that the contribution of reducing sugar to the molasses sugar can vary considerably. Therfore, the amount of reducing sugars should be taken into account, if the concentration is not more or less constant for the delivered sugar beet.

The recoverable white sugar on beet can be calculated by:

Srec = Spol – Sm – C, with

Srec = recoverable white sugar in g sugar/100g beet

Spol = sugar content based on polarisation

C = constant for "fixed losses" in g sugar/100g beet.

The fixed losses often are estimated by a figure of 0.6% . However, in some

7. DEVILLERS, P., DETAVERNIER, R. & ROGER, J.: Nouvelles mesures de pouvoirs mélassigènes. *Sucrerie Française*, 181-192, 1984.

8. DEVILLERS, P. : Prévision du sucre mélasse. *Sucrerie Française*, 190-200, 1988.

9. IIRB-STUDYGROUP ON QUALITY AND STORAGE: sugar beet composition and effects on technological quality. *Proceedings of the 59th IIRB Congress*, 405-407, 1996.

10. HUIJBREGTS, A.W.M.: Kwaliteitsonderzoek. Kwaliteitsanalyses van bieten geteeld onder diverse omstandigheden. *IRS jaarverslag*, 81-84, 1996.

11. HUIJBREGTS, T.: New Dutch sugar recovery formula for sugar beet. *Zuckerind. 124*, 698-701, 1999.

12. HUNGERFORD, E.H. & Mc GINNIS, R.A.: By-Products. Molasses. *Beet-sugar technology, Third Edition, Ed .Mc Ginnis*, 617-625, 1982

13. OLTMANN, W., BURBA, M. & BOLZ, G.: Die Qualität der Zuckerrübe Bedeutung, Beurteilungskriterien und züchterische Maßnahmen zu ihrer Verbesserung. *Fortschritte der Pflanzenzüchtung, Heft 12*, 1984.

14. POLLACH, G., HEIN, W, & RÖSNER, G.: Definition der Qualität von Zuckerrüben. *Zuckerind. 121*, 332-344, 1996.