# Evaluation of the Sugar Beet According to its Technical Quality[1]

M. BURBA[2]

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## Introduction

The "technical quality of sugar beets," which is oriented towards an economical production of sucrose, is not only dependent on the sugar content of the beets, but also on several other properties of the root which affect to different degrees the industrial processing of beets in the sugar factory, Table I, (20).[3] Technical quality comprises chiefly the mechanical and chemical properties of the root, properties which can largely be influenced by variety and environment as well as by agronomic and cultural practices (62, 70, 71). For many of these properties, sufficient analytical methods are not yet available to allow us to determine how many quality characteristics of the beet we need to consider, let alone express their varying influence on the sugar manufacturing (workability) in a single index number.

Therefore all attempts that have been made so far to determine the technical quality of sugar beets are approximate solutions which can merely take into account certain aspects (juice quality) of the processing procedures, which we shall assume are under standard conditions (64, 79, 45). The opportunity to influence the quality by factory processes is relatively small, considering the thick juice purity, which is almost constant during the campaign; so basically only variations in the composition and the consistency of the beet material can account for differences in the technical quality. A summarized presentation of the whole set of problems up to 1967 was given by Chelemskij (18).

Some of the most important statistics of a sugar factory are the white sugar yield, and the amount of molasses produced, and the alkalinity of the juice. The prediction of the technical quality is therefore confined to the determination of those quantities which are mainly dependent on the chemical properties of the beet. Thus the purities of the thin and thick juice, respectively, produced by standard laboratory methods, are measured for the evaluation of the quality of the beet from purified juices. Besides such other parameters as filtration and settling speed, alkalinity, lime salt content, color, pH value, and others,

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[2]Manager of chemical and biochemical research, Department of Chemistry and Biochemistry, Plant Breeding Institute of the Kleinwanzlebener Saatzucht AG, D-3352 Einbeck, West Germany.

[3]Numbers in parentheses refer to literature cited.

hexokinase-PGI-G-6-PDH enzyme system. The hexokinase-G-6-PDH system would be the most advantageous overall if enzyme preparations could be purchased absolutely free of hexose isomerase impurities. As it now stands, the choice of the proper enzyme system will depend on the raffinose content in the sample being analyzed.

Compared to polarimetry, the enzyme method is more expensive, but much more specific for sucrose. The enzyme system has an extra advantage over polarimetry of practically eliminating the error due to insoluble matter (mark) in the analysis of beets which plagues the hot digestion method used with polarimetry.

When comparing the enzyme method to the popular gas chromatography method, it was found that gas chromatography had the higher correlation with polarimetry. The main advantages of the enzyme methods are the lower initial investment cost and the simplicity of sample preparation and analysis which results in a less skilled technician being required.

The insignificant difference found between the method of standard addition and the method of standard comparison indicates that the various components of beet homogenates do not significantly enhance or suppress the enzyme reaction mechanism.

**Appendix I**

| Reagent | Supplier | Cat. No. | Cost as of May 1975 |
|---|---|---|---|
| ATP | NBC | | $3.83/10 gm |
| NAD | Sigma | N-7004 | $10.00/gm |
| Hexokinase F-300 | Sigma | N-4502 | $8.00/1000 units |
| G-6-PDH (use with NAD) | Worthington | ZFLD | $55.00/1800 units |
| Triethanolamine HCl | Sigma | T1502 | $4.75/500 gm |
| Invertase | NBC | | $4.75/5 gm |
| PGI | Sigma | P-9010 | $5.00/1000 units |

**References**

(1) ANON. "Glucose and Fructose." *Food Analysis Manual.* Mannheim, West Germany: Boehrringer Mannheim GMBH. Biochemical Department, 1971.

(2) BERGMEYER, H. H. *Methods of Enzymatic Analysis.* New York: Academic Press, Inc., 1963.

(3) COLOWICK, SIDNEY P. and NATHAN O. KAPLAN. *Methods in Enzymology.* New York: Academic Press, Inc., 1957. Vol. I.

(4) GUILBAULT, G. G. *Enzymatic Methods of Analysis.* Elmsford, New York: Pergamon Press, Inc., 1970.

(5) HALDANE, J. B. S. *Enzymes.* Cambridge, Massachusetts: M.I.T. Press, 1965.

(6) LAIDLER, KEITH J. *The Chemical Kinetics of Enzyme Action.* Oxford: Clarendon Press, 1958.

they serve for the evaluation of the juice quality; and together with the molasses quotient, generally assumed to be constant, they are used to estimate the white sugar yield and the amount of molasses produced.

In applying these more or less complicated laboratory methods which individually correspond more or less to the different stages of production in a sugar factory, only a small number of samples can be analyzed in a time unit, and although these methods yield the most accurate and comprehensive information (72), they are in general of no consequence to the routine determination of the technical quality.

In the sugar industry and in beet breeding, where analyzing the greatest possible number of samples with the smallest possible sacrifice of time is essential, the quality is evaluated on the basis of aqueous extracts of the beet which can be prepared relatively rapidly from fresh or frozen brei. In the extracts, mainly lead acetate extracts, various nonsugars of the beet (9, 28, 34) are determined by means of fully automatic analytical apparatus (28, 35). These nonsugars, which, like alkali ions (potassium and sodium) and the amino acids and amides

**Table 1.—Characteristics governing the quality of the sugar beet root and its juices.**

| | |
|---|---|
| 1) Biological: | external constitution<br>(form of the root, fanginess, crown height and others) |
| | resistance to external influences<br>(damages) |
| | bolting resistance and resistance to diseases |
| | variety and dependence on the environment<br>(environmental stability) |
| | storageability<br>(respiration losses, infections) |
| 2) Chemical: | sugar content |
| | non-sugars:<br>(potassium, sodium, amino-N, particularly glutamine, invert sugar, betaine, raffinose and others) |
| | marc content |
| 3) Physical: | washing and slicing capacity<br>elasticity and compressibility } of the cossettes |
| 4) Industrial: | extraction, filtration and sedimentation capacity<br>formation of coloring matter |
| | effective alkalinity<br>(corrosions, inversions, incrustations) |
| | and others |

combined in the amino nitrogen, cannot be removed during the conventional purification process, are closely related to the molasses sugar, the alkalinity, and the purity of purified juices.

To what extent the result of such a simplified quality analysis still corresponds in the individual case to full-scale industrial realities depends on the choice of the starting products (cossettes, brei, or expressed juice) and on the extraction methods used (69). Add to this the fact that the sampling (5, 11), the brei preparation, often also the storage of the deep frozen brei samples (12), and finally the automatized analysis itself (68) entail mistakes which altogether permit only a relative determination of the technical quality of the specific material, and the accuracy of the test becomes questionable.

Nevertheless the accuracy of the prediction by means of the quality concept developed by *Wieninger* and *Kubadinow* (75) is amazingly good and fully sufficient for agricultural experimentation, as *Devillers* et al. (21) as well as *Reinefeld* et al. (49) have recently shown in comparative analyses in six French sugar factories, and in comparison with semi-industrially produced thick juices, respectively.

Below is given a systematic survey of the criteria which are actually employed for assessing the technical quality of sugar beets in the different countries (10).

*Evaluation of quality from aqueous extracts*

The evaluation of quality from aqueous extracts is confined to the determination of a few nonsugars of the beet which, being chief components of the molasses, affect the white sugar yield. Today these determinations can be made rapidly and safely, and they are particularly suited to analyses in series.

However, there is no consensus as to the certainly varying value of the different criteria for the technical quality that have been deduced from these analyses.

Thus Dedek (19) and Wiklund (76) made the since often confirmed finding that in molasses of different origin, the ratio of sucrose to alkali and of sucrose to nitrogen, respectively, is almost constant:

$$\frac{\text{meq sucrose}}{\text{meq}\,(K + Na)} = \text{const.} \sim 1.0\,(\text{alkali factor})$$

1 meq (N+Na) in the beet is thus on the average equivalent to 0.342 g of sucrose in molasses.

$$\text{Molasses sugar } (S_M) = \text{meq } (K+Na) \cdot 0.342 \text{ in percent}$$

In similar studies, made by Carolan (15), Asselbergs et al. (4), Henry et al. (29) and Wieninger (75) which in part also considered the

calcium content of the molasses, the "constant" can show values ranging from 0.8 to 1.3 in the different European beet growing regions. In South Germany, for instance, a mean value of 1.06 was determined in the molasses of a sugar factory during two campaigns (74).

Although these proportional numbers vary from place to place and depend on the technical facilities of a sugar factory, they yield in general fairly reliable statements as to the average molasses sugar to be expected from the processed beets in the course of a campaign.

Sandera (50) has shown that the finding of Dedek and Wiklund represents only a conformity to statistic laws which depends on the respective conditions of the after-product processing (ratio of non-sugars to water, purging temperature).

A similar case is the MW factor introduced by Drachowska and Sandera (26)

$$\text{MW factor} = \frac{M}{W} \cdot 100\ (\%)$$

Amount of molasses produced (M) = 8 · ash; white sugar yield (W) = Pol - 1.2 - 4 ash; $S_M = 4 \cdot$ ash; ash = conductivity ash; all data in percent.

With this equation, which has been computed for a sucrose content of the molasses of 50%, the amount of molasses produced is determined by the ash and the sucrose content of the beets alone, in percent of the white sugar yield and the percentage of sugar yield ($Y_B$), respectively.

Although Sommer (60) adapted the relationship to German conditions (W = Pol − 3.6 ash; M = 7.5 ash), it gained ground mainly in the East European countries and the DDR where the formula was recently examined and confirmed by Schmidt et al. (52). Vukov et al. (73) and Henry et al. (30) arrived at similarly simple valuation criteria for fresh harvested beets:

$$Y_B = \text{Pol} - 1.0 - S_M$$

$$S_M = 1.61 \text{ ash} + 1.35$$

Pol and ash respectively = sucrose and conductivity ash content, respectively, in percent on beets.

This relationship, which has a relatively low correlation coefficient of r = + 0.58, has been used in Hungary since 1958 for the quality evaluation of sugar beets. In the case of beets stored for a prolonged period of time the invert sugar content is also taken into account.

$$S_M = 0.71 + 0.0021 \cdot æ(\%);\ r = 0.989$$

æ = electrical conductivity in $\mu$S cm$^{-1}$/100°S measured at 20°C in an extract of 26 g of brei and 177 cm$^3$ of water.

In the aforementioned equation the Belgian authors computed the molasses sugar with an alkali factor of 0.9 (see above).

There is, however, a close connection (78) between the alkali content used, which was determined by flame photometry, and the conductivity ash of the same extract, so that the high correlation coefficient of this relationship is not unexpected.

Another possiblity for determining the quality of sugar beets is "the corrected sugar content" of Reinefeld et al. (49) corresponding to the RSPT (23):

$$\text{Corrected sugar content} = \text{Pol} - S_M - 0.6$$

$$S_M = 0.343\,(K + Na) + 0.094\,N_B - 0.31$$

All data in meq on beets; $N_B$ = amino nitrogen (blue number method) (14).

This valuation criterion has been used officially since 1974 by the Institute for Sugar Beet Research in West Germany for quality comparison in agriculture. The indication of a "corrected sugar yield" (product from corrected sugar content and yield) is inexpedient in view of more differentiated evaluations of quality.

Spengler et al. (61), Andrlik (2), and Krüger (37) stress the particular importance of ash and amino-N content (so-called noxious amino nitrogen) of the beets for the evaluation of the quality.

The rendement factors 5 and 25 for ash and amino nitrogen which are supposed to be constant have been used as standard values for years (38). However, in any individual case, they can cause considerable deviations (particularly with the prediction of molasses sugar from the amino-N content). Today the ash factor is generally assumed to be lower (26, 29, 60, 73), whereas for the Andrlik factor of 25 essentially higher values have also been found (24). On the basis of weekly mean values of a sugar factory obtained in two campaigns we calculated e.g. 3.8 ± 0.3 for the ash factor and 40 ± 2.0 for the N factor.

Lüdecke and Nitzsche (34) suggested the $Q_R$ value for determining the "physiological maturity" of sugar beets, and Trzcinski (67) employed this value together with the potassium, sodium, and ash content of the beets for the evaluation of the technical quality of stored beets (66).

$$Q_R = \frac{\text{Pol}}{Na_2O \cdot 1000}$$

(Pol and $Na_2O$ content in % on beets. Limit to exceeded approx. 1.2)

For the calculation of a white sugar yield which forms a suitable basis of comparison for all valuation criteria, the following formula, which is briefly deduced here, has to be used:

$$Y_B = \text{Pol} - L_B - S_M\,(\%) \qquad \text{(I)}$$

$Y_B$ = sugar yield in % on beets; Pol = sugar content; $L_B$ = known and undetermined factory losses; $S_M$ = sugar in molasses. All data in %.

When $Y_B$ is related to the sugar content of the beets, we obtain

$$Y_S = \frac{Y_B \cdot 100}{Pol} \quad (\%) \qquad II$$

$Y_S$ = sugar yield in % on sugar in beets.

By substituting $Y_B$ from (I) and recalculating, we arrive at

$$Y_S = 100\,\frac{Pol - L_B - S_M}{Pol} = 100\left(\frac{Pol - L_B}{Pol} - \frac{S_M}{Pol}\right)$$

$$Y_S = 100\left(1 - \frac{S_M}{Pol - L_B}\right)\frac{Pol - L_B}{Pol} \qquad III$$

The formula is reduced to

$$Y_S = 100\left(1 - \frac{S_M}{Pol}\right) \qquad IIIa$$

if no allowance is made for the determined and undetermined factory losses ($L_B$ = O).

Several nonsugars, such as raffinose, glutamine, glutamic acid, invert sugar, and others, have also frequently been used for special quality studies (13).

Since the computed crystal yield can only be expected from juices with sufficient alkalinity, it is necessary to consider, besides the estimation of molasses sugar, the "effective alkalinity" (7, 36) of the thick juice as an additional quality criterion and to make, if necessary, allowance for it.

Wiklund (77) had already suggested that the alkalinity ratios in the thick juice are closely related to the alkali content and to the ratio of alkali to amino nitrogen, respectively. Therefore Andersen and Smed (1) based a regression equation for the prediction of the effective alkalinity on the difference between these two groups of substances competing for alkalinity:

Effective alkalinity (EA) = 0.58 (K + N − Amino nitrogen) − 6.8. in meq/100°S $\quad r = +0.91$.

For the estimation of natural alkalinity Wieninger (75) starts with the ratio of the alkali and amino-N content (alkalinity coefficient) and

indicates as a lower limit the value 1.8, which, when applied to semi-industrial juices, was found accurate for maintaining a thick juice pH value of $\geq$ 8.6 at 20°C. However, these ratios can only be applied to healthy and freshly harvested beets which have a low invert sugar content (0.35 – 0.75 % on 100°S). This and the preceding formula are designed to predict the alkalinity of juices obtained from beet analyses. They are based on the assumption that the alkalinity suppliers can summarily be covered by the easily determinable alkali ions potassium and sodium, and the alkalinity consumers by amino-N.

However, it follows from recent gas-chromatographic analyses of the anion composition of the beet juices that these simple formulae cannot satisfactorily reflect the real alkalinity conditions in the juices (48) (as it was to be expected for theoretical reasons). This is also indicated by the practical experiences which have meanwhile been made with the alkalinity criteria in various sugar factories.

*Evaluation of Quality from Purified Juices*

The following valuation measures are exclusively based on analytical results from purified juices which had been determined under different standard conditions on a laboratory level and were used for estimating the white sugar yield and the amount of molasses produced.

The basis of the calculation is formed by the equation of Paar (41, 42, 43), which had been derived from formulae of Hulla-Suchamel and Schneider (65) for the computation of white sugar yields via the purities of thick juices and molasses.

When the expression of Paar for the computation of molasses sugar is substituted in formula (III)

$$S_M = \frac{Q_M}{100 - Q} \cdot \frac{100 - Q_D}{Q_D} (Pol - L_B) \text{in } \%$$

we obtain the following relationship:

$$Y_S = 100 \left(1 - \frac{Q_M}{100 - Q_M} \frac{100 - Q_D}{Q_D}\right) \frac{Pol - L_B}{Pol} \% \qquad (IV)$$

$Q_M$ = percent molasses purity; $Q_D$ = percent thin juice and thick juice purity, respectively; $S_B$ = percent sucrose content of the beet; $L_B$ = determined and undetermined factory losses of the beet without losses of molasses.

By rearranging, we arrive at a more suitable expression for this calculation

$$Y_S = \frac{10\,000}{Q_D} \cdot \left(\frac{Q_D - Q_M}{100 - Q_D}\right) \cdot \frac{Pol - L_B}{Pol} \qquad (IVa)$$

As a paper by Cecil (17) indicates, an analogous relationship is applicable to the amount of molasses produced (M) if the sucrose content of the molasses is assumed to be 50%

$$M = 2\,(Pol - L_B) \cdot \frac{Q_M}{Q_D} \frac{100 - Q_D}{100 - Q_M} = 2\,(Pol - \frac{Y_S \cdot Pol}{100} - L_B)\ \%\ (V)$$

This relationship has been used in a more reduced form for predicting the amount of molasses produced, e.g. by Sandera (51).

The main dependent variables of these equations are the sucrose content of the beet and $Q_D$. Because of the accuracy of the calculation it is essential to measure them carefully, particularly the relatively low refractometric dry substance of the thin juice (by means of a high precision refractometer having the correct temperature).

The valuation proposals of different authors known from literature differ chiefly only by the way in which $Q_M$ and $Q_D$ were determined or computed for the application of the Paar equation.

Silin (55) obtains the quotient $Q_M/100 - Q_M$ of a molasses of 44 Poise corresponding to 82% RDS which is saturated at 40°C (Silin's normal molasses) with the aid of a semi-industrial laboratory method of his own using the coefficient of molasses formation $m_k$ (which corresponds to the sucrose quantity falling to 1 g of nonsugars).

The thick juice purity $Q_D$ which is further required for the calculation of the white sugar yield is directly measured in the thick juice produced during the process, and the losses are assumed to be $L_B = 0.9\%$ of the beet.

According to Vukov and Barany (73), the molasses formation coefficient $m_k$, otherwise only attainable by experiments, can also be computed with a good approximation from the purity and the ash and lime salt content of the thin juice (extracted through a simplified processing technique of Silin); this finding was also confirmed by Racik (46, 47). Below is the equation of Vukov and Barany;

$$m_k = 0.028\ a + 0.80 \qquad (r = +0.81;\ s = \pm 0.09\ \%)$$

$$a = \frac{100\ (ash - 1.8\ CaO)}{100 - Q_D}$$

ash = percent conductivity ash of thin juice and thick juice, respectively, on solids; CaO = lime salts in thin juice in % CaO on solids; $Q_D$ = thin juice purity.

When $m_k$ is known, the Hugarian authors computed the losses of sugar in the molasses (percent on beets) using the method of Paar with $L_B = 1.08\%$.

According to Silin (55) the molasses purity $Q_M$ itself can also be calculated from the ash and nonsugar content of the thick juice. This is

done by means of a regression equation which is shown here only approximately (the following mathematical formulation was derived from a graph in the paper quoted above):

$$Q_M = f\left(\frac{A}{NS}\right)$$

and

$$Q_M = 50.5 \cdot \frac{A}{NS} + 45.8\ (\%)\ \text{respectively.}$$

A = sulfated ash − $CaSO_4$ (alkali ash) in %; nonsugars (NS) = RDS − Pol; molasses RDS = 82% corresponding to a nonsugar-water ratio (NS/W) ranging from 1.6 to 1.7).

From the analyses of 34 samples of molasses Schneider et al. (54) found a similar formula for predicting the purity (molasses polarisation quotient $Q_P$) of industrial molasses from thick juice data:

$$Q_P = f\left(\frac{\text{residual NS}}{\text{total NS}}\right);\ r = +0.91$$

or when disregarding the CaO portion

$$Q_P = 39.9\,\frac{A}{NS} + 49.9\,(\%)$$

Residual nonsugars (RNS) = NS − 1.9 (ash − 2.35 CaO); A = percent conductivity ash; NS/W = 2.5; purging temperature = 40°C; NS = RDS − Pol in %.

As compared to the valuation criteria of Drachowska and Sandera as well as that of Lüdecke, Scheider et al. (54) found average deviations of the individual values of ± 10% and maximum deviations up to 30% when they calculated the molasses sugar on the basis of this regression equation.

Brieghel-Müller (6) suggests the following empirical formulation for predicting the polarization quotient of the molasses:

$$Q_P = 100\,\frac{R}{R + 1 + ONS / ash}\ \%$$

ONS (organic nonsugars) in the thick juice = RDS − (Pol + ash); ash = conductivity ash in %; R = 4.5 (average rendement value which is dependent upon nonsugar composition in molasses).

The connection between the chloride of thin juices and the molasses purity shown by Stark (63) seems to be of dubious value for estimating the quotient; this is so, among other reasons, because of the only slightly distinctive correlation ($r = -0.71$).

Since the molasses purity, from the viewpoint of its sucrose quotient, changes only slightly during the campaign (53), the $Q_M$ can be regarded as constant with sufficient accuracy for many practical purposes, a fact which facilitates greatly the analysis of quality and the calculation of the yield.

For instance, Partale et al. (44) found the almost constant value of 1.224 with only ± 0.02 error for the individual determination for the quotient $Q_S/100 - Q_S$ ($Q_S$ = molasses sucrose quotient) from analyses of molasses of different sugar factories under standard conditions (non-sugar − water ratio = 2.8; 45°C purging temperature).

Henry et al. (29) report on the valuation of beets with $Q_M = 60\%$ and $L_B = 0.8\%$ of losses, whereas Junghans (32), basing his calculation on these studies, assumes 1.1% of losses with the same molasses purity. For the determination of $Q_D$ the authors made the thin juice extraction on pilot plants which they designed especially for this purpose, and they computed the sugar yield as stated previously (33).

In order to avoid time-consuming semi-industrial juice extraction and purification processes, Brown and Sero (8) developed a rapid laboratory method for the production of purified juices from beet brei extracts or press juices (treatment with oxalic acid). This method was used by Carruthers and Oldfield (16) in continuation of the work of Kruger (36) for serial determinations of thin juice purities (clear juice purity) (treatment with phosphoric acid).

The authors found high degrees of correlation between various nonsugars of the brei extracts and the measured purities of the purified juices. This presents the possiblity of predicting the thin juice purities, with a correspondingly higher probability of error, from the nonsugar content of the original brei extract by means of a regression equation:

$$Q_D = 98.5 - 8.31 \cdot 10^{4} \cdot \text{Impurity value} \quad r = -0.95$$

Impurity value = 2.5 K + 3.5 Na + 10 Amino-N + betaine in mg/100°S. (The constant factors of this equation serve for the conversion to the actually existing alkali compounds and the Amino-N compounds, respectively, of the thin juice.) This concept of beet quality evaluation (impurity index determination) has been used by several authors (31, 34, 40).

Using a clear juice purity (CJP) $Q_D$ that is measured or predicted in the course of this laboratory purification process, a molasses purity $Q_M = 62.0\%$, and $L_B = 0.55\%$ of losses, the British Sugar Corporation computes a theoretical white sugar yield as the criterion of the technical beet quality. If necessary, allowance will be made for the differences

between the thin juice values which are determined in the laboratory and those ascertained in the factory.

In the same manner (assuming $Q_M = 62.5\%$ and $L_B = 0.3\%$) Dexter, Frakes and Snyder (21, 23, 27) determine the recoverable white sugar (RWS after the so-called Great Western formula) from composite samples of American beets.

Wieninger (75) indicated the following regression equation for computing a purity coefficient RK (probable thick juice purity) from lead acetate extracts of brei:

$$RK = 99.4 - 0.14 \cdot NSP; \qquad r = -0.95$$

Proportion of nonsugars (NSP) = K + Na + Amino-N in meq/100°S

This relationship was found through a standard laboratory purification method (using lime and carbon dioxide), and according to comparative tests that the author made over several years, it proved to conform well to the standard methods commonly employed in Austrian sugar factories. This concept of beet quality evaluation (impurity index determination) has been used by several authors (31, 34, 40).

*KWS Quality Index*

After reviewing the existing literature we feel that at the time being the best solution for the determination of the technical quality of sugar beets from purified juices is to compute a white sugar yield from the analysis results of the juices produced according to Carruthers and Oldfield (16) and to state it as a measure of quality.

For this purpose the purity $Q_D$ of the purified juice is directly determined by measuring the sugar content and the refractometric dry substance, whereas the expected molasses purity $Q_D$ and the molasses formation coefficient $m_k$ respectively are estimated from the conductometric ash A and the nonsugar content NS as described by Schneider and co-workers (54):

$$m_k = \frac{Q_M}{100 - Q_M} - \frac{A \cdot 1.23 \cdot NS}{1.28NS - A} \quad \text{(ignoring the CaO content).}$$

When the factory losses which are supposed to be constant are assumed to be 0.6%, the expression for the theoretical white sugar yield according to Paar is:

$$\text{KWS quality index} = 100\left(1 - m_k \frac{100 - Q_D}{Q_D}\right) \frac{Pol - 0.6}{Pol} \% \text{ on sugar in beets}$$

The KWS quality index does not take ion exchange processes into account. Furthermore it is based on the assumption that the purified

**Table 2.—Quality criteria of the sugar beet.**

$$Y_B = S_B - L_B - S_M \text{ \% on beets} \qquad Y_S = \frac{Y_B \cdot 100}{S_B} \text{ \% on sugar in beets}$$

($Y_S$ – Sugar yield in % on beets; $S_B$ – Sugar content; $L_B$ – Known and undetermined factory losses; $S_M$ – Sugar in molasses. All data in % on beets. $Y_S$ – Sugar yield in % on sugar in beets)

$$Y_S = 100\,(1 - \frac{S_M}{S_B - L_B}\,\frac{S_B - L_B}{S_B}) \text{ \% on sugar in beets}$$

*Sugar in molasses predicted from various individual non sugars of aqueous brei extracts of the beet*

| | | |
|---|---|---|
| 1) $S_M = (K + Na) \cdot 0.342$ | % on beets | *Dedek* (19): *Wiklund* (76) |
| 2) $S_M = 3.6 \cdot$ ash | | *Drachowska* and *Sandera* (26) |
| 3) $S_M = 0.343\,(K + Na) + 0.094\,N_B - 0.31$ | | *Reinefeld* et al. and others |

*Sugar in molasses calculated from thick juice- and molasses purity*

$$S_M = \frac{Q_M}{100 - Q_M}\,\frac{100 - Q_J}{Q_J}(S_B - L_B) \text{ \% on beets } \textit{Paar} \text{ (42)}$$

($Q_M$ – Molasses purity, not corrected for raffinose and reducing sugars; $Q_J$ – Thick juice purity)

$$Y_S = 100\,(1 - \frac{Q_M}{100 - Q_M}\,\frac{100 - Q_J}{Q_J})\,\frac{S_B - L_B}{S_B} \text{ \% on sugar in beets}$$

| | | |
|---|---|---|
| 1) $Q_M$ = 60.0 %; $L_B$ = 0.8 %; $Q_J$ | From thick juices of pilot plants measured as described by *Carruthers* et. al. (16) | *Henry* et al. (29) |
| 2) $Q_M$ = 60.0 %; $L_B$ = 1.1 %; $Q_J$ | | *Junghans* (32) |
| 3) $Q_M$ = 62.0 %; $L_B$ = 0.55 %; $Q_J$ | | *Oldfield* (BSC) |
| 4) $Q_M$ = 62.5 %; $L_B$ = 0.3 %; $Q_J$ | | *Dexter, Frakes* and *Snyder* (23) |
| 5) $Q_M$ = var. %; $L_B$ = 0.6 %; $Q_J$ | | |

*KWS quality index*

$$Q_M = f(\frac{\text{organic NS}}{\text{total NS}}) = 39.9 \cdot \frac{A}{NS} + 49.9\% \quad \begin{matrix}\textit{Silin} \text{ (57)} \\ \textit{Schneider} \text{ et al. (54)}\end{matrix}$$

(NS – nonsugars; A – conductometric ash. All data in % on thick juice)

$$\text{KWS quality index} = 100\,(1 - \frac{Q_M}{100 - Q_M}\,\frac{100 - Q_J}{Q_J})\,\frac{S_B - 0.6\%}{S_B} \text{ on sugar in beets}$$

juices have sufficient alkalinity reserves so that no disturbance of the given alkalinity content will occur in case soda is added in the factory.

For the routine determination of the technical quality of breeding material and comprehensive variety trials in an automatic beet laboratory, we use for the computation of $Q_D$ a regression equation between the quotient and the sum of potassium, sodium, and amino-N content of lead acetate extracts of the beets, as 210 individual analyses of a trial with different harvest dates which were determined by the laboratory juice purification method and which utilize press juice, showed:

$$Q_D = 97.4 - 0.10\ (K + Na + \text{amino-N})\ \text{in meq/100°S};\ r = -0.96$$

In this case the effective alkalinity of the purified beet juices is considered at the time of the selection on the basis of the method described by Krüger (36).

Table II lists again in a clear arrangement all the criteria of the technical quality of sugar beets which have so far been discussed.

## Summary

In a systematic review of the extant literature the author of this paper presents the criteria actually employed for the determination of the technological quality of sugar beets in the different countries. In this regard a fundamental differentiation has to be made between quality evaluations from aqueous extracts and from purified juices of the beet. For the evaluation of the beet quality from purified juices a valuation criterion from the literature which is called the KWS quality index is proposed.

## References Cited

(1) ANDERSEN, E. and E. SMED. 1963. The chemical composition of sugar beets and the effective alkalinity and the sugar loss in molasses. Comptes Rendus de la 12$^{e}$ Assemblée Génélrale de la CITS, Paris S. 395-406.

(2) ANDRLIK, K. 1905. Eine chemisch-technische Studie der Diffusion im Groβbetriebe. A. Zuckerind. Böhmen. 10-29.

(3) ANDRLIK, K. and J. URBAN. 1905. Der Einfluβ des Stickstoffs auf die Reinheit der Dicksäfte. Z. Zuckerind. Böhmen 29: 519-522.

(4) ASSELBERGS, C.J., P.W. VAN DER POL, M.L.A. VERHAART, and N.H.M. DE VISSER. 1963. Rohsaftgewinnung im Laboratorium zum Studium des technischen Wertes der Zuckerrübe. In (64) S. 78-93. See also Comptes Rendus de la 12$^{e}$ Assemblée Générale de la CITS, Paris, S. 264-283.

(5) BEIβ, U. and A. VON MÜLLER. 1974. Beiträge zur Methodik der Ertrags- und Qualitätsbestimmung bei Zuckerrüben. Zucker 27: 173-178.

(6) BRIEGHEL-MÜLLER, A. 1955. Dicksaftreinheit und Zuckerausbeute. Zucker 8: 497-502.

(7) BRIEGHEL-MÜLLER, A. and H. BRÜNICHE-OHLSEN. 1953. Neuere Gesichtspunkte zur zweiten Saturation. Zucker 6: 443-446.

(8) BROWN, R.J. and R.E. SERRO. 1954. A method for determination of thin juice purity from individual mother beets. Proc. Am. Soc. Sugar Beet Technol. 8: 274-278.

(9) BURBA, M. 1970. Analytische Methoden zur serienmäβigen Bestimmung der technischen Qualität von Zuckerrüben in der Züchtung. Z. Zuckerind. 20: 403-409.

(10) BURBA, M. 1971. Beitrag zur Beurteilung der technischen Qualität von Zuckerrüben. Zucker 24: 103-112.

(11) BURBA, M. and W. HAUFE. 1972. Beitrag zur Ermittlung der optimalen Stichprobengröβe bei Zuckerrüben. Eine Voraussetzung für die repräsentative Bestimmung von Ertrag und Qualität. Z. Zuckerind. 22: 75-80.

(12) BURBA, M., W. HUAFE, and W. KRÜGER. 1975. Verhalten von qualitätsbestimmenden Inhaltsstoffen der Zuckerrübe während der Herstellung und Lagerung von Gefrierbrei. Zucker 28: 411-418 see also Comptes Rendus de la 15$^{e}$ Assemblée Générale de la CITS, Vienna 1975.

(13) BURBA, M. and M. KASTNING. 1971. Stoffwechselphysiologische Untersuchungen an Zuckerrüben während der Vegetationszeit. I. Glutamin, Glutaminsäure, Asparagin und Asparaginsäure. Zucker 24: 386-396.
— and NITZSCHKE, U. II. Citronensäure, Äpfelsäure und — Ketoglutarsäure. ibid. 25 (1972): 509-518. III. Glucose, Fructose, Galactose and Raffinose. ibid. 26 (1973): 356-366. Oxalic acid in sugar beet roots. Int. Sugar J. 76 (1974): 326-330.

(14) BURBA, M. and E. LURZ. 1972. Vergleichende Untersuchungen zur Blauzahl-Methode. Z. Zuckerind. 22: 566-576.

(15) CAROLAN, R.J. 1949. The formation of beet molasses. Int. Sugar J. 5: 227-279 and in (64) S. 203-233. Laboruntersuchungen über die Melasseerschöpfung. Z. Zuckerind. 14 (1964): 189-197.

(16) CARRUTHERS, A., J.F.T. OLDFIELD, and H.J. TEAGUE. 1961. Methods for the assessment of beet quality. Int. Sugar J. 63: 72-74; 103-105, 137-139 and in (64), 224-248. Beurteilung der Rübenqualität. Z. Zuckerind. 13 (1963): 23-31. Quality for Processing. J. Nat. Inst. Agricult. Bot. 9 (1963): 427-431.

(17) CECIL, F. 1952. Zuckerhausrechnungen. Z. Zuckerind. 1: 53-56.

(18) CHELEMSKIJ, M.Z. Vol. I (1967), Vol. II (1973). Die technologischen Eigenschaften der Zuckerrübe. Moskau.

(19) DEDEK, J. 1927. Der Ursprung und das Wesen der Melasse. Z. Ver. Dt. Zuckerind. 77: 495-561.

(20) DEDEK, J. 1958. Der technische Wert der Zuckerrübe Z. Zuckerind. 8: 221-224.

(21) DEVILLERS, P., C. CORNET, Ph. GORY, M. LOILIER, and J. ROGER. 1973. Evolution de la qualité des betteraves pendant la campagne 1972-1973. Sucrerie Franc. 114: 536-541. ibid. 115 (1974): 30-36.

(22) DEXTER, S.T. 1973. A program for reducing impurities in sugarbeets. 36th I.I.R.B. Winter Congress, Brussels.
—M.G. FRAKESand R.E. WYSE. 1970. A method of evaluating and processings characteristics of sugarbeets, based on juice constituents: A prescription of beet quality. J. Am. Soc. Sugar Beet Technol. 16: 128-135.

(23) DEXTER, S.T., M.G. FRAKES, and F.W. SNYDER. 1967. A rapid and practical method of determining extractable white sugar as may be applied to the evaluation of agronomic practices and grower deliveries in the sugar beet industry. J. Am. Soc. Sugar Beet Technol. 14: 443-454.

(24) DÖRFELDT, W. 1951. Über die Verarbeitungsfähigkeit von drei charakteristischen Zuckerrübensorten. Kleinwanzleben E., Kleinwanzleben Z. and Hilleshög. Z. Zuckerind. 1: 1-5; 20-23; 65-67.

(25) DRACHOWSKA, M. 1961. Über Ergebnisse bei der Erforschung des technologischen Wertes der Zuckerrübe. Zucker 14: 182-187 and in (64), S. 55-66.

(26) DRACHOWSKA, M. and K. SANDERA. 1954. Diskuse jakostnich ukazatelü u cukrovky. Listy Cukr. 70: 6-9, 149-152, ibid. 71: 209.

(27) FRAKES, M.G. 1972. Estimating the average recoverable white sugar per ton (RWST) for a campaign from analyses of freshly harvested sugar beets. Paper presented at the 17th General Meeting of the ASSBT in Phoenix (Arizona) Quality Tests on Beet Deliveries Expanded for 1974. Sugar Beet J. 38 (1974): 12-15.

(28) HARTL, H. 1970. Die Bestimmung des technischen Wertes der Rüben in einem vollautomatisierten Rübenlaboratorium. Zucker 23: 472-482.

(29) HENRY, J. and R. VANDEWYER. 1960. Quelques aspects de la campagne sucrière 1959. Sucr. Belge 79: 417-434.

(30) HENRY, J., R. VANDEWYER, R. PIECK, G. RENS AND A. VANDEZANDE. 1962. Etude préliminaire sur la valeur technique de la bertterave d'apres les analyses de betteraves sucrières de champs d'essai de 1959. In (64) S. 94-168, ref. in Zucker 15: 556-560; 572-577; 604-610 see also Sucr. Belge 80: 173-191; 217-234; 265-288; 313-330.

(31) HOBBIS, J. and L. BATTERMAN. 1975. Storageability characteristics of sugarbeet varieties. Sugar J. 37: 32-35.

(32) JUNGHANS, E. 1970. Kleinwanzlebener Verfahren zur Bestimmung der technoligischen Qualität von Zuckerrüben. Lebensmittelindustrie 17: 218-219. see also Ph. Thesis, Berlin 1969.
(33) JUNGHANS, E. 1973. Bestimmung der Zuckerrübenqualität unter besonderer Berücksichtigung des Kleinwanzlebener Verfahrens. Biuletyn Oceny Odmian 4: 145-156.
(34) KEARNEY, P.A. 1971. Methodology of sugarbeet analysis. J. Sci. Fd. Agric. 22: 342-348.
(35) KERNCHEN, W. 1975. BETALYSER: An automatic system for large scale analyses of sugar beet quality. Booklet.
(36) KRÜGER, W. 1959. Uber Kalksalze und deren Kontrolle durch schnelle Bestimmung der effektiven Alkalität. Zucker 12: 560-565.
(37) KRÜGER, W. 1961. Über die Bewertung der Rübe nach der konduktometrischen Asche und dem schädlichen Stickstoff. Zucker 14: 238-243 and in (64) S. 67-77.
(38) LÜDECKE, H. 1954. Der Begriff des "bereinigten Zuckerertrages" als Bewertungsgröβe für die Leistung der Zuckerrübe. Landw. Forschung 7: 24-30.
(39) LÜDECKE, J. and M. NITZSCHE. 1959. Zucker-und Natriumgehalt der Rübenwurzel als Kriterium der Sortenzugehörigkeit und des Reifegrades von Zuckerrüben. Zucker 12: 392-401.
(40) MAKITA, M. and J. NAKAJIMA. 1973. Studies on the nonsugars causing the formation of molasses, especially on the soluble ash, in the breeding of sugarbeets. Bull. Sugar Beet Res. (Tokyo) 16: 1-114. ibid. 9 (1967): 66-75.
(41) PAAR, W. 1931. Zur Kenntnis der Ausbeuteformein und Ausnutzungsformeln. Dt. Zuckerind. 56: 1209-1211.
(42) PAAR, W. 1932. Rendement und Ausbeuteformeln. Dt. Zuckerind. 57: 75-77.; 89-101.
(43) PAAR, W. 1932. Die Schneidersche Nichtzuckerformel und die Ermittlung des Reiningungseffektes. Dt. Zuckerind. 57: 795-796.
(44) PARTALE, W., R. BUBE, H. SCHIWECK and T. CRONEWITZ. 1970. Die Bestimmung der Saccharoselöslichkeit in Melassen als Kriterium für die Nachproduktarbeit. Zucker 23: 155-167.
(45) PIECK, R. and G. RENS. 1959. L'équisemant industriel des mélasses. Sucr. Belge 78: 357-374.
(46) RÁCIK, G.: Hauptzuchstation für Samenhackfrüchte, Bucany (CSSR), personal communication.
(47) RÁCIK, G. 1969. Die technologische Qualität von Zuckerrüben nach der modifizierten Silinschen Methode. Z. Zuckerind. 19: 133-137.
(48) REINEFELD, E., K.M. BLIESENER, A. REINEFLED, and L. REXILIUS. 1975. Gaschromatographische Untersuchungen zum Verhalten von Nichtzuckerstoffen beim technischen Prozeβ der Zuckergewinnung. Comptes Rendus de la 15$^{e}$ Assemblée Génénerale de la CITS, Vienna.
(49) REINEFELD, E., A. EMMERICH, G. BAUMGARTEN, C. WINNER, and U. BEIβ. 1974. Zur Voraussage des Melassezuckers aus Rübenanalysen. Zucker 27: 2-15.
(50) SANDERA, K. 1928. Studie über die Zusammensetzung und die physikalischen Eigenschaften der Melasse. Z. Zuckerind. csl. Rep. 53: 1-11.
(51) SANDERS, K. 1952. Technologische Rübenqualität. Zusammensetzung des Dicksaftes und Mellasseanfall. Listy Cukr. 68: 83-88.

(52) SCHMIDT, L. 1972. Einfluß der Entwicklung der Zuckerrüben in den Jahren 1966-1970 auf deren technoligische Qualität. Listy Cukr. 88: 265-271.
— A. HAVRANEK and B. VORLICKOVA. 1966. Beiträge zur Bewertung der Zuckerrüben-Formeln für Melasseerzeugung und Ertragsfähigkeit. ibid. 82: 81-84.
(53) SSCHWECK, H. and L. BÜSCHING. 1970. Raffinose in Zuckerrübben- und Zuckerrohrprodukten. Zucker 23: 405-409.
(54) SCHNEIDER, F., A. EMMERICH, E. REINEFELD, E. WALTER and W. KELM. 1961. Auswirkung der Nichtzuckerstoffe der Rübe, insbesondere auf die Melassebildung.
I. Beziehung zwischen Nichtzuckerzusammenstezung und Entzuckerungsgrad von Melassen. Zucker 14: 208-212 and in (64) 171-180.
II. Einfluß einzelner Nichtzuckerfraktionen auf die Melassebildung. Zucker 14: 234-238 and in (64) 181-189, see also Zucker-Beihefte 4: 55-71.
III. Beurteilung der Nichtzuckerstoffe, in (64), 190-202. "Kristallisation und Gewinnung des Zuckers" in: Technologie des Zuckers, Hrsg.: F. Schneider 2. Auflage. Hannover 1968 418-426.
(55) SILIN, P.M. 1964. Molasses formation. Int. Sugar J. 66: 255-258.
(56) SILIN, P.M. 1963. Formation de la Mélasse. Comptes Rendus de la 12e Assemblée Générale de la CITS, Paris 1963 s. 253-263.
(57) SILIN, P.M. 1950. Questions de la technologie des sucres, Moskau, S. 182-216; 452.
(58) SILIN, P.M. 1958. Die Bewertung der technologischen Qualität. Cukoripar 11: 106-107.
(59) SILIN, P.M. 1955. Technologische Bewertung der Zuckerrübe. Abhandlungen der Konferenz fur Zucker und Rübe, Prag. 704-710.
(60) SOMMER, E. 1958. Der MW-Factor als Maßstab für die Verarbeitungsfahigkeit der Rübe. Z. Zuckerind. 8: 323-325.
(61) SPENGLER, O., ST. BÖTTGER, G. LINDER, and W. WÖRFELDT. 1933. Untersuchungen über die Verarbeitungsfahigkeit verschiedener: Zuckerrübensorten. Z. Ver. Dt. Zuckerind. 83: 895-931; ibid., 84: 365-399; 88: 779-800.
(62) STANKE, V. and P. PAVLAS. 1938. Studien über die physikalischen Eigenschaften der Zuckerrübenqurzel. Z. Zuckerind. csl. Rep. 63: 203-216; 219-224; 241-252.
(63) STARK, J.B. 1968. Beet molasses true purity predicted from thin juice chloride content. Part I. Composition. The relation of beet molasses composition to true purity. J. Am. Soc. Sugar Beet Technol. 15: 61-72.
(64) The technological value of the sugar beet. Amsterdam-London-New York, 1962. Proc. of the XIth Sess. of the CITS, Frankfurt, 1960.
(65) Technologie des Zuckers. Hrsg.: F. Schneider. 2. Auflage, Hannover 1968, S. 430-432.
(66) TRZCINSKI, W. 1970. Results of recent experiments on the technological value of sugar beet. Gas. Cukr. 78: 225-228.
(67) TRZCINSKI, W. 1971. Studies of sugar beet varieties in the light of sugar industry requirements. Gas. Cukr. 79: 45-50.
(68) UHLENBROCK, W. 1973. Rübeninhaltsstoffe und Voraussagegrenzen für die Rübenqualität. Zucker 26: 469-478. Die Aussagequalität

der vollautomatischen Rübenanalytik. Zucker 27 (1974): 289-291.
(69) VAVRA, I. 1970. Labor-Extraktor für Zuckerrübenschnitzel. Z. Zuckerind. 20: 569-574.
(70) VUKOV, K. 1958. Die Mechanischen Eigenschaften der Zuckerrübe. Zuckererzeugung 2: 245-247; 267-271; ibid., 3: 9-12; 43-45 and in (64), S. 291-305.
(71) VUKOV, K. 1972. Physik und Chemie der Zuckerrübe als Grundlage der Verarbeitungsverfahren. Budapest.
(72) VUKOV, K. 1974. Methoden zur vergleichenden Wertung der technologischen Ergebnisse bei der Verarbeitung von Zuckerrüben abweichender Beschaffenheit. Zucker 27: 23-26.
(73) VUKOV, K. and L. BARÁNY. 1963. Ermittlung der Weißzuckerausbeute und des melassezuckeranfalls bei Zuckerrüben. Cukoripar 16: 217-219.
(74) WEIDENHAGEN, R. and H. SCHIWECK. 1968. "Ionenaustausch" in: Technologie des Zuckers. Hrsg.: F. Schneider, 2. Auflage Hannover. S. 611.
(75) WIENINGER, L. and N. KUBADINOW. 1971. Beziehungen zwischen Rübenanalysen und technischer Bewertung von Zuckerrüben. Zucker 24: 599-604.
(76) WIKLUND, O. 1943. Das Verhältnis von Zucker, schädlichem Stickstoff, Asche und Alkalisalzen in einigen schwedischen Mellasen. Centralbl. Zuckerind. 51: 21 and in (64), S. 13-27.
(77) WIKLUND, O. 1949. The industrial value of the sugar beet. Socker 5: 41-63 and in (64) S. 13-27.
(78) WIKLUND, O., B. EWERTZ, and G. FLINK, 1951. Conductometric determination of alkali salts in sugar beets, thick juice, refinery syrup and molasses. Socker 7: 25-32.
(79) WINNER, C. 1970. Maßstäbe zur Beurteilung der Qualität der Zuckerrübe. Landw. Forschung 23: 1-12.