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Beet Technological Value Under Mediterranean Storage Conditions

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ABSTRACT

Beet technological value is determined by non-traditional parameters which relate better to the problems of processing. In particular the dry substance determination and the composition of the juice extracted at diffusion temperature are considered. These evaluation criteria are particularly interesting in the case of damaged roots which are stored under unfavourable conditions due to high temperatures. Storage of sound and damaged beets either in piles in the fields or in the factory silo for a maximum of four days with temperatures between 20 and 35°C, is taken into consideration. The results are also relevant to problems arising from short storage in warm, humid climatic conditions. In order to achieve a more complete view of the consequences of storage on the technological value of beet it is necessary to extend the field of investigation to non-traditional parameters.

INTRODUCTION

Assessment of beet technological value has been the object of investigation by a number of researchers. Obviously, the problems that arise differ not only with the type of beet, but also with climate, storage conditions, and plant pathology. The purpose of these investigations has been to improve beet technological qualities, particularly the amount of sucrose produced per hectare. However, this does not always represent the raw matter to be processed in sugar factories. It is important also to take into account increases of non-sucrose compounds that may make factory processing more difficult.

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Normally, assessment of technological value is carried out by means of direct analysis of brei, by sodium, potassium, and α-amino nitrogen (α-N) as well as polarization. These parameters, in particular for damaged beets, and possibly for beets stored under particular climatic conditions, cannot always determine the technological quality of the juices obtained during processing.

The above-mentioned parameters are, as is known, utilized through particular formulae, which differ from country to country, with the aim of evaluating both the theoretical sugar yield and the thick juice purity quotient (Carruthers & Oldfield, 1961; Wieninger & Kubadinow, 1971; Reinefeld *et al.*, 1974; Akyar *et al.* 1979; van Geijn *et al.*, 1983; Devillers, 1988; de Nie, 1988).

For some time we have been studying this problem (Mantovani, 1981; Vaccari *et al.*, 1983, 1988*a*; Baraldi *et al.*, 1984; Bentini *et al.*, 1987), concentrating not only on the parameters that can be considered traditional, but also on others which, in our opinion, can better correlate the composition of beet to its utilization as raw matter for sugar production. In particular, we judge it essential to investigate the composition of brei hot extraction juice which represents, as much as possible, the factory raw juice characteristics. Moreover, taking into account the particular climatic conditions existing in Italy, which are similar to those existing also in other countries, we judge it important to relate the brei analytical data not to the brei as such but to its dry substance.

We report, in the following, the results of some experiments on the variation of the technological characteristics of beets under different storage conditions.

MATERIALS AND METHODS

Because the climatic conditions of our country do not allow long storage periods, we followed the quality of sound and damaged roots either stored in piles on the field for a maximum period of four days, or in a factory silo.

Sugar beets (NZ-type) were planted at the beginning of March on clay soil in a hilly region of the centre of Italy and harvested at the beginning of September. Owing to the land slope, harvesting machines caused a high number of breakages. About ten tons of just harvested beets were piled on the field for four days.

At the time of pile formation, that is at zero time, samples of sound and damaged beets were collected. Every sample contained 50 beets and was replicated four times. To avoid variation of composition caused by root size, only beets having a diameter between 10·5 and 12·5 cm, and carefully topped by hand, were taken. Damaged beets were those presenting injuries, cuts or

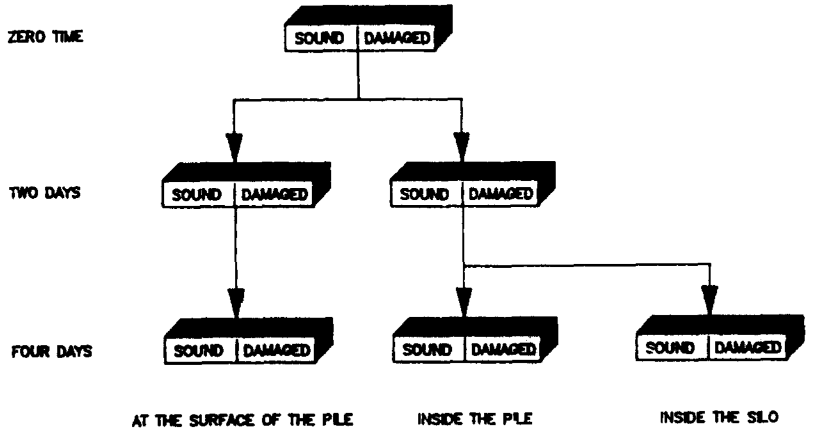

Fig. 1. Scheme of the whole experiment.

breakages with surface diameter greater than 4 cm. During the period of experiments the daily maximum temperature was between 32 and 34°C, and the minimum was between 19 and 21°C. In the same period the minimum relative humidity was from 58–70% whereas the maximum was between 85 and 97%. The scheme of the whole experiment is shown in Fig. 1. After two days of storage in piles in the field, samples of sound and damaged beets (50 beets and four replications) were taken both from the surface and the interior of the pile. Simultaneously, samples of sound and damaged beets, taken from the interior of the pile, were placed inside the factory silo (Fig. 2). After another two days of storage, samples of sound and damaged beets (50 beets and four replications) which were at the surface and inside the pile respectively, and samples placed inside the factory silo, were taken.

All the samples, just after their collection, were immediately washed and transformed to brei by grinding with a RE.LO.BO. machine. Part of the brei was analysed immediately, through a Venema apparatus, for sugar content (Schneider, 1979), for sodium and potassium by flame photometry and for α-amino nitrogen by the 'blue number' method (Schneider, 1979). The remainder of the brei was frozen and later utilized for the analysis of the dry matter and the preparation of hot extraction juice. Dry matter content of brei was determined from weight lost after drying weighed samples for 16 h at 105°C. Hot extraction juice was prepared after the four replications of each sample were composited. About 500 g of brei and 400 g of boiled distilled water was mixed and put in a thermostatted bath at 75°C. The mixture was continuously stirred for 40 min at this temperature, then filtered under vacuum, and the extraction juice at once cooled. On this juice, the purity quotient by determination of ° Brix and polarization, and the reducing sugars content by the Berlin method (Schneider, 1979), were determined. From the data of the direct analysis of the brei (sodium, potassium and α-amino

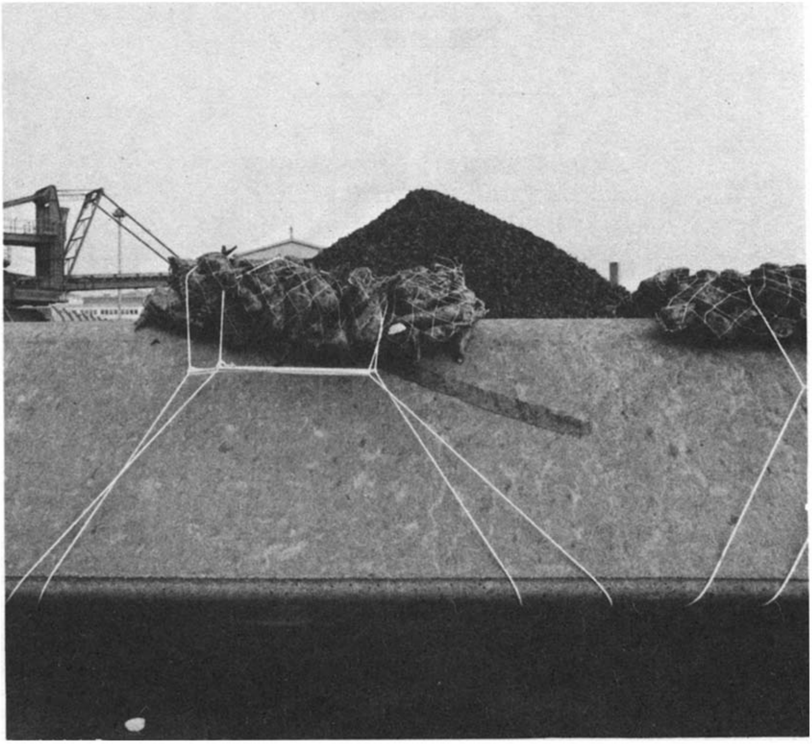

Fig. 2. Beet samples placed inside the factory silo.

nitrogen determined on the cold extraction of the brei) we calculated the theoretical sucromolasses using the Wieninger & Kubadinow's formula (Wieninger & Kubadinow, 1971):

$$SM = 0{\cdot}349(K + Na) \qquad AK > 1{\cdot}8 \tag{1}$$

$$SM = 0{\cdot}628\ \alpha\text{-N} \qquad AK < 1{\cdot}8 \tag{2}$$

$$AK = (K + Na)/\alpha\text{-N} \tag{3}$$

The theoretical recoverable sugar index was calculated as:

$$\text{Recoverable Sugar Index} = 100 - SM \tag{4}$$

From the same potassium, sodium, and α-amino nitrogen data we calculated the theoretical purity quotient of thick juice by the Carruthers & Oldfield's formula (Carruthers & Oldfield, 1961):

$$Q_z \text{ thick juice} = 97 - 0{\cdot}8(2{\cdot}5\,K + 3{\cdot}5\,Na + 10\,\alpha\text{-N}) \tag{5}$$

where K, Na and α-amino nitrogen are in g% Pol.

RESULTS AND DISCUSSION

Some of the data concerning the characteristics of sound and damaged sugar beets prior to storage and after two days or four days of storage in a pile or a silo are shown in Table 1.

Although damaged beets give, as is to be expected, yield and purity values in general lower than sound ones, we observe data which can hardly be justified since the stored beets do not always exhibit yield and purity decreases as might reasonably be expected.

As far as the change of root polarization is concerned we can observe an increase of polarization for beets that were at the surface of the pile. This increase continued during four days of experiment, although it was less on the fourth day for damaged roots. For beets inside the pile, the polarization increase that was observed after two days was followed by a decrease during the following two days (although the values remain higher than at zero time). For beets placed inside the factory silo, after storage inside the field pile for two days, polarization was lower than that at zero time. Damaged beets had lower polarization than that of sound beets, and that difference became more evident with continued storage. The difference of polarization between sound and damaged beets, which was observed at zero time, is ascribed to the fact that the beet samples, for technical reasons, were analysed several hours after harvesting. Obviously, the increase of polarization during storage cannot be ascribed to an increase of sucrose content, but is due to decrease in the roots' moisture content. The change in root dry substance is clear for the roots on the pile surface, where the effects of the climatic conditions were stronger.

Polarization per cent on dry substance showed the decrease of the roots' quality. There was a drastic decrease in this character for beets at the surface of the pile, a lesser decrease for beets inside the pile, and a particularly important decrease for the beets inside the factory silo. Damaged beets always had values of polarization (% dry substance) lower than that of sound ones, and such differences increased as storage continued.

The sucrose percentage losses during storage, calculated on the grounds of polarization and dry substance variations, are shown in Fig. 3. The sugar loss was more pronounced for beets at the surface of the pile, and for damaged beets versus sound ones. The loss became particularly high after the storage in the factory silo, reaching almost 9% for sound beets and exceeding 10% for damaged ones. This corresponds to a sucrose loss of 4 and 5 kilos per ton of beets per day.

The sucrose loss does not represent the only negative point of storage as we must consider also the decrease of extraction juice purity caused both by sucrose loss and non-sugar production. The hot extraction juice purity

TABLE 1

Physical and Chemical Characteristics of Sound (S) or Damaged (D) Sugar Beets at Harvest, and after Two or Four Days of Storage in a Pile or Silo

Character	*At harvest*		*Storage*									
			Pile surface				*Pile interior*				*Silo*	
			2 days		*4 days*		*2 days*		*4 days*		*4 days*	
	S	*D*	*S*	*D*	*S*	*D*	*S*	*D*	*S*	*D*	*S*	*D*
Recoverable sugar index[a]	77·32	76·74	78·46	74·74	79·22	75·20	77·54	75·16	76·11	76·61	75·49	72·12
Q_z thick juice[b]	85·97	84·95	86·28	84·66	86·63	84·45	85·29	84·66	85·79	85·29	84·29	83·16
Pol. of beet (Sucrose degrees)	16·64	16·18	17·43	17·20	18·02	17·35	17·40	16·85	17·08	16·31	16·24	15·62
Dry substance (%)	21·72	21·22	23·68	24·00	24·57	24·94	23·18	23·39	23·20	23·10	23·27	22·97
Pol. % dry substance	76·61	76·25	73·61	71·67	73·34	69·57	75·06	72·04	73·62	70·60	69·79	68·00
Q_z hot extraction juice[c]	82·59	81·01	81·94	80·76	80·08	79·76	81·41	80·57	81·32	80·25	80·25	77·52
Reducing sugars[d]	1·39	1·66	3·22	3·26	4·69	4·21	2·39	2·97	3·26	4·68	4·74	5·29

[a] Calculated by eqn (4).
[b] Thick juice purity calculated by eqn (5).
[c] Thick juice purity calculated for hot extraction juice (Q_z = Pol. × 100/° Brix).
[d] Reducing sugar content of hot extraction juice (g % Pol.).

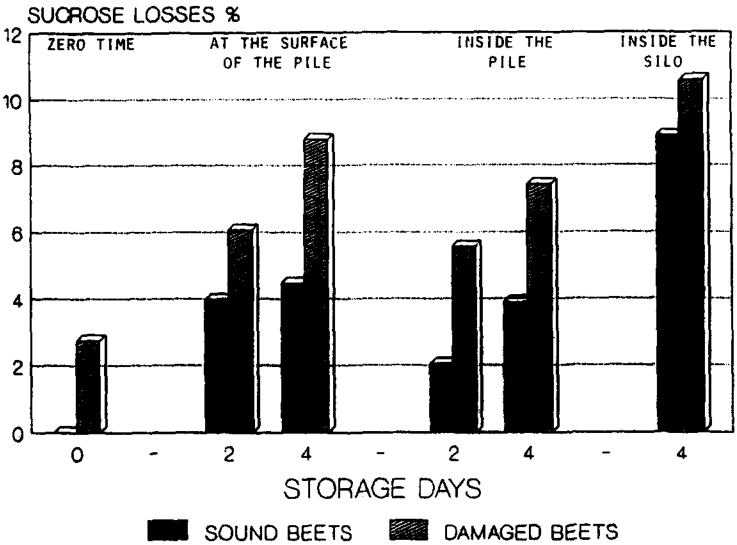

Fig. 3. Sucrose losses (%) during storage.

quotient showed a storage effect that was particularly notable for damaged beets placed inside the factory silo. In fact, the purity quotient changed from 82·6 for sound beets just harvested, to 77·5 for damaged beets stored for two days in the field pile and then two days in the factory silo.

Reducing sugars, which represent only intermediate sucrose degradation products, and which cannot be directly correlated to lost sucrose, also showed a remarkable increase during the storage.

CONCLUSIONS

The non-traditional parameters indicate the difficulty of maintaining beet technological value during even short periods of storage in the particular climatic conditions existing in our country, particularly for damaged beets. These unfavourable consequences cannot always be discovered, as observed above, by evaluation of sodium, potassium and α-amino nitrogen using the Venema equipment, and applying the formulae mentioned above. However, within a total statistical picture, these formulae remain valid, particularly if special situations are not taken into consideration.

For routine control of the raw matter entering the processing, more reliable parameters may be taken into consideration, such as the composition of the hot extraction juice and the dry matter of beet. These determinations might not be a hindrance bearing in mind the possible utilization of the NIR technique, which could allow the rapid determination of the hot extraction juice °Brix and polarization (Vaccari *et al.*, 1987, 1988*b*)

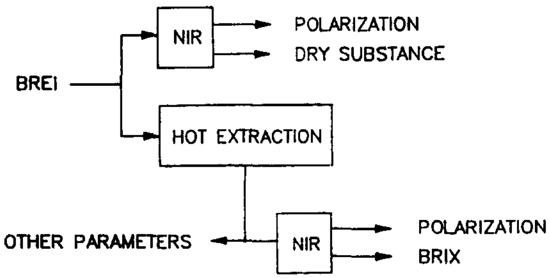

Fig. 4. Hypothesis of a working scheme which could replace the traditional Venema equipment.

as well as the beet dry substance (Vaccari *et al.*, 1990). In Fig. 4 a hypothesis of a working scheme which could replace the traditional Venema equipment is shown. A small portion of brei might be directly employed for the determination of its polarization and dry substance by means of an NIR apparatus. Another portion of the same brei, about 300 g, might be employed for the preparation of the hot extraction juice in a continuous apparatus. After filtration and cooling, the juice might be directly analysed by means of another NIR apparatus for polarization and °Brix. On the same juice other parameters, for instance sodium, potassium, α-amino nitrogen, glucose and fructose, could be determined. From time to time both brei and hot extraction juice could be analysed by traditional methods with the aim of checking the reliability of the data given by the two NIR analysers.

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