# External factors and their impact on the metabolism and technological quality of stored sugar beet

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**ABSTRACT**: Technological quality of sugar beet is a complex of biological, chemical, physico-chemical and mechanical properties of the sugar beet root, which are conclusive to decide upon a proper warehousing and subsequent processing of the crop aimed at reaching a maximum yield of white refined sugar (raffinade). It is affected by a number of external and internal factors of the field during the growing season and during the post-harvest storage. This particularly applies to sugar beet meant for sugar factory processing in the months of November and December, i.e. to about 40–60% of total sugar beet crop harvested in the Czech Republic. Having been lifted at the end of vegetation, the root still remains to be a living organism with its specific metabolism which can be characterized by a high loss of bioenergy the size of which can be influenced not only by the harvest quality as expressed by the rate of surface damage to the roots, but also by weather factors such as alternating temperatures, solar radiation intensity, precipitations, etc. For this part of the production it is necessary to adopt measures that would minimize the loss of sugar beet roots weight and technological quality during the storage. One of possibilities to slow down the process of this mechanism of losses is to cover the mechanical beet storage in order to create a semi-permeable layer between the beet floor and the surrounding environment, which would slow-down the process of respiration.

**Keywords**: sugar beet; storage; losses; sugar content

A problem which has been recently paid a lot of attention to is the reduction of losses at sugar beet storage. Czech Republic is a typical representative of countries in which the collection of sugar beet usually ends at the beginning of November but the sugar-production campaign normally lasts until the end of the year. In the course of October, sugar factories can process about only a third of the harvested crop, the second portion being processed in November and the last one in December. Sugar beet ploughed out in September and October is usually meant for direct processing but roots harvested in November or December are kept on the field with the storage duration ranging from 10 to 30 days. The lifted sugar beet root remains to be a living organism even after the tops have been cut-off. Its metabolism is however characterized by high losses of bioenergy with the main physiological process being respiration at which saccharose is being burnt. At a long-time sugar beet storage, this physiological process is responsible for 70–80% of total sugar loss with the remaining 20–30% being microbiological losses resulting from the destructive activity of phytopathogenic micro-organisms in the storage (fungi and bacterial rots). The development of phytopathogenic micro-organisms is

Fig. 1. Beet storages shortly after having been established

Supported by Ministry of Education, Youth and Sports of the Czech Republic, Research Project MŠM No. 432100001.

conditioned primarily by two factors – temperature and water content. This paper presents results from practical measurements carried out in 2003 and aimed at a comparison of differences detected between the losses in an unprotected sugar beet storage and in a storage covered by a leyer of short-cut straw.

## MATERIAL AND METHODS

In order to make an objective assessment, two storages of triangular cross-section were established (base 7 m, height 2.6 m, length 58 m) with a total volume of 2 × 320 tons sugar beet roots (Fig. 1). Orientation of the storages was with their longer side – axis oriented in the south-west direction. One of these storages was left untreated and the second one was covered by short-cut straw. Chopped straw length ranged between 3–5 cm and its average blown thickness on the storage was 15 cm (maximum 38 cm at the storage foot; minimum 5 cm on the top). The storage treatment was made with using the Schöpstal Maschinenbau GmbH adapter model SHV 150 in combination with the Class forage harvestor.

To establish the beet storages, control samples (10 for each storage) were placed in the storage cross section in jute bags each containing 15 beet roots. Prior to the placement of the samples into the storage, the roots were weighed, sampled for initial sugar content, with a share of stuck-on and loose earth being detected by a dry method. The individual samples were numbered. In order to achieve a precise location of the samples in the storage during the experiment, the cross section profile of storage was scanned before the coverage of the samples by using a digital camera. The photograph was evaluated by photogrammetry by using a computer and each sample was allocated a sector corresponding to a concrete position of the sample in the storage (Fig. 2). Temperature and moisture content detecting sensors were installed in the storages at depths of 0.25, 0.5, 1.0 and 2.0 meters by means of probes in order to monitor the biochemical processes passing in the storages. The sensing elements used were temperature and air humidity registrators made by AMET Velké Bílovice, equipped with internal memory and programmable adjustment of measuring intervals. The measuring interval was set up to 1 hour and the measurement was made continually 24 hours a day. The meters were checked for their proper functioning at all times once in 4 days with the measured data being entered in the computer. At the end of the experiment, the samples were weighed once again to determine the difference in their weight at the beginning and at the end of the trial (Table 2). The experiment proper was launched in 4 November 2003 and terminated on 3 December 2003, which means that the total time of storage was 29 days. Average initial sugar content values measured was 18.03 (17.97 and 18.1 in the covered and uncovered storage, respectively).

The sugar content determination was made with a solution polarized by cold digestion.

The amount of material which is ploughed out during the harvest together with beet roots as an undesirable admixture is referred to as a share of mineral admixtures whose main constituent (98%) is earth. In harvesting beet roots the earth occurs in two forms: as a *earth stuck on* the root surface ($Z_u$) and as *loose earth* ($Z_v$) which fills the room between the beet roots when loaded on the storage or during transport. The share of earth ($Z_{v+p}$), and particularly a separate assessment of the proportion

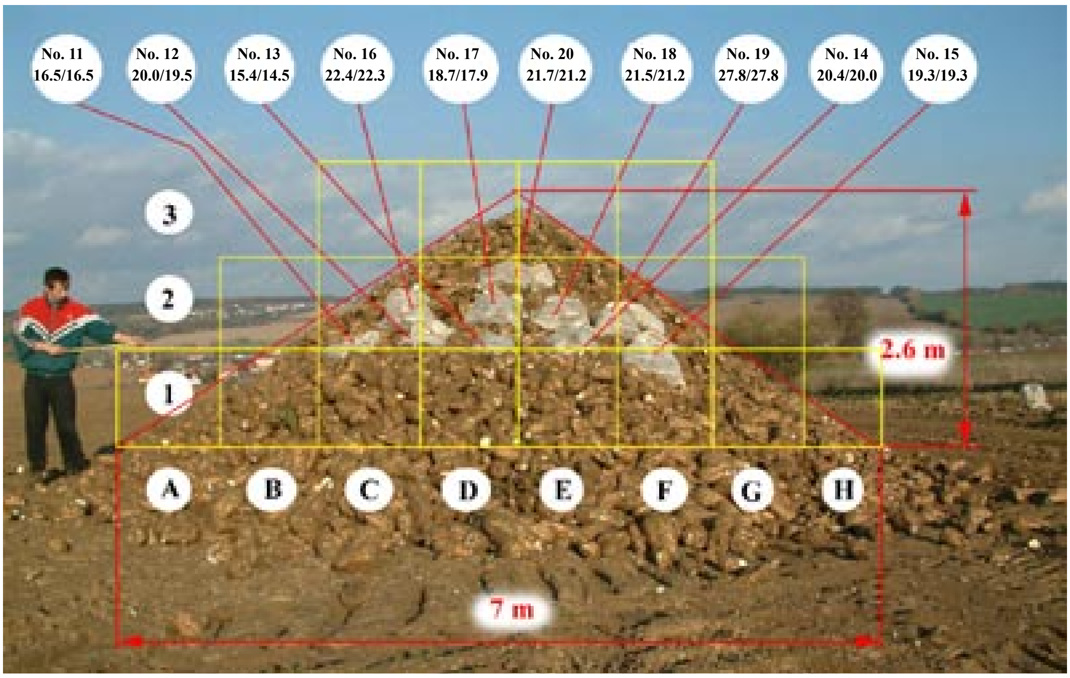


Fig. 2. Photogrammetrical determination of the position of individual samples in the storage

Table 1. Basic data on harvest quality indicators

| | |
|---|---|
| Root surface damage | 98 cm²/100 roots |
| Sugar content at harvest | 18.1 (17.97) |
| Proportion of loose earth at harvest | 10.3% |
| Proportion of stuck-on earth at harvest | 4.2% |
| Soil moisture content at harvest – measured on the surface | 14.8% |
| Soil moisture content at harvest – measured at a depth of 5 cm | 16.2% |

of loose ($Z_v$) and stuck-on ($Z_u$) earth was determined by using the following relations.

Relative proportion of stuck-on earth:

$$Z_{u,rel} = \frac{\sum Z_u}{\sum Z_u + \sum m_p} \cdot 100 \qquad (\%) \qquad (1)$$

Relative proportion of loose earth:

$$Z_{v,rel} = \frac{\sum Z_v}{\sum Z_v + \sum m_p} \cdot 100 \qquad (\%) \qquad (2)$$

where: $\sum m_p$ – total weight of roots in the sample (kg),
$\sum Z_u$ – total weight of stuck-on earth in the sample (kg),
$\sum Z_v$ – total weight of loose earth in the sample (kg).

## RESULTS

Economic benefits of the field storage protection technologies are to a considerable measure given by climatic conditions at harvest (Fig. 3), damage to root surface during the harvest, and by the share of loose and stuck-on earth and its moisture content (Table 1).

Climatic and soil conditions at harvest were classified as very favourable. The rate of surface damage to beet roots and the share of stuck-on and loose earth are specified in Table 1. According to the above criteria, the quality of stored beet roots was classified as above-average in the conditions of Czech agriculture. The fact was also contributed to by average daily air temperatures at harvest – on 3 and 4 November 2004 (8°C).

Temperature curves during the experiment are presented in Fig. 3. In the period from 3–8 November 2003, the average daily temperatures ranged by 1–4°C above the long-term average. In the period from 9–16 November 2003, i.e. for eight days, the average daily temperatures fell by 1–8°C below the long-term normal down to a minimum temperature of –3°C (14 November 2003). However, ground minimum temperatures in this period of 8 days dropped as low as to –7°C, which resulted in a frost damage to roots situated at the foot of the uncovered storage up to a height of 70 cm. In the period from 17 November to the end of the experiment on 3 December 2003, the outdoor temperatures ranged high above the long-term normal. In the final period of the experiment, the average daily temperatures ranged by 10–12°C above the long-term average (26–29 November 2003). The unusually warm period gave rise to

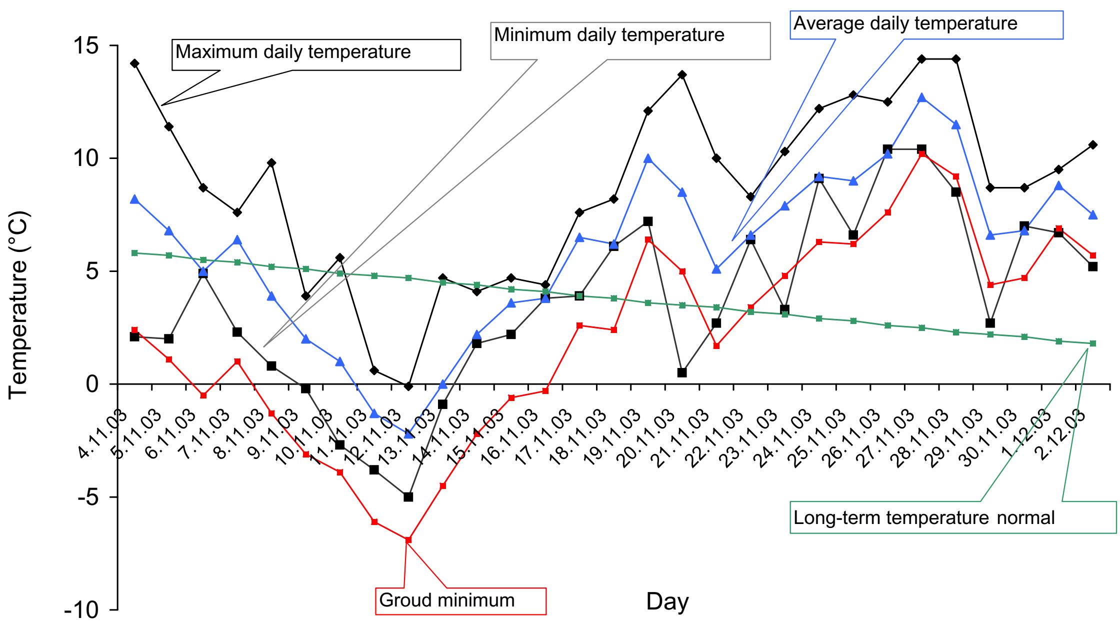


Fig. 3. Curves of outdoor temperatures during the experiment

Table 2. Weight and sugar content values of individual samples from the covered beet storage

| Sample No. | Weight before the experiment (kg) | Weight after t he experiment (kg) | Weight difference (kg) | Sugar content after the experiment (%) | Sugar content difference (%) |
|---|---|---|---|---|---|
| 11 | 16.5 | 16.5 | 0 | 17.8 | 0.2 |
| 12 | 20 | 19.5 | 0.5 | 17.6 | 0.5 |
| 13 | 15.4 | 14.5 | 0.9 | 17.3 | 0.8 |
| 14 | 20.4 | 20 | 0.4 | 17.5 | 0.6 |
| 15 | 19.3 | 19.3 | 0 | 17.5 | 0.6 |
| 16 | 22.4 | 22.4 | 0 | 17.2 | 0.9 |
| 17 | 18.7 | 17.9 | 0.8 | 17.3 | 0.8 |
| 18 | 21.5 | 21.2 | 0.3 | 17.9 | 0.2 |
| 19 | 27.8 | 27.8 | 0 | 17.5 | 0.6 |
| 20 | 21.7 | 21.7 | 0.5 | 17.5 | 0.6 |
| Total | 203.7 | 200.3 | 3.4 | 17.51 | 0.59 |

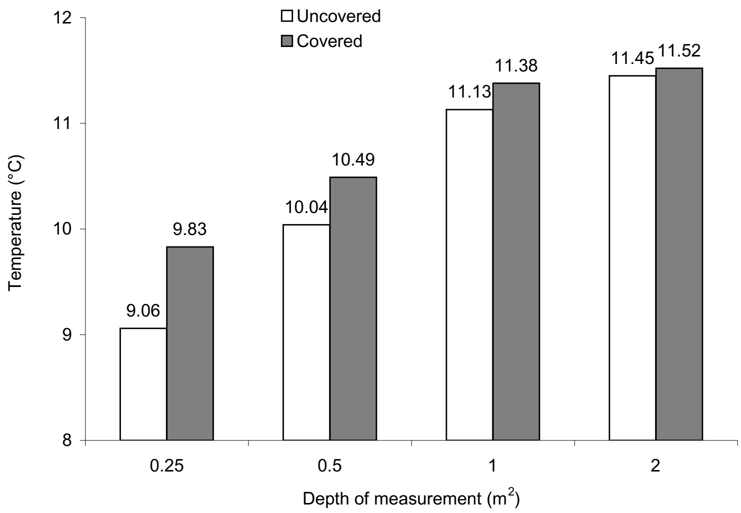


Fig. 4. Average temperature values at the respective depths (0.25, 0.5, 1.0 and 2.0 m) at the end of the experiment

putrification processes on the roots damaged by frost and to a partial contamination of healthy roots in the uncovered storage.

The greatest losses at storage are due to respiration. The process of root respiration is primarily affected by temperature and its dynamics is increasing with the increasing temperature. Due to this process, changes can be detected in the physical and biochemical properties of root tissues, which result in the loss of weight and reduced sugar content. Optimum storage temperature is considered to range from 1–5°C. Actual average temperature values measured in the beet storage in the period from 25–30 November 2003 are presented in Fig. 4. The average outdoor temperature in this period amounted to 9.47°C and the value was corresponded to by storage temperatures at a depth of 0.25 m (Fig. 4). At a depth of 2 m (sample No. 13 and sample No. 23), the temperatures were high above the optimum value with the difference between the covered and uncovered storages being minimal (11.45°C and 11.52°C uncovered and covered storage, resp.). Due to the high temperatures, samples 13 and 23 showed the highest loss of both sugar content and weight (Tables 2 and 3). Higher losses of weight and sug-

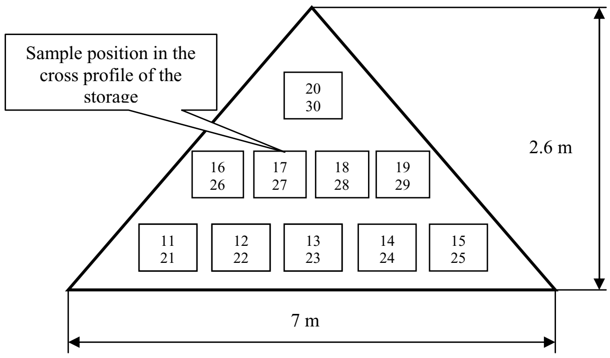


Fig. 5. Position of individual samples in the cross-sectional profile of the storage

Table 3. Weight and sugar content values f individual samples from the uncovered beet storage

| Sample No. | Weight before the experiment (kg) | Weight after the experiment (kg) | Weight difference (kg) | Sugar content after the experiment (%) | Sugar content difference (%) |
|---|---|---|---|---|---|
| 21 | 24.5 | 24 | 0.5 | 17.7 | 0.23 |
| 22 | 18.4 | 17.8 | 0.6 | 17.4 | 0.53 |
| 23 | 16.6 | 15.8 | 0.8 | 17.3 | 0.63 |
| 24 | 21.2 | 20.8 | 0.4 | 17.1 | 0.83 |
| 25 | 21.1 | 20.1 | 1 | 17 | 0.93 |
| 26 | 21 | 20.5 | 0.5 | 17.4 | 0.53 |
| 27 | 18.5 | 18.5 | 0 | 17.9 | 0.03 |
| 28 | 20.3 | 20 | 0.3 | 17.1 | 0.83 |
| 29 | 19 | 18.8 | 0.2 | 17.8 | 0.13 |
| 30 | 21.9 | 21.2 | 0.7 | 17.1 | 0.83 |
| Total | 202.5 | 197.5 | 5 | 17.38 | 0.55 |

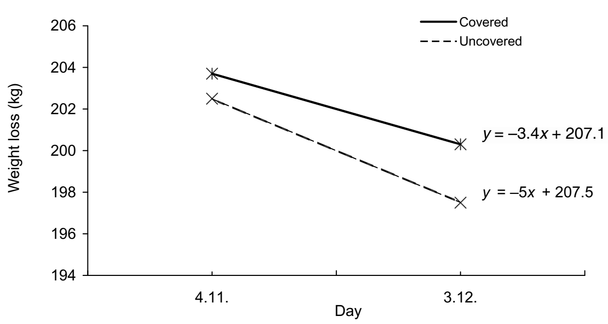


Fig. 6. Weight loss – aggregative sample

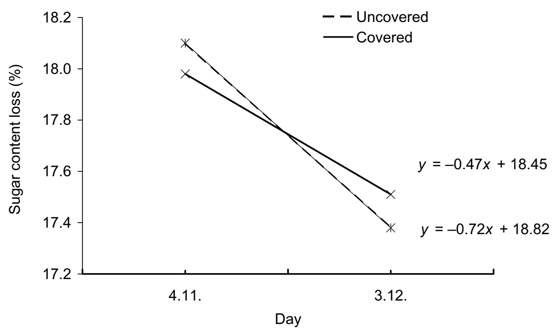


Fig. 7. Sugar content loss during the experiment

ar content were recorded only in sample No. 25 from the uncovered storage. The sample was exposed to temperatures ranging from –4.2°C to 22.5°C during the storage. The comparable sample No. 15 from the covered storage showed the beneficial heat-insulation properties of straw. Resulting changes in the weight and sugar content of individual samples are presented in Tables 2 and 3.

The uncovered beet storage exhibited considerable temperature fluctuations during the storage, which nearly copied the course of environmental temperatures (Fig. 5). The covered storage showed a considerably lower temperature fluctuation. Chopped straw appeared to be a very good insulation layer to eliminate extreme temperature differences, especially on the south-eastern side of the storage. The generally more favourable results recorded in the covered beet storage were at a greater part contributed to by the root layer to a depth of 1 meter. As it follows out from the results of measurements, the weight loss was (as expressed in per cent) by 0.8% lower in the covered beet storage (Fig. 6).

The beneficial influence of chopped straw showed also in the slowed-down root metabolism. Sugar content decreased by 0.4% and 0.72% in the covered and uncovered beet storages, respectively. The sugar content yield of covered storage technology was 0.32% (Fig. 7).

Fig. 8. Stuck-on earth in the area of the root ripple

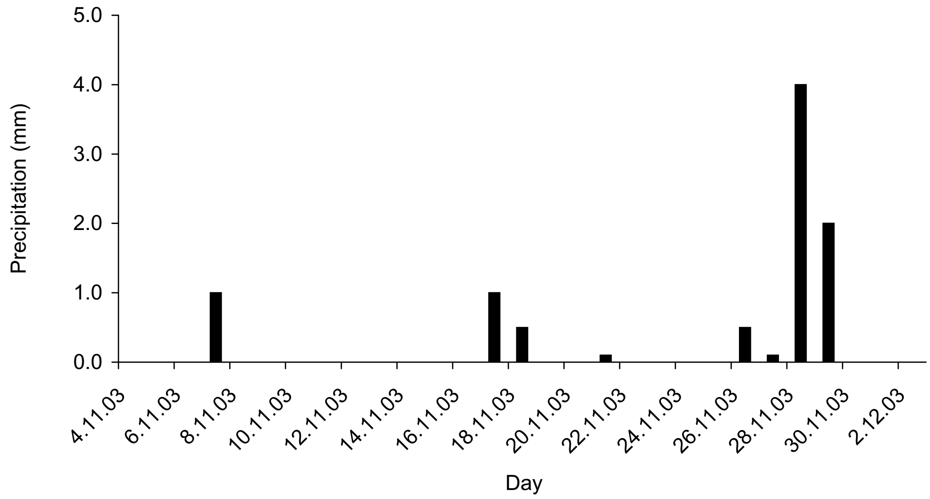


Fig. 9. The course of precipitation during the experiment

The proportion of admixtures was assessed with a special emphasis on the evaluation of straw as a protective layer against rain water percolating into the beet storage. It was experimentally demonstrated that a reduction of moisture content in earth stuck on the roots results in a spontaneous conversion of stuck-on earth into loose earth. The stuck-on earth which is the earth bound by root hairs around the root ripple (Fig. 8) cannot be removed by the cleaning elements of harvesters without impacting the quality of beet root surface.

Utilization of the exothermic reaction of biochemical processing happening in the beet root combined with the covering semi-permeable layer (of straw) brings a solution to the problem of reducing the mineral admixtures. In 2003, the influence of the protective straw layer on the percolation of precipitation into the beet storage could not be objectively evaluated with respect to the low intensity of precipitation (Fig. 9). Total precipitation for the entire experimental period was mere 10 mm.

The average measured value of stuck-on earth at harvest was 4.2% with its moisture content amounting to 16.2% (Table 1). Due to the biochemical processes happening in the beet storage during the storage time of 29 days, a conversion of the stuck-on earth into the loose earth was 1.6% and 1.3% in the covered and uncovered beet storage, respectively. The figures indicate that the proportion of stuck-on earth was reduced from 4.2% to 2.6% and 2.9% in the covered and uncovered beet storage, respectively.

## DISCUSSION

In spite of very favourable conditions at harvest and during the subsequent storage of sugar beet roots in the autumn of the year 2003, all three measured basic indicators demonstrated the benefits of covered storage – by 0.8% in weight, 0.32% in sugar content, and by 6% in stuck-on earth proportion.

The experiment demonstrated a substantiated use of covering the field sugar beet storages prior to the processing of roots in sugar factories provided that some general principles are observed as follows:

- Long-term storage of sugar beet roots ploughed out under temperatures below –2°C should be prevented. Under these temperatures, the quality of harvested sugar beet is considerably impaired (increased surface damage to roots).
- If allowed by access conditions, the beet storage should be preferrably oriented with its longer side (axis) in the NS direction.
- The storage should be covered immediately after its formation, particularly so if a pronounced temperature drop or rains are expected.
- The beet storage should not be covered as long as the average daily temperature is above 12°C.
- The beet storage should be uncovered immediately before loading the roots for further processing.

## CONCLUSION

Sugar beet harvest terminates the period of vegetation, i.e. the process of assimilation is substituted by the process of respiration characterized as a metabolism of losses. The losses increase with the increasing temperature and moisture content. Alternating high and low temperatures lead to a damage to tissues and to a subsequent contamination of beet roots by micro-organisms. Latent infection can be under certain conditions a cause to the deterioration of the entire beet storage or its part. Adhering to the principles recommended for harvest and beet storage formation combined with the use of a suitable covering material – both organic (straw) or inorganic (nonwoven semi-permeable textile – vlies) contributes not only to the protection of the beet storage against micro-organisms but it also enables to store the roots at a higher quality and lower losses as compared with uncovered beet root storages.

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Received for publication March 24, 2004

Accepted after corrections May 31, 2004


## Vliv vnějších činitelů na metabolismus a technologickou jakost skladované cukrovky


**ABSTRAKT**: Technologická jakost cukrovky je komplex biologických, chemických, fyzikálně chemických a mechanických vlastností řepné bulvy, které rozhodují o jejím vhodném skladování a následném zpracování s cílem dosažení maximální výtěžnosti bílého rafinovaného cukru (rafinády). Je ovlivňována řadou vnějších a vnitřních činitelů na poli v době vegetace i v posklizňovém období při skladování. To platí především o cukrovce určené pro zpracování v cukrovaru v listopadu a prosinci, což představuje v České republice 40–60 % celkového množství sklízené cukrovky. Bezprostředně po sklizni – ukončení období vegetace – zůstává vyoraná bulva stále živým organismem se svým specifickým bioenergeticky vysoce ztrátovým metabolismem. Jeho ztrátovost je ovlivněna nejen kvalitou sklizně, vyjádřenou mírou povrchového poškození bulev, ale i působícími povětrnostními vlivy (střídání teplot, intenzita slunečního svitu, vodní srážky atd.). Pro tuto část produkce je nutné přijmout taková opatření, aby v průběhu skladování byly ztráty na hmotě a technologické kvalitě minimalizovány. Jednou z možností, jak zpomalit proces ztrátového metabolismu, je zakrýt skládku a vytvořit tím mezi skládkou bulev a okolním prostředím polopropustnou vrstvu, která zpomalí proces dýchání.



**Klíčová slova***:* cukrovka; skladování; ztráty; výtěžnost cukru


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