Scientific Papers. Series B, Horticulture. Vol. LXVI, No. 1, 2022
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

BIOCHEMICAL CHANGES DURING THE STORAGE OF SWEET POTATO ROOTS

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Abstract

The biochemical changes during storage targeted the total dry matter, total soluble solids content, the total and reducing sugar content, the glucose content as well as the starch content, from the roots of six sweet potato genotype (Ipomoea batatas L.*).*
Determinations were performed at harvest and then during storage after 30 days and 90 days. The results showed that the investigated biochemical indices vary during storage depending on genotype and period. Thus, after 30 days of storage, the DM content varied from 21.56% to 29.85% and then increased from 23.75% to 32.42% at 90 days of storage. For the TSS content, values between 9.20% (cultivar 2) and 12.80% (cultivar 3) were initially recorded, so that after 90 days of storage, the values increased from 11.3% (cultivar 6) to 16.26% (cultivar 3). The content of glucose and reducing sugars increased during the storage period of the sweet potato. Storage had little influence on the starch content. There was considerable genotypic variation of this constituent with a reduction of up to 11.30% after 90 days of storage.

Key words*: Ipomoea batatas; genotype, carbohydrate; storage.*

INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) belongs to *Convolvulaceae* family and originates in Central America, species from which the tuberous roots are consumed. The largest cultivated areas are in China, India, Japan, USA, but also in some European countries. Sweet potato is one of the crops with good adaptability to ecological conditions, the global production in 2020 being about 89.5 million t, and 55 million t in the EU (Eurostat, 2021).
Vegetables are essential foods for a well-balanced diet because they contain high concentrations of vitamins, minerals, fibers and phytochemicals that act as antioxidants. Sweet potatoes can be considered a staple food due to their abundant nutrients, antioxidant capacity and ability to grow in different climates. For a sustainable agriculture, it is recommended to promote those plant species that are more adaptable to the conditions of thermohydric stress and ensure a good stability of production (Matei et al., 2015).
Sweet potato is appreciated for its very high nutritional value, both for the tubers and for the young aerial parts. Thickened roots rich in carbohydrates, starch, minerals (Ca, Mn, Cu Fe, P, K) and vitamins (ßcaroten, vitamin C, B6) can be used in various food forms: bread, puree, soups, juices, French fries, desserts (Dinu et al., 2015).
Sweet potato leaves are important sources of nutrients and antioxidants and should be eaten as leafy vegetables in an attempt to reduce malnutrition, especially in developing countries (Dinu et al., 2021a; Dinu et al., 2018). Due to its high starch content, sweet potatoes are a good source of bioethanol (Lareo et al., 2013).
Root production is influenced by climate. It influences important metabolites in tubers, playing an essential role in the organoleptic properties of the species and in the level of resistance to stress and disease and implicitly to a low number of chemical treatments that are essential elements of sustainable agriculture (Dinu et al., 2021b). Climatic conditions, culture system and characteristics of the genotype have an impact on the quality parameters of grapes (Costea et al., 2015), tomatoes (Draghici & Pele, 2012) or *Luffa* spp. (Vinatoru et al., 2014).
Lebot (2009) states that sweet potato roots contain large amounts of carbohydrates, 80–

90% of the dry matter, most of which is starch (50-80%). Numerous studies have shown that during the storage of sweet potato roots there are a number of changes in carbohydrate components, such as a decrease in starch content and an increase in sugar content, especially reducing sugars (Takahata et al., 1995). Changes in the starch and sugar content of sweet potato roots during the storage process are attributed to the activities of endogenous amylolytic enzymes.

Sweet potato is a staple food in many parts of the world, especially in the tropics. In Romania, sweet potato is a less cultivated species, but the biochemical composition of tuberous roots makes it very important both in terms of food and industry, and therefore the culture should be expanded. The tuberous roots of the sweet potato genotype are differentiated by the different colour of the rhizoderm and the pulp, as well as by the nutritive composition. The sugar content of sweet potato roots varies depending on the genotype, the culture system or certain technological sequences (Dinu et al., 2021b). The content of free sugars and starch in sweet potato roots has a considerable impact on the processing.

Numerous studies have been carried out in large sweet potato growing countries with reference to the stages of handling the harvest and the methods of storage. Moyo et al. (2004) mentioned the storage of roots in pits in the ground or in environmental conditions, in bags, in some countries in South Africa. What is certain is the fact that this species has very thin root rhizoderm and if lesions occur during harvesting, they will reduce the storage period and implicitly loss of nutrients. Resistance or susceptibility to disease is largely due to genotype and environmental conditions (Paraschivu et al., 2020).

The storage of tuberous sweet potato roots is essential to ensure a constant supply both for the population consumption and especially for the food industry in juices production or flours obtaining used in pastry.

Therefore, keeping the sweet potato roots quality during storage is necessary both for the processing industry and to avoid large economic losses. During storage, the roots are very perishable because they have a high moisture content (60-75%), therefore mechanical strength is low, as well as high susceptibility to microbial degradation (Sugri et al., 2017). It is preferable to store them in cool spaces in order to preserve their quality as well as possible (Krochmal-Marczak et al., 2020). However, long-term storage at low temperatures results in cold-induced sweetening (CIS) (Amjad et al., 2020).

Sweet potatoes nutritional quality depends largely on the quantity and quality of carbohydrates. The aim of this study was to present the metabolic changes of the carbohydrate components of six sweet potato genotypes, which occurred during storage, in environmental conditions, over a period of 90 days after harvest.

MATERIALS AND METHODS

Six sweet potato genotypes from South Korea were used in this study, which differ in terms of the skin shape and colour and in flesh colour (Table 1). The experiment took place in the experimental field of the Faculties of Horticulture and Agronomy from Craiova, Romania, in 2019. After 160 days from the planting moment, the harvest was carried out and the roots were sorted and the healthy ones were stored at a temperature of 18-20^{0}C and 75% RH (relative humidity). The biochemical determinations concerned the DM, TSS content, total and reducing sugar content, glucose content, and starch content. The determinations were performed when harvested, then after 30 and 60 storage days. For the analysis, roots of 150-200 g were used; 6 of each genotype and then washed, chopped and well homogenized.

Table 1. Basic characteristics evaluated of sweet potato tubers

Genotype	The tuber shape	The colour of the skin/flesh
Genotype 1	Ovate-elongated	Yellow skin with white flesh
Genotype 2	Ovate-elongated	Yellow skin with white flesh
Genotype 3	Ovate	Purple skin with white flesh
Genotype 4	Ovate	Purple skin with white flesh
Genotype 5	Ovate	Red skin with orange flesh
Genotype 6	Ovate	Purple skin with purple flesh

The dry matter content (DM %) was determined gravimetrically by sample drying to a constant weight at 105°C.

Total soluble solids (TSS %) were determined using a digital refractometer (Kruss Optronic DR 301-95) at 20°C and expressed as %.
Reducing sugars (%) were extracted in distilled water (1:20 g:mL), 60 minutes at 60°C and assayed colorimetric at 540 nm with 3,5 dinitrosalicylic acid reagent using glucose as standard.
Glucose (%) content was assayed at 500 nm by glucose oxidase/peroxidase method (GOD/POD). Glucose oxidase (GOD) is used to oxidize glucose by the oxygen in the air to gluconolactone and hydrogen peroxide. Under the influence of peroxidase (POD) the hydrogen peroxide reacts with colour indicator forming a pink compound. The glucose content was calculated from calibration curve using glucose (5 mg/mL) as standard.
Total sugar content (%) and non-reducing sugars were converting by hydrochloric acid hydrolysis, 15 min at 100°C to reducing sugars. After neutralization, total sugar content (%) was assayed colorimetric with 3,5 dinitrosalicylic acid reagent at 540 nm. Non-reducing sugars (%) is the difference of total soluble sugars and reducing sugars.
The starch content (%) was determined by using Ewers polarimetric method. Starch from the ethanol-insoluble material is extracted into hot dilute hydrochloric acid (Soare et al., 2019). After having cooled, phosphotungstic acid is added to precipitate the proteins and the solution is filtered. The optical rotation of the filtrate is measured using a Carl Zeiss JENA polarimeter and the results were calculated with a specific optical rotation of the potato starch [α] D20°=185.4°. All the spectrophotometric measurements were performed with a Thermo Scientific Evolution 600 UV-Vis spectrophotometer with VISION PRO software.
Statistical calculations were performed in Microsoft Office Excel 2007. For the significance analysis, the data were analyzed by one-way ANOVA. Means were compared using LSD at 5% level of significance.

RESULTS AND DISCUSSIONS

DM and TSS content vary within the studied genotype and storage time (Table 2). When harvested, DM recorded values between 21.39% (genotype 4) and 27.53% (genotype 5) with an average of 24.88%. After 30 storage days, the dry matter content increased to values between 21.56% (genotype 4) and 29.85% (genotype 5) with an average value of 26.19% and after 90 storage days it increased to values between 23.75% (genotype 4) and 32.42% (genotype 5) with an average value of 28.56%. Both when harvested and after storage, genotype 4 has the lowest dry matter content and genotype 5 has the highest value. At 90 storage days, the values increased as a result of increased evaporation.
The change in dry matter content may be a result of physiological processes such as transpiration and respiration that occur during storage and which are influenced by the temperature and air relative humidity. These variations in dry matter content have been observed by several authors. Thus, after eight weeks of storage in normal environment temperature, the highest dry matter content (35.13%) of sweet potatoes was in a pot with moist soil and the lowest in dry sand (31.13%) (Bhattarai et al., 2021).
Krochmal-Marczak et al. (2020) in their study for 5 sweet potato cultivars stored for 6 months reported an increase in dry matter content from 26.61% when harvested to 29.19% (at 5°C) and up to 33.59% (at a temperature of 15°C).
Dandago & Gungula (2011) reported that dry matter content decreased after 5 months of storage for samples stored in pit with alternate layer of river sand and increased in samples stored in moist sawdust in wooden box. Also, Agbemafle at al. (2014), show that dry matter content was 40.68 % in freshly harvested sweet potato and increase to 43.85 % after six weeks storage in ambient condition. For storage in moist sawdust the dry matter content decreased to 37.20 % in week six and for sweet potatoes stored in wood ash the dry matter content increased to 49.09 % in week six.
The comparison of total soluble substance between sweet potato genotypes, at harvest, indicates values from 7.13% for genotype 2 to 8.78% for genotype 1. After 30 storage days, the recorded values show slight increases, from 9.2% for genotype 2 to 11.8% for genotype 3.

Table 2. DM and TSS content in sweet potato roots during storage

Genotype	DM %			TSS %		
	When harvested	30 storage days	90 storage days	When harvested	30 storage days	90 Storage days
Genotype 1	24.82 ab	25.11 c	27.34 c	8.78 a	9.80 ab	13.70 b
Genotype 2	25.19 ab	26.70 b	28.06 c	7.13 b	9.20 b	13.12 b
Genotype 3	26.04 a	27.18 b	29.92 b	7.91 ab	11.80 a	16.26 a
Genotype 4	21.39 b	21.56 d	23.75 d	7.90 ab	10.12 ab	12.40 bc
Genotype 5	27.53 a	29.85 a	32.42 a	8.48 ab	9.30 b	12.30 bc
Genotype 6	25.30 ab	26.76 b	29.85 b	8.36 ab	9.84 ab	11.30 c
P≤0.05	4.18	1.20	1.77	1.59	2.23	1.68

The differences between the averages indicated by different letters are significant (p≤0.05).

After 90 storage days the total soluble matter values increased from 11.3% for genotype 6 to 16.26% for genotype 3. The results show significant differences between genotypes. Our results are in agreement with reported data in other studies. In Ghana, during the 3 weeks of storage, the values of some varieties ranged from 6.2 to 9.55 g / 100g TSS (Adu-Kwarteng et al., 2014).

The increase in TSS may also be a result to the conversion of starch into monosaccharides.

The structure of carbohydrates in sweet potato roots influences the nutritional quality and processing characteristics. Generally speaking, longer storage periods of raw roots, prior to processing, result in low-strength raw material.

Regarding the quantitative and qualitative spectrum of sugars, it varies according to the genotype and the storage period (Table 3). Thus, when harvested the glucose content varied from 0.68% (genotype 4) to 1.75% (genotype 1), in order genotype 4 < genotype 6 < genotype 3 < genotype 5 < genotype 2 to < genotype 1. The glucose content increased after 30 storage days with values between 0.89% (genotype 4) and 2.07% (genotype 1), and after 90 storage days, the values also increased between 2.05% (genotype 3) and 3.87% (genotype 6). The results indicated that the highest glucose contents were recorded after a longer storage period for genotypes 5 and 6.

Total soluble content is another useful parameter for selecting genotypes that can accumulate higher levels of total sugar (Babeanu et al., 2017).

Reducing sugars present in sweet potatoes are glucose and fructose. In the present study, the content of reducing sugars varied from 2.23% (genotype 6) to 4.12% (genotype 5).

This indicator increased after 30 storage days to values between 3.35% (genotype 3) and 6.8% (genotype 1), and after 90 storage days; the values are much higher compared to harvest period from 4.87% (genotype 3) to 8.2% (genotype 1).

It can be observed that after 30 and 90 storage days, all genotypes get an increase in glucose and reducing sugars. During storage periods, the variation in reducing sugars was significantly different.

Table 3. Carbohydrates variation during sweet potato roots storage

Genotype	Glucose			Reducing sugars (%)				Total Sugars (%)	
	When harvested	30 storage days	90 storage days	When harvested	30 storage days	90 storage days	When harvested	30 storage days	90 storage days
Genotype 1	1.75 a	2,07 a	3.25 a	2.45 e	6.8 a	8.2 a	5.82 b	8.74 b	11.45 b
Genotype 2	1.18 b	1.64 ab	3.18 ab	3.17 c	5.06 b	6.32 c	5.67 b	7.42 d	10.8 cd
Genotype 3	0.97 bc	1.12 bc	2.05 c	2.84 d	3.35 d	4.87 d	7.62 a	9.72 a	12.60 a
Genotype 4	0.68 c	0.89 c	2.52 bc	3.35 b	4.13 c	5.44 d	7.34 a	8.48 b	9.54 e
Genotype 5	1.11 bc	1.76 a	3.78 a	4.12 a	5.07 b	6.8 bc	7.26 a	7.86 c	10.98 c
Genotype 6	0.83 bc	1.04 bc	3.87 a	2.23 f	4.12 c	7.36 b	6.72 ab	7.75 cd	10.41 d
P≤0.05	0.45	0.60	0.71	0.04	0.30	0.80	0.18	0.34	0.46

The differences between the averages indicated by different letters are significant (p≤0.05).

Obtained results are in agreement with reported data in other studies. Agbemafle et al. (2014) reported that during the six weeks storage period, the reducing sugar content of sweet potato stored under ambient conditions increased from 2.41 % to 3.24%, under moist

saw dust increased to 3.74% and under wood ash the reducing sugar content increased to 2.84 % at the end of the storage period at the end of the storage period. In another study, for 3 cultures 12 weeks inside dry sand the content in reducing sugars increased from 3.16% and 4.66% to 4.72%-9.79% (Bhattarai et al., 2021).

Total soluble sugars present in sweet potato tubers are glucose, fructose and sucrose (Adu-Kwarteng et al., 2014). When harvested, total soluble sugars content varied from 5.67% (genotype 2) to 7.62% (genotype 3) ranging from genotype 2 < genotype 1 < genotype 6 < genotype 5 < genotype 4 < genotype 3. In all genotypes, total soluble sugars content increased after 30 storage days from 7.42% (genotype 2) to 9.72% (genotype 3) and after 90 storage days from 9.54% (genotype 4) to 11.45% (genotype 1). The results obtained pointed out the fact that the content in total soluble sugars varied significantly ($p < 0.05\%$) within the analysed genotype.

Total sugar content increase is also presented in other studies. After a 6 month storage in a climatic chamber with temperature control of 5 sweet potato cultivars, an increase from an average value of 5.27% when harvested to an average value of 5.97% at 5°C and an average value of 7.39% at 15°C was reported (Krochmal-Marczak et al., 2020).

Yamdeu et al. (2015), proved that low-temperature storage negligibly influenced starch and maltose contents of the tubers but induced a significant increase of reducing sugars and total soluble sugars.

Percentages of glucose, reducing sugars without glucose and non-reducing sugars in total sugar soluble in the 6 genotypes are presented in Figures 1, 2 and 3. The content of each indicator varies by genotype and storage period. The results obtained show that sucrose is the major component (except genotype 1, 2, and 5 after 30 days of storage).

Starch content in sweet potato tubers varies in terms of the the cultivar analyzed and storage time (Table 4). When harvested starch content has values ranging from 15.94% (Genotype 1) to 21.77% (genotype 5) in order, genotype 1 < genotype 6 < genotype 2 < genotype 3 < genotype 4 < genotype 5. After storage all genotypes record a decrease in starch content.

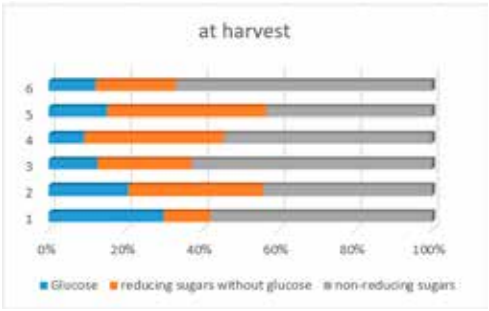

Figure 1. Content of glucose, reducing sugars and non-reducing sugars (%) in the 6 genotypes (%) at harvest

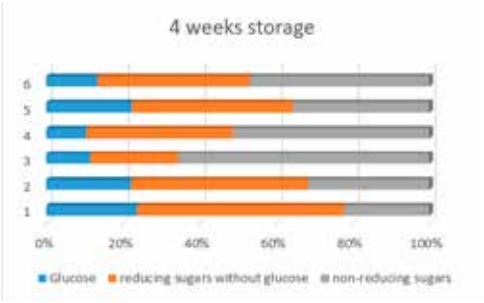

Figure 2. Content of glucose, reducing sugars and non-reducing sugars (%) in the 6 genotypes at 4 weeks storage

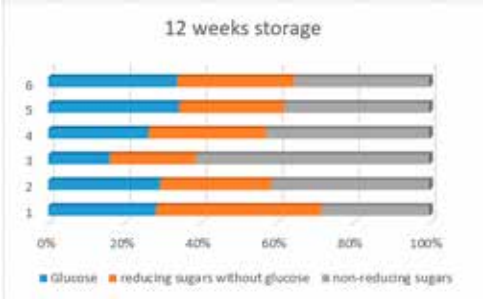

Figure 3. Content of glucose, reducing sugars and non-reducing sugars (%) in the 6 genotypes (%) at 12 weeks storage

Table 4. Evolution of starch content during the storage period of sweet potato roots

Genotype	Starch (%)		
	When harvested	30 days storage	90 days storage
Genotype 1	15.94 e	15.37 c	11.20 b
Genotype 2	17.06 c	17.06 b	13.73 ab
Genotype 3	20.41 b	18.11 b	12.06 b
Genotype 4	20.68 b	20.12 a	14.65 a
Genotype 5	21.77 a	20.29 a	15.12 a
Genotype 6	16.97 d	14.05 d	11.07 b
P≤0.05	0.57	1.06	1.82

The differences between the averages indicated by different letters are significant (p≤0.05)

The starch content after 30 storage days recorded values between 14.05% (genotype 6) and 20.29% (genotype 5), and after 90 storage days, the values were between 11.07% (genotype 6) and 15.12% (genotype 5).
Decreased starch content is illustrated by other studies, also. After 5 months of storage of 5 sweet potato cultivars, a decrease is reported from an average value of 19.16% when harvested to an average value of 17.16% at 5ºC and an average value of 14.68% at 15°C (Krochmal-Marczak et al., 2020).
Recently, a decrease in the starch content was reported from values between 22.73% and 25.51% when harvested to values in the range of 15.12 -19.53 for 3 crops stored for 12 weeks inside dry sand (Bhattarai et al., 2021). In a research paper studying the effects of five different storage methods on the quality and nutritional composition of sweet potatoes is recorded that the amount of starch decreased from the initial value of 16.95 to various values as storage period progressed. The lowest value (10.03%) was obtained in sample stored in pits with layers of river sand under shade (Dandago & Gungula, 2011)
Zhang et al. (2002) and Niu et al. (2019) also observed a decrease in starch content during tuber storage depending on genotype. This variation in starch can be explained by the biochemical and physiological processes occurring during storage. The decrease in starch content in sweet potato roots and the increase in sugar content during storage is caused by enzymatic hydrolysis catalysed by α and β amylases. Their activity increases during storage (Nabubuya et al., 2012). After harvest, starch biosynthesis can also take place, using sucrose as a carbon source (Preiss, 1982).

CONCLUSIONS

The obtained results show that the quantitative and qualitative spectrum of sugars varies from one genotype to another and also in terms of storage period. When stored for 30 days, there is a slight increase in the content of soluble substances, glucose, reducing sugars and total soluble sugars and a decrease in the starch content. After 90 storage days, all genotypes have a higher carbohydrate content, which ensures a proper quality of consumption, but a more pronounced decrease in starch, the differences is given by the genotype. The highest total sugar content was for genotype 3 with 12.60%.
By carefully sorting the roots, managing the temperature and storage period, it can be recommended to keep the roots for a period of 90 days in environmental conditions, for small growers. Knowing these changes in sugars during storage can be useful in planning the seasons of establishment and harvesting at the optimal time, in choosing the genotype with valuable properties and shelf life.

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