Original Scientific paper
10.7251/AGRENG2201115K
UDC 633.541

FEATURES OF CHEMICAL COMPOSITION AND TECHNOLOGICAL CHARACTERISTICS OF ROOT OF SUGAR BEET GENOTYPES

Oksana KLIACHENKO[1*], Larysa PRYSIAZHNIUK[2]

[1]National University of Life and Environmental Sciences of Ukraine, Ukraine
[2]Ukrainian Institute for Plant Variety Examination, Ukraine
*Corresponding author: klyachenko@ukr.net

ABSTRACT

Sugar beet breeding aimed at improving root processability involves the selection of breeding genotypes for the content of harmful non-sugars − K^+, Na^+, non-protein nitrogen − directly affecting the technological white sugar yield. The relevant are the researches on the chemical composition of plant organs of sugar beet breeding genotypes, including the content and patterns of ash, macro- and micronutrients, nitrogenous and insoluble substances distribution in order to improve beet processability. As a result of vegetation and field experiments, significant genotypic differences of the pectin substances content in sugar beet roots of Ukrainian and foreign breeding were found. The dynamics of accumulation of various forms of pectin substances in ontogenesis and the phase of development of sugar beet with the maximum accumulation of pectin and protopectin in roots were detected. The studied sugar beet genotypes were cultivated in different soil-climatic zones of the Forest-Steppe of Ukraine. Dependence of the increase in the content of pectin substances in roots from the northwest to the southeast was found. The regularities of changes in technological quality indicators during long-term storage of roots and their affection by phytopathogenic microorganisms were studied. It was proved that hybrids of foreign breeding accumulated significantly more reducing sugars and soluble nitrogenous substances during storage, which negatively affected the juice purity and increased the loss of sucrose in molasses. It was shown that varieties and hybrids of Ukrainian breeding and the hybrid Taltos (Belgian breeding) were the most resistant to affection by phytopathogenic microorganisms. Hybrids of German and Swedish breeding were characterized by a high content of rotten mass.

Keywords: *sugar beet, roots storage, technological quality.*

INTRODUCTION

In the processing of roots, sugar losses in molasses are caused mainly by soluble nitrogenous substances (α-amine nitrogen), potassium, and sodium, which inhibit the crystallisation of a certain part of sucrose (1.5−2.0%) (Yapo *et al.*, 2005;

Askarova *et al*., 2017). Beet processability is also negatively affected by calcium, magnesium, trace elements, nitrate forms of nitrogen, and pectin. The latter forms hydrophilic colloids and impair the filtration of beet juice (Chee, 2008; Zaidel *et al*., 2013; Zheryakov *et al*., 2016) and storage conditions of roots at beet collection points (root loss, phytopathogenic damage). At sugar factories, short-term (2−10 days) storage of roots in adverse conditions along with simultaneous drying causes considerable sugar loss (0.15% daily) due to enzymatic sucrose splitt followed by an increased content of monosaccharides, which reduces sugar content and beet processability indicators (Balakhontsev, 1979; Boiko, 2015).

Beet processability is significantly influenced by the varietal characteristics of sugar beet and the factors that modify these indicators (Dautova & Alimgafarov, 2013). Efficient from the agro-chemical point of view beet cultivars are characterized by high nutrient absorption from fertilisers and soil, physiologically balanced systems of adsorption, ion transport and metabolism, stability of homeostasis, rational expenditure of absorbed ions for the synthesis of organic matter in photosynthetic and storage organs. Varietal charactristics are attributed to breeding and genetic factors, which, in contrast to the environmental factors and together with existing breeding methods, significantly improve the components of beet quality (processability) (Boiko, 2015).

Sugar beet plants absorb nitrogen from the soil mainly in the form of nitrates, which are subsequently converted in the process of metabolism into organic compounds (amino acids, proteins, etc.). In the process of assimilation reduction of NO_3^-, glutamine (nitrogen acceptor) is formed from ammonia and glutamate. Glutamine, transported to the roots, is the main source of amine nitrogen. Many researchers place a high emphasis on the ratio of sugar-soluble carbohydrates and nitrogen-containing compounds in beet leaves as one of the regulatory mechanisms that trigger the aging process (Kliachenko, & Funina, 2002; Roik, 2003).

Sugar beet breeding aimed at improving root processability involves the selection of breeding genotypes for the content of harmful non-sugars − K^+, Na^+, non-protein nitrogen − directly affecting the technological white sugar yield. Today, hybrid heterosis breeding of sugar beet for improving root processability is aimed at overcoming genetically determined physiological limit of sucrose accumulation in roots and a planned change in the chemical composition of plants (Kliachenko, 2002; Kliachenko, 2006; Kliachenko, 2015). It was shown that the inheritance of the content of K^+ and Na^+ ions related to the gene effects of multigerm pollinator lines with low general combination ability (Combo *et al*., 2013.

Therefore, still relevant are the researches on the chemical composition of plant organs of sugar beet breeding genotypes, including the content and patterns of ash, macro- and micronutrients, nitrogenous and insoluble substances distribution in order to improve beet processability.

The goal of the research was to evaluate the most common in modern sugar beet production monogerm varieties, di- and triploid hybrids of Ukrainian and foreign breeding for productivity, pectin content, root processability indicators as well as their resistance to phytopathogenic organisms during long-term storage.

MATERIALS AND METHODS

Vegetation experiments were carried out by the method of soil culture in 14-kg Wagner vessels at 60% of full soil water capacity. The objects of research were Ukrainian and foreign sugar beet varieties and hybrids: Bilotserkivskyi Odnonasinnyi 45, Bilotserkivskyi Odnonasinnyi 50, Yaltushkivskyi Odnonasinnyi 64, Yuvileinyi, Ivanivskyi CMS 33, Ukrainskyi CMS 70, Slovianskyi CMS 94, Reno (Germany), Tsermo (Germany), Matador (Sweden). Countings were carried out in six replications on plots of an area of 100 m^2. Determination of the sugar content in roots was performed by the polarimetric method of cold digestion according to Pochynko (Yakovets *et al.*, 2007). Pectin substances in roots were determined by the volumetric method according to Rayk (Vasilieva, 2002; Hlevaskyi, 2015).

Determination of beet processability indicators was performed according to generally accepted methods (Dautova & Alimgafarov, 2013). Root samples in mesh bags were stored in stationary root storage. They were analyzed for damage by rot and reduction of technological indicators after 70 days of storage. The roots affected during vegetation were not taken to mesh bags. All experiments were conducted during 2015-2018 at experimental plots and laboratories of National University of Life and Environmental Sciences of Ukraine (Kyiv, Ukraine).

Statistical processing of the obtained experimental data was carried out using the Excel Data Analysis package.

RESULTS AND DISCUSSION

It is known that pectins are accumulated in sugar beet roots in the form of water-soluble pectin, Ca-Mg pectic acid, and protopectin, which significantly increases the accumulation of colloids (araban) and calcium salts during sugar beet processing and eventually deteriorate juice filtration and reduces quality. Particularly undesirable for sugar production is the high content of water-soluble pectin, which completely goes into diffusion juice, prevents the optimal course of the technological process, and increases sugar loss in molasses. Water-insoluble protopectin, which together with other macromolecular components constitutes a cell wall, has a high ability to swell and only partially (0.04−0.25%) passes into diffusion juice. The content of pectin substances in sugar beet roots is greatly influenced by the conditions of mineral nutrition, water availability, soil, climate, and other factors (Stepovyi & Rodionova, 2015).

As a result of our experimental studies, it was found that studied sugar beet varieties and CMS hybrids differed more in terms of the content of water-soluble pectin in the roots than protopectin. Noticeably, there was no clear relationship between the level of pectin accumulation in roots and the sugar content. Low content of pectin substances was observed both in low sugar content cultivars Uladivskyi odnonasinnyi 35, Ukrainskyi CMS 70 and high sugar content cultivar Slovianskyi CMS 94.

Table 1. The content of pectin substances and sugar in roots of sugar beet varieties and hybrids

Variety/ hybrid	Water-soluble pectin	Protopectin	Total pectin	Sugar content (% wet mass)
	(% dry matter)			
Bilotserkivskyi Odnonasinnyi 45	1.006	2.389	3.395	18.1
Yaltushkivskyi Odnonasinnyi 64	0.869	3.303	4.172	18.5
Yuvileinyi	0.988	2.951	3.939	18.2
Ivanivskyi CMS 33	0.985	2.804	3.789	18.9
Ukrainskyi CMS 70	0.666	2.929	3.595	17.9
Slovianskyi CMS 94	0.676	2.596	3.272	20.4
$LSD_{0,5}$	0.027	0.101	-	0.30

It was revealed that the processes of biosynthesis and accumulation of pectin substances in sugar beet roots intensively continues until the end of the growing season (Table 2). Regardless of the cultivar, there was an increase in the content of pectin substances, mainly due to the increase in the content of water-soluble pectin.

Table 2. The content of pectin substances in the roots of different sugar beet varieties and hybrids as affected by the harvest date

Variety/ hybrid	Water-soluble pectin	Protopectin	Total pectin	Water-soluble pectin	Protopectin	Total pectin
(% dry matter)						
30 August				10 October		
Bilotserkivskyi Odnonasinnyi 45	1.604	2.393	3.997	2.502	2.791	5.293
Bilotserkivskyi Odnonasinnyi 64	0.867	2.883	3.750	1.765	3.280	5.045
Yaltushkivskyi Odnonasinnyi 30	0.875	3.415	4.290	1.774	3.812	5.586
Yuvileinyi	0.991	2.975	3.966	1.889	3.375	5.264
Ivanivskyi CMS 33	0.989	2.875	3.864	1.888	3.272	5.160
Ukrainskyi CMS 70	0.673	2.989	3.662	1.571	3.387	4.958
Slovianskyi CMS 94	0.689	2.631	3.320	1.588	3.030	4.618
$LSD_{0,5}$	0.031	0.115		0.043	0.131	

The level of pectin accumulation in sugar beet roots is significantly affected by harvest time. To illustrate, in late August, the content of water-soluble pectin on average, regardless of cultivar, amounted to 20−25% of the total pectin, while in early October, the content reached 30−37% with a simultaneous slight increase in the level of protopectin.

The results of our studies of the pectin content in the roots of different sugar beet cultivars can be used in practical breeding to produce hybrids with improved root processability. The increase in the content of pectin substances in roots detected by us at late harvest dates can serve as substantiation for earlier harvest time.

One of the significant reserves for further increase in the production of sugar beet and sugar in Ukraine is to provide the industry with highly productive disease-resistant competitive monogem sugar beet hybrids (Roik, 2003). Researchers found that the yield potential of new Ukrainian hybrids is 80−90 t/ha. Alongside, sugar yield potential is not less than 18% (Roik & Kornieieva, 2010). However, recently the seeds of KWS, Dutch, Danish and Swedish breeding gained demand. Roots of foreign breeding become affected by root rot and have low sugar content when grown in different sugar beet growing regions of Ukraine (Roik & Lytvyniuk, 2010; Yakovets *et al*., 2007; Strausbaugh *et al*. 2010).

In our comparative evaluation of the most common in contemporary production monogerm diploid sugar beet varieties and hybrids of Ukrainian and foreign breeding in terms of productivity, root processability, and disease resistance during storage, the highest root yield (60.5 t/ha) and sugar yield (11.67 t/ha) was demonstrated by a Belgian hybrid Rima. Slightly lower values (57.5 t/ha and 11.37 t/ha, respectively) had German hybrid Reno. Among Ukrainian varieties and hybrids, high root and sugar yields were demonstrated by variety Yaltushkivskyi Odnonasinnyi 64, hybrids Ivanivskyi CMS 33, Lyhovsko-Verkhniatskyi CMS 21, Ukrainskyi CMS 70, and Yuvileinyi. Root yield in these cultivars ranged between 47.8 and 55.0 t/ha and sugar yield between 9.21 and 10.19 t/ha. Compared to other varieties, Uladivskyi Odnonasinnyi 35 (sugar yield 7.06 t/ha) was significantly inferior in the studied sugar beet collection. Determination of the chemical composition and technological indicators of the roots harvested in different periods revealed high-quality cultivars: hybrids ‘Reno’, Taltos, Ivanivskyi CMS 33, Ukrainskyi CMS 70; variety Yaltushkivskyi Odnonasinnyi 64. In these cultivars, sugar content varied with a range of 18.70−19.83%, juice purity 92.3−93.43%, sugar yield 15.60−16.91% **(**Table 3). It should be emphasized that at harvest, and especially during storage, hybrids Reno and Tsermo (Germany), Matador (Sweden) accumulated much more reduced sugars and soluble nitrogenous substances compared to Ukrainian varieties and CMS hybrids, which negatively affected juice purity and increased sugar loss in molasses.

Table 3. Chemical composition and technological indicators of different sugar beet varieties and hybrids

Variety/ hybrid	Sugar content (%)	Reduced substances (%)	K + Na	*α-amine N*	Juice purity (%)	Sugar loss in molasses (%)	Sugar yield (%)
			(Mmol/100 g of wet root mass)				

Bilotserkivskyi Odnonasinnyi 64	19.30	0.146	4.50	1.79	92.60	1.84	16.20
Yaltushkivskyi Odnonasinnyi 45	18.20	0.123	5.82	3.61	91.70	2.01	15.11
Yuvileinyi	17.40	0.148	6.07	3.05	90.80	2.13	14.14
Ivanivskyi CMS 33	18.90	0.139	4.17	2.50	93.00	1.78	15.71
Ukrainskyi CMS 70	18.70	0.106	5.05	2.28	92.30	1.90	15.60
Taltos	19.10	0.131	4.20	1.56	92.90	1.77	16,11
Reno	19.83	0.335	4.23	2.71	93.43	1.72	16.91
Tsermo	19.12	0.319	4.58	3.42	91.92	1.99	15.93
Matador	17.89	0.319	4.34	4.26	91.48	2.01	14.68
$LSD_{0,5}$	0.50	0.09	1.02	0.96	4.5	0.56	1.03

It is known that the storage stability of sugar beet is determined by the degree of damage to roots by clamp rot and decrease in technological indicators. In stable beet cultivars, the level of rotten mass after storage does not exceed 0.1%, and the purity of the clarified juice does not decrease by more than 1%, which corresponds to an increase in sugar loss in molasses by 0.2% (Yakovets *et al*., 2007; Piskureva, 2012). Our research results revealed the most resistant to phytopathogenic microorganisms cultivars: variety Yaltushkivskyi Odnonasinnyi 64 and hybrid Ukrainskyi CMS 70, in which the share of rotten mass reached 0.3−0.4%, and rotten roots 8.30−15.90% (Table 4).

Table 4. Preservation of roots of different sugar beet varieties and hybrids after storage for 70 days

Variety/ hybrid	**Roots (mass %)**		**Rotten mass (%)**
	sprouted	**rotten**	
Yaltushkivskyi Odnonasinnyi 30	42.9	11.2	0.3
Yaltushkivskyi Odnonasinnyi 64	23.8	18.2	0.8
Bilotserkivskyi Odnonasinnyi 45	51.6	20.6	1.0
Yuvileinyi	49.3	21.2	0.6
Ukrainskyi CMS 70	21.4	15.9	0.3
Ivanivskyi CMS 33	25.7	28.9	1.5
Taltos	32.8	20,6	0.6
Reno	63.2	53.4	5.6

Tsermo	48.3	47.8	7.0
Matador	41.6	33.2	3.6
$LSD_{0,5}$			0.11

The decrease in the juice purity made up 1.3−1.9%. Sugar loss in molasses was 0.17−0.18% (Table 5). The hybrids of foreign breeding, except for Taltos, were significantly inferior to Ukrainian cultivars in terms of resistance to rot (Table 5). Thus, the share of rotten mass in Ukrainian cultivars ranged between 3.6 and 7.0%, with the share of rotten roots reaching 33.2−53.4%, syrup purity decreasing by 5.02−5.25%, and sugar loss in molasses increasing by 1.03−1.23%.

Table 5. Chemical composition and technological indicators of sugar beet roots after storage for 70 days

Variety/ hybrid	Sugar content (%)	Reduced substances (%)	K + Na	α-amine N	Juice purity (%)	Sugar loss in molasses (%)	Sugar yield (%)
			(Mmol/100 g of wet root mass)				
Yaltushkivskyi Odnonasinnyi 64	17.80	0.352	5.28	1.94	90.90	2.10	14.54
Bilotserkivskyi Odnonasinnyi 45	17.00	0.403	5.01	3.54	90.00	2.23	13.68
Uladivskyi Odnonasinnyi 35	15.30	0.309	5.98	4.07	88.90	2.42	12.18
Yuvileinyi	16.10	0.296	5.40	3.67	89.50	2.31	12.78
Ivanivskyi CMS 33	17.20	0.355	4.56	2.45	91.10	2.08	13.92
Ukrainskyi CMS 70	17.70	0.257	4.73	1.86	91.40	2.03	14.50
Taltos	18.30	0.264	4.55	2.36	91.90	1.93	15.17
Reno	18.54	0.840	4.96	4.56	88.18	2.92	14.42
Tsermo	17.00	0.957	4.85	3.83	86.90	3.22	12.58
Matador	16.70	0.740	7.04	5.70	86.34	3.04	12.46
$LSD_{0,5}$	1.50	0.021	0.24	0.15	4.3	0.11	0.68

Thus, a comparative evaluation showed that of the studied sugar beet cultivars, foreign hybrids do not have advantages over Ukrainian varieties and hybrids. This became especially evident after storage (70 days). Therefore, varieties and hybrids of Ukrainian breeding can fully provide the sugar industry of Ukraine. They all are well-adapted to the zonal variations of the Ukrainian intensive technology of sugar beet cultivation and are quite competitive providing adherence to the technology.

New generation Ukrainian hybrids Bilotserkivskyi CMS 51, Bilotserkivskyi CMS 57, and Oleksandria will help to overcome the crisis in beet cultivation.
From the literature, it is known that chemical elements in plant organisms have certain physiological functions in metabolism, which are crucial for their growth and productivity. This is the difficulty of the breeding aimed at increasing quality, i.e. the breeder has to combine not only high sugar content breeding genotypes with low potassium, sodium, and α-amine nitrogen content but also those with high root yield. This contradicts the existing correlations between these traits (that is, in roots with high sugar content, the content of chemical elements is reduced and vice versa). However, these correlations are not so strict to give a breeder no chance for success. It should be noted that there are some limits to improve the technological quality of roots through breeding, as the quality indicators are significantly affected by environmental conditions and agronomic practices. Nevertheless, breeding sets the borders within which the agronomic practices can be effective. Given that the indicators of technological quality used in this comparative study can be easily measured or determined, under similar conditions they should be considered in the tasks of breeding for quality.

CONCLUSIONS

The studied hybrids of foreign breeding accumulated much more reducing sugars and soluble nitrogen substances during storage, which negatively affected juice purity and increased sugar loss in molasses. The most resistant to phytopathogenic microorganisms are varieties and hybrids of Ukrainian breeding and hybrid Taltos of Belgian breeding. The studied hybrids of German and Swedish breeding demonstrated a high content of rotten mass during storage.

REFERENCES

Askarova, G., Orynbekov, D., & Asanova, G. (2017). Phytoremediation of saline soil of Kyzylorda region with the use of sugar beet. *International Journal of Applied and Fundamental Research*, *6*(1), 79−82. [in Russian]

Balakhontsev, E. (1979). Influence of the mineral nutrition regime and climate on the accumulation of polysaccharides in sugar beet roots. In: Mineral nutrition, metabolism, and productivity of sugar beet. Ufa. [in Russian]

Boiko, I. (2015). Productivity and technological qualities of different biological forms of sugar beets. *Agrobiology*, *2*, 32−36. [in Ukrainian]

Chee, K. S., Williams, P. A., Steve, W. C, & Qi, W. (2008). Characterization of the surface -active components of sugar beet pectin and the hydrodynamic thickness of the adsorbed pectin layer. *J. Agric. Food Chem*, 56, 8111−8120**.**

Combo, A., Aguedo, M., Quievy, N., Danthine, S., Goffin, D., Jacquet, N., Blecker, C., Devaux, J., & Pagout, M. (2013). Characterization of sugar beet pectin-derived oligosaccharides obtained by enzymatic hydrolysis. *International Journal of Biological Macromolecules,* 52, 148−156. dx.doi.org/10.1016.

Dautova, Z. & Alimgafarov, R. (2013). Chemical composition of sugar beet root. *Contemporary research-intensive technologies*, 9, 12−13. [in Russian]

Hlevaskyi, V. (2015). Quality of sugar beet roots of domestic and foreign breeding after storage. *Agrobiology*, *2*(121), 28−32. [in Ukrainian]

Kliachenko, O. (2002). Distribution of macronutrients in the tissues of sugar beet roots in connection with the localization of sucrose. *Physiology and biochemistry of cultivated plants*. *34*(6), 481−490. [in Russian]

Kliachenko, O. (2006). The effect of shading on the chemical composition and productivity of different genotypes of sugar beet (*Beta vulgaris* L.). *Bulletin of Agrarian Science*, *2*, 44−47. [in Ukrainian]

Kliachenko, O. (2015). Variety-specific features of pectin substance accumulation in sugar beet roots. Scientific Bulletin of NAU, 84, 264−269. [in Ukrainian]

Kliachenko, O. & Funina, I. (2002). Chemical composition of sugar beet roots depending on their varietal differences. *Scientific Bulletin of NAU*, *47*, 100−104. [in Ukrainian]

Piskureva, V. (2012). Dynamics of pectin substance accumulation in beet (*Beta vulgaris* L.) roots in ontogenesis. Cand. Sc. (Agr.) thesis. Orel. [in Russian]

Roik, M. & Kornieieva, M. (2010). Sugar beet breeding. In: Special breeding of field crops. Bila Tserkva: BTs NAU, 276−314. [in Ukrainian]

Roik, M. & Lytvyniuk, V. (2010). Implementation and maintenance of monogerm varieties of Yaltushkiv breeding in production. *Scientific papers of IBCSB*, *11*, 126−132. [in Ukrainian]

Roik, M. (2003). Complex scientific support for the development of modern technology of the breeding process. *Bulletin of Ukr. Society of Geneticists and Breeders*, *1*, 17−37. [in Ukrainian]

Stepovyi, A., Rodionova, L. (2015). Improving beet pulp pre-treatment to obtain food pectin extract. *Young researcher*, *5*(85). [in Russian]

Strausbaugh, C., Eujayl, I. & Foote, P. (2010). Sugar beet cultivar evaluation for bacterial root rot. *Journal of Sugar Beet Research*, *47*(1−2), 51−64.

Vasilieva, I. (2000). The use of sugar beet in the development of technology and recipes for catering products. Cand. Sc. (Tech.) thesis, St. Petersburg. [in Russian]

Yakovets, V., Lytvyniuk, V. & Yakovets, H. (2007). Method of complex selection of breeding genotypes of sugar beets for resistance to root rot. *Scientific papers of IBCSB*, *9*,113−117. [in Ukrainian]

Yapo, B., Robert, C., Etienne, I., Wathelet, B. & Paquot, M. (2007). Effect of extraction conditions on the yield, purity and surface properties of sugar beet pulp pectin extracts. Food Chemistry, 100, 1356−1364. doi^10.1016/j.foodchem.2005.12.012.

Zaidel, D., Norulfairuz, A. & Meyer, A. (2013). Oxidative enzymatic gelation of sugar beet pectin for emulsion stabilization. Research Journal of biotechnology, *8*(7), 81−86.

Zheryakov, E. V., Breducheva, E. S., Kotlov S. A., Rozhkov, S. S. (2016). Technological qualities of sugar beet roots in the forest-steppe conditions of the middle Volga region. *International research journal*, *12*(54), 130−132. [in Russian]