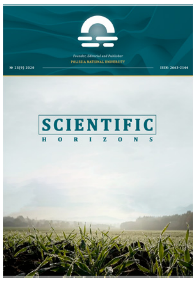
SCIENTIFIC HORIZONS

Journal homepage: https://sciencehorizon.com.ua
Scientific Horizons, 27(10), 43-54



UDC: 634.8:634.86:631.95
Doi: 10.48077/scihor10.2024.43

Biochemical value of table grape varieties when grown in the Northern Steppe of Ukraine

Alla Petrenko
Postgraduate Student
Dnipro State Agrarian and Economic University
49600, 25 S. Efremov Str., Dnipro, Ukraine
https://orcid.org/0009-0005-6755-3667

Mykola Nazarenko*
Doctor at Agricultural Sciences, Professor
Dnipro State Agrarian and Economic University
49600, 25 S. Efremov Str., Dnipro, Ukraine
https://orcid.org/0000-0002-6604-0123

Article's History:
Received: 11.04.2024
Revised: 20.08.2024
Accepted: 25.09.2024

Abstract. The study of the possibilities of using the existing biodiversity of table grape varieties to meet the usefulness of the human diet is a key component of improving the existing cultivation of fruit products within the framework of modern agricultural development strategies. The purpose of the study was to establish the possibilities of meeting the needs of the population for valuable nutritional elements based on traditional table grape varieties, which are mainly introduced in the region at the level of small farms and household plots. Five table grape varieties – Arcadia, Nadezhda AZOS, Preobrazhenie, Rumeyka, Dubovsky pink – were investigated for the content of calcium, phosphorus, sulphur, magnesium, potassium, zinc, copper, selenium, manganese, glucose, dietary fibre, vitamins A, C, E, PP, and the dependence on the factors of the year and variety, their interaction, and the classifying ability of features in the space of canonical functions were calculated. The presence of minerals was analysed by atomic emission spectrometry, glucose – by sugar meter, dietary fibre – by enzymatic gravimetric method, vitamins – by fluorometric method, and vitamin C – by titrometric analysis. The possibilities of traditional table grape varieties in meeting the needs for basic valuable food elements are shown and a conclusion is made about the possibilities of selecting appropriate forms, which in the complex are quite capable of meeting modern requirements in this aspect of agricultural development. A predominantly low variability of the studied traits was revealed, which indicates the good reproducibility of the obtained result and the predominant influence of the genotype on the development of the corresponding trait in conditions of contrasting environmental characteristics of years. It was found that improvement in only one of the signs – the content of vitamin PP – is problematic. The low differentiating ability

Suggested Citation:
Petrenko, A., & Nazarenko, M. (2024). Biochemical value of table grape varieties when grown in the Northern Steppe of Ukraine. *Scientific Horizons*, 27(10), 43-54. doi: 10.48077/scihor10.2024.43.

*Corresponding author

of varieties of the Dubovsky pink, Preobrazhenie, and Rumeyka group leads to the need for further clarification of the ability of only the first of the varieties to be a component in the proposed complex. It is recommended to grow a complex of varieties Nadezhda AZOS and Dubovsky pink

Keywords: viticulture; genotype; nutritional value; trace elements; product quality; biologically active substances

INTRODUCTION

Production variety testing of grapes is a long process that takes approximately ten years from the initial stages to the introduction of a promising adapted genotype. Although certain goals, such as yield and basic product quality, are always important, general consumption characteristics, environment, marketing, and production trends influence the strategy that is used as a basis in research programmes in this area, trying to anticipate the future needs of the fruit industry. The importance of each trend depends on the level of performance and the environment. The main trends are the introduction of varieties that simplify production technology, have increased resistance to biotic and abiotic stresses, expand the adaptation zones of the crop, create new types of fruits, primarily more attractive in shape and colour, grow grape varieties with increased health benefits, and ensure stable high quality (Cichi *et al.*, 2023).

Breeders in the fruit growing industry should anticipate the need for varieties at least 10 years in the future, as this is the minimum time that most grape varieties need for the maturation process from the first pollination to zoning. This aspect examines general trends such as environmental issues, healthy eating, consumer lifestyle trends (Farvid *et al.,* 2021), and the expectations and needs of producers to determine how they will affect the future strategy of consumption of manufactured products (Ağızan *et al.,* 2024). Much attention has been paid to the health benefits of grapes and grape products, primarily due to the antioxidant activity of various phenolic compounds, especially flavonoids, and the high content of beneficial trace elements that are deficient in traditional foods. Manufacturers have widely launched programmes to introduce new and increase the introduction of traditional products that are more complete for human biochemistry, with increased levels of health benefits in grapes and processed products (Koyama *et al.,* 2020).

Constant efforts to introduce new varieties with different parameters of valuable elements, different colours with an attractive berry shape, texture from hard to crisp, attractive clusters of acceptable size for packaging and ripening at different points in time (Navarro-Caldero *et al.,* 2023) during the growing season led to the creation of a fundamentally new cluster of products. Producers in important table grape growing areas focus their efforts on grape (Cameron *et al.,* 2022) that is suitable for different market niches based on availability at a unique time of year, with quality characteristics that exceed varieties that may already be on the market. Suitability for storage, and avoiding problems after harvesting (grinding, rot, market damage) is also important, especially for varieties of later maturation.

The objective of the study was to identify the limits of variability of different varieties of table grapes in terms of the content of valuable food elements that determine the consumer usefulness of products, provided that these varieties are widely distributed in the production of the region, mainly at the level of small farms, to identify genotypic and annual variations, and their interaction. These varietal resources are a local source of biodiversity and enrichment of the human diet.

MATERIALS AND METHODS

The study was conducted at the LLC "Agrosilprom", Znamenivka village, Novomoskovsk District of the Dnipropetrovsk Oblast in 2021-2023. Five table grape varieties – Arcadia, Nadezhda AZOS, Preobrazhenie, Rumeyka, and Dubovsky pink – were studied by biochemical analysis methods (an average sample of 1 kg with each repetition, three repetitions for each variety at full ripeness). The cultivation technology was recommended for the region, with drip irrigation.

The content of such valuable elements as calcium, phosphorus, sulphur, magnesium, potassium, zinc, copper, selenium, and manganese was studied in the laboratory of the Research Centre for Biosafety and Environmental Control of Agricultural Resources of the Dnipro State Agrarian and Economic University. The sample preparation protocol provided for mineralisation using the MultiWave Go Plus microwave decomposition system (manufacturer Anton Paar, Austria), with the addition of 0.5 g of 10 ml of 65% nitric acid and 1 ml of concentrated hydrochloric acid to the resulting suspension of each sample. The mineralisation time (together with the cooling time) was 45 minutes at a temperature of 185°C. The presence of minerals was analysed using an atomic emission spectrometer with inductively coupled Agilent 5110 plasma at the emission intensity of the light flux at the wavelengths corresponding to each element. Multi-element solutions produced by Agilent (Ca, S, Mg, K, P, Zn, Se, Mn, Cu) were used as reference standards.

The content (per 100 g) of the following substances: glucose, dietary fibre in berries, vitamins A, E, C, PP was determined in the Laboratory of Biochemistry and Plant Physiology of the Department of Plant Physiology and Introduction of O. Honchar State University (DSTU EN 12822:2005, 2006; DSTU EN 12823-

2:2006, 2006; DSTU EN 7803:2015, 2016; DSTU EN 12630:2019, 2019). To determine the glucose content, extraction was performed and a VPCH-17 sugar meter (manufactured by Elcantr (Spain)) was used. Extraction of the solution to determine the percentage of glucose was performed by the standard method. Dietary fibre was investigated by enzymatic-gravimetric methods. The presence of A, E (tocopherol), PP (nicotinamide) content in the samples was studied using a standardised fluorometric method at the corresponding light wavelengths using an ULAB 102UV spectrophotometer, and vitamin C was detected by titrometric method through oxidation in dehydroascorbic acid of grape samples (5 g sample) (Badenes & Byrne, 2012).

Mathematical and statistical analysis of the obtained values was investigated by Anova method, grouping, and estimation of parameters were performed using discriminant and cluster analysis modules (Euclidean distance, single links) (Statistica 10.0, multivariate statistics module, TIBCO, Palo Alto, USA). The compliance of the obtained data with the normal distribution was established by calculating the Shapiro-Wilk W test. Pairwise comparison between varieties and years of variety testing was performed using the Tukey' range test (factor analysis package). Experimental studies of plants (both cultivated and wild), including the collection of plant material, were in accordance with institutional, national or international guidelines. The authors adhered to the standards of the Convention for the Protection of Biological Diversity (1992) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1979).

RESULTS AND DISCUSSION

The study of the obtained material took place in several stages. During the first stage, the content of key valuable macronutrients – calcium, phosphorus, sulphur, magnesium, and potassium – was determined. Usually, problems can be caused by the low presence primarily of sulphur and magnesium, sources of other elements are usually sufficient. Also significant was the fact that the content of these elements depended on both the variety and the growing conditions (year). In total, three samples were examined for variants (varieties) during three years of cultivation. According to the results of factor analysis, the calcium content was significantly affected as a Variety factor ($F = 257.19$; $F_{0.05} = 2.66$; $P = 3.47*10^{-32}$), and the Year factor ($F = 13.62$; $F_{0.05} = 2.44$; $P = 2.33*10^{-6}$), although with a very significant difference. The interaction of factors by influence was not significant ($F = 3.22$; $F_{0.05} = 3.50$; $P = 0.06$). By pairwise comparison (Tukey's range test), the Nadezhda AZOS variety was ahead with a high calcium content, then Preobrazhenie and Rumeyka (were at the same level), then Dubovsky pink, and the lowest content was in the Arcadia variety. The trait varies very significantly between varieties, but within the same variety it is considered low-varietal (less than 5%). The results are presented in Table 1.

***Table 1**. Content of table macronutrients in grapes depending on genotype (2021-2023), (x = 27, ±SD)*

Indicators	Arcadia	Nadezhda AZOS	Preobrazhenie	Rumeyka	Dubovsky pink
Calcium, mg/kg	22.78 ± 1.24^{a}	86.93 ± 2.09^{b}	43.32 ± 1.39^{c}	40.11 ± 1.11^{c}	35.67 ± 1.18^{d}
Phosphorus, mg/kg	24.70 ± 1.74^{a}	85.10 ± 2.92^{b}	29.20 ± 2.04^{c}	32.90 ± 2.05^{c}	33.80 ± 2.05^{cd}
Sulphur, g/kg	0.31 ± 0.06^{ab}	0.40 ± 0.07^{a}	0.21 ± 0.05^{ab}	0.19 ± 0.04^{b}	0.29 ± 0.07^{ab}
Magnesium, mg/kg	17.23 ± 1.47^{a}	41.22 ± 1.65^{b}	29.34 ± 1.16^{c}	35.67 ± 1.25^{d}	32.56 ± 1.57^{d}
Potassium, g/kg	2.13 ± 0.19^{a}	8.92 ± 0.31^{b}	3.12 ± 0.25^{c}	3.09 ± 0.23^{c}	3.49 ± 0.21^{c}

***Note:** indicates a significant difference at P < 0.05 for the Tukey's range test with Bonferroni correction. Comparison within varieties*
***Source:** compiled by the authors*

According to the results of the factor analysis, the phosphorus content was significantly influenced by the variety factor ($F = 112.14$, $F_{0.05} = 2.66$, $P = 7.17*10^{-14}$), but not by the year factor ($F = 2.42$, $F_{0.05} = 2.44$, $P = 0.06$). The interaction of factors by influence was also not significant ($F = 2.65$; $F_{0.05} = 3.50$; $P = 0.08$). By pairwise comparison (Tukey's range test), the Nadezhda AZOS variety was ahead with a high phosphorus content, Dubovsky Pink was on the same level as the Rumeyka variety, but significantly higher content than the Preobrazhenie variety (which was on the same level as the Rumeyka variety), significantly lower content was in the Arcadia variety, as in the previous case. The trait again varies very significantly between varieties, and within one variety it is considered medium-variable (at the level of 7-9%, except for the Rumeyka variety, where it showed itself as weakly variable). Thus, a set of varieties can have a fairly significant polymorphism on this feature in most cases.

The sulphur content is particularly interesting, since the sources of this element in the diet are more limited. According to the results of factor analysis, the variety factor was significantly affected ($F = 34.90$; $F_{0.05} = 2.66$; $P = 6.22*10^{-6}$), the Year factor was not significant ($F = 2.02$; $F_{0.05} = 2.44$; $P = 0.08$). The genotype-environment interaction was also not significant ($F = 2.11$; $F_{0.05} = 3.50$; $P = 0.09$). By pairwise comparison (Tukey's range test), the Nadezhda AZOS variety was ahead with high sulphur content, Arcadia was on par with the Nadezhda AZOS and Dubovsky pink varieties (which was already inferior to the best), in turn, the Dubovsky pink variety was on par with the Preobrazhenie variety, which was statistically significantly inferior in sulphur content to Arcadia and Nadezhda AZOS. The Rumeyka variety was worse, but the sulphur content in it did not differ statistically from the Preobrazhenie variety. The attribute varies less significantly between varieties, and within the same variety, it is considered slightly variable (at the level of 3-4%). The studied varieties show the absence of significant polymorphism in this trait, but it is quite difficult to manifest.

For magnesium content according to the results of factor analysis, the variety factor significantly affected ($F = 119.19$; $F_{0.05} = 2.66$; $P = 3.22*10^{-15}$), but not the Year factor ($F = 2.34$; $F_{0.05} = 2.44$; $P = 0.06$). The interaction of factors by influence was also not significant ($F = 2.87$; $F_{0.05} = 3.50$; $P = 0.07$). By pairwise comparison (Tukey's range test), the Nadezhda AZOS variety was ahead with a high magnesium content, then the Dubovsky pink and Rumeyka varieties (without significant differences between the varieties), the Preobrazhenie variety had a significantly lower content, and the Arcadia variety had the lowest content. The trait varies significantly between varieties, and within the same variety it is considered slightly variable (at the level of 3-5%). Thus, the set of varieties does not have a significant polymorphism in this trait.

According to the results of the factor analysis, potassium content significantly depended on the Variety factor ($F = 93.10$; $F_{0.05} = 2.66$; $P = 1.34*10^{-12}$), but not from the Year factor ($F = 2.31$; $F_{0.05} = 2.44$; $P = 0.06$). The interaction of factors by influence was also not significant ($F = 2.11$; $F_{0.05} = 3.50$; $P = 0.09$). By pairwise comparison (Tukey's range test), the Nadezhda AZOS variety was ahead with a high potassium content, followed by the Dubovsky pink, Preobrazhenie and Rumeyka varieties (they were at the same level in the trait), and the Arcadia variety had a significantly lower content. The trait varies significantly between varieties, and within the same variety, it is considered slightly variable (at the level of 2-4%). Thus, the set of varieties does not show significant polymorphism in this trait. The results of the discriminant analysis showed that the content of sulphur and potassium is less variable in the component determined by the variety, and the variability in the content of calcium, phosphorus, and magnesium is much more determined (Table 2).

***Table 2**. Results of discriminant analysis of the reliability of individual parameters by macronutrient content*

Indicators	Wilks' criterion	Partial	F	p-level
By varieties ($F_{critical} = 4.36$)				
Calcium, mg/kg	0.01	0.01	2,957.20	<0.01
Phosphorus, mg/kg	0.01	0.01	1,200.63	<0.01
Sulphur, g/kg	0.01	0.64	5.09	0.03
Magnesium, mg/kg	0.01	0.01	1,616.17	<0.01
Potassium, g/kg	0.01	0.36	15.90	<0.01
By year ($F_{critical} = 2.38$)				
Calcium, mg/kg	0.08	0.74	3.78	0.04
Phosphorus, mg/kg	0.98	0.997	0.02	0.97
Sulphur, g/kg	0.99	0.99	0.18	0.83
Magnesium, mg/kg	0.99	0.99	0.16	0.84
Potassium, g/kg	0.98	0.99	0.09	0.90

***Source:** compiled by the authors*

The Year factor, i.e., the environment, was significant only for the calcium content. It can be concluded that the content of the relevant substances is mediated only by genotypic features, given that the years were quite contrasting in their conditions according to the results of the calculated centroid distances (Fig. 1).

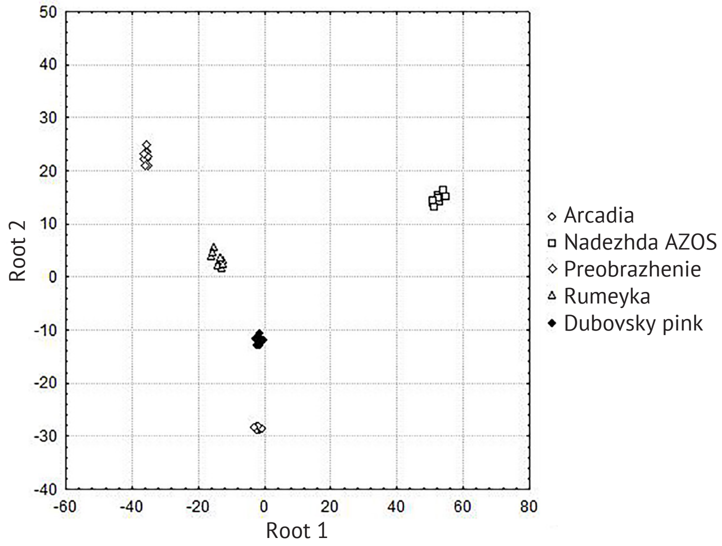


***Figure 1**. Identification of the influence of individual indicators by Variety*
***Source:** compiled by the authors*

The obtained characteristics of clusters in the factor space by canonical functions show a clear differentiation and differentiation of each of the varieties, significantly lower variability in the group than between genotypes. Each variety had its own significant features in the complex, a slight sparsity is observed only for the Rumeyka variety. Thus, with the exception of the phosphorus content, the studied features are mainly slightly variable, which indicates a significant uniformity of the studied material. In terms of calcium, magnesium, phosphorus and potassium, the Nadezhda AZOS variety prevailed, while the Arcadia variety, which showed the lowest performance in all other parameters, was also at its level in terms of sulphur content. According to factor analysis, the Variety factor was always significant, the Year factor was only in terms of calcium content, and the genotype-environment interaction was always unreliable. At the next stage, the content of valuable trace elements zinc, copper, selenium, and manganese for all five table grape varieties was analysed (Table 3).

***Table 3**. Content of table trace elements in grape berries depending on genotype (2021-2023), (x = 27, ±SD)*

Indicators	Arcadia	Nadezhda AZOS	Preobrazhenie	Rumeyka	Dubovsky pink
Zinc, mg/kg	0.17 ± 0.04^{a}	0.66 ± 0.09^{b}	0.12 ± 0.03^{a}	0.06 ± 0.01^{c}	0.07 ± 0.02^{c}
Copper, mg/kg	0.34 ± 0.04^{a}	0.47 ± 0.02^{b}	0.39 ± 0.04^{a}	0.38 ± 0.05^{a}	0.42 ± 0.05^{ab}
Selenium, µg/kg	0.12 ± 0.02^{a}	0.19 ± 0.03^{b}	0.21 ± 0.03^{b}	0.20 ± 0.03^{b}	0.28 ± 0.04^{bc}
Manganese, mg/kg	0.12 ± 0.02^{a}	0.47 ± 0.04^{b}	0.41 ± 0.05^{b}	0.38 ± 0.04^{b}	0.35 ± 0.04^{bc}

***Note:** indicates a significant difference at P < 0.05 for the Tukey's range test with Bonferroni correction. Comparison within varieties*
***Source:** compiled by the authors*

According to the results of factor analysis, the zinc content was significantly affected by the Variety factor ($F = 311.45$; $F_{0.05} = 2.66$; $P = 2.66*10^{-36}$), the Year factor was not significant ($F = 1.65$; $F_{0.05} = 2.44$; $P = 0.09$). The interaction of factors by influence was not significant ($F = 1.11$; $F_{0.05} = 3.50$; $P = 0.11$). By pairwise comparison (Tukey's range test), the Nadezhda AZOS variety was ahead with a high zinc content, next Arcadia and Preobrazhenie (they were on the same level), then Dubovsky pink and Rumeyka. The trait varies very significantly between varieties, but within the same variety it is considered low-varietal (at the level of 2-3%).

As for copper content, according to the results of factor analysis, this trait was significantly influenced by the Variety factor ($F = 27.17$; $F_{0.05} = 2.66$; $P = 7.11*10^{-5}$), the Year factor was not significant ($F = 1.87$; $F_{0.05} = 2.44$; $P = 0.08$). The interaction of factors by influence was not significant ($F = 1.42$; $F_{0.05} = 3.50$; $P = 0.09$). By pairwise comparison (Tukey's range test), the Nadezhda AZOS variety was ahead with a high copper content, at its level, but with an unreliable difference from the following varieties: Dubovsky pink, then Arcadia, Rumeyka, and Preobrazhenie (they were on the same level). The attribute varies less significantly between varieties, within the same variety, it is classified as low-varietal (at the level of 2-3%).

According to the selenium content according to the results of factor analysis, this trait was significantly affected by the variety factor ($F = 35.12$; $F_{0.05} = 2.66$; $P = 5.98*10^{-7}$), the Year factor was not significant ($F = 1.91$; $F_{0.05} = 2.44$; $P = 0.08$). The interaction of factors by influence was not significant ($F = 1.48$; $F_{0.05} = 3.50$; $P = 0.09$). By pairwise comparison (Tukey's range test), the high selenium variety Dubovsky pink was ahead of the Preobrazhenie variety, which was at its level, but with a not significant difference from the next varieties, Nadezhda AZOS and Rumeyka (which were at the same level), and Arcadia, which was significantly inferior. The attribute varies slightly between varieties, within the same variety, it is classified as low-varietal (at the level of 2-3%). It can be concluded that there is a slight polymorphism of the variety and a slight variability of the trait.

According to the results of factor analysis, the manganese content was significantly affected by the Variety factor ($F = 113.12$; $F_{0.05} = 2.66$; $P = 4.43*10^{-14}$), the Year factor was not significant ($F = 1.73$; $F_{0.05} = 2.44$; $P = 0.09$). The interaction of factors by influence was not significant ($F = 1.10$; $F_{0.05} = 3.50$; $P = 0.11$). In the pairwise comparison (Tukey's range test), Nadezhda AZOS, Preobrazhenie and Rumeyka were ahead of the high manganese varieties (at the same level), while the first two varieties were inferior to Rumeyka, but not to Dubovsky pink, and Arcadia was the worst. The attribute varies slightly between varieties, and within one variety it is considered low-varietal (at the level of 2-3 %). The results of the discriminant analysis showed that the copper and selenium content is less variable in terms of the component caused by the variety, while the variation in the zinc and manganese content is much more conditioned (Table 4).

***Table 4**. Results of discriminant analysis of the reliability of individual parameters for the content of trace elements*

Indicators	Wilks' criterion	Partial	F	p-level
		By varieties ($F_{critical} = 4.37$)		
Zinc, mg/kg	0.01	0.02	311.44	P < 0.01
Copper, mg/kg	0.01	0.55	7.54	P < 0.01
Selenium, μg/kg	0.01	0.40	13.40	P < 0.01
Manganese, mg/kg	0.01	0.07	115.47	P < 0.01
		By year ($F_{critical} = 2.39$)		
Zinc, mg/kg	0.98	0.99	0.02	0.98
Copper, mg/kg	0.99	0.98	0.23	0.79
Selenium, μg/kg	0.98	0.99	0.01	0.99
Manganese, mg/kg	0.98	0.99	0.01	0.98

Source: *compiled by the authors*

The Year factor, i.e., the environment, was not significant for any of the indicators. It can be concluded that the content of the relevant substances is mediated only by genotypic features, given that the years were quite contrasting in their conditions according to the results of the calculated centroid distances (Fig. 2).

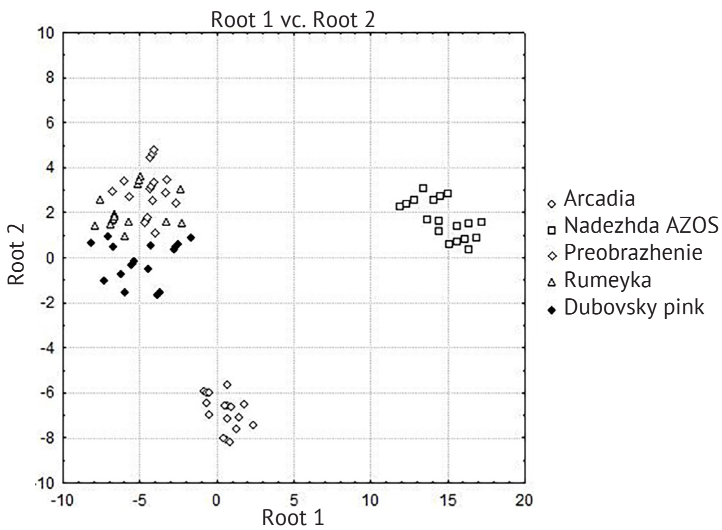


***Figure 2**. Identification of the influence of individual indicators by Variety*

Source: *compiled by the authors*

The obtained characteristics of clusters in the factor space according to canonical functions show a clear differentiation of Arcadia and Nadezhda AZOS varieties, a fairly significant variability in the group, varieties Preobrazhenie, Dubovsky pink and Rumeyka form one group. Clusters of varieties, in contrast to the previous group of traits, are quite sparse. Thus, the studied features are mainly weakly variable, which indicates a significant uniformity of the studied material. Complex in terms of the best content of zinc (the first with a significant difference), copper and manganese, the Nadezhda AZOS variety prevailed, but with some problems regarding the selenium content, which was preceded by the Dubovsky pink variety, which is a valuable source of this trace element. According to factor analysis, the variety factor was always significant, the Year factor was never significant, and the genotype-environmental interaction was always not significant. The group of traits is characterised by a significantly lower differentiating ability. It is difficult to note a definite better option, only the shortcomings of the Arcadia variety can be noted. At the last stage, the content of biologically active components – glucose, dietary fibre, vitamins A, E, C, PP, mg – was analysed for all five table grape varieties (Table 5).

***Table 5**. Content of biologically active components in table grapes depending on the genotype, recalculated per 100 g (2021-2023), (x = 27, ±SD)*

Indicators	Arcadia	Nadezhda AZOS	Preobrazhenie	Rumeyka	Dubovsky pink
Glucose, g	15.05 ± 0.34[a]	16.55 ± 0.39[b]	17.12 ± 0.43[b]	12.53 ± 0.31[c]	13.61 ± 0.32[d]
Dietary fibre, g	1.91 ± 0.24[a]	6.77 ± 0.82[b]	1.11 ± 0.24[c]	1.34 ± 0.25[as]	1.25 ± 0.25[ac]
Vitamin A, μg	3.12 ± 0.12[a]	4.34 ± 0.17[b]	3.09 ± 0.13[a]	3.45 ± 0.14[a]	3.12 ± 0.14[a]
Vitamin E, mg	0.17 ± 0.02[a]	0.11 ± 0.01[b]	0.15 ± 0.01[ab]	0.13 ± 0.02[b]	0.16 ± 0.01[a]
Vitamin C, mg	10.20 ± 0.24[a]	4.70 ± 0.11[b]	8.91 ± 0.25[c]	9.67 ± 0.22[c]	10.21 ± 0.27[a]
PP, mg	0.189 ± 0.04[a]	0.143 ± 0.03[b]	0.182 ± 0.03[a]	0.179 ± 0.04[a]	0.188 ± 0.05[a]

***Note:** indicates a significant difference at P < 0.05 for the Tukey's range test with Bonferroni correction. Comparison within varieties*
***Source:** compiled by the authors*

According to the results of factor analysis, the glucose content was significantly affected by the Variety factor ($F = 111.45$; $F_{0.05} = 2.66$; $P = 1.33*10^{-14}$), the Year factor was also significant ($F = 32.15$; $F_{0.05} = 2.44$; $P = 3.18*10^{-8}$). The interaction of factors by influence was significant ($F = 6.34$; $F_{0.05} = 3.50$; $P = 0.01$). By pairwise comparison (Tukey's range test), Preobrazhenie and Nadezhda AZOS were ahead of the high-glucose varieties (they were at the same level), followed by Arcadia, then Dubovsky pink, and the worst was Rumeyka. The trait varies quite significantly between varieties, within the same variety, it is classified as medium-varietal (at the level of 7-8 %, except for the Arcadia variety – 5%).

According to the results of factor analysis, the content of dietary fibre was also significantly affected by the Variety factor ($F = 345.15$; $F_{0.05} = 2.66$; $P = 6.67*10^{-43}$), the Year factor was not significant ($F = 2.25$; $F_{0.05} = 2.44$; $P = 0.06$). The interaction of factors by influence was not reliable ($F = 3.35$; $F_{0.05} = 3.50$; $P = 0.06$). By pairwise comparison (Tukey's range test), the Nadezhda AZOS variety was ahead with a higher content of dietary fibre, then Arcadia, then Dubovsky pink and Rumeyka (at the same level), and the Preobrazhenie variety was worse. The trait varies quite significantly between varieties, within the same variety, it is classified as medium-varietal (at the level of 7-10%, which indicates a significant hidden polymorphism in this parameter).

According to the results of factor analysis, the content of vitamin A was also significantly affected by the variety factor ($F = 25.17$; $F_{0.05} = 2.66$; $P = 3.47*10^{-6}$), the Year factor was more significant ($F = 52.15$; $F_{0.05} = 2.44$; $P = 1.1*10^{-18}$). The interaction of factors by influence was also significant ($F = 9.90$; $F_{0.05} = 3.50$; $P = 0.002$). By pairwise comparison (Tukey's range test), the Nadezhda AZOS variety was ahead with a higher vitamin A content, followed by all other varieties (they were at the same level). The trait varies slightly between varieties, within the same variety, it is considered slightly variable (at the level of 2-4 %, which indicates that there is no hidden polymorphism in this parameter). All this is shown in Table 6.

***Table 6**. Results of discriminant analysis of the reliability of individual parameters for the content of biologically active components*

Indicators	Wilks' criterion	Partial	F	p-level
By varieties ($F_{critical}$ =4.35)				
Glucose, g	0.01	0.07	119.25	P < 0.01
Dietary fibre, g	0.01	0.02	445.69	P < 0.01
Vitamin A, μg	0.01	0.24	27.45	P < 0.01
Vitamin E, mg	0.01	0.34	16.50	P < 0.01
Vitamin C, mg	0.01	0.36	14.98	P < 0.01

Table 6. Continued

Indicators	Wilks' criterion	Partial	F	p-level
PP, mg	0.01	0.88	1.09	0.37
By year ($F_{critical}$ = 2.37)				
Glucose, g	0.58	0.37	31.36	P < 0.01
Dietary fibre, g	0.24	0.86	2.80	0.07
Vitamin A, µg	0.85	0.25	54.78	P < 0.01
Vitamin E, mg	0.22	0.95	0.95	0.39
Vitamin C, mg	0.41	0.51	17.18	P < 0.01
PP, mg	0.32	0.66	9.32	P < 0.01

Source: *compiled by the authors*

The content of vitamin E was significantly affected by the Variety factor ($F = 15.47$; $F_{0.05} = 2.66$; $P = 2.12*10^{-5}$), the Year factor was not significant ($F = 1.00$; $F_{0.05} = 2.44$; $P = 0.12$). The interaction of factors by influence was also not significant ($F = 0.71$; $F_{0.05} = 3.50$; $P = 0.22$). According to pairwise comparisons (Tukey's range test), Arcadia and Dubovsky pink varieties were ahead with a high vitamin E content, Nadezhda AZOS and Rumeyka varieties were significantly worse, and the Preobrazhenie variety occupied an intermediate position. The trait varies slightly between varieties, within the same variety, it is considered slightly variable (at the level of 2-3 %, which indicates that there is no hidden polymorphism in this parameter).

The content of vitamin C was significantly affected by the Variety factor ($F = 15.07$; $F_{0.05} = 2.66$; $P = 1.14*10^{-5}$), the Year factor was more significant ($F = 17.10$; $F_{0.05} = 2.44$; $P = 5.64*10^{-8}$). The interaction of factors by influence was also significant ($F = 9.12$; $F_{0.05} = 3.50$; $P = 0.004$). By pairwise comparison (Tukey's range test), the Arcadia and Dubovsky pink varieties were ahead with a higher vitamin C content, then there were Preobrazhenie and Rumeyka varieties, and the Nadezhda AZOS variety was worse. The trait varies slightly between varieties, within the same variety, it is considered slightly variable (at the level of 4-5%, which indicates that there is no hidden polymorphism in this parameter).

The content of vitamin PP was not significantly affected by the Variety factor ($F = 2.07$; $F_{0.05} = 2.66$; $P = 0.07$), the Year factor was significant ($F = 7.80$; $F_{0.05} = 2.44$; $P = 0.002$). The interaction of factors by influence was not reliable ($F = 2.92$; $F_{0.05} = 3.50$; $P = 0.07$). According to pairwise comparisons (Tukey's range test), the varieties Arcadia and Dubovsky pink, Preobrazhenie, and Rumeyka were ahead with a high content of vitamin PP, while the variety Nadezhda AZOS was worse. The trait varies slightly between varieties, within the same variety, it is considered slightly variable (at the level of 1-2 %, which indicates that there is no hidden polymorphism in this parameter).

Results of the discriminant analysis performed in Table 6 showed that the content of vitamins is less variable in the component due to the variety, the genotype factor did not affect the content of vitamin PP at all, and the variability in the content of glucose and dietary fibre is much more determined. The Year factor, i.e., the environment, was significant for most indicators (except for the content of dietary fibre and vitamin E). It can be concluded that the content of the corresponding substances is mediated by both varietal diversity and environmental effect, especially for the content of glucose and dietary fibre traits, given that according to the results of the calculated centroid distances, the years were quite contrasting in their conditions (Fig. 3).

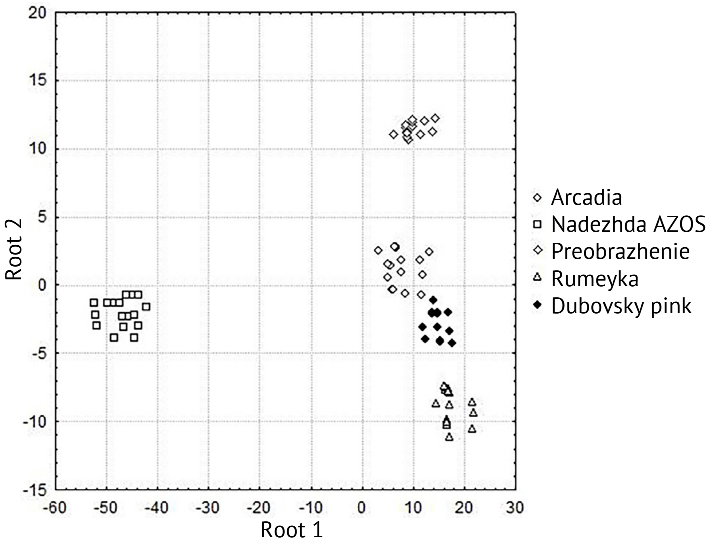


Figure 3*. Identification of the influence of individual indicators by Variety*

Source: *compiled by the authors*

However, the obtained characteristics of the clusters in the factor space by canonical functions show a clear differentiation and separation of varieties Arcadia and Nadezhda AZOS, less so of the variety Rumeyka, quite significant variability in the group, varieties Preobrazhenie and Dubovsky pink form one group. Clusters of varieties of this group of traits are quite sparse, which indicates a significant polymorphism of traits.

It was found that local material can also have a sufficient level of latent polymorphism to be used as a source of primary selection for improving certain traits, which was also partially noted earlier (mainly the first and second groups, glucose and dietary fibre traits) (Nazarenko & Simchenko, 2023). High varietal differentiation (the first group of traits) indicates the possibility of impoverishment of biodiversity with careful selection of more positive forms for full nutrition, while the lower (second-third group of traits) leads to a significant complication in the selection of more useful varieties, although in these studies it can be considered quite optimal for the second group of traits (Eyiz *et al.,* 2020).

In turn, higher variability in the variety itself by feature can lead to a more significant variation in the parameter depending on environmental conditions, which is not always positive for the producer. However, given the latest trends in the promotion of culture to the south due to global climate change, this problem can be ignored for some of the studied features (Leão *et al.,* 2020; Petretto *et al.,* 2021). The possibility of finding a variety with a high level of key characteristics and the need to supplement with other material is proved, primarily in terms of the content of necessary vitamins (Alem *et al*., 2019; Klimek *et al.,* 2022).

New varieties are being introduced faster in the raisin and table grape production sectors, but according to N. Khan *et al*. (2020), A. Atak (2024), the importance of local varietal resources for these areas cannot be ignored. There are also less valuable varieties in production, which may be appropriate to use according to marketing preferences, but they can significantly worsen the level of consumption of valuable food elements (mainly in this study this concerned the Arcadia variety). But any final recommendation needs to be clarified from the standpoint of such important features for table grapes as taste, preferences for the shape and colour of berries, processing capabilities and technological qualities of products (de Oliveira *et al.,* 2024). The consumption strategy changes significantly and promotes the introduction of more fruits in the diet. In eastern North America and Asia, fruit and aromatic flavours of V. Labrusca were actively used. Some American breeders also use this variety as a source of valuable food elements, which may be promising for local improvement (Arnold & Schnitzler, 2020).

The problem of preserving the corresponding biodiversity of the main cultivated plants is largely based on the possibility of using local varietal resources, in this case, traditional grape varieties for growing in farms in the region, which, mainly based on conservative trends in viticulture, can be created decades ago (Nazarenko *et al.,* 2022). These varieties can be the basis for improving the nutritional value of the diet and contain a high level of relevant nutrients for consumption. Moreover, as already partially noted earlier, such an advantage can be either complex or tied to the use of several varieties in production, which is all the more relevant, given the need for grapes as a crop to form a conveyor belt according to the maturation period and external characteristics (colour and shape of the berry) of its kind during the corresponding marketing period (De Palma *et al.,* 2020; Wang *et al.,* 2023).

Global warming significantly affects the strategy of agricultural development, as this industry negatively affects the intensity of forest stands and significantly increases the carbon footprint that is created during the production and sale of fruit. The system of long-term fruit production is more sustainable than the system of annual cultivation of crops, but in both cases, natural vegetation is replaced by cultivated plants, which significantly impoverishes biodiversity (Costa *et al.,* 2020; Pisciotta *et al.,* 2022).

The studied traits of vitamin content are mainly low-variable, which indicates a significant homogeneity of the studied material, the traits of glucose and dietary fibre content are medium-variable, i.e., there is a significant varietal polymorphism, which is typical for older varieties. Collectively, the best content of glucose, dietary fibre, and vitamin A was dominated by the Nadezhda AZOS variety, but there are problems with the other three vitamins. In view of this, it is a good idea to introduce the Dubovsky pink variety for this group of traits. In addition to the content of vitamin PP, the Year factor was not significant for the content of dietary fibre and vitamin E, and the genotype-environment interaction was significant for the content of glucose, vitamins A and C. The group of traits is characterised by a significant intermediate differentiating ability between the first and second. The best option is to use the Nadezhda AZOS variety in combination with Dubovsky pink.

CONCLUSIONS

The studied traits indicate a significant homogeneity of the varietal set. Only three medium-variable features can be used for primary selection to improve the source material. In terms of calcium, magnesium, phosphorus, potassium, zinc, copper, manganese, glucose, dietary fibre, and vitamin A, the Nadezhda AZOS variety prevailed, but only together with the cultivation of the Dubovsky pink variety, a comprehensive supply of useful food elements at the appropriate level is possible. The classification shows that Nadezhda AZOS and Arcadia are more unique, which indicates complex problems of Arcadia in terms of the content of necessary substances and undesirability of its use. In fact, the content of vitamin PP is not determined by the genotype, which indicates the need to introduce additional sources of this trait to local biodiversity. The characteristics of the medium were significant for the content of calcium, glucose, vitamins A, C, and PP. The genotype-environment interaction was factually derivative for traits where the influence of the environment was significant. In the future, it is planned to compare more modern and intensive varieties of table grapes according to this set of characteristics, to establish the variability of these forms in comparison and the level of necessary provision of the usefulness of the diet with varieties that are more traditional for growing by small agricultural firms by farms in the region, which mainly provide the production of table grapes for the region.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to the Czech Development Cooperation for making this research project possible.

CONFLICT OF INTEREST

None.

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Біохімічна цінність сортів винограду столового при вирощуванні в умовах Півночі Степу України

Алла Петренко
Аспірант
Дніпровський державний аграрно-економічний університет
49600, вул. С. Єфремова, 25, м. Дніпро, Україна
https://orcid.org/0009-0005-6755-3667

Микола Назаренко
Доктор сільськогосподарських наук, професор
Дніпровський державний аграрно-економічний університет
49600, вул. С. Єфремова, 25, м. Дніпро, Україна
https://orcid.org/0000-0002-6604-0123

Анотація. Дослідження можливостей використання існуючого біорізноманіття сортів винограду столового для задоволення повноцінності раціону людини є ключовим компонентом вдосконалення існуючого виробництва плодової продукції в рамках сучасних стратегій розвитку сільського господарства. Метою було встановити можливості задоволення в цінних елементах харчування потреб населення на базі традиційних сортів винограду столового, котрі переважно впроваджені у регіоні на рівні невеликих господарств та на присадибних ділянках. Досліджували п'ять сортів винограду столового Аркадія, Надєжда АЗОС, Преображеніє, Румейка, Дубовський розовий на вміст кальцію, фосфору, сірки, магнію, калію, цинку, міді, селену, марганецю, глюкози, харчових волокон, вітамінів А, С, Е, РР, обраховували залежність від факторів року та сорту, їх взаємодії, класифікуючої спроможності ознак у просторі канонічних функцій. Наявність мінеральних речовин досліджували атомно-емісійною спектрометрією, глюкози цукрометром, харчові волокна ферментативно-гравіметричними методом, вітаміни флюорометричним, вітамін С титрометричним методами. Показано можливості традиційних сортів винограду столового у задоволенню потреб у основних цінних харчових елементах та зроблено висновок щодо можливостей добору відповідних форм, котрі у комплексі цілком спроможні вдовольнити сучасні вимоги в даному аспекті розвитку сільського господарства. Виявлена переважно низька мінливість досліджених ознак, що дозволяє зробити висновок щодо гарно відтворюваності отриманого результату та переважний влив генотипу на формування відповідної ознаки в умовах контрастних за середовищними характеристиками років. Встановлено, що проблемним є поліпшення лише за однією з ознак – вмісту вітаміну РР. Низька диференціююча здатність сортів групи Дубовський розовий, Преображеніє, Румейка призводить до необхідності подальшого уточнення спроможності лише першого з сортів бути складовою у запропонованому комплексі. Рекомендовано вирощування комплексу сортів Надєжда АЗОС та Дубовський розовий

Ключові слова: виноградарство; генотип; харчова повноцінність; мікроелементи; якість продукції; біологічно-активні речовини
