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Biochemical composition and yield of new Ukrainian varieties of persimmon

L. M. Shevchuk*, O. G. Hrabovetska**, Y. Y. Vintskovska***, V. O. Tonkha***, R. I. Grynyk***

**National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine*
***Institute of Climate-Oriented Agriculture of the National Academy of Agrarian Sciences of Ukraine, Khlybodarske, Ukraine*
****Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine, Novosilky, Ukraine*

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National University of Life and Environmental Sciences of Ukraine, Heroiv Oborony st., 13, Kyiv, 03041, Ukraine. Tel.: +38-050-383-10-81. E-mail: l.shevchuk_2021@ukr.net

Institute of Climate-Oriented Agriculture of the National Academy of Agrarian Sciences of Ukraine, Khlybodarske, Odesa district, Odesa region, Ukraine. E-mail: olgagrabovetskay@ukr.net

Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine, Novosilky, Kyiv Region, Ukraine. E-mail: roma.grynyk1999@gmail.com

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Global warming is prompting significant changes and improvements in fruit-growing technologies. This is why many heat-loving crops are being cultivated in regions with a temperate continental climate. Breeders are developing frost- and winter-hardy varieties of subtropical crops, including persimmons, that are suitable for growing in different regions of Ukraine. Currently, two persimmon varieties are recommended for cultivation across Ukraine's various natural and climatic zones, but many more have been developed. One of the tasks of scientists is to study the adaptability of new varieties, as well as the commercial and consumer quality of their fruit. Research conducted at the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine aimed to study the quality indicators of two new Ukrainian persimmon varieties, Agrarna and Stepova Krasunia, which can withstand short-term temperature drops of minus 22–24 °C. These varieties are also resistant to disease and pest damage. We examined the weight, size, and shape of the fruit, as well as their nutrient and biologically active substance content. Trees of the Agrarna variety yield 69.7–71.3 kg per tree, with fruit weighing 153.0–164.4 g. Trees of the Stepova Krasunia variety yield 94.0–87.0 kg per tree, with fruit weighing 171.6–182.7 g. When ripe, Agrarna's skin and flesh turn orange, while those of Stepnaya Krasunia turn red-orange.

Keywords: *Diospyros kaki*; yield; fruit weight; fruit size; organic matter; polyphenols; biologically active compounds.

Introduction

Persimmon is a subtropical fruit that belongs to the order Ebenales and genus *Diospyros*. The family Ebenaceae includes 6 genera and 400 species, and the genus *Diospyros* includes 200 species, of which only four species are cultivated (Gautam et al., 2020). It is widely cultivated in subtropical and tropical regions of East Asia. Persimmon is commonly grown in China, Japan and Korea, and is the fifth fastest growing fruit in the world (Hossain & Shahidi, 2023). World breeders have created more than 1,000 varieties of persimmons that differ in tartness (Plaza et al., 2012). There are strongly astringent and non-astringent varieties (Shinji et al., 2003), the first group of varieties cannot be used immediately after harvesting due to the astringent taste, which is due to the high level of tannin, more than 0.2%, and the second – you can, since the content of this substance in them is less than 0.1% (Kato, 1984).

Persimmon fruits are a good source of bioactive compounds such as ascorbic acid, tannins and carotenoids, which have a positive effect on human health, mainly due to their antioxidant properties (Manach et al, 2004; Rao & Rao 2007; Murali et al., 2023), they are a potential source of functional foods and nutraceuticals (Abeysinghe et al., 2007; Kim et al., 2014), and therefore are a popular dessert product in many countries around the world. According to Matheus et al. (2022), the most important macro- and microelements present in persimmon are carbohydrates, fibre, organic acids, phenolic compounds and carotenoids, which give it antioxidant, cytotoxic and anti-diabetic properties. Persimmon grows well and bears fruit in a warm, moderate subtropical climate with an optimal temperature of 14–22 °C and an amount of precipitation of 762 mm. The annual temperature for the formation of sweet persimmon fruits varies in the range of 14.6–15.7 °C, it needs higher temperatures than astringent species. Sweet types of persimmon varieties are not winter-hardy, the maximum minus temperatures they can withstand are –15 °C, and tart types can withstand temperatures below –25 °C (Gautam et al., 2020). Therefore, the main regions of its cultivation are South Korea, China and Japan (Song et al., 2005), as well as Brazil, Italy, Israel and New Zealand (Yamagishi et al., 2005). However, according to Karakasova et al. (2013), Japanese persimmon (*Diospyros kaki* L.), also known as "Japanese apple" or "Asian apple", has been grown all over the world in recent years, including its European part (Shevchuk et al., 2023). Persimmon culture as a fruit plant has been known in Ukraine since the last century, currently it is represented here by three deciduous species (Caucasian, American, Japanese), as well as American and Japanese persimmon hybrids, which produce edible fruits and are quite widely used in southern and subtropical gardening.

The climatic conditions of Ukraine, in particular its mainland part, are characterized by harsher winters and cooler summers than those countries where persimmon culture is widely grown. In Ukraine, the average temperature of the coldest month of the year, January, is minus 6 °C, and in the warmest July it is plus 19.5 °C. Due to such meteorological differences, there is no question about the adaptability of introduced varieties created in other countries with a temperate climate in Ukraine. Ukrainian breeders create their own varieties of persimmons, which are winter-hardy and frost-resistant and at the same time endowed with high productivity and excellent fruit quality. After all, the most commercially important properties of fruits are the ripening time and their weight and productivity, which usually vary with environmental factors (Yamada & Kurihara, 1984; Yamada et al., 1986). Therefore, it is important to have varieties whose productivity does not depend on the climate and weather of the region where they are grown. According to the Ukrainian breeders, the best varieties of persimmons of their selection, in the conditions of Ukraine, are able to withstand temperature drops to minus 30...32 °C without damage, that is, in terms of frost resistance, they are not inferior to winter-hardy varieties of stone fruits which are grown in a large area of Ukraine (Derevianko et al., 2020).

The objective of the research was to study the yield and quality of persimmon harvest of new Ukrainian varieties – Agrarna and Stepova Krasyna. Among the physical quality indicators, the weight, size and shape of persimmons were studied. The content of organic and biologically active substances was studied for consumer quality. In addition, the aim was to analyse the differences between the quality of

Ukrainian persimmon varieties and those grown in countries where the climate is more favourable for its growth and development.

Materials and methods

The objects of research were new varieties of persimmons of Ukrainian selection Agrarna and Stepova Krasunia, both of which belong to astringent species. The varieties are vigorous trees up to 3.0–4.0 m high. Both varieties are monoecious and can be pollinators for each other and for other varieties. Agrarna and Steppe krasunia varieties are sufficiently winter-hardy, they can withstand a short-term temperature drop to minus 22–24 °C without significant damage. These varieties are resistant to diseases and damage by pests. In the conditions of Ukrainian farms, chemical treatment with pesticides was not required, which allowed persimmons, unlike other fruit crops, to yield high-quality ecologically clean products.

The ripeness of the fruits of the Agrarna persimmon (Fig. 1a) and the Stepova Krasunia (Fig. 1b) comes in the third decade of October – in the first decade of November (before the onset of frost). 18–23 days at a temperature of plus 19 °C are enough for fruits to reach consumer ripeness after their collection. Both varieties can be stored in the fruit storage until January.

a *b*

Fig. 1. Persimmon fruits of the researched varieties: *a* – Agrarna; *b* – Stepova Krasunia

Plantations of experimental varieties of persimmons are located on the lands of the State Enterprise "Experimental Farming "Novokakhovsk" of the Institute of Climate-Oriented Agriculture of the National Academy of Agrarian Sciences of Ukraine, which is located in Skadovsky district, Kherson region, altitude 8 m, 46°08′34″ N and 32°57′15″ E.

The soils of the research site are chernozem light loam with a thickness of the humus layer of 76 cm, and the content of humus in the arable layer (0–25 cm) is 1.33%.

The climate of the region where persimmon plantations are located is characterized by the sum of active temperatures of 10 ºC and above – 3,200–3,300 ºC, the amount of precipitation during the persimmon vegetation period is 215–230 mm, the annual amount is 380–430 mm, the hydrothermal coefficient is 1.2–1.3. The average duration of the persimmon growing season is 185–195 days. Spring frosts stop on average in the third decade of March, but in some years the latest are observed in the second decade of May. Autumn frosts occur on average in the second – third decades of October, and the earliest – at the beginning of October.

Care of persimmon plantations of the Agrarna and Stepova krasunia varieties is generally accepted for this Steppe zone of Ukraine, the tree planting scheme in the experimental garden is 6 x 6 m, all varieties are grafted on *Diospyros virginiana* L. rootstock.

Analytical studies were conducted in the laboratory of storage and processing of fruits and berries of the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine. Fruits of the Agrarna variety with a characteristic shape and colour were selected at the stage of marketable ripeness and weighed at least one kilogram, according to the 'Methodology for assessing the quality of fruit and berry products' (Kondratenko et al., 2008). The average fruit weight was determined by weighing 20 fruits on a laboratory balance. Analytical studies of persimmons of both varieties were carried out immediately after harvesting and after 20 days of storage at a temperature of plus 19 ± 1 °C.

The average weight of the persimmon fruits was determined by weighing them on a laboratory balance to the nearest decimal place; the largest transverse diameter (width) and height of the fruit were determined by calipers; the hardness of the pulp was determined by a portable penetrometer 'Wagner Fruit Test' (USA) with a nozzle FT 30 FT716 with a diameter of 11 mm. The shape index was determined by dividing the height by the largest transverse diameter of the fruit. For the study, 20 fruits of each pomological variety were randomly selected. Fruit and laboratory samples for analytical analysis were weighed on a second-class laboratory balance A&D EK-610i (Japan).

The dry matter was determined by drying in a SP-30 desiccator (Ukraine) at a temperature of 98–100 °C. To do this, 5 g of crushed persimmon pulp with persimmon peel was mixed with dried sea sand. The sample was weighed before and after drying. It was dried to a constant weight. The difference between the wet weight and the dry weight expressed as a percentage was presented as dry matter (%).

The content of soluble solids in persimmon fruits was determined by the refractometric method. For this purpose, a portable refractometer Atago Pal-1 (Japan) was used. The analytical sample was prepared from 5 fruits. The fruits were cut into pieces and ground with a homeogeniser. Subsequently, a drop of juice was squeezed through the tissue onto the refractometer glass, and the temperature error was taken into account when recording the data. The data were expressed as a percentage of the raw weight (%/100 g).

Organic titratable acids were determined by the titration method. For the extraction of acids, 25 g of persimmon fruit pulp crushed by a homeogeniser was taken and transferred without loss, by washing

with hot distilled water, in a volume of no more than 150 mL, to a 250 mL volumetric flask. The flask was kept in a water bath for 30 min at 80 °C and cooled. The contents of the flask were made up to the mark with distilled water and filtered through a filter into a 250 mL conical flask. After that, 20 mL of the extract was pipetted into a 250 mL conical flask, 3–4 drops of phenolphthalein were added and titrated with 0.1 N sodium hydroxide solution until a pink colour appeared, corresponding to pH 7.0. The content of titratable acids in the sample was calculated according to the formula using the titre index of 0.1 N sodium hydroxide and the conversion factor to citric acid. The content of titratable acids in the sample was calculated according to the formula using the titre value of 0.1 N sodium hydroxide and the conversion factor to malic acid. The data were expressed as a percentage of the raw weight (%/100 g).

The content of titrated organic acids in the sample is calculated according to the formula:

$$X = \frac{A * T * V * 100 * 0.0067}{V_1 * M}$$

where X – content of titrated acids (% in terms of malic acid); A– volume of 0.1 N sodium hydroxide used for titration (mL); T – titer of 0.1 N sodium hydroxide; V – total volume of the final sample extract (mL); V_1 – volume of aliquot of the final sample extract taken for analysis (mL); M – mass of the sample (g); 0.0067 – malic acid conversion factor.

The content of total sugars was determined by the colometric method. Sugars in persimmons were extracted with hot water. The extract was then purified from proteins and pigments by precipitation with lead acetic acid. Sucrose was hydrolysed to glucose and fructose by heating in the presence of 10% hydrochloric acid. The hydrolysis products were oxidised with Fehling's solution. The optical density of the resulting solutions was determined using a ULAB 102UV (China) spectrophotometer at a wavelength of 640 nm. The sugar content in the sample was calculated using the formula and a graduated graph indicator. Standard glucose solutions with different concentrations were used to construct a graduated graph of the dependence of optical density (optical density unit) on glucose concentration (mg/mL). The data were expressed as a percentage of the wet weight (%/100 g).

The sugar-acid index (CAI) of persimmon fruits was determined as the ratio of total sugars to the amount of titratable acids.

To determine the pectin substances, the sample was pre-purified from sugars and pigments with ethyl alcohol. Extraction of soluble pectin was carried out with water, and extraction of protopectin with 1 N sulfuric acid, hydrolysis of the latter to galacturonic acid – with heating. To the extracts acidified with concentrated sulfuric acid, soluble pectin and protopectin extracts, 0.2% carbazole solution was added to form a colored complex. The optical density of the resulting solutions was recorded on a ULAB 102UV (China) spectrophotometer at a wavelength of 535 nm. The content of soluble pectin and protopectin in the sample was calculated according to the formula, using the coefficient of conversion to apple pectin and the indicators of the grading graph. Standard solutions of galacturonic acid with different concentrations were used to construct a graduated curve of the dependence of optical density (unit of optical density) on the concentration of galacturonic acid (μg/mL). The data were expressed as a percentage of the wet weight (%/100 g).

The content of ascorbic acid in persimmon fruits was determined by the titration method. For this purpose, the pulp of the fruit together with the peel was ground in a porcelain mortar with the addition of broken glass and a mixture of 2% oxalic and 1% hydrochloric acids (80+20, v/v). After grinding, the mixture was transferred to a 100 mL volumetric flask. The contents of the flask were adjusted to the mark with a mixture of 2% oxalic and 1% hydrochloric acids (80+20, v+v) and filtered. The resulting extract was titrated with a solution of 2,6-dichlorophenolindophenol. The content of ascorbic acid in the sample was calculated by the formula using the Tillmans' method. The obtained result was expressed in g per kg of fresh weight of fruit (mg/g).

The content of total polyphenols in persimmon fruits was determined by the spectrometric method. For the extraction of polyphenols, the sample was ground in a porcelain mortar with a small amount of ethyl alcohol and filtered using a VF-15S vacuum filtration system, filtered through a paper filter with a blue ribbon into a Bunsen flask. The residue on the filter was washed with a small amount of ethanol until the sample was completely discoloured. The volume of alcohol used (ml) was recorded. 7.9 mL of distilled water, 0.1 mL of extract, 1 mL of Folin-Denis reagent, were added to the test tube,the content was stirred and after 3 minutes 1 mL of saturated sodium carbonate solution was added and the content stirred again. Within an hour, the optical density of the content of the tubes was recorded using a ULAB 102UV (China) spectrophotometer at a wavelength of 640 nm. A mixture prepared as follows was used as a control: 8 mL of distilled water and 1 mL of Folin-Denis reagent were poured into a test tube, stirred, 1 mL of saturated sodium carbonate solution was added after 3 minutes and stirred again. At least three parallel measurements were made and the average value of the optical density was found. The content of total polyphenols in the sample was calculated by the formula using the values of the graduated graph. Standard solutions of chlorogenic acid with different concentrations were used to construct a graduated graph of the dependence of optical density (optical density unit) on the concentration of chlorogenic acid (μg/mL). The data obtained were expressed as g per kg of fresh weight of the fruit (mg/g).

Statistical data processing was performed using Statistica 13.1 (StatSoft, Inc., USA). The results are presented as mean values for the indicators with standard errors in the form of mean ± standard error (x ± SE). Differences between replications and years of research for each variety were determined by ANOVA. The results are presented at the level of significance $P < 0.05$. Pairwise comparison was used to establish a significant difference in the data obtained.

Results

The yield of a ten-year-old plant of Agrarna variety was 70.5 kg, and of Stepnaya Krasunia variety – 90.5 kg per tree, fluctuations over the years of research were insignificant – 69.7–71.3 for Agrarna variety and 94.0–87.0 kg/tree for Stepnaya Krasunia variety (Table 1).

The fruits of the Agrarna variety were characterised by a fruit height of 66.3 to 64.0 mm and the largest transverse diameter of 64.0 to 63.0 mm, which provides a roundness index of 1.04–1.02. The fruits of the persimmon variety Stepnaya Krasunia had a rounded-flat shape, the index of which was 0.77 in 2020 and 0.71 in 2021. This fruit shape index was provided by the height of the fruit – 58.3 mm and the largest transverse diameter of 75.7 mm in 2020 and 55.0 and 78.0 mm, respectively, in 2021 (Table 1).

The average weight of fruits of Agrarna variety ranged from 153.0 to 164.4 g during the years of research, and of the Stepnaya Krasunia variety – from 171.6 to 182.7 g (Table 1).

Table 1

Yield, weight, size and shape index of persimmon fruit (n = 21, x ± SE, 2020–2021)

Varieties	Years of research	Yield kg/tree	Weight fruit, g	Height, mm	Transverse diameter, mm	Shape index*
Agrarna	2020	69.7 ± 4.7^{b}	153.0 ± 8.5^{b}	66.3 ± 2.0^{a}	64.0 ± 1.0^{b}	1.04 ± 0.12^{a}
	2021	71.3 ± 6.0^{ab}	164.4 ± 8.4^{ab}	64.0 ± 2.3^{ab}	63.0 ± 2.7^{b}	1.02 ± 0.14^{ab}
Stepova Krasunia	2020	94.0 ± 7.2^{a}	171.6 ± 6.0^{ab}	58.3 ± 1.8^{ab}	75.7 ± 1.9^{ab}	0.77 ± 0.11^{ab}
	2021	87.0 ± 5.5^{ab}	182.7 ± 8.1^{b}	55.0 ± 2.2^{b}	78.0 ± 1.5^{a}	0.71 ± 0.20^{b}

Notes: [a] and [b] indicate values that differ significantly from the average; values within the mean are indicated by [ab]; the results of the comparison were obtained using Tukey's test with the Bonferroni correction; * – shape index – persimmon fruit shape index: index > 1/0 – oval fruits, < 1.0 – plum-shaped fruits.

When ripe, the colour of the skin and flesh of Agrarna is orange, and that of Stepova Krasunia is red-orange, and both varieties have a strongly pronounced waxy coating. The fruits of Agrarna are juicy, with a pleasant sweet taste, and the sugar acid index at the harvested stage of ripeness was 57–56, and the consumer index was 59–62. The flesh of the mature fruit of Stepnaya Krasunia is also very juicy, with a sugar acid index of 63–66 at harvesting ripeness and 72–70 at consumer ripeness (Table 1).

The dry matter content in the fruits of Agrarna variety varied from 22.98% to 21.66% in the state of harvest ripeness and from 23.55% to 20.39% in the state of consumer ripeness over the years of research. The average indicator for the years was: in the harvesting ripeness 22.32% and in the consumer ripeness – 21.97% (Table 2). In the fruits of the Stepova Krasunia variety, the amount of dry matter in 2020 in the state of harvest ripeness was 21.34% and in 2021 – 21.65%, and in the state of consumer ripeness – 21.16% and 19.49%, respectively, the average content over the years of research was 21.50% and 20.33%, respectively (Table 2).

The amount of soluble solids in the years of research in the fruits of the Agrarna variety, which were in harvesting ripeness, ranged from 22.57% in 2020 to 20.08% in 2021, with an average of 21.33%, in the Stepova Krasunia variety – from 22.24% to 22.25%, with an average of 22.25%. In the process of ripening, their content changed slightly, in particular, in 2020 in the fruits of the Agrarian variety it was 4.66% lower, and in 2021 – by 1.96% (Table 2). In the Stepova Krasunia variety, the decrease in soluble solids content in the first year of research was 4.5%, a slightly more significant decrease in soluble solids was observed in 2021 and amounted to 4.7%.

Table 2

Content of organic substances in persimmon fruits of the Agrarna and Stepova Krasunia variety (n = 9, x ± SE, 2020–2021)

Indicators	Maturity	Agrarna		Stepova Krasunia	
		2020	2021	2020	2021
Dry solids, %	harvesting	22.98 ± 0.17^{a}	21.66 ± 0.19^{ab}	21.34 ± 0.16^{b}	21.65 ± 0.14^{ab}
	consumer	23.55 ± 0.09^{a}	20.39 ± 0.07^{ab}	21.16 ± 0.08^{ab}	19.49 ± 0.09^{b}
Dry soluble solids,%	harvesting	22.57 ± 0.17^{a}	20.08 ± 0.10^{b}	22.24 ± 0.14^{ab}	22.25 ± 0.17^{ab}
	consumer	$17{,}91 \pm 0.15^{ab}$	18.12 ± 0.12^{a}	17.74 ± 0.13^{ab}	17.55 ± 0.11^{b}
Sugars,%	harvesting	10.23 ± 0.05^{b}	10.83 ± 0.10^{ab}	12.49 ± 0.07^{a}	11.77 ± 0.11^{ab}
	consumer	9.92 ± 0.09^{ab}	10.54 ± 0.06^{ab}	10.61 ± 0.10^{a}	8.53 ± 0.11^{b}
Organic titrated acids,%	harvesting	0.18 ± 0.01	0.19 ± 0.01	0.19 ± 0.01	0.20 ± 0.01
	consumer	0.17 ± 0.01	0.17 ± 0.01	0.16 ± 0.01	0.13 ± 0.02
Sugar/organic acids	harvesting	57 ± 5^{ab}	56 ± 5^{ab}	63 ± 4^{ab}	66 ± 0^{a}
	consumer	59 ± 4^{ab}	62 ± 5^{ab}	72 ± 4^{ab}	70 ± 9^{ab}
Protopectin,%	harvesting	0.991 ± 0.035^{a}	0.863 ± 0.021^{ab}	0.806 ± 0.048^{ab}	0.755 ± 0.026^{b}
	consumer	0.720 ± 0.031^{a}	0.701 ± 0.022^{ab}	0.701 ± 0.010^{ab}	0.638 ± 0.014^{b}
Hydropectin,%	harvesting	0.401 ± 0.012^{ab}	0.521 ± 0.013^{a}	0.325 ± 0.015^{b}	0.394 ± 0.033^{ab}
	consumer	0.283 ± 0.032^{ab}	0.332 ± 0.022^{ab}	0.260 ± 0.033^{ab}	0.317 ± 0.014^{ab}
Pectin substances,%	harvesting	1.392 ± 0.031^{a}	1.384 ± 0.008^{a}	1.131 ± 0.033^{b}	1.149 ± 0.031^{ab}
	consumer	1.003 ± 0.058^{ab}	1.033 ± 0.008^{a}	0.961 ± 0.031^{ab}	0.955 ± 0.015^{ab}
Ascorbic acid, mg/g	harvesting	19.43 ± 1.55^{ab}	13.75 ± 1.26^{b}	36.71 ± 1.63^{a}	36.50 ± 1.54^{a}
	consumer	10.39 ± 1.06^{b}	7.30 ± 1.24^{b}	33.05 ± 1.65^{a}	35.33 ± 1.31^{a}
Polyphenolic substances, mg/g	harvesting	839.0 ± 16.5^{a}	777.3 ± 13.3^{ab}	616.7 ± 8.3^{b}	670.2 ± 13.1^{ab}
	consumer	130.7 ± 4.4^{ab}	147.3 ± 5.6^{ab}	122.1 ± 5.2^{b}	229.0 ± 11.9^{a}

Notes: see Table 1.

In persimmon fruits of the Agrarna variety, the amount of total sugars in the ripening stage was 10.23% in 2020 and 10.83% in 2021, the average was 10.53%. In the variety Stepova Krasunia, their content in the ripening stage was higher, but not significantly, and was 12.49% in 2020, 11.77% in 2021, and the average was 12.13%. In the state of consumer ripeness, the sugar content in both varieties under study decreased, namely in the Agrarnaya variety by 0.30%, in the Stepova Krasunia variety their decrease was more significant and amounted to 2.56% on average (Tables 2).

The amount of titratable organic acids in the fruits of the studied persimmons in harvest ripeness almost did not change over the years of research, and amounted to 0.18 in 2020 and 0.19% in 2021 in the Agrarna variety and 0.19 and 0.20% of the Stepova Krasunia variety. In the process of post-harvest ripening, the acidity of both varieties decreased, in the Agrarna variety by 0.2%, in the Stepova Krasunia variety by 0.4% (Tables 2).

The ratio of sugars to titratable acids in the studied varieties in the state of harvest ripeness was 56 for Agrarna and 64 for Stepova Krasunia. A slight increase in this indicator in fruits that were in consumer ripeness was due to a decrease in titrated acids, since their sugar content did not increase, but rather vice versa. In consumer ripeness, the fruits of the Agrarna variety had a sugar acid index of 59 in 2020 and 62 in 2021, and the Stepova Krasunia variety – 72 and 70, respectively (Tables 2).

The total content of pectin substances in the studied persimmon fruits that were in harvest ripeness was 1.392–1.384% in the Agrarna variety and 1.131–1.149% in the Stepova Krasunia variety.

The amount of protopectin in Agrarna was 0.991–0.863%, and in Stepova Krasunia – 0.806 and 0.755% (Tables 2, 3). Its share in the total amount was 71–51% in the first of the mentioned varieties and 70–67% in the second. In the process of ripening, changes occurred in the pectin complex. In the Agrarna variety, a decrease in the content of protopectin and soluble pectin substances was observed during post-harvest ripening. Specifically, the decrease in protopectin was 0.271% in 2020 and 0.162% in 2021, while the decrease in hydropectin was 0.118% and 0.189% in the same years, respectively. Accordingly, the total amount of pectin substances decreased by an average of 0.370% over the course of the research. A decrease in both components of pectin substances was also observed in the fruit of the Stepova Krasnya variety when it was at the stage of consumer ripeness. However, only the content of hydropectin decreased significantly: by 0.065% in 2020, by 0.077% in 2021, and by an average of 0.071%. Additionally, a decrease in the total amount of pectin substances was observed in the Stepova Krasunia variety in both years of the study. In 2020, this was 0.170%; in 2021, it was 0.24%; and the average over the years of research was 0.209% (Table 2).

The content of vitamin C in fresh persimmon fruits of the Agrarna variety varied depending on the year of cultivation – from 19.43 in 2020 to 13.75 in 2021, with an average value of 16.59 mg/kg. In the Stepova variety, from 36.71 in 2020 to 36.50 in 2021, with an average of 36.60 mg/kg. In the process of ripening, the content of ascorbic acid in persimmon fruits decreased, but not significantly, in particular, in the Agrarna variety in 2020 it decreased by 9.04, in 2021 by 6.45 mg, and in the Stepnaya Krasunia variety by 3.66 and 1.17 mg, respectively (Table 2).

The content of polyphenols in persimmons of the Agrarna variety in the state of harvest ripeness was 839.0 in 2020 and 777.3 mg/kg in 2021, with an average value of 808.15 mg/kg (Table 2). In the variety Stepova Krasunia, 616.7 in 2020, 670.2 in 2021, the average was 643.5 mg/kg (Table 2).

During the ripening process, the polyphenol content of persimmon fruits decreased significantly. For the Agrana variety, this de-

crease was 708.3 mg/100 g in 2020 and 630.0 mg/100 g in 2021. For the Stepnaya Krasunia variety, the respective figures were 494.6 and 441.2 mg/100 g. Alongside the decrease in polyphenolic substances, there was a reduction in the tannin content, which was responsible for the fruit's viscosity. This significant reduction in tannins improved the taste of the studied persimmon varieties.

Discusion

According to Brazilian scientists, in a subtropical climate in a well-maintained orchard, persimmon, depending on the variety, usually produces 100 to 150 kg of fruit per year (Nascimento et al., 2014). Grellmann et al. (2003), in Veranópolis, Brazil, obtained a much lower yield of 25.94 kg of persimmon from trees aged five to twelve years, which is similar to the results obtained in another region of Brazil, where 28.4 kg per tree was collected (Nascimento et al., 2017). Peche (2016) studied persimmon fruit production in the Mantiqueira Mountains of Brazil, and recorded a yield of 206.82 kg of fruit per plant. Turkish scientists have studied the productivity and quality of persimmon fruits of the 10 most widespread varieties in the world and found that their yield varied from 52.9 to 185.6 kg per tree. The yields of persimmon fruits of new Ukrainian varieties compared to those obtained by scientists in the traditional regions of its cultivation are not the lowest, as evidenced by the above data. These data are a confirmation that yield is a genetically fixed trait and depends on the genotype of the variety, growing conditions and the age of the plant.

A high sugar-acid index is an indication that the fruit has a pleasant taste, and persimmons have a sweet taste. Typically, the SAI increases during ripening due to a decrease in acidity, allowing for a high ratio in fruits with low soluble solids (Carvalho et al., 2011).

The average fruit weight of other persimmon varieties of Ukrainian selection was 74.2 g, with a maximum of 113.2 g and a minimum of 48.4 g (Shevchuk et al., 2023). The weight of persimmon fruits grown in Turkey was 87–251 g (Toplu et al., 2009). Savalcante (2007) noted that in humid tropical climates with dry winters, the average weight of persimmons varies from 86.2 to 124.6 g, depending on the variety.

Persimmon is known for its nutritional value, as noted by Achiwa et al. (1997), it contains 80.3% water, so the amount of dry matter is 19.7% according to Gautam et al. (2020), the dry matter content of persimmon varieties studied by them was 21.8% and 21.9%.

In the samples studied by Ozen et al. (2004) and Ercisli et al. (2007), the soluble solids content was 18.6%, almost the same amount (18.9%) as in the fruits studied by Egyptian scientists (Makhzangy et al., 2023), and the content of PCA in persimmon fruits of Ukrainian selection was within the same range. According to Koshita et al. (2007), persimmon studied in Japan contained less soluble solids – 16.5%, which is comparable to the data obtained by Indian and Iranian scientists, where their content was 16.16 and 16.50 ˚Brix (Gautam et al., 2020), even less (11.5 ˚Brix) in the fruits studied by Turkish scientists (Altuntas et al., 2011).

According to Piretti, (1991), the amount of sugars (12.5 g/100 g) in persimmon is higher than in other commonly consumed fruits such as apple, peach, pear and orange, in particular, in the fruits of the Ukrainian apple tree the sugar content was 10.7% (Shevchuk et al., 2022), which is at the level of the content of the studied samples. The data obtained as a result of the studies differ from those obtained by Egyptian and Bulgarian scientists, where the sugar content in the fruits studied by them was 18.0% (Denev & Yordanov 2013; Homnava et al., 2014; Makhzangy et al., 2023). Piretti (1991) obtained significantly higher sugar content of persimmon in his studies. According to Del Bubba et al. (2009), the amount of sugars in the fruits of persimmon studied by them was 12.5%, which is not much different from the data obtained as a result of studying persimmon varieties Stepova Krasunia and Agrarna. A fairly wide range of sugars from 10.0% to 19.5% was found in the persimmon samples studied by Porfirio-da-Silva et al. According to Novillo et al. (2015), the ambiguity of data on the sugar content of persimmon fruits depends on the variety and growing conditions, in particular light and temperature conditions, humidity, etc.

The content of titratable acids in the fruits of the studied persimmon varieties was almost identical to the content of some varieties grown in China. However, the range of inter-varietal variations in the content of these substances in the Chinese varieties was much greater than in the Ukrainian varieties, from 0.03% to 0.18% (Chen et al., 2016). A much higher content of titratable acids (2.06%) was observed in persimmon fruits studied by Turkish scientists (Celik & Ercisli, 2008). It was much lower in persimmons studied in India (0.13%) (Gautam et al., 2020) and 0.14% (Murali, 2023).

According to Porfirio-da-Silva et al. (2011), persimmon is rich in pectin substances, its amount is almost at the level of that accumulated by apple fruits (0.93–1.14%) (Shevchuk et al., 2021). This is more than in persimmon studied by Pachisia (2020), where their content was 0.70%, the same was the lower limit of pectin content (0.69%) in Chinese fruits, but the upper limit was 2.39% (Chen et al., 2016). The existence of a significant variation in the content of pectin substances in persimmon is caused by varietal differences and growing conditions, as evidenced by the data obtained by Taira et al. (1997) and Asgar et al. (2003), where the content of these substances was 0.3% and 1.6%, respectively.

Earlier, a decrease in protopectin and an increase in soluble pectin during persimmon ripening was reported by Kashyap et al. (2001). This statement is not comparable to the data obtained in the study of fruits of Agrarna and Stepova Krasunia varieties. In both varieties, a decrease in the amount of both soluble and insoluble pectin was observed during the ripening process.

The amount of ascorbic acid in persimmon fruits is higher than in apples, where its maximum is 11.5 mg/100 g (Shevchuk et al., 2021), but at the level of blueberries (18.24 mg/100) (Shevchuk et al, 2022). The content of ascorbic acid (15.90 mg/100 g) in persimmon studied by Iranian (Gautam et al., 2020) and Brazilian (Özen et al., 2004) scientists was also at the level of the Agrarna variety.

The data obtained from the studies of Ukrainian breeding varieties do not agree with the results of Ozen et al. (2004) and Sharma et al. (2021), where they noted that the content of ascorbic acid in the persimmon fruits of the persimmon they studied was 7.50 and 8.71 mg/100 g, respectively. The vitamin content of persimmons studied in Spain was almost within the same range (4.62–10.25 mg/100 g) (Domínguez Díaz et al., 2022). Significantly higher limits of vitamin C content (85.6–102.5 mg/100 g) were found in fruits studied by Butt et al. (2015) in Pakistan, Pachisia (2020) in India (70.0 mg/100 g) and Makhzangy et al. (2023) in Egypt (58.0 mg/100 g), which is not consistent with the data obtained in the study of Agrarna and Stepnaya Krasunia varieties.

A decrease in the level of C vitamin in persimmon fruits during storage was previously reported by Shahkoomahally et al. (2013), in particular, at the beginning of storage, the fruits they studied contained 39.75, and after a month of storage 30.3 mg/100 g. The data are comparable to those obtained as a result of our studies, in particular in the variety Stepova Krasunia.

The results of studies on the content of polyphenolic substances in persimmon fruits of Ukrainian selection differ from the results obtained by Denev & Yordanov (2013). The mentioned scientists noted that persimmon studied by them contained 916.8 mg/100 g of polyphenolic substances. Considerably more polyphenolic substances (1480 mg/100 g) were accumulated in the fruits studied by Katsube et al. (2004), and less (454 mg/100 g) in persimmon studied by Jang et al. (2010). The content of polyphenolic substances (642–649 mg/100 g) in the fruits studied by Joslyn & Goldstein, (1964) was almost at the level of those obtained as a result of the study of persimmon fruits Stepnaya Krasavitsa and Agrarna.

The astringency of persimmon fruits of astringent varieties, such as Agrarna and Stepnaya Krasunia, is directly related to the presence and a certain amount of bioactive substances, especially tannins, which are part of polyphenols. However, persimmon astringency levels can change during ripening depending on changes in the chemical and bioactive profile of varieties (Ayala-Lee & Kader, 2000; Zavala et al., 2004; Murali et al., 2023), i.e. tannins polymerise into insoluble form, which reduces astringency (Vázquez-Gutiérrez et al., 2013).

Özdemir et al. (2022) focused on the study of changes in volatile aromatic compounds in the production of persimmon vinegar.

Canadian scientists Hossain & Shahidi, (2023), in their study of persimmon leaves, established their value for the food, beverage, pharmaceutical and cosmetic industries. Yildiz et al. (2024) proved that persimmons dried at 100 W had a higher total anthocyanin content. Researchers in Azerbaijan have developed a scheme for the preparation of persimmon fruit concentrate, which is rich in nutrients necessary for human life (Mikayilov et al., 2024). Taking into account the achievements in persimmon research and identification of promising areas of research, further research on persimmon varieties of Ukrainian selection will be aimed at studying the chemical composition of leaves and prospects for their use, as well as the production of functional processed products that will be useful for the human body.

Conclusion

As a result of the conducted research, it was established that Agrarna and Stepova Krasunia accumulate fruit mass and have productivity at the level of varieties that are widely cultivated in areas with a favorable climate for its cultivation. At the same time, the content of soluble solids is higher than that of persimmon varieties grown in Egypt, India and Iran. It was established that the sugar content of fruit of the Agrarna and Stepova Krasunia varieties at the stage of consumer ripeness is similar to that of Ukrainian apple varieties, at 10.23% and 9.57% respectively. This is lower than that of widely cultivated varieties in many countries around the world. The amount of ascorbic acid in the fruits of the studied varieties at the consumer stage of fruit ripeness does not significantly decrease in relation to the one they contained in filming stage. The amount of ascorbic acid in the fruits of the studied persimmon varieties at the consumer stage of ripeness did not decrease significantly compared to the harvest stage. With an excellent sugar and acid index of over 60 for both varieties, as well as good winter hardiness and yield, Agrarna and Stepova Krasunia are viable competitors to existing persimmon varieties and can be used to create industrial plantations in the steppe zone of Ukraine.

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