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Sensory evaluation of sweet cherries for sustainable fruit production in the European market

Iryna Ivanova

PhD in Agricultural Sciences, Associate Professor
Dmytro Motorny Tavria State Agrotechnological University
69002, 66 Zhukovskiy Str., Zaporizhzhia, Ukraine
<https://orcid.org/0000-0003-2711-2021>

Tetiana Tymoshchuk*

PhD in Agricultural Sciences, Associate Professor
Polissia National University
10008, 7 Staryi Blvd., Zhytomyr, Ukraine
<https://orcid.org/0000-0001-8980-7334>

Mykola Kravchuk

PhD in Agricultural Sciences, Associate Professor
Polissia National University
10008, 7 Staryi Blvd., Zhytomyr, Ukraine
<https://orcid.org/0000-0003-3405-9206>

Iryna Ishchenko

PhD in Agricultural Sciences, Associate Professor
Odesa State Agrarian University
65044, 99 Kanatna Str., Odesa, Ukraine
<https://orcid.org/0000-0003-0255-4843>

Anna Kryvenko

Doctor of Agricultural Sciences, Professor
Odesa State Agrarian University
65044, 99 Kanatna Str., Odesa, Ukraine
<https://orcid.org/0000-0002-2133-3010>

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Abstract. The competitiveness of fresh fruit in the modern market substantially depends on sensory quality indicators. Sweet cherries are a top fruit that is highly valued by consumers due to their taste and visual attractiveness. For the growing demand for fruits on the European market, it is important to examine the sensory properties of cherry fruits in combination with their weight and diameter. The purpose of the study was to substantiate sensory indicators for examining the quality of cherry fruits of different maturation periods and selecting the most competitive varieties for the

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*Corresponding author

sustainable provision of fresh fruit in accordance with the requirements of the modern market. In the course of the study, the following methods were used: field, laboratory, and comparative. Determination of the mass, diameter, and sensory assessment of fruits was conducted on 33 varieties of sweet cherries. Experts conducted rating tests on a 9-point scale on ten fruit samples of the examined varieties. Fruits were evaluated by their appearance, aroma, taste, and texture. At the final stage of the assessment, experts calculated the average value of sensory indicators. A sensory profile was set for the fruits of each cherry variety and assigned a score based on the following descriptors: colour intensity, taste, pulp hardness and juiciness, and skin density. The standard methodology for evaluating the sensory properties of fresh fruits has been improved. The average weight (8.41 g) and diameter (22.63 mm) of sweet cherry fruits for three ripening groups were determined. Varieties (Kazka, Dilema, and Udivitielna) with the largest mass and diameter of fruits are identified. According to the complex of sensory indicators, the varieties Kazka, Vynka, and Krupnoplidna were distinguished. According to the external attractiveness, consistency, and taste qualities of fruits, a sensory profile has been formed for varieties of different maturation periods. Sensory evaluation of sweet cherry fruits will allow distributing fruit products and selecting raw materials for further use in fresh form, long-term storage, freezing and production of processed products by thermal sterilisation

Keywords: weight; diameter; varieties; expertise; external attractiveness; consistency; taste

INTRODUCTION

Sustainable development of horticulture is essential in ensuring food security and competitiveness of the country since fruit is an indispensable component of a healthy human diet. The development of this industry also guarantees a high economic effect and stable sales of high-quality fruit products not only in Ukraine but also in the European market. The level of quality of horticultural products is a serious issue for all stakeholders. Growing sweet cherries allows for diversifying the diet and extends the time of consumption of fresh fruit due to the early ripening of fruits. The formation of a sensory profile of fruits of different varieties of sweet cherries will allow selecting of the best products at the visual level for the consumer and choosing the most optimal method of processing them, considering the specific features of raw material parameters. Conducting a sensory assessment of fruits of varieties of different maturation periods becomes relevant due to the need of consumers for high-quality dessert products and raw materials for the processing industry.

T. Narandžić & M. Ljubojević (2023) describe sweet cherries as an important and valuable fruit crop of temperate climate, which is very much appreciated by consumers in the market. Now there is an increase in the volume of global production of sweet cherries. The market season for fresh sweet cherries is short. The fruits deteriorate quickly and have a short shelf life. P. Wu *et al.* (2018) believe that consumers expect producers to provide quality sweet cherries for a longer period of time. In addition, there is a tendency to consume cherry varieties with different taste and organoleptic properties. In this regard, there is an urgent need to grow various varieties of sweet cherries with early and late maturation periods with high quality parameters of their fruits.

The studies by researchers U. Ates & B. Ozturk (2022) established the dependence of the quality of fruit raw materials on the weather and climatic conditions of the

growing year and varietal characteristics. The production of fruit products does not fully meet the demand of the food market due to the negative impact of stressful weather factors. Global warming and climate change are the basis for deepening research on the response of sweet cherries to abiotic factors. H. Demirsoy *et al.* (2022) determined that fluctuations in air temperature pose a threat to fruit trees. Spring frosts are particularly dangerous for early-blooming sweet cherries. This affects the sustainable development of horticulture in most regions and requires the improvement of fruit quality management methods to minimise economic risks in the activities of fruit producers.

Sweet cherries are recognised as the leader of fruit crops in many countries of the world. Melitopolska sweet cherry has become a geographical brand and is a priority business card of gastronomy in the southern region of Ukraine in accordance with Decision No. 587 of the state enterprise "Ukrainian Institute of Intellectual Property" dated September 8, 2020 (Trusova *et al.*, 2020). The demand for cherry consumption leads to an increase in fruit production and the analysis of sensory parameters of fruit varieties of different maturation periods. This motivates researchers to examine fruit raw materials on the global market to determine the sensory profile of fruits. L. López *et al.* (2023) proved that the organoleptic quality parameters of sweet cherries are determined by the preferences of consumers who are willing to pay high prices for fruits with the desired characteristics. Expert study was aimed at identifying the most important external parameters and taste qualities of fruits to meet the needs of the consumer.

Identification of the most competitive varieties of sweet cherries for consumers is conducted by interviewing them with an assessment of the most important visual and sensory quality indicators. As a result of the survey in the study by G. Paunović *et al.* (2022), it was determined that the attitude of respondents to the

size and hardness of fruits and the presence of a peduncle depended on their place of residence. Consumers have identified the most attractive indicators of cherry fruits: the size and shape of the fruit, the presence of damage on the fruit, and the length of the peduncle.

According to F. Antognoni *et al.* (2020), the commercial value of sweet cherries is determined by the weight and size of the fruit. This is due to the fact that consumers are attracted to larger cherry fruits. That is why the main area of modern breeding research is the creation of cherry varieties with the specified quality indicators. Greek researchers E. Karagiannis *et al.* (2021) analysed 22 samples of cherry fruits of different varieties in terms of quality parameters such as colour, texture, and sensory properties (taste intensity and general perception). Among the examined samples, two varieties Tsolakeika and Bakirtzeika received high consumer recognition. E. Szpadzik *et al.* (2022) highlight the results of evaluating the dessert quality of seven cherry varieties of Czech selection (Horka, Jacinta, Helga, Tamara, Kasandra, Fabiola, Kordia) to determine the most valuable variety in central Poland. Among the examined varieties, Horka, Jacinta, Fabiola, and Tamara had the largest fruits, while Kordia and Fabiola had the highest hardness.

The growth of consumer demand for fruits with excellent quality parameters is a prerequisite for conducting a sensory assessment of the fruits of sweet cherry varieties of early, medium, and late ripening. Studies of fruit quality indicators of cherry varieties are important since those grown in the south of Ukraine may differ slightly from the same varieties in other countries. Therefore, the purpose of the study was to substantiate the sensory parameters of sweet cherry fruits for a comprehensive assessment of their quality, followed by identifying the best varieties of different maturation periods and ensuring sustainable fruit production in the European market.

The following tasks were planned to achieve the goal: to identify the best varieties of sweet cherries of different maturation periods by their weight and fruit diameter; describe the methods that were used for sensory testing of cherry fruit quality indicators in accordance with the requirements of the European market; assess the feasibility of effectively distinguishing the fruits of cherry varieties of different maturation periods by sensory indicators; understand the relationship

between sensory parameters and signs of the quality of cherry fruits of three maturation periods to satisfy the preferences of all interested parties and promote food security.

MATERIALS AND METHODS

The study was conducted during 2008-2019 in the laboratories of the Research Institute of Agrotechnology and Ecology of the Dmytro Motornyi Tavria State Agrotechnological University. Cherry fruits of common and promising varieties in Ukraine of three maturation periods were selected to assess quality indicators: 1st (early) – Sweet Earlise, Merchant, Bigaro Burlat, Rubinova rannia, Valerii Chkalov, Kazka, Zabuta; 2nd (medium) – Kordia, Octaviia, Vynka, Pervistok, Temp, Liubymytsia Turovtseva, Talisman, Dilema, Melitopolska chorna, Orion, Chervneva rannia, Dachnytsia, Prostir; 3rd (late) – Karina, Regina, Mirazh, Krupnoplidna, Udivitielna, Zodiac, Siurpryz, Kolkhoznitsia, Kosmichna, Prazdnichna, Anons, Temporion, Meotyda. For the study, fruits were selected from typical trees for each pomological variety of the same age with an average fruiting intensity. Tasting evaluation of sweet cherry fruits was conducted during the period of economic ripeness.

During this period, the fruit pulp was still quite dense, the taste and colour were characteristic of the pomological variety under study. A sample was taken from 100 fruits (in each repetition) from 3-5 typical trees during the period of economic ripeness to determine the weight of one cherry fruit. The repetition of the experiment is threefold (Serdyuk *et al.*, 2020). Fruits should be selected in such a way that the sample taken is characteristic in quality for the harvest of this season. Fruits from trees of the examined varieties were completely removed. With uneven ripening of fruits, they were removed partially – in proportion to the placement of the crop on the tree. Fruit quality assessment was performed in the sorting room. All selected fruits were calibrated by diameter, and then the diameter of one fruit was determined by dividing the total mass by their number (100 pcs). Normally developed, typical-sized fruits without defects in the economic ripeness phase were taken to assess sensory properties. The mass of the sample was 1.0-1.5 kg. A sensory assessment of the quality of cherry fruits was conducted on a 9-point scale (Table 1).

Table 1. Scale of sensory evaluation of cherry fruits

Indicator	Compliance parameters on a 9-point scale, score				
	1	3	5	7	9
Fruit size	very small fruits	small fruits	medium fruits	large fruits	very large fruits
Visual attractiveness*	very unattractive fruits (very small, irregular in shape, poorly coloured)	unattractive fruits (small, unattractive in colour and shape)	mediocre fruits (not large enough, less attractive in colour and shape)	attractive, but not large	very attractive, large, pretty in shape and colour

Table 1, Continued

Indicator	Compliance parameters on a 9-point scale, score				
	1	3	5	7	9
Taste	fruits are completely inedible in fresh form	fruits that had an unpleasant taste and are almost unsuitable for consumption	mediocre with a tolerable taste	fruits with a good table taste	fruits with excellent taste with a harmonious ratio of sourness and sweetness
Overall fruit quality assessment**	fruits are unsuitable for fresh consumption	fruits of poor quality	fruits of mediocre quality	fruits of good quality	fruits of high quality
Average value of sensory indicators***	It was determined as the average value of the size, attractiveness, taste, and overall perception of the cherry variety on a 9-point scale				

Note: *The external attractiveness of fruits was evaluated by indicators: size, shape, and colour; **the overall assessment of fruit quality was conducted separately as a general impression of the quality of the variety on a 9-point scale; ***the average value of sensory indicators was calculated additionally for a comprehensive assessment of cherry varieties

Source: compiled by the authors

The tasters' point scores were supplemented with indicators: external attractiveness of fruits (size, shape, colour); consistency of fruits (consistency of pulp, juiciness of fruits, and the nature of the skin); taste qualities of fruits (nature of taste, individual shades

of taste). Taste qualities depend mainly on the ratio of sugars and sourness in fruits (berries), the presence of tannins. The sensory profile of the taste qualities of sweet cherries was established according to seven criteria (Table 2).

Table 2. Criteria for the sensory profile of sweet cherry fruit taste qualities

Sweet	Sour-sweet	Sour and sweet	Sweet-sour	Sweet and sour	Sour	Wine-sweet
there is no sour taste	the sweet taste prevails, but the presence of sourness is felt	the presence of sourness and sugar is felt, but the taste of sugar prevails	sour taste prevails, but a little sugar is felt	the sugar and sourness can be felt with the advantage of the latter	there is no sweet taste	it resembles the taste of dessert semi-sweet wine

Source: compiled by the authors

Sensory evaluation of the fruits of the examined cherry varieties was conducted by 10 trained experts. The fruits of each variety had a code. Experts entered their ratings in the tasting lists. Tasters additionally recorded various individual shades of taste, the presence of tartness, bitterness, and various tastes. Next, the average value of sensory indicators of the quality of cherry fruits was calculated. This indicator was introduced to select the best varieties of sweet cherries for all maturation periods.

Such methods of mathematical statistics as correlation-regression and variance (ANOVA) analyses were used to ensure the objectivity, reliability, and reproducibility of the results of the experiment. The data array was previously tested for normality using the Shapiro-Wilk criterion and uniformity of variance using the Leuven criterion (Zhang *et al.*, 2018). Confidence

intervals and levels of variation were determined for all data series. The calculation of the main statistical values of the experiment was performed using the Statistica (version 10.0) and MS Excel. The substantiality level was set to $p < 0.05$.

RESULTS

The competitiveness of fruits in the modern market depends on important external and sensory properties of fruits. Among the most important parameters of the quality of cherry fruits are the size, diameter, colour, hardness, texture, taste and aroma of fruits. The average weight and diameter of sweet cherries of early ripening varieties is 7.61 g and 19.43 mm, respectively, which is 10.51 and 14.1% lower compared to the average values (Table 3).

Table 3. Weight and diameter of fruits of early ripening varieties (2008-2019), $\bar{x} \pm s\bar{x}$, $n=5$

Variety	Fruit weight				Fruit diameter			
	average, g	min, g	max, g	Vp, %	average, mm	min, mm	max, mm	Vp, %
Merchant	6.25±0.40	4.46	8.34	22.5	16.13±1.76	14.20	18.05	10.90

Table 3, Continued

Variety	Fruit weight				Fruit diameter			
	average, g	min, g	max, g	Vp, %	average, mm	min, mm	max, mm	Vp, %
Sweet Erlise	7.73±0.23	6.51	9.03	10.6	18.21±1.2	16.51	19.70	6.60
Bigarro Burlat	6.79±0.29	5.38	8.25	14.9	16.42±2.21	13.79	18.91	13.45
Valerii Chkalov	8.35±0.29	6.46	9.43	12.2	22.49±1.63	20.34	24.64	7.24
Zabuta	7.73±0.33	6.38	9.60	15.1	18.93±2.14	16.36	21.44	11.33
Kazka	9.10±0.36	7.17	11.56	14.0	25.72±1.6	23.94	27.54	6.20
Rubinova rannia	7.33±0.41	5.05	9.07	19.4	18.13±1	16.85	19.36	5.53
Average value	7.61±0.33	5.91	9.32	15.5	19.43±1.55	17.48	21.37	7.95
LSD ₀₅		0.649				0.57		

Source: compiled by the authors

The minimum weight of sweet cherries (4.46 g) of early ripening was determined in the Merchant variety of the 2018 harvest, which is 41.39% less than the average varietal value of the group. Kazka fruits in 2016 had a maximum fruit weight of 11.56 g, which is 52.03% more than the average varietal value in the early ripening group. The difference in fruit mass values is substantial since it substantially exceeded the LSD₀₅ – 0.649. In 2018, the minimum fruit diameter was determined in fruits of the Bigaro Bulat (13.79 mm) and Merchant (14.20 mm) varieties. Fruit diameter indicators in these varieties were 26.72-29.03% lower than

the average varietal value in the early ripening group. In 2011, the maximum fruit diameter of the Kazka variety was recorded at 27.54 mm, which is 41.73% more than the average varietal value of the group. The obtained deviations are statistically substantial (HIP₀₅ – 0.57). A strong direct positive correlation was determined between the weight and diameter of the fruit in the group of early ripening varieties ($r=0.805$). The average weight and diameter of the cherry fruit of varieties with an average maturation period are 8.40 g and 22.39 mm, respectively, which is 0.11 and 1.06% lower than the average value (Table 4).

Table 4. Weight and diameter of fruits of medium-maturing varieties (2008-2019), $\bar{x} \pm s\bar{x}$, $n=5$

Variety	Fruit weight				Fruit diameter			
	average, g	min, g	max, g	Vp, %	average, mm	min, mm	max, mm	Vp, %
Vynka	7.46±0.25	6.34	8.89	11.8	17.99±1.56	15.45	19.97	8.68
Dachnytsia	8.09±0.40	5.71	9.98	17.2	20.35±1.25	18.63	22.05	6.14
Dilema	9.91±0.43	7.92	12.01	15.0	31.35±1.63	28.78	33.48	5.21
Kordia	8.54±0.65	5.51	11.75	26.6	23.13±1.21	21.21	25.00	5.24
Lyubimitsa Turovtseva	7.47±0.48	5.11	10.09	22.5	17.99±1.57	15.74	20.11	8.71
Melitopolska chorna	9.37±0.38	7.63	11.81	14.2	25.72±1.93	22.85	27.94	7.50
Octavia	8.69±0.45	6.01	10.77	18.2	24.28±1.4	21.78	26.01	5.77
Orion	6.85±0.40	4.61	8.77	20.7	16.12±0.63	15.00	16.71	3.91
Pervystok	8.13±0.37	6.69	10.98	15.9	20.66±1.39	18.71	22.59	6.74
Prostir	9.34±0.35	7.78	11.67	13.2	25.19±1.43	23.08	27.02	5.68
Talisman	8.93±0.51	6.80	11.81	19.8	25.41±2.13	22.28	28.20	8.39
Temp	8.90±0.27	7.65	10.55	10.8	25.35±1.17	23.65	26.93	4.62
Chervneva rannia	7.48±0.27	5.90	8.68	12.8	17.52±1.78	15.10	19.91	10.14
Average value	8.39±0.40	6.43	10.59	16.8	22.39±1.38	20.35	24.29	6.18
LSD ₀₅		0.520				0.74		

Source: compiled by the authors

The minimum weight of cherry fruits (4.61 g) of the average maturation period was determined in the Orion variety of the 2012 harvest, which is 45.05% less

than the average varietal value of the group. Fruits of the Dilema variety in 2010 had a maximum fruit weight of 12.01 g, which is 43.14% more than the average

varietal value in the group of the average maturation period. The difference in fruit mass values is substantial since it substantially exceeded the $LSD_{05} = 0.52$. In 2008, the minimum fruit diameter was determined in the Orion variety (15.0 mm), which is 33% less than the average varietal value for the group.

The maximum fruit diameter was recorded in the Dilema variety of 27.54 mm of the 2010 harvest, which is 49.53% more than the average varietal value in the

group of average maturation period. The data obtained are statistically reliable ($HIP_{05} = 0.74$). An average direct positive correlation was determined between the indicators of fruit weight and diameter in the group of varieties with an average maturation period ($r=0.691$). The average weight and diameter of the sweet cherry fruit of late-ripening varieties are 9.24 g and 26.08 mm, respectively, which is 9.86 and 15.24% lower than the average varietal value (Table 5).

Table 5. Weight and diameter of fruits of late ripening varieties (2008-2019), $\bar{x} \pm s\bar{x}$, $n=5$

Variety	Fruit weight				Fruit diameter			
	average, g	min, g	max, g	Vp, %	average, mm	min, mm	max, mm	Vp, %
Anons	9.84±0.37	7.96	11.77	13.2	31.22±1.15	29.73	32.71	3.69
Zodiak	8.95±0.29	7.23	10.05	11.2	25.36±1.26	23.73	27.00	4.98
Karina	9.57±0.37	7.55	11.94	13.5	26.79±1.48	24.93	28.64	5.52
Kolkhoznitsia	8.14±0.37	5.67	9.93	16.0	20.81±2.54	17.72	23.90	12.21
Kosmichna	9.91±0.41	8.05	12.21	14.6	32.19±1.08	30.85	33.81	3.36
Krupnoplidna	11.67±0.47	8.73	13.72	14.0	33.11±1.84	29.85	35.11	5.55
Meotida	9.78±0.39	7.21	11.72	14.1	30.53±1.92	28.01	33.04	6.29
Mirazh	7.73±0.24	6.30	8.81	11.1	20.16±1.47	18.29	22.01	7.27
Festive	7.27±0.27	5.71	8.76	13.2	16.92±1.61	14.87	18.94	9.52
Regina	7.99±0.23	6.71	9.00	10.1	20.45±1.52	18.44	22.47	7.42
Siurpryz	7.37±0.28	6.00	9.40	13.2	18.26±0.82	17.19	19.34	4.47
Temporion	9.68±0.43	7.44	12.01	15.4	29.14±1.21	27.47	30.79	4.16
Udivitielna	12.18±0.51	10.01	14.60	14.7	34.09±1.49	32.07	36.11	4.36
Average value	9.23±0.35	7.27	11.07	13.4	26.08±1.45	24.19	27.99	5.56

Source: compiled by the authors

The minimum weight of sweet cherries (5.67 g) of late ripening was determined in the Kolkhoznitsia variety of the 2008 harvest, which is 38.57% less than the average varietal value of the group. Fruits of the Udivitielna variety in 2011 had a maximum fruit weight of 14.60 g, which is 58.0% more than the average varietal value in the late-ripening group. The difference in fruit mass values is substantial since it substantially exceeded the $LSD_{05} = 0.538$. The minimum fruit diameter was determined for fruits of the Prazdnichnaya variety (14.87 mm) of the 2008 harvest, which is 43% less than the average varietal value of the late-ripening group. In 2010, the maximum fruit diameter of the Udivitielna variety was recorded (36.11 mm), which is 38.45% more than the average varietal value of the group. The data obtained are statistically reliable ($HIP_{05} = 0.68$). A strong direct positive correlation was determined between the indicators of fruit weight and diameter for late-maturing varieties ($r=0.815$).

In the results of twelve-year studies, it was established that the average total fruit weight in cherry varieties of three maturation periods is 8.41 g, and the fruit diameter is 22.63 mm. Among the three groups

of varieties examined, the optimal fruit weight (9.24 g) and diameter (26.08 mm) was characteristic of late-maturing cherry fruits. From a consumer standpoint, fruits of varieties that are characterised by a stable maximum weight and diameter are of particular value. The coefficient of variation V_p was used to assess the stability of the variety by weight and diameter of the fruit of the different years' harvest. The variability of the sample of the examined indicator for $V_p < 10\%$ is low or insubstantial, for $V_p = 10-20\%$ – average, for $V_p > 20\%$ – strong or substantial. In the group of early ripening varieties, the average and high variability ($V_p = 10.64-22.54\%$) of fruit weight was determined (Table 2). The greatest variability in fruit mass was established in the Merchant variety, and the smallest – Sweet Erlise. Low and medium variability ($V_p = 5.53-13.45\%$) in the fruit diameter is established for varieties of early maturation period. The smallest variability in fruit diameter was established in the Rubinovanna variety, and the largest – Bigaro Burlat. For varieties of the average maturation period, the variability of fruit weight ranged from $V_p = 10.81-26.69\%$ (Table 3).

The minimum variability in fruit weight was determined in the Temp variety, and the maximum – in

the Kordia variety. For varieties with an average maturation period, the variability of fruit diameter ranged between $V_p=3.91-10.14\%$. The minimum variability in fruit diameter was determined in the Orion variety and the maximum – in the Chervneva rannia variety. In the group of late-maturing varieties, the average variability ($V_p=10.20-16.03\%$) of fruit weight was determined (Table 4). The lowest variability in fruit mass was established in the Regina variety, and the greatest –

Kolkhoznitsia. For late-maturing varieties, low and medium variability ($V_p=3.36-12.21\%$) of fruit diameter variability was established. The smallest variability in the diameter of fruits was established in the Kosmichna variety, and the largest – Kolkhoznitsia. It was established that for the formation of fruit mass in three groups of ripeness varieties, the dominant influence was exerted by the weather conditions of years of research – factor A (Table 6).

Table 6. Results of two-factor analysis of variance in the formation of the mass of cherry fruits

Source of variation	Sum of squares	Degree of freedom	Variance	F_{fact}	$F_{\text{tab.095}}$	Impact, %
early ripening cherry varieties						
Factor A (year)	215.7	11	19.61	123.2	1.8	39.7
Factor B (variety)	194.1	6	32.35	203.3	2.2	35.7
AB interaction	106.7	66	1.61	10.1	1.4	19.6
medium ripening cherry varieties						
Factor A (year)	671.9	11	61.08	598.7	1.8	51.5
Factor B (variety)	356.5	12	29.71	291.2	1.8	27.3
AB interaction	236.9	132	1.795	17.5	1.3	18.1
late ripening cherry varieties						
Factor A (year)	463.7	11	42.16	384.7	1.8	26.1
Factor B (variety)	1024.4	12	85.37	778.9	1.8	57.8
AB interaction	248.9	132	1.88	17.2	1.3	14.0

Source: compiled by the authors

The share of influence of factor A for varieties of early maturation period is 39.7%, average maturation period – 51.5% and late maturation period – 26.1%. The influence of varietal characteristics (factor B) was less substantial. The share of influence of factor B on the

formation of fruit mass for varieties of early, medium, and late maturation periods was 35.7, 27.3 and 1.8%, respectively. It was established that varietal characteristics – factor B dominated the formation of fruit diameter in three groups of ripeness varieties (Table 7).

Table 7. Results of two-factor analysis of variance in the formation of the diameter of cherry fruits

Source of variation	Sum of squares	Degree of freedom	Variance	F_{fact}	$F_{\text{tab.095}}$	Impact, %
early ripening cherry varieties						
Factor A (year)	551.8	11	50.2	401.85	1.85	16.75
Factor B (variety)	2605.9	6	434.3	3478.94	2.15	79.09
AB interaction	115.0	66	1.7	13.96	1.38	3.49
medium ripening cherry varieties						
Factor A (year)	820.4	11	74.6	349.59	1.82	8.79
Factor B (variety)	8282.4	12	690.2	3235.17	1.78	88.70
AB interaction	160.6	132	1.2	5.70	1.27	1.72
late ripening cherry varieties						
Factor A (year)	901.3	11	81.9	450.03	1.82	5.25
Factor B (variety)	16087.9	12	1340.7	7363.00	1.78	93.67
AB interaction	128.1	132	1.0	5.33	1.27	0.75

Source: compiled by the authors

The share of influence of factor B for varieties of early maturation period is 79.09%, medium maturation period – 88.70%, and late maturation period – 93.67%. The impact of years of the study (factor A) was less substantial. The share of influence of factor A on the

formation of fruit diameter for early, medium, and late varieties was 16.7, 8.79 and 5.25%, respectively. The results of the sensory evaluation of fruits by size, appearance, taste, and general perception of each early-ripening cherry variety by experts are shown in Table 8.

Table 8. Sensory assessment of fresh fruits of early ripening cherry varieties (average for 2007-2019)

Variety	Sensory indicators, score					
	size	appearance	consistency	taste qualities	general perception	average value
Merchant	5.8	8.0	7.9	9.0	7.9	7.7
Sweet Erlise	7.5	8.9	8.1	8.2	8.2	8.2
Bigarro Burlat	7.4	7.8	7.8	7.9	7.9	7.8
Valerii Chkalov	8.9	8.8	8.8	8.8	8.8	8.9
Zabuta	7.7	7.9	7.8	8.2	7.8	7.9
Kazka	9.0	9.0	8.9	9.0	9.0	9.0
Rubanova rannia	7.6	7.4	7.6	8.1	7.7	7.7

Source: compiled by the authors

The maximum size score was awarded to Kazka cherry fruits (9.0 points) and Valery Chkalov (8.9 points). The fruits of sweet cherries of the early ripening varieties Bigarro Burlat and Sweet Erlise were characterised by a minimum size, so they received tasting points of 7.4 and 7.5 points. The appearance of cherry fruits was evaluated in points comprehensively by such sensory indicators as size, shape, and colour. According to the appearance of the fruit, the varieties Kazka (9.0 points) and Sweet Erlise (8.9 points) were distinguished. The fruits of the Kazka variety were very large, elongated and rounded in shape, and had an intense dark red almost black colour. In the sweet Erlise variety, the fruits were large in size, broad heart-shaped, dark red in colour with a glossy sheen. The minimum score in appearance was awarded to fruits of the Rubinova rannia variety (7.4 points). The assessment of the consistency of fruits included a sensory characteristic of the degree of hardness and juiciness of the pulp, the nature of the skin. In terms of consistency, the highest scores were awarded to Valery Chkalov (8.8 points) and Kazka (8.9 points) varieties.

The fruits of the Valery Chkalov variety were characterised by a semi-grassy, dark red with white veins

juicy pulp and dense skin. In the Kazka variety, the flesh of the fruit was juicy, dense, slightly crispy, and the skin was thin. The minimum score in terms of pulp consistency was awarded to fruits of the Rubinova rannia variety (7.6 points). The taste qualities of cherry fruits were evaluated in points comprehensively by nature (the ratio of sourness and sugar) and individual shades of taste (the presence or absence of taste, clearly defined taste or absence). The maximum score (9.0) in terms of taste was awarded to cherry fruits of the Kazka and Merchant varieties. The fruits of these varieties were distinguished by a fragrant sweet and sour taste. The minimum score in terms of taste was awarded to the Bigarro Burlat variety (7.9 points). According to the overall perception of fruit quality, the Kazka cherry variety received the highest score (9.0 points), and the lowest – Rubinova rannia (7.7). As a result of a comprehensive assessment of cherry fruits by average value, the Kazka variety received the maximum score (9.0), and the minimum (7.7) – Rubinova rannia and Merchant varieties. The results of the sensory evaluation of fruits by size, appearance, taste, and general perception of each cherry variety of average maturation period by experts are shown in Table 9.

Table 9. Sensory assessment of fresh fruits of cherry varieties of average maturation period (average for 2007-2019)

Variety	Sensory indicators, score					
	size	appearance	consistency	taste qualities	general perception	average value
Vynka	8.9	9.0	8.9	9.0	9.0	9.0
Dachnytsia	8.7	8.8	8.7	8.9	8.8	8.8
Dilema	9.0	8.5	8.4	8.5	8.2	8.5
Kordia	8.0	8.5	8.3	8.8	8.2	8.4
Lyubimitsa Turovtseva	7.4	8.2	8.2	8.4	8.3	8.0

Table 9, Continued

Variety	Sensory indicators, score					
	size	appearance	consistency	taste qualities	general perception	average value
Melitopolska chorna	9.0	8.5	8.4	8.5	8.2	8.5
Octavia	8.5	8.9	8.6	8.6	8.7	8.7
Orion	7.9	8.8	8.5	9.0	8.6	8.6
Pervystok	8.1	8.4	8.4	8.3	8.5	8.3
Prostir	9.0	8.4	8.5	8.6	8.6	8.6
Talisman	9.0	9.0	8.7	8.8	8.8	8.9
Temp	8.4	8.4	8.5	8.3	8.6	8.4
Chervneva rannia	7.5	7.9	7.6	8.0	7.7	7.7

Source: compiled by the authors

The maximum score (9.0) in size was awarded to the fruits of sweet cherries of the Talisman, Dilema, Melitopolska chorna, and Prostir varieties. Cherry fruits of the medium-maturing varieties Lyubimitsa Turovtseva (7.4 points) and Chervneva rannia (7.5 points) were characterised by a minimum size. According to the appearance of the fruit, the Vynka and Talisman varieties were highlighted (9.0 points). The fruits of the Vynka variety are very large, rounded heart-shaped, with a dark red colour. In the talisman variety, the fruits are large in size, wide-rounded in shape, and dark red in colour. The minimum score in appearance was awarded to fruits of the Chervneva rannia variety (7.9 points). The fruit was red in colour and was more vulnerable to mechanical damage. In terms of consistency, the highest score was received by the Vynka variety – 8.9 points. The fruits of the Vynka variety were characterised by juicy tender flesh and dense thin skin. The minimum score in terms of pulp consistency was

received by fruits of the Chervneva rannia variety – 7.6 points. The maximum score (9.0) in terms of taste was awarded to cherry fruits of the Vynka and Orion varieties.

The fruits of the Vynka variety were distinguished by a refreshing, wine-sweet taste. The harmonious sweet and sour taste was characteristic of Orion fruits. The minimum taste score was awarded to the Chervneva rannia variety (8.0 points). According to the overall perception of fruit quality, the highest score was received by the Vynka variety (9.0 points), and the lowest – by Chervneva rannia (7.7). As a result of a comprehensive assessment of cherry fruits of the average ripening period by the average value, the maximum score (9.0) was received by the Vynka variety, and the minimum (7.7) – by the Chervneva rannia variety. The results of the sensory evaluation of fruits by size, appearance, taste and general perception of each late-ripening cherry variety by experts are shown in Table 10.

Table 10. Sensory assessment of fresh fruits of late-maturing sweet cherry varieties (average for 2007-2019)

Variety	Sensory indicators, score					
	size	appearance	consistency	taste qualities	general perception	average value
Anons	8.5	8.5	8.4	8.4	8.5	8.5
Zodiak	8.6	8.7	8.6	8.7	8.6	8.7
Karina	8.5	8.4	8.3	8.3	8.4	8.4
Kolkhoznitsia	8.0	8.1	7.9	8.2	8.0	8.0
Kosmichna	9.0	8.7	8.7	8.6	8.7	8.8
Krupnoplidna	9	9.0	8.9	9.0	9.0	9.0
Meotida	8.8	8.8	8.7	8.8	8.8	8.8
Mirazh	8.4	8.6	8.6	8.9	8.8	8.7
Festive	8.2	8.2	8.3	8.6	8.5	8.4
Regina	7.8	8.2	8.0	8.2	8.2	8.1
Siurpryz	8.5	8.8	8.6	8.8	8.7	8.7
Temporion	8.6	8.6	8.4	8.4	8.5	8.5
Udivitielna	9	8.9	8.8	8.9	8.9	8.9

Source: compiled by the authors

The maximum score (9.0) in size was awarded to the fruits of sweet cherries of the Kosmichna, Krupnoplidna, and Udivitielna varieties. The fruits of sweet cherries of the Kolkhoznitsia (8.0) variety of late ripening were characterised by a minimum size. The highest score in all sensory indicators was received by fruits of the Krupnoplidna variety. The fruits of the Krupnoplidna cherry variety were very large, wide-rounded in shape, and had a dark red colour. The fruits of this variety were characterised by a very juicy, cartilaginous pulp and a thin, dense skin. Experts noted the harmonious, sweet and sour taste of Krupnoplidna fruits. The lowest scores on all sensory indicators were awarded to fruits of the Kolkhoznitsia variety (7.9-8.2 points). The fruits of this variety had a red colour and were more vulnerable to mechanical damage.

DISCUSSION

Researchers in many countries are investigating the key challenges of increasing the production of fresh, high-quality fruit products to meet consumer preferences and ways to solve them (Pinto *et al.*, 2018). There has always been a demand for sweet cherries, due to their organoleptic properties, colour, nutritional value (Gonçalves *et al.*, 2019; Faienza *et al.*, 2020). Research by the scientific community is focused on determining the most important external and sensory parameters of sweet cherries, considering the preferences of all interested parties (Palacios-Peralta *et al.*, 2022). In the study by V. Silva *et al.* (2021), the parameters and methodology for assessing the quality of sweet cherries meet the needs of consumers in the market are highlighted. Researchers say that standardisation of cherry fruit quality parameters will help preserve and extend their shelf life, and valorise the entire supply chain. M. Fodor (2022) developed the FT-NIR method for a comprehensive assessment of the ripeness of sweet cherries, which will facilitate rapid sorting of fruits by quality.

The requirements of international markets for the quality of sweet cherries, especially the size of fruits, have increased substantially. Fruit size is a crucial parameter in evaluating fruit quality, which affects consumer perception. According to researchers, the main qualitative characteristics of sweet cherries that affect the perception of consumers are the diameter and size of the fruit, the colour of the peel and hardness (Di Matteo *et al.*, 2017). It is recognised that the weight and size, hardness of the peel of sweet cherries primarily depends on the genotype, climatic conditions, and garden management strategy (Lanauskas *et al.*, 2023).

According to a result of the study conducted by M. Corneanu (2020), the largest fruit sizes were formed by cherry varieties Bucium, Andreiaș, Paulică, Ștefan, Van, Stella, and Golia. The smallest diameter of sweet cherries over the years of research was determined in the George variety (22.4 mm), and the largest in the Paulică variety (25.8 mm). As a result of evaluating 45

varieties of sweet cherries by Iranian researchers, it was established that the diameter of the fruit varied from 18.88 to 28.45 mm (Khadivi *et al.*, 2019). According to the study by E. Iurea (2019), the largest fruit diameter was established in the Cetățuia variety (21.8), and the largest in the Cătălina variety (24.0 mm). According to E. Szpadzik *et al.* (2022), the main characteristic that determines the commercial value of sweet cherries is the size of the fruit. Consumers claim that the most attractive fruits are large in size and dark in colour. In the conducted studies, a larger mass of cherry fruits was noted compared to the results of other researchers. In the conditions of Iran, researchers determined that the average weight of sweet cherries was 2.04 g (Khadivi *et al.*, 2019). The results of the study confirm the conclusions of other researchers regarding the dependence of fruit weight and size on varietal characteristics (Šebek, 2019; Ivanova *et al.*, 2022).

Consumer preferences regarding the quality parameters of sweet cherries differ substantially in different regions of the world. According to G. Bujdosó *et al.* (2020), in some countries, a high percentage of consumers prefer medium (diameter from 21.4 to 25.4 mm) and large (diameter up to 29.8 mm) fruits. Therewith, other countries tend to prefer very large fruits. This confirms the data obtained regarding the target area of using fruits of different sizes. Consumer perception is also undoubtedly influenced by the colour of the fruit. In the study by A. Magri *et al.* (2023), the substantial variability of the four cherry varieties examined in the colour of the peel and pulp of sweet cherries from yellow-red (Limoncella variety) to dark red (Montenero) was highlighted. Darker coloured cherry fruits are considered to be more sweet. In addition to the size and colour of the fruit, consumers evaluate the cherry fruit by such an important sensory indicator as hardness. Consumers prefer high-hardness sweet cherries (Aglar *et al.*, 2019).

The sweetness of the fruit is one of the most attractive parameters of sweet cherries, for which consumers are willing to pay a high price. The standard indicator for determining the sweetness of fruit is the content of dry solutes (Scalisi & O'Connell, 2021). However, the unique taste of sweet cherries is explained not only by the sugar content, but also by the combination of the ratio of sugars and sourness (Ivanova *et al.*, 2023). The content of soluble solids and titrated sourness in cherry fruits are quite important quality parameters since taste and consumer choice are mainly related to the balance between sugar and sourness content (Szpadzik *et al.*, 2022). A high ratio of dry solutes to titrated acids is desirable (Aglar *et al.*, 2019).

The colour of fruits and their size substantially depend on the genetic characteristics of the variety, the climatic conditions, and the ripeness of the fruit. The experimental data obtained are consistent with the justifications of other researchers regarding the difference in skin colour, texture, and taste of fruits depending

on the variety (Papapetros *et al.*, 2019). According to researchers, the Lapins variety had the darkest fruit skin, and the Germersdorfer variety had the lightest. Canada Giant and Germersdorfer varieties were the most susceptible in structure. The results of the studies by researchers confirm the data obtained regarding the influence of varietal characteristics and weather conditions of growing years on a substantial variation in the quality parameters of sweet cherry fruits (Proietti *et al.*, 2019). Producers must determine the optimal time for harvesting sweet cherries to obtain fruits with high quality indicators. The implementation of new adaptive varieties in production contributes to the supply of fruits with a better sensory profile of fruits to the market (Malchev & Vasileva, 2023).

The results obtained represent a valuable resource for breeding work on creating cherry varieties with high quality indicators. It is advisable to develop strategies for growing different varieties of sweet cherries, which will help improve the quality attributes of the fruit to meet the requirements of consumers

CONCLUSIONS

In the conditions of the southern region of Ukraine, the average weight of cherry fruits is 8.41 g, and the average diameter of fruits is 22.63 mm. It was established that the maximum mass and diameter of fruits were fruits of late-maturing cherry varieties. The highest average weight and diameter of fruits is established in the varieties Kazka (early-maturing), Dilema (medium-maturing), and Udovitielna (late-maturing). A strong ($r=0.805-0.815$) correlation was established between the indicators of fruit weight and diameter for early and late ripening varieties, and an average direct positive correlation was established for medium-ripening varieties ($r=0.691$).

The lowest variability in fruit weight was established in the early-maturing sweet Erlise variety ($V_p=10.6\%$), the medium-maturing Temp variety ($V_p=10.8\%$), and the late-maturing Regina variety

($V_p=10.1\%$). The lowest variability in fruit diameter was established in the early-maturing Rubinova rannia variety ($V_p=5.53\%$), the medium-maturing Orion variety ($V_p=3.91\%$), and the late-maturing Anons variety ($V_p=3.36\%$). The determining factor for the formation of fruit mass is the years of research (26.1-21.5%) and for the diameter-varietal characteristics (79.09-93.67%). The maximum score (9.0) on the complex of sensory indicators was obtained by the following cherry varieties: Kazka (early-maturing), Vynka (medium-maturing) and Krupnoplidna (late-maturing).

Experts noted samples of the Kazka early-maturing variety with the following sensory parameters: the fruits are very large, elongated-rounded shape, intense dark red almost black colour with juicy dense slightly crisp flesh and thin skin, characterised by a harmonious, pleasant, aromatic sweet and sour taste. Among the varieties of medium maturation, experts singled out the fruits of the Vynka variety for the following sensory indicators: very large rounded heart-shaped, dark red colour, juicy tender flesh, dense thin skin, refreshing, wine-sweet taste. From late-maturing varieties, experts highlighted the Krupnoplidna variety, which is characterised by the following sensory indicators: very juicy, large, wide-rounded, dark red fruits, with cartilaginous pulp and a thin dense skin, a harmonious sweet and sour taste.

The prospect of further research is the examination of commercial properties of fruits of sweet cherry varieties of early, medium, and late ripening. In combination with sensory parameters, this will allow forming a waste-free chain of using fruit products of various commercial classes in fresh form and choosing the optimal storage and processing of fruits.

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CONFLICT OF INTEREST

None.

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Сенсорна оцінка плодів черешні для стійкого виробництва фруктів в умовах європейського ринку

Ірина Євгенівна Іванова

Кандидат сільськогосподарських наук, доцент
Таврійський державний агротехнологічний університет імені Дмитра Моторного
69002, вул. Жуковського, 66, м. Запоріжжя, Україна
<https://orcid.org/0000-0003-2711-2021>

Тетяна Миколаївна Тимощук

Кандидат сільськогосподарських наук, доцент
Поліський національний університет
10008, Старий бульвар, 7, м. Житомир, Україна
<https://orcid.org/0000-0001-8980-7334>

Микола Миколайович Кравчук

Кандидат сільськогосподарських наук, доцент
Поліський національний університет
10008, Старий бульвар, 7, м. Житомир, Україна
<https://orcid.org/0000-0003-3405-9206>

Ірина Олександрівна Іщенко

Кандидат сільськогосподарських наук, доцент
Одеський державний аграрний університет
65012, вул. Канатна, 99, м. Одеса, Україна
<https://orcid.org/0000-0003-0255-4843>

Анна Іванівна Кривенко

Доктор сільськогосподарських наук, професор
Одеський державний аграрний університет
65012, вул. Канатна, 99, м. Одеса, Україна
<https://orcid.org/0000-0002-2133-3010>

Анотація. Конкурентоспроможність свіжих фруктів на сучасному ринку суттєво залежить від сенсорних показників якості. Черешня є топ-фруктом, що високо цінується споживачами завдяки смаку і зовнішній привабливості. Для зростання попиту фруктів на європейському ринку актуальним є дослідження сенсорних властивостей плодів черешні в комплексі з їх масою і діаметром. Метою дослідження було обґрунтування сенсорних показників для експертизи якості плодів черешні різних строків досягання та вибору найбільш конкурентоспроможних сортів для стійкого забезпечення свіжими фруктами відповідно до вимог сучасного ринку. У ході дослідження використано методи: польовий, лабораторний і порівняльний. Визначення маси, діаметру і сенсорної оцінки плодів проводили на 33 сортах черешні. Експерти проводили рейтингові тести за 9-ти бальною шкалою на десяти зразках плодів досліджуваних сортів. Плоди оцінювали за зовнішнім виглядом, ароматом, смаком і текстурою. На завершальному етапі оцінювання експерти підраховували середнє значення сенсорних показників. Сенсорний профіль було встановлено для плодів кожного сорту черешні та присвоєно бальну оцінку за наступними дескрипторами: інтенсивність кольору, смак, твердість та соковитість м'якоті, щільність шкірочки. Було удосконалено стандартну методику оцінки сенсорних властивостей свіжих плодів. Визначено середню масу (8,41 г) і діаметр (22,63 мм) плодів черешні для трьох груп досягання. Виділено сорти черешні (Казка, Ділема і Удівительна) з найбільшою масою і діаметром плодів. За комплексом сенсорних показників було виділено сорти Казка, Винка і Крупноплідна. За зовнішньою привабливістю, консистенцією і смаковими якостями плодів сформований сенсорний профіль для сортів різних строків досягання. Сенсорна оцінка плодів сортів черешні дозволить розподілити плодіву продукцію та підібрати сировину для подальшого використання у свіжому вигляді, довготривалого зберігання, заморожування і виготовлення продуктів переробки методом теплової стерилізації

Ключові слова: маса; діаметр; сорти; експертиза; зовнішня привабливість; консистенція; смакові якості