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New Approaches to Assessing the Quality of Cherry Fruit

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Sour Cherry is among the most consumed fruits which is highly appreciated by consumers, it is studied by the world community due to its pleasant taste, appearance, nutritional and biochemical properties. Therefore, new approaches to assessing the quality of cherry fruit aimed at reducing post-harvest losses and further extending the shelf life of the fruit remain relevant. The aim of the study was to substantiate commercial and sensory indicators for a comprehensive assessment of the quality of cherry fruit to select the best varieties and ensure sustainable fruit production for the improvement of diets. In the course of the experiment, we used the descriptive-profile and scoring methods of sensory analysis. To determine sensory and commercial properties, 10 model cherry varieties were selected. The cherry fruits of the model varieties were divided into two commercial classes according to technological parameters and the presence of defects. For each cultivar of fruits a sensory profile was compiled and a score was assigned to the following descriptors: colour intensity, taste, firmness and juiciness of flesh, skin density. Each expert of the group conducted rating tests on ten fruit samples and evaluated them in order of advantage in appearance, aroma, taste and texture. Then, the comparative total score was calculated. The description of commercial and organoleptic parameters for fresh sour cherries has been improved on a 9-point scale, which increases the objectivity of the analysis for stakeholders. According to the indicators of fruit size and presence of defects, the fruits were distributed into 1st and 2nd commercial classes. The cherry cultivar Solidarnist, which provided the maximum number of 1st class fruits, was selected as the most valuable. The cherry cultivar Hriot Melitopolskyi produced the largest number of 2nd class fruits. According to the comprehensive assessment, the highest sensory indicators have been found in Hriot Melitopolskyi and Modnytsia cultivars. The complex interpretation of the main commercial and sensory indicators of sour cherries makes it possible to further integrate them into a criterion-based express method for determining the fruit quality of different varieties by visual indicators. This can then be used to optimize the quality of raw materials and select the method of fruit processing.

1. Introduction

The primary direction of food systems transformation is aimed at finding ways to achieve the agricultural sustainable development goals and to introduce new approaches to forming the balanced diet of the population (Deaconu et al., 2021; Farrell et al., 2023). Reducing the environmental impact of food systems is critical for ensuring sustainable supply chains (Dogbe & Revoredo-Giha, 2021). The key sustainable development vectors are aimed at the production of healthy and varied food in sufficient quantity as well as changing the culture of food consumption (Bujdosó et al., 2020). It is especially important to promote achieving sustainable development goals in agriculture as both the prosperity level of the country and the ecological sustainability depend on the health condition of its population (Deaconu et al., 2021; Fanzo et al., 2021; Nishi, 2022). Sustainable gardening plays a significant role in solving the problems of the country's food security, as fruit is an integral component of a person's healthy diet (Dogbe & Revoredo-Giha, 2021; Janda et al., 2022). This is confirmed by the fact that the General Assembly of the United Nations announced year 2021 the International Year of Fruit and Vegetables. The role of fruit and vegetable produce in the food system is linked to multiple United Nations Sustainable Development Goals (SDGs) (FAO, 2021). One of valuable fruits grown in many countries is cherry (*Prunus cerasus* L.). The consumption demand for cherry has grown considerably in recent years, which has led to an increase in its production. In addition to its attractive appearance and pleasant taste, cherry also has nutraceutical and health-beneficial properties (Ivanova et al., 2022b; Serdyuk et al., 2020; Serradilla et al., 2016). The nutritional, therapeutic and dietary value of cherry is explained by a high content of organic acids, sugars, vitamins, minerals, bioactive and antioxidant compounds (Ferretti et al., 2010; Vignati et al., 2022). Due to the content of dietary phenolic compounds and antioxidants, cherry fruits have anti-inflammatory, cancer-fighting and antioxidant properties (Butu & Rodino, 2019; Ivanova et al., 2021b; Siddiq et al., 2011). Consumption of cherry fruits reduces the risk of oxidative stress, cardiovascular diseases, cancer, type 2 diabetes, decreases inflammation and arthritis pain, regulates blood glucose levels and improves cognitive functions (Cairone et al., 2023; Vignati et al., 2022). The study of the quality of fruit raw materials is becoming increasingly important due to the value of cherries as a food product for dessert and technological purposes in the processing industry.

2. Literature Review

The commercial significance of cherry as a nourishing and functional food product encourages researchers around the world to study their quality parameters (Gonçalves et al., 2021; Ivanova et al., 2021a; Vursavuş, Kelebek, & Selli, 2006). However, the market season of fresh fruit is relatively short. Cherries are perishable and have a short shelf life (Wu et al., 2018). Reducing fruit losses is one of the most important strategies for improving diets and strengthening food systems. The quality of cherry fruits is determined by means of subjective assessment (colour, aroma, taste, firmness and other attributes) conditioned by the consumers' perception level, which cannot be standardized (Ivanova et al., 2023b). The sensory attributes of cherry are determined by the preferences of the consumers, who are ready to pay high prices for fruit with desired characteristics. In order to meet the increased market demand for cherries, a large number of studies have focused on identifying the most important quality parameters of the fruits, determining consumer preferences (Cliff, Stanich, & Toivonen, 2017; Correia et al., 2019; Ivanova et al., 2022a). For overall perception of fruits by the consumers, colour, taste and the combination of these attributes are important (Amidei et al., 2013; López et al., 2023). The key parameter for consumers when choosing fruit is taste (Ahmad & Siddiqui, 2015; Ivanova et al., 2020; Ivanova et al., 2024). An online consumer survey held in Serbia and Bosnia & Herzegovina (B&H) helped to identify the most important external (fruit colour, fruit size, fruit shape, presence of damage to the fruit, presence of a stalk on the fruit and the length of the stalk) and internal (fruit taste, fruit firmness) characteristics of cherry fruits (Paunović et al., 2022). The respondents' opinion about fruit size and firmness and presence of a stalk depended on their place of residence. Studies have confirmed the correlation between the sensory attributes of cherry (appearance of skin and stalk, firmness, weight) and the acceptability of cherry fruits by experts and consumers (Crisosto, Crisosto, & Metheney, 2003; Dever et al., 1996; Silva et al., 2021). According to Cliff et al. (2017) treatment of the fruits with a commercial cherry cuticle supplement reduced their sensory firmness and increased juiciness compared to untreated fruits.

In Greece, the Tsolakeika and Bakirtzeika varieties were identified by consumers based on the results of fruit assessment of 22 sweet cherry varieties for their sensory properties (colour, texture, taste and overall assessment) (Karagiannis et al., 2021). Polish scientists evaluated seven varieties of sweet cherries of Czech

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selection. Horka, Jacinta, Fabiola, and Tamara were rated the highest in terms of fruit size; Kordia and Fabiola were rated the highest in terms of fruit firmness (Szpadzik et al., 2022). The commercial value of sour cherries and sweet cherries is determined by the weight and size of the fruit. The marketing value of the fruit is determined by the reaction of consumers to large sour cherries. In this regard, modern breeding is aimed at creating sour cherry and sweet cherry varieties with a large diameter and weight (Antognoni et al., 2020).

The studies of S.R. Rodrigues have specified and set quality assessment parameters and methodology for the whole cherry supply chain to satisfy the commercial and sensory preferences of all stakeholders (Ricardo-Rodrigues, Laranjo, & Agulheiro-Santos, 2023). According to scientists' forecasts, standardization of quality parameters will contribute to valorisation of the whole supply chain. In terms of marketing, the sale of fresh cherry fruits depends on their quality. Fruits should be competitive and have specific sensory attributes. Consumers prefer fruits without external defects, free from insect pest and disease, crunchy, with balanced taste and aroma (Ahmad & Siddiqui, 2015). Analysis of literary sources shows that the commonly known colour assessment method of fresh fruit is sensory analysis (Savchovska & Nesheva, 2021). However, there is no universal instrumental method for colour assessment. Studies conducted in northern Portugal have found that fruit size and weight, flesh firmness and fruit cracking depend on the cultivar (Pereira et al., 2020). Fruit cracking is one of the main problems in cherry production and is caused by heavy precipitation before harvesting time and while harvesting. This physiological disorder leads to major economic losses, which can be more or less significant depending on crack placement: in the cheeks (side cracks), in the stylar scar region or in the stem cavity region. Fruit cracking can be affected by a number of factors including cultivar, growing conditions, rootstock, fruit size, flesh osmotic potential, cuticular characteristics of the skin and fruit development stage.

The research of X. Zhang et al. looks into the impact of fruit transportation conditions on preserving the qualitative indicators, as well as the dependence of the sale price on fruit quality, especially in express logistics (Zhang et al., 2020). In order to reduce the quality loss of fresh cherry fruit in express logistics, a system of dynamic monitoring and quality assessment system (DMQAS) based on multi-sensors has been offered. Fruit evaluation based on the scale of "standards of excellence" proposed by R. Amidei et al. involves testing the sensory attributes of new cherry cultivars (Amidei et al., 2013). In the research of C. R. Hampson et al. the hardness of the pulp and crispness of cherry fruit was assessed using a 7-point JAR scale from "too soft" to "too hard/crisp" (Hampson et al., 2014). The growing interest in increasing the planted area of cherry has led to the creation and implementation in production of new cultivars adaptive to biotic and abiotic stress factors, oriented towards the market with the best sensory fruit profile (Malchev & Vasileva, 2023). In addition, cultivation of such cultivars and their inclusion in selection programs as donors of valuable biological and economic attributes will contribute to preservation of biodiversity and sustainability of agriculture. The analysis of literature sources indicates the need to find improved methodological approaches to assessing the quality of sensory and commercial properties of raw materials that can be used in the waste-free supply chain of fruit products to all interested groups to address food security issues.

Based on the analysis of scientific papers on the study of sensory and commercial parameters of fruits, it can be concluded that the methodological approach to the comprehensive assessment of the quality of fruit raw materials has not yet been improved. From a theoretical point of view, it is interesting to modernise the parameters of sensory analysis of fruits in combination with commercial indicators. These studies may be useful for visual assessment of fruit raw materials by express method by all stakeholders to address food security issues. In this regard, to ensure a sustainable supply of fresh fruit to the European market in a waste-free chain of use, it is advisable to evaluate the quality of different sour cherry varieties in terms of sensory and commercial parameters.

3. Materials and Methods

The aim of the research was to evaluate the quality of cherry fruit according to sensory and commercial parameters and to identify the most valuable varieties for sustainable supply of fresh fruit in accordance with the requirements of the European market and to meet the preferences of all interested groups.

To achieve the research objective, the following tasks had to be solved:

- To describe the methodology used for joint sensory testing of the fruit quality according to European requirements in detail;
- To assess the feasibility of effective fruit

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differentiation of cherry cultivars by a number of sensory indicators and commercial classes;
- To understand the relationships between the sensory attributes and the fruit quality parameters in order to satisfy the preferences of all stakeholders and promote food security.

The research was conducted from 2007 till 2019 in conditions of the Southern Steppe subzone of Ukraine (46°46'N, 35°17'E). The climate of the region where the research was conducted is Atlantic continental. The average annual air temperature fluctuates between 9.1°C and 9.9°C. The average monthly temperatures in July and August ranging from 20.5 to 23.1°C are the warmest. The average annual amount of active temperatures above 10°C from April through October is 3316°C. The average annual precipitation in the region is 475 mm, which is insufficient for moistening the region. The average annual relative humidity is 73% (Ivanova et al., 2020). The agricultural background of the research sites throughout the research years met the agricultural engineering requirements. The soil of the research areas is light loamy southern black soil. The soil-forming material is loess. For the study, the trees typical of a certain pomological cultivar were chosen, of the same age, with average fruitage intensity. Year of planting was 2001, the planting scheme was 5×3, the interrows were under bare fallow. The fruits of 10 sample cultivars were selected for the experiment: Vstriecha, Ozhydaniie, Shalunia, Turovtseva Siianets, Hriot Melitopolskyi, Solidarnist, Ihrushka, Melitopolska purple, Modnytsia, Ekspromt. The scheme of the experiment on commercial and sensory evaluation of fruits, fruit size indicators is shown in Figure 1.

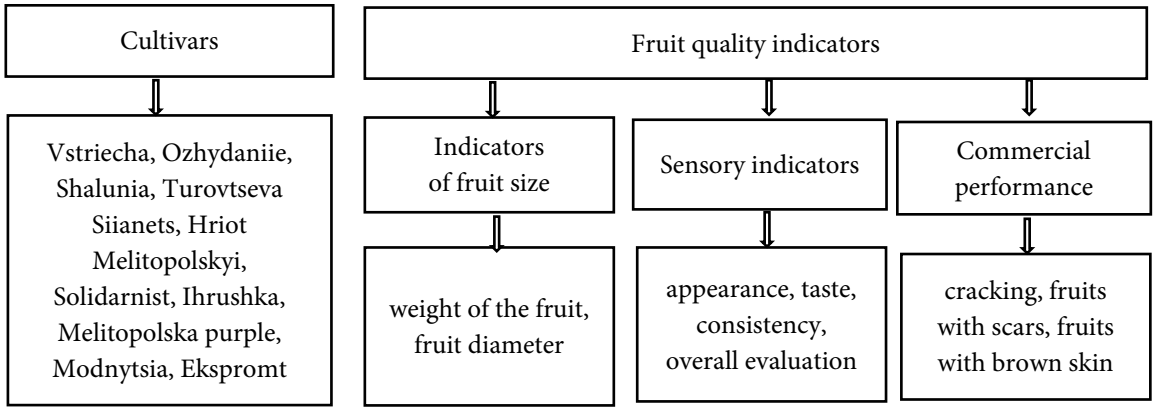

Figure 1: Research Design.

The following methods were used to perform the research tasks: theoretical, laboratory, measuring and weighing, and statistical. The evaluation of commercial and sensory attributes of fruits was performed in 2 stages: Step 1. Commercial evaluation of fresh cherry fruits by class; Step 2. Sensory evaluation of fresh cherry fruits of the selected cultivars.

The weight and diameter of the fruits were measured for all the cherry cultivars. To determine the weight and diameter of one fruit, a sample of 100 fruits was taken from 3–5 typical trees at the stage of economic maturity. The investigation was performed in triplicate (Ivanova et al., 2020; Ivanova et al., 2023a). The fruits were selected in such a way that the quality of the sample chosen was typical of the season's yield. All the selected fruits were weighed, and then the weight of one fruit was determined by dividing the total weight by their number (100 pieces).

Step 1: The commercial properties of cherry fruits were determined according to the current State Standard of Ukraine DSTU 8325:2015 Fresh Cherries. Technical Conditions. Fresh fruits were distributed into two classes (categories) depending on their quality and size: 1st class and 2nd class. Commercial assessment and distribution of the fruits into classes were conducted taking into account the following quality indicators: fruit size, cracked fruit number, number of fruits with recent and scarred mechanical damage; number of fruits with skin browning in the form of spots measuring 0.2 cm^2 (Table 1). Quality evaluation of the fruits was performed in the sorting facility. All the fruits from the trees of the studied cultivars were removed. When ripening of the fruits was uneven, they were removed partially – in proportion to yield placement on the tree. Fruit samples were selected in 4 repetitions).

A packing unit was taken as one repetition. For quality

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evaluation and distribution of the fruits into 1st and 2nd classes an average sample in the amount of 5 % from each packing unit was taken. The weight of the package unit was 12 kg. The average sample was divided into two classes according to DSTU 8325:2015 Fresh Cherries. Technical Conditions. The quality of each class was described according to the corresponding indicators (Table 1). The distribution of fresh fruit samples into classes was determined in percent. The fruits were distributed into commercial classes depending on diameter, and their number was determined as a percentage of the total number of fruits.

Table 1: Commercial Characteristic of the Classes of Fresh Cherry Fruits and Permissible Deviation of Quality Indicators.

Indicator	Class Characteristic	
	1st	2nd
Fruit size according to the largest transverse diameter mm, at least	16	13
Permissible quality deviation, %, less than		
Cracked fruit	2	4
Fruits with mechanical damage		
Scarred	4	10
Recent	2	4
Fruits with skin browning in the form of spots measuring 0.2 cm^2, less than	4	8

Step 2: For sensory attribute assessment normally developed fruits of typical size, without defects were selected at the stage of economic maturity. The weight of the sample was 1.0–1.5 kg. Sensory assessment of the fruits of the studied cherry cultivars was performed by 10 trained experts. The fruits of each cultivar had a code. The expert's assessment was noted down in the tasting sheet.

The fruit size was estimated on a 9-point scale: 1 point – very small fruits; 3 – small fruits; 5 – medium fruits; 7 – large fruits; 9 – very large fruits.

The appearance was estimated on a 9-point scale. The fruits were evaluated by size, shape, and colour. The assessment criteria for visual attractiveness were as follows: 1 point – very unattractive fruits (very small, of irregular shape, poorly coloured); 3 – unattractive fruits (small, unattractive by colour and shape); 5 – mediocre fruits (not large enough, unattractive by colour and shape); 7 – attractive, but not very large; 9 – very attractive, large, of regular shape and colour.

The taste was assessed on a 9-point scale: 1 point – fresh fruits are absolutely inedible; 3 – fruits with unpleasant taste, almost inedible; 5 – mediocre taste; 7 – fruits with pleasant taste; 9 – fruits with excellent taste, with a balanced ratio of sourness and sugar content.

The taste depends mainly on the ratio of sugar and acids in the fruits, the presence of tannins. The sensory evaluation criteria for fruit taste were as follows: sweet (no taste of acid); sourish-sweet (sweet taste prevails, but sourness is present); sour-sweet (both sourness and sweetness are present, but sugar prevails); sweetish-sour (sour taste predominates, but sugar is present); sweet-sour (both sweetness and sourness are present, the latter predominates); sour (sugar is not tasted); wine-sweet (reminds of semi-sweet dessert wine). Different individual shades of taste, the presence of astringency, bitterness and various flavours were also observed.

An overall assessment (overall perception) of fruit quality was conducted. It was defined separately as an overall impression from the quality of the cultivar on a 9-point scale. The following criteria for overall assessment of fruit quality were used: 1 point – fruits are unsuitable for use in fresh form; 3 – fruits of poor quality; 5 – fruits of mediocre quality; 7 – fruits of good quality; 9 – fruits of high quality.

In order to select the best cherry cultivar, the standard evaluation method of sensory attributes of fresh fruit was improved. The comprehensive evaluation of cherry cultivars was supplemented by a new indicator – the average value of sensory indicators. For this purpose, the average value of size, attractiveness, taste and overall perception of the cultivar were assessed on a 9-point scale. To determine the sensory profile for the most advantageous cultivars, the score points given by the tasters were supplemented with additional indicators: visual attractiveness of the fruits (size, shape, colour), fruit consistency (flesh consistency, fruit juiciness and skin density), taste of the fruits (flavour, individual shades of taste). The results of the tasters' work (10 experts) were noted down in protocols (tasting sheets). After that, the average score was calculated.

To ensure the accuracy, credibility, reproducibility and reliability of the experiment results, methods of mathematical statistics were used, including dispersion (ANOVA), correlation and regression analysis (Schmider

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et al., 2010). The basic statistical values of the experiment were calculated using Statistica (version 10.0) and Excel software. The data were first checked for normal and homogeneous dispersion using the Shapiro-Wilk and Levene tests respectively (Zhang, Liu, & Chen, 2018). The average values and standard deviations were calculated for all the data rows (variables). The significance level was set to $p<0.05$.

4. Results of Studying the Technological Parameters of Cherry Fruit

4.1. Study of Fruit Weight and Diameter

The main fruit size indicators included weight and diameter. The average weight of the fruits of the studied cultivars was distributed into four groups: Group 1 – with very large fruits (over 6.2 g); Group 2 – with large fruits (4–2 g); Group 3 – with medium fruits (3.6–4.7 g); Group 4 – with small fruits (2.7–3.5 g). Group 1 included the following cultivars: Vstriecha, Turovtseva Siianets, Hriot Melitopolskyi, Ihrushka with the average fruit weight of 6.71–7.87 g. Group 2 was presented by Modnytsia, Shalunia, Ekspromt, Solidarnist, Melitopolska purple cultivar with the average fruit weight of 4.78–5.99 g. Ozhydaniie cultivar with the average weight of 4.41 g was placed into Group 3. The average fruit weight of the 10 cultivars under study was 5.93±1.19 g (Table 2).

Table 2: The Weight (gram) and Diameter (mm) of Cherry Fruits (average for 2007–2019).

Cultivar	Fruit Weight (gram)				Diameter (mm)			
	Average Weight, Gram	Min Weight, Gram	Max Weight, Gram	Variation by Year, Vp, %	Average Diameter, Mm	Min Diameter, Mm	Max Diameter, Mm	Variation by Year, Vp, %
Vstrecha	7.87±1.48	6.07	11.19	18.82	23.75±2.65	16.05	25.30	11.15
Expromt	4.80±0.75	3.24	5.89	15.68	19.02±3.24	14.30	24.90	17.03
Igrushka	6.71±1.33	5.22	8.96	19.85	19.45±3.19	14.20	24.10	16.42
Griot Melitopolskyi	7.48±2.01	5.18	10.89	26.88	21.23±3.68	12.80	24.90	17.32
Modnytsia	4.78±0.82	3.43	5.89	17.20	19.28±3.15	13.90	22.80	16.36
Melitopolska Purpurna	5.99±0.99	3.78	7.00	16.48	21.00±1.82	15.20	22.00	8.65
Ozhydanie	4.41±1.12	2.93	6.28	25.38	18.58±2.86	14.60	22.80	15.38
Siyanets Turovtsevoi	7.59±1.27	6.27	9.98	16.68	22.44±2.34	18.00	25.00	10.43
Shalunia	4.91±1.38	3.03	8.05	27.99	19.95±2.41	14.30	21.90	12.10
Solidarnist	4.80±0.75	3.24	5.89	15.68	20.55±3.73	14.90	25.40	18.18
Average value	5.93 ± 1.19	4.24	8.00	20.00	20.94±1.8	16.97	23.61	8.59
LSD_{05}	0.74				1.93			

The largest average fruit weight in our research was found in the cultivars Hriot Melitopolskyi (7.48 g), Turovtseva Siianets (7.59 g) and Vstriecha (7.87 g), which was 26.14–32.72% higher compared to the average cultivar value. The smallest fruit weight was found in Ozhydaniie cherry cultivar (4.41 g), which was 25.63 % less than the average cultivar value. The cherry cultivars producing fruits of optimal weight steadily over the years of research have had a significant value. The variation coefficient (Vp) was used to assess the stability of the studied cultivars in relation to the weather conditions of the growing years. Within the years of research, medium and significant variation of fruit weight has been established for the cherry cultivars under study (Table 2). The most significant influence of the growing conditions of the research years on the formation of fruit weight has been established for the cultivars Ozhydaniie (Vp=25.38%) and Shalunia (Vp=27.99%). The most stable cultivars according to the studied indicator in the years of research were Solidarnist and Ekspromt (Vp=15.68%). Two cherry cultivars (Turovtseva Siianets and Vstriecha) with the largest fruit weight and the optimal value of variation – 16.68% and 18.82% respectively – have been distinguished. In the 10 cherry cultivars under study the average fruit diameter was 20.94 mm (Table 2). The cultivars with the largest average diameter of the fruit were Turovtseva Siianets (22.44 mm) and Vstriecha (23.75 mm). Ozhydaniie cultivar had the smallest fruit diameter (18.58 mm). LSD_{05} was 1.93 mm. A strong direct correlation r=0.91 has been established between the weight and the diameter of the fruit. For the years of research, a small and medium variation level (Vp=8.65–18.1%) for fruit diameter of the cherry cultivars under study (Table 2) has been established. For 9 cultivars, the variation coefficient (Vp=10.4–18.8%) has been established as average. Melitopolska purple cultivar was an exception, since its variation coefficient was minimal – 8.6%.

According to the results of two-factor dispersion analysis, the dependence of fruit weight and diameter formation on the year of research has been established in the cultivars under study (Table 3).

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Table 3: Results of Two-factor Dispersion Analysis of Weight and Diameter Formation in Cherry Fruits.

Source of Variation	Sum of Squares	Degree of Freedom	Dispersion	F_{fact}	$F_{table095}$	Impact,%
Fruit Diameter, cm						
Factor A (year)	1163.9	12.0	97.0	1189.4	1.8	28.1
Factor B (cultivar)	932.3	9.0	103.6	1270.3	1.9	22.5
Interaction AB	1999.2	108.0	18.5	227.0	1.3	48.3
Fruit Weight, g						
Factor A (year)	699.2	12.00	77.7	770.8	1.9	52.2
Factor B (cultivar)	321.8	9.00	35.8	354.7	1.8	23.9
Interaction AB	320.1	108.00	35.6	352.9	1.3	23.9
Source: own elaboration						

The year of research (Factor A) had a partial influence on fruit weight and diameter – 52.2% and 28.1% respectively. The influence of cultivar peculiarities (Factor B) on the formation of fruit weight and diameter was less significant – 23.9% and 22.5%. Thus, the fruits of Prunus cerasus L. have been characterized by a considerable variability of fruit weight and diameter depending on the year of research, that is, the weather conditions of the particular season.

4.2. Research of Commercial Attributes of Cherry Fruits

The Commercial attributes are among the most important indicators of the product's competitiveness in the market. The percentage of fresh cherry fruit of 1st and 2nd classes (categories) for the cultivars under study is 90.0–92.7% (Table 4).

Table 4: Commercial Characteristics of Fresh Cherry Fruits of 1st and 2nd Classes, Non-standard Produce (average for 2007–2019).

Cultivar	Commercial Produce, % Fruit Size According to the Largest Transverse Diameter, mm Not Less than:								Total, %	Non-standard Produce, % According to Fruit Size Indicator
	1st Class, %				2nd Class, %					
	Fruits Sized Over 16 mm	Cracked Fruits, Up to 2 %	Scarred Fruits, Up to 4 %	Fruits with Skin Browning, Up to 4 %	Fruits Sized Under 13 mm	Cracked Fruits, 2–4 %	Scarred Fruits, Up to 10 %	Fruits with Skin Browning, Up to 8 %		
Vstriecha	81.2	0.7	0.2	0.5	6.0	0	4.1	0	92.7	7.3
Ozhydaniie	82.0	0.5	0.1	0.9	8.2	0	0	0	91.7	8.3
Shalunia	70.1	0.9	0.2	1.8	11.0	2.2	0	6.0	92.2	7.8
Turovtseva Siianets	71.7	1.0	0.2	2.1	7.5	0	4.2	5.6	92.3	7.7
Hriot Melitopolskyi	66.8	1.2	0.4	0.7	10.8	2.1	4.1	5.1	91.2	8.8
Melitopolska purple	82.6	0.8	0.1	0.9	7.4	0	0	0	91.8	8.2
Modnytsia	81.7	0.4	0.5	2.3	6.7	0	0	0	91.6	8.4
Ekspromt	81.8	0.6	0.4	2.2	5.8	0	0	0	90.8	9.2
Ihrushka	67.2	0.8	0.9	1.1	11.6	2.3	0	7,1	91.0	9.0
Solidarnist	83.6	0.5	0.6	1.3	6.1	0	0	0	92.1	7.9
Average	76.6	0.6	0.4	1.1	8.4	0.7	1.2	2.4	91.4	8.6
Source: own elaboration										

It has been established that the fruits of Solidarnist cultivar had the maximum amount of 1st class fruits (86%). The amount of 1st class fruits in the sample of Hriot Melitopolskyi cultivar was minimal – 69.1%. The largest amount of 2nd class fruits has been observed in the sample of Hriot Melitopolskyi cherry cultivar – 22.1%. The assessment of fruit size of the 10 cultivars under study was based on their diameter. It has been determined that the maximum number of fruits with the diameter of over 16 mm was found in the fruits of Solidarnist cultivar (83.6%), which is 7% higher than the average cultivar value (76.6%). The maximum output of 2nd class produce (between 17.3% and 22.1%) has been found in the cultivars Shalunia, Turovtseva Siianets, Hriot Melitopolskyi, Ihrushka. In the studied cultivars the share of fruits smaller than 13 mm in diameter ranged from 7.5% to 11.6%. The number of fruits not belonging to 1st and 2nd classes was 7.3–9.2%. This indicator was the lowest in the sample of Vstriecha cultivar, and the highest in Ekspromt cultivar. It was established that the fruits of Solidarnist cultivar had the highest indicator of 1st class produce – 86%. The output of 1st class produce in the sample of Hriot Melitopolskyi cultivar was minimal – 69.1%. The largest amount of 2nd class produce was found in the sample of Hriot Melitopolskyi cultivar – 22.1%

4.3. Research of Sensory Attributes of Cherry Fruits

The score estimation of fruit size was maximum (8.5 points) for the cultivars Turovtseva Siianets, Vstriecha, Modnytsia (Table 5).

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Table 5: Sensory Assessment of Fresh Cherry Fruits in Appearance and Taste Qualities (average for 2007–2019).

Parameters	Cultivar									
	Vstriecha	Ozhydaniie	Shalunia	Turovtseva Siianets	Hriot Melitopolsky	Melitopolska Purple	Modnytsia	Ekspromt	Ihrushka	Solidarnist
Fruit size, score	8.5	8.2	8.2	8.5	8.3	8.2	8.5	8.2	8.4	8.2
Appearance: - size	large	large medium	large	large	large	large medium	large	large	large	large
- shape	flat round	round	flat round	round	round	round	round	round	round, heart-shaped	round
- colour	dark red	dark red	dark red	dark red	dark red	dark red	dark red	dark red	dark red	dark red
Appearance, score	8.5	8.4	8.5	8.5	8.6	8.4	8.5	8.5	8.6	8.4
Sensory assessment of fruit consistency: - consistency	tender	very pleasant tender	tender	tender	tender	tender, very pleasant	tender	tender	tender	tender
- flesh juiciness	juicy	juicy	juicy	juicy	very juicy	juicy	very juicy	juicy	juicy	juicy
- skin type	thin-thick	thin	thin, firm	thin	very thin	thin	thin	thin	thin	thin
Fruit consistency, score	8.3	8.7	8.3	8.4	8.8	8.6	8.8	8.4	8.4	8.3
Sensory assessment of fruit taste: - flavour	sour-sweet	sour-sweet	sour-sweet	sour-sweet	sourrish-sweet	sourrish-sweet	sourrish-sweet	sweetish-sour	soursweet	sweetish-sour
- individual shades of taste	firm consistency	balanced	refreshing	refreshing	sweet, balanced		balanced			
Taste, score	8.5	8.8	8.6	8.7	8.9	8.8	8.9	8.7	8.7	8.5
Overall perception, score	8.8	8.8	8.8	8.7	8.8	8.8	8.9	8.7	8.7	8.6
Average, score	8.5	8.6	8.5	8.5	8.7	8.6	8.7	8.5	8.6	8.4
Source: own elaboration.										

The sensory assessment of fruit appearance was based of the analysis of size, shape and colour. According to fruit appearance indicator, Ihrushka and Hriot Melitopolskyi cultivars were selected (8.6 points). The fruits of these cultivars had the maximum sensory perception indicator (impression) according to the experts and were large, round or heart-shaped, of intense dark red colour. As a result of sensory assessment of fruit consistency, Hriot Melitopolskyi and Modnytsia cultivars (8.8 points) have been selected. The fruits of these cultivars had tender consistency, the juiciest flesh and a thin skin. According to fruit taste, the experts have selected Modnytsia and Hriot Melitopolskyi cultivars. The taste qualities of the fruits of these cultivars were highly evaluated – 8.9 points. Fruits of Modnytsia and Hriot Melitopolskyi cultivars were sourish-sweet, with a balanced taste. For comprehensive assessment and selection of the best cherry cultivars, the standard method of fruit quality estimation was enhanced with such indicator as the average value of sensory attributes. The fruits of Modnytsia and Hriot Melitopolskyi cultivars we ranked highest (8.7) by the average value of sensory attributes.

5. Discussion

The present paper has analysed different sensory and commercial attributes of fruits to identify the obstacles and opportunities to increase fresh fruit consumption taking into account the preferences of all stakeholders. One of the priority goals of COST Action FA1104: "Sustainable production of high-quality cherries for the European market" is the exchange of information about new findings related to cherry production and its cultivars (Bujdosó et al., 2020). In order to meet the growing market demand for cherries, a large number of studies have focused on identifying the most important quality characteristics of the fruits conditioning consumers' preference for cherries. The main conclusion against the background of Italian and Iranian scientists' research is related to the fact that the fruits of the studied cultivars are characterized by a larger weight. In Central Italy S. Proietti et al. determined that the average weight of cherry fruits was 2.5 g, with the minimum value of 1.8 g and the maximum value of 3.6 g (Proietti et al., 2019). Research of the average fruit weight by Iranian scientists, according to A.Khadivi et al., showed that this value equals 2.04 g (Khadivi, Mohammadi, & Asgari, 2019). Most of the cultivars studied in Poland were formed with an average weight of over 4.15 g (Wojdyło et al., 2014).

According The results of the research show that the cherry cultivars under study differ in fruit weight. This conclusion is confirmed by the data of other scientists (Borowy, Chrzanowska, & Kapłan, 2018; Corneanu, Iurea, & Sîrbu, 2020; *Šebek, 2019*). The studies of M. Siddiq et al. found that the weight of cherries ranged widely depending on the cultivar from 3.95 to 8.17 g (Siddiq et al., 2011). The largest weight of fruits was found in Balaton (8.7 g) cultivar. According to G. Šebek in Montenegro, Oblačinska cultivar had the smallest weight (3 g) and Heimanns Konservenweichsel cultivar had the largest weight indicator (5.7 g) (*Šebek, 2019*). Variations of fruit weight depending on the cultivar were studied earlier. The average weight of cherry fruits in the studies of Wojdyło et al. (2014)

ranged from 2.10 g (Stevensbaer) to 6.10 g (Ksiazėcė), in the research conducted by Papp et al. (2010) – from 3.40 g (Oblachinskha) to 7.17 g (Pándy 279), in Pérez-Sánchez's et al. (2008) study – from 3.2 g (Guindo del País 1) to 4.72 g (Guindo Tomatiillo 2), in the study of Wang et al. (2021) – from 2.495 g (BS 5) to 5.890 g (Earey hunazihn). Khadivi et al. (2019) in Iran assessed the morphological and pomological variability of 62 cherry accessions. High variability of indicators of the studied accessions was established. Thus, the fruit weight of cherry cultivars varied from 1.36 to 2.67 g. The work of Milošević, Milošević, & Mladenović (2020) and Milošević et al. (2023). demonstrated that the cherry fruit size is significantly affected by the rootstock. Overall, the fruits of cherry cultivars had a smaller weight than those of black cherry (Ivanova et al., 2022a). The results of the research confirm the data we have obtained regarding the dependence of genotypes and growing conditions in different years on large variability of the studied parameters (Borowy et al., 2018; Grafe & Schuster, 2014; Proietti et al., 2019).

To assess the sensory properties of cherry fruits, various tests and scales are used (Höfer & Giovannini, 2017). For consumers, the primary sensory attribute of cherry quality is the taste of the cultivar. Similar results regarding the cherry cultivar choice according to overall perception of the fruit were found according to the consumer survey conducted in seven countries, specifically Bulgaria, Hungary, Chile, Italy, Japan, Turkey and Latvia. The refined comprehensive sensory assessment of fruits includes the average values of size, visual attractiveness, taste and overall perception. The proposed approach allows evaluating each cherry cultivar in a balanced way according to the size, taste and consistency of the fruit (Bujdosó et al., 2020). According to the commercial quality standards developed by the Working Party on Agricultural Quality Standards in the USA, the United Nations Economic Commission for Europe (UNECE) distributed the cultivars into commercial classes by size. The cultivars of Vstriecha, Turovtseva Siianets, Hriot Melitopolskyi, Melitopolska purple, Ihrushka were classified as "Extra" class with the size of over 20 mm. The fruits of Ozhydaniie, Shalunia, Modnytsia, Ekspromt, Solidarnist cultivars with the size of up to 17 mm were ranked as 1st and 2nd class. The distribution of fruits into classes according to UNECE standards promotes international trade, encourages high quality of produce, increases profitability and ensures protection of consumer interests. Based on these results, it can be concluded that the environmental conditions of cultivation were favourable to cherries, most cultivars in the study achieved relatively good quality indicators for the domestic market by external and internal quality parameters of the fruits. This information obtained is useful for a comprehensive assessment of cherry cultivars, but further research is needed to determine their suitability for post-harvest processing.

6. Conclusion

The average weight of cherry fruit was 5.93 g, and the average fruit diameter was 20.94 mm. The largest average weight of cherry fruit (7.48–7.87 g) has been found in Hriot Melitopolskyi, Turovtseva Siianets and Vstriecha cultivars. The cultivars Turovtseva Siianets and Vstriecha have demonstrated the largest average fruit diameter (22.44–23.75 mm). According to the largest weight of fruits and the optimal variation value (Vp=16.68% and Vp=18.82%), Turovtseva Siianets and Vstriecha cultivars have been selected. Years of research proved to have a great influence on fruit weight and diameter (52.17% and 28.10%).

The analysis of distribution of the products into classes will provide ground for identifying and recommending the most valuable cultivars for marketing in fresh form of high quality products (1st class) as well as the cultivars (2nd class) that can be used for food processing and manufacturing. The cherry cultivar Solidarnist has produced the maximum number of 1st class fruits. Hriot Melitopolskyi cultivar has given the largest number of 2nd class fruits.

Hriot Melitopolskyi and Modnytsia cherry cultivars have demonstrated high sensory indicators by a complex of parameters (8.7 points). Hriot Melitopolskyi and Modnytsia cherry cultivars have been ranked the highest in the comprehensive evaluation by sensory parameters. Fruits of these cultivars have the largest size, are round, of intense dark red colour, tender, with very juicy flesh, thin skin, and a balanced sour-sweet taste.

A two-factor analysis of variance will determine the proportion of influence of years of research and varietal characteristics of sour cherries on the formation of sensory and commercial fruit quality indicators. In the future, this will help to distribute fruit raw materials to form a waste-free chain of its use in fresh form, during long-term storage and processing. The sour cherry varieties were evaluated for their sensory and commercial characteristics to ensure a sustainable supply of fresh fruit to meet the requirements of the European market and the preferences of all stakeholders.

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The conducted commercial and sensory assessment of sour cherries makes it possible to develop an improved criterion-based express method for stakeholders to determine the quality of fruits of different varieties by visual indicators. The use of the multicriteria optimisation method will allow to exclude units of measurement, as well as the size of the intervals of acceptable values of each criterion for the selection of a sour cherry variety. The integration of sensory, biochemical and commercial analysis of fruit raw materials according to many incompatible criteria will facilitate the grading of fruit products for further use in fresh, long-term storage, freezing and food production.

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6.2. Conflict of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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