Research Paper

Future of Food: Journal on Food, Agriculture and Society
11 (1) December 2022

The effects of weather factors on titrating acids accumulation in sweet cherry fruits

IRYNA IVANOVA[1], MARINA SERDYUK[2], VIRA MALKINA[3], TETIANA TYMOSHCHUK[4,*] LIUDMYLA SHLIEINA[5], LIUBOV POKOPTSEVA[6], MYKHAILO ZORIA[7], AND HALYNA TARANENKO[5]

[1]Department of Horticulture, Viticulture and Biochemistry, Dmytro Motornyi Tavria State Agrotechnological University, Melitopol, Zaporizhzhia region, Ukraine
[2]Department of Food Technology and Hotel and Restaurant Business, Dmytro Motornyi Tavria State Agrotechnological University, Melitopol, Zaporizhzhia region, Ukraine
[3]Department of Higher Mathematics and Physics, Faculty of Energy and Computer Technology, Dmytro Motornyi Tavria State Agrotechnological University, Melitopol, Zaporizhzhia region, Ukraine
[4]Department of Health of Phytocenoses and Trophology, Polissia National University, Zhytomyr, Ukraine
[5]Department of Social Sciences and Humanities, Dmytro Motornyi Tavria State Agrotechnological University, Melitopol, Zaporizhzhia region, Ukraine
[6]Deaprtment of Crop Production and Horticulture named after V.V.Kalytka, Dmytro Motornyi Tavria State Agrotechnological University, Melitopol, Zaporizhzhia region, Ukraine
[7]Department of Civil Security, Dmytro Motornyi Tavria State Agrotechnological University, Melitopol, Zaporizhzhia region, Ukraine

* Corresponding author: tat-niktim@ukr.net

Data of the article

First received : 05 October 2021 | Last revision received : 15 August 2022
Accepted : 05 December 2022| Published online :30 December 2022
DOI : 10.17170/kobra-202210056938

Keywords

fruits crops; organic acids; climate; periods of ripening; statistical analysis.

During fruit formation, the weather conditions have a decisive influence on the organic acids accumulation. In the context of global climate change, this issue has become new. The study of the titrated acids content in sweet cherry fruits was carried out for 12 years. Cherry fruits of the groups of three terms of ripening were selected for the study. The average and strong correlation between 11 weather factors and the titrated acids content for the sweet cherry cultivars of the early, medium, and late ripening terms were determined. The ranges of the weather factors that have the maximum influence on the formation of the titrated acid found in sweet cherry fruits (Δ_i 10.37-34.06%) were established. The research showed that the rate of maximal titrating acids content has been found in Valeriy Chkalov, Dilema, and Udivitelna cultivars. The optimal values of sugar-acid indices in the fruits of 31 sort samples of sweet cherry in all terms of ripening have been established. Weather conditions, which were during the years of the research, had dominating effects on the formation of titrating acids fund for all groups of cultivars irrespective of the term of fruit ripening. Ranking of weather factors according to the degree of their influence on the titrated acids accumulation in sweet cherry fruits three times of ripening has revealed that for cultivars of early, medium and late ripening terms of sweet cherry fruits the average monthly precipitation in May has a maximal influence and is a rank 1 factor; the average minimum relative humidity in May is essential for the cultivars of a medium-term of ripening.

1. Introduction

Orchards occupy a large area in Ukraine. One of the favourite fruits of consumers is sweet cherry fruits (Dziedzic et al., 2017; Szpadzik et al., 2019; Ivanova et al., 2022). The popularity of this fruit crop is stipulated by attractive cherries, high-taste qualities of fruits (Cao et al., 2015; Pereira et al., 2020; Ivanova et al., 2021), and early term of ripening (Pérez-Sánchez et al., 2008; Savchovska & Nesheva, 2021). But the demand for high-quality sweet cherry fruits still exceeds the supply in the European and World markets (Faniadis et al., 2010; Serra et al., 2011; Liu et al., 2011). Researchers from many countries pay much attention in their studies to the problems and perspectives of growing sweet cherry cultivars of early and late terms of fruits ripening as well as to improving sweet cherry quality (Jänes et al., 2010; Kask et al., 2010; Sîrbu et al., 2012). Under favourable weather conditions, the fruits of sweet cherry cultivars become good shippers, have a marketable state, and have excellent flavor (Einhorn et al., 2013). Many scientists study the biochemical composition and taste of sweet cherry fruits depending on the conditions of the fruit growing area (Borovinova et al., 2008; Radicevic et al., 2019; Szpadzik et al., 2019). The problem of the quality of sweet cherry fruits is widely discussed by scholars in the scientific literature (Usenik et al., 2010; Szpadzik et al., 2019; Antognoni et al., 2020; Ivanova et al., 2022).

The researchers dedicated their studies to determine the optimal set of sweet cherry fruits quality indices by different parameters (Ivanova et al., 2022; Serdiuk et al., 2020a). As many as 53 sweet cherry fruit samples of different cultivars were analyzed by the researchers from the South of Ukraine. In sweet cherry fruits, sweetness is harmoniously combined with palatable sourness, there are some vitamins, enzymes, and mineral salts, that are very beneficial for people's organisms. As many as 35 varieties of Ukrainian selection (Novynka Turovtseva, Bigaro Turovtseva, Chorna Turovtseva, Vypusknutsia, Impuls, Slavianovka, Supernytsia, Vizitka) were selected as the sources of excellent flavor with the highest tasting evaluation (Malyuk et al., 2014). The genetic features of pomological cultivars and weather conditions in a region of sweet cherry trees growing have a significant influence on the formation of biochemical parameters in fruits (Ivanova et al., 2020; Shubenko et al., 2021; Usenik et al., 2008; Picariello et al., 2016). The research by Todd C. Einhorn et al. (2013) established that under the effects of gibberellin acid (25 ppm GA) the content of titrating acids in sweet cherry fruits of a cultivar Swetheart increased at a range of 0,89-0,95%. Sugar-acid index (SAI) points to a harmonious flavor of crop fruits. It is determined as the sugar/acid contents ratio. As some authors state, the fruit with SAI 15-30 n.u. have the most harmonious flavor (Serdyuk & Stepanenko, 2015). Hydroxysuccinic acid makes up 90% of total acidity in fruits of sweet cherry and cherry trees (Radunic et al., 2014). Foreign scientists have established some changes in the biochemical composition of sweet cherry fruits of cultivars with different periods of ripening depending on the region of growing (Basanta et al., 2014). The rate of titrating acid accumulation can change depending on the effects of soil and weather conditions, crop yield, and degree of fruit ripeness. Such stone fruit crops like apricots, peaches, and sweet cherries are standing crops. Insufficient amount of moisture in the soil and in the air has negative effects on the growth of the vegetative organs, yield capacity, as well as on the worsening of the flavour of the fruit (Zeman et al., 2013; Shaaban et al., 2020). Thus, it has been admitted that during the years with a maximal amount of precipitation there are fewer dry substances in fruits. During the period of droughts, there is more sugar but less moisture in fruit cells. Acids accumulation is closely connected with a complex of biochemical transformations of organic acids taken as a whole (Serdyuk & Stepanenko, 2015). A frequent effect of a combination of unfavourable stress factors on sweet cherry trees results in the loss of stress resistance and is manifested in the quality degradation of fruits (Martini & Man, 2014; Dziedzic et al., 2017). To analyze the effects of weather conditions factors on the accumulation of quality indices of fruits (dry soluble substances, sugars, titrating acids) in sweet cherry fruits it was suggested to utilize the Methods of Regressive Correlation Analysis, as well as the Methods of Factor Analysis, in particular – the Method of Principal Component Analysis. The fact, that the amount of test factors exceeds the number of experimental values of a test index within the period of 12 years, is an important problem while developing and analyzing the regressive model. Thus, it is impossible to use the Least Square Method for developing a regressive model. To develop a regressive dependence, the researchers advised in the first stage to develop the system of principal components which will later function as the factors of a regressive model (Kelechi, 2012). The literature sources analysis substantiates the existence of a strong correlation between the taste qualities of sweet cherry fruits and the content of organic acids in them, the amount of which, in its turn, is associated with the weather conditions of the region of plants growing. Under conditions of climate change, the problem of the effects of stress weather factors on the prognostication of titrating

ISSN-Internet 2197-411x OLCL 862804632

acids content in sweet cherry fruits, depending on the rate of weather factors effects, has not been highlighted in literature sources, that determine the topicality of the conducted research. The purpose of the research was to develop a mathematical model which will help to improve the forecasting of titrating acids content in sweet cherry fruits under various weather conditions. This mathematical model can be used under conditions of the regions with similar hydrothermal indices to the southern regions of a Steppe zone of Ukraine. The research program is planning to determine the varieties of three terms of ripening with a high titrating acids rate for preserving both fruit quality and biological value.

2. Materials and Methods

The research was conducted during the period of 2008-2019. The everyday meteorological data of Melitopol (Ukraine) Weather Station were used. Fruit farms, where the research was conducted, were located in a Southern Steppe Subzone of Ukraine. The landscape of the area is plain, with an Atlantic-continental climate and high-temperature regime. The annual air temperature range is 9.1-9.9 °C. The average monthly air temperatures in the hottest months were from 20.5 to 23.1 °C. The effective heat sum above 10 °C from April to October totals 3316 °C, and the annual amount of precipitation totals 475 mm. The region, according to the amount of precipitation, belongs to the zone with an insufficient amount of moisture. The average annual relative humidity is within 73%. The average annual air velocity is 3.7 m/s. The climate is dry with eastern and northeastern winds. The readings of the hydrothermal index are in the range of 0.22-0.77.

The agricultural background of the experimental plots during the years of research met the agrotechnology requirements. Moisture accumulation in soil happens preferably in autumn, partly in winter, and in early spring. The crop is grown on southern light loamy soils. Forest is a soil-forming material. This type of soil by its granulometric composition has a large content of physical sand. The fruits of 33 varieties were selected for studying and according to the ripeness stage, they were divided into 3 groups (Table 1).

To estimate the titrating acids content, as many as 100 fruits from 6 trees that were in the fruit-bearing period, were selected for each pomological cultivar. There was threefold repeatability. In 2001 the trees were planted on the pattern 5×3 with weed-free fallow spacings. The trees typical for a separate pomological cultivar, of the same age, with an average fruiting intensity were selected for the study. The fruits were weighed and counted when picking (Serdiuk et al, 2020b; Ivanova et al, 2021). The sweet cherries fruits of each commercial sort were carefully picked on the stage of economic maturity when the fruit pulp is firm, but the flavor and the color are typical for a given pomological cultivar.

The fruits were picked from the trees from four different sides of a crown. The fruits from each pomological cultivar were of the first commercial sort and picked with fruit stalks. The date of picking fruits will be established according to the following quality indices of sweet cherry fruits: visual appearance (fruit analysis in terms of form and colour which must be typical for a given pomological cultivar, fruit-stalk availability, determining the rate of mechanical damages of fruits, their infestation with pests and fungus diseases), the size of the fruits in cross-section diameter. The fruits were kept and transported to the laboratory under favourable conditions so that the fruits had a good visual appearance and flavor typical for a pomological cultivar.

Table 1. The list of varieties taken for studying

1st variety group (early term of ripening)	2nd variety group (medium term of ripening)	3rd variety group (late term of ripening)
Swit Erliz, Merchant, Bigaro Burlat, Rubinova Early, Valeriy Chkalov, Kazka, Zabuta	Kordia, Oktavia, Vynka, Pervistok,Temp, Uliublenytsia Turovtseva, Talisman, Dilema, Melitopolska Chorna,Orion, Chervneva Early, Dachnytsia, Prostir	Karina, Regina, Mirazh, Krupnoplidna, Udivitelna, Zodiak, Ciurpryz, Kolhoznytsia, Prazdnichna, Anons, Temporion, Meotyd

Mass concentration of titrating acids (TA) was defined by a titrimetric method (Serdiuk et al, 2020) – by titrating 0.1 H by solution NaOH. The titrimetric method determined the mass concentration of titrated acids (TA). The essence is to neutralize organic acids in the experimental product with 0.1 n alkali solution. Titrating is carried out before the transition of the solution from an acidic medium to an alkaline one. The moment of transition of the medium to an alkaline one is visually fixed by appearing the pink colour of the solution in the presence of a phenolphthalein indicator. Using formula 1:

$$X = (M \cdot K \cdot Vas \cdot 100) \div (Ms \cdot Vs) \quad (1)$$

X – total acidity, % (100 g); M – the amount of 0.1 H of an alkaline solution used for titrating, cm3; K – conversion factor to apple acid 0.0067; Vas – the volume of an assay sample, ml; MS – assay sample of a tested substance, g; Vs – the volume of the solution which was taken for titrating, ml.

Measurement instruments, auxiliary equipment, utensil, reagents, and materials: a homogenizer; a blender or a mortar with a pestle; a 25, 50, or 100 cm^3 pipette; an Erlenmeyer flask that can be connected to a reflux condenser; a 250 cm^3 graduated cylinder; a 250 cm^3 beaker with a magnetic or mechanical stirrer; a 50 cm^3 burette; a reflux condenser; analytical scales with weighing accuracy up to 0,01 g; a water bath. Reagents: only reagents of the established analytical purity and distilled or demineralized water or water of equivalent purity were used for the analysis; Sodium hydroxide NaOH with 0.1 mol/dm^3 (0.1N) concentration; phenolphthalein, a solution with 10 g/dm^3 (1%) mass concentration in ethyl alcohol with 95% volume concentration.

Experimental techniques

The dependence of titrating acids on weather factors was studied according to the following patterns:

1. To determine the titrating acids content according to the method mentioned above by conducting experimental research.

2. Systematization of information and organization of structural data concerning weather conditions during the research period. During this period, the following indices were selected: average minimal air temperatures, average air temperatures, average maximal air temperatures, absolute minimal air temperatures, absolute maximal air temperatures, amount of precipitation, average relative humidity, minimal relative humidity, and maximal relative humidity.

3. On the basis of these indices the following indices were counted: hydrothermal coefficient, the difference in temperatures in different periods, the sums of active temperatures, and the sums of effective temperatures.

4. The correlation analysis made it possible to determine the weather factors which have a significant influence on the accumulation of titrating acids of sweet cherry fruits for the fruits of early, medium, and late periods of ripening.

5. The factors, mentioned in paragraph 4, were analyzed by Regressive Analysis Methods in order to determine the degree of impact of each factor on the titrating acids index for the sweet cherry fruits cultivars of three periods of ripening.

As it is known, the analysis of matching correlation coefficients is a primary estimation of the degree of impact of a separate factor on the test index. To compare the degree of the factors' impact on the test index, it is expedient to use another method of statistic analysis, such as Regression Analysis.

But, as the amount of test – factors $X_j,\ j = 1..11$, are one less than the number of observations, (Y_i, for i=1…12 years of investigation), it is not efficient to use a classical pattern of studying the regressive analysis. The factors correlate among themselves, as most of factors matching coefficients are close to k±1. That suggests that there is a multicollinearity effect available.

Thus, it is suggested to develop a regressive model on the basis of the Principal Components Method (principal components analysis, PCA). The Principal Components Method makes it possible to reduce the number of variables by creating artificial factors (principal components). Principal components $(PC_i, i = 1 \dots n)$ represent a linear combination of background factors x_i and don't correlate among themselves. For further analysis is chosen the set of those principal components which takes maximal cumulative dispersion from the variables (Kelechi, 2012; Chen & Ma, 2015).

The creation and the analysis of a regressive model

ISSN-Internet 2197-411x OLCL 862804632
UniKassel & VDW, Germany- December 2022

should be done according to the following stages:

1. On the basis of factors values (indices x_{ij}, $i = 1 \dots n$ – the number of a weather factor, $j = 1 \dots$ the number of a research year) the set of principal components is created $(PC_i, i = 1..n)$. Then the first principal components are selected $(PC_i, i = 1..k, k < n)$, which ensure the main part of a cumulative dispersion efficiency – more than 90 % (Kelechi, 2012).

2. Develop a regressive dependence of the indices y_1, y_2, y_3 on the developed principal components $(PC_i, i = 1 \dots k)$:

$$\hat{Y} = b_0 + \sum_{j=1}^{k} b_j \cdot PCA_j \qquad (2)$$

3. Transform the regressive model (2) by replacing the principal components of their formulas through the background factors $(x_i, i = 1 \dots n)$. After such transformations regressive dependences of titrating acids indices on the background factors can be analyzed:

$$\hat{Y} = a_0 + \sum_{j=1}^{n} a_j \cdot X_j, \qquad (3)$$

where X_j – factors; a_j – model parameters; $\hat{Y}$ – the value of titrating acids content in sweet cherry fruits.

4. On the basis of a developed model (3), the degree of impact of each factor on the resulting indices is analyzed.

The comparative analysis of the degree of impact of each weather factor X_j on the value of titrating acids content in sweet cherry fruits is done on the basis of coefficients Δ_j. These coefficients characterize the relative degree of each factor's impact $(X_j, j = 1..n)$ on the analyzed index Y. Coefficients Δ_j are counted according to the formula:

$$\Delta_i = \left|\frac{\tilde{a}_i \cdot r_{YX_i}}{R^2}\right|, \qquad (4)$$

$\tilde{a}_i$ – parameters of a regressive model in standardized factors values;

Standardized factors values are counted according to the formula:

$\tilde{x}_{ij} = \frac{x_{ij} - \bar{X}_j}{sd(X_j)}$ –, i=1..12, j=1..11; x_{ij} – base value of a factor, i=1..12, j=1..11; $\bar{X}_j$ – average value of a factor, j=1..11; $sd(X_j)$ – standard factors deviations, j=1..11. r_{YX_i} – matching coefficients of correlation; R^2 – determination coefficient.

On the basis of calculated values on the formula (4), factors according to their impact degree were arranged.

Some tools of modern computer technologies of Data Mining – software environment of RStudio – were used to make statistical analysis.

3. Results

Among the most important indicators of sweet cherry fruits for consumers, when they choose fruits, is taste. The formation of taste qualities of fruits depends on a harmonious combination of sugar and organic acid [Hajagos et al., 2012]. But there is not enough information in the available literature about the content of titrating acids in sweet cherry fruits which are grown in Ukraine. The experiment of 2008-2019 established that the average amount of titrating acids in sweet cherry fruits, grown under conditions of fruit farms in the analyzed region of Ukraine, amounted to 0.61% (Table 2-4). Maximal average titrating acids content of 1.00% was registered in sweet cherry fruits of the Udivitelna cultivar in a group of late ripening cultivars. Among the cultivars of two other groups, the fruits of cultivars Valeriy Chkalov and Dilema were characterised by the largest average titrating acids content. They accumulated 0.53% and 0.72% of titrating acids respectively. According to studies by *L. Shubenko et al.* (2021) which were conducted in the conditions of Ukraine, the highest content of titrating acids was recorded in the fruits of a medium-term ripening Alionushka (0.75%), and the lowest one in the fruits of a late-term of ripening Amazonka (0.45%). According to the data of Polish researchers (Bieniek et al., 2011), among the cultivars which were studied for three years a cultivar Agila had the highest content of organic acids in sweet cherry fruits (1.07%), and a cultivar Seda had the lowest content (0.45%). As follows from a 20-year-long study, the cultivars of an early term of ripening (Zabuta, Valeriy Chkalov, Swit

Earlies) accumulated a maximal amount of titrating acids, and the cultivars Merchant, Rubinova Rannia – accumulated the least amount of titrating acids (Table 2).

The fruits of the Chervneva Rannia cultivar, which were picked in 2015 and 2011, were respectively characterised by a minimal and maximal titrating acids content in a group of cultivars of medium-term ripening (Table 3).

A maximal mass portion of titrating acids in a group of cultivars of a late-term of ripening was established in the fruits crop of 2016 of the Udivitelna cultivar (Table 4).

In a group of cultivars of medium-term ripening, a maximal average content of titrating acids was recorded in the fruits of Dilema and Chervneva Rannia cultivars and in the group of late-term ripening – in the fruits of Colhoznitsa and Crupnoplidna cultivars (Table 3, 4). The results of the scientific research show that the sweet cherry cultivars, which were studied, differ in biochemical composition of fruits, in titrating acids content, in particular. This conclusion is proved by the data received by other researchers (Usenik et al., 2008; Antognoni et al., 2020; Corneanu et al., 2020). The estimation of 15 sweet cherry cultivars as to fruit quality was conducted in conditions in Romania (Corneanu et al., 2020). It was found that the titrating acids content fluctuates at a range of 0,39% (cultivar 'Andreiaş') – 0.87% (cultivar 'Cătălina'). It was found by E. Szpadzik et al. (2019) that in conditions of Poland the fruits of sweet cherry cultivars Sylvia and Regina had the lowest acidity (about 0.5%), and the fruits of a cultivar Techlovan had the highest acidity (above 0.7%). As a result of research by A. Hajagos (2012) it was found that there is a significant difference between the cultivars Regina and Kordia as to the accumulation of common acids in sweet cherry fruits. Besides, according to the research data, the content of a test index in fruits of both cultivars depended on the stock and on the stage of ripening of sweet cherry fruits. The analysis of the values of the coefficients of variations showed that the weather factors most affected the titrating acids content in Sweet Earlies and Kazka varieties (Vp=21.6% and 21,4% respectively). Valeriy Chkalov variety had a minimal variation coefficient on the level of 19.7%. From among the cultivars of medium-term ripening the fruits of Vynka, Talisman, Octavia, Prostir were characterised by a minimal variation coefficient (Vp=19.7%). In a group of cultivars of late-term ripening, the most stable TA content was the Karina variety (Vp=17.7%).

Table 2. Titrating acids content (TA) and sugar-acid index (SAI) in the sweet cherry fruits of the varieties of an early term of ripening, % (2008-2019), , n=5

Pomological variety	Average titrating acids content, %	Titrating acids content, %		Variation according to years, Vp, %	Sugar-acid index (SAI)
		min	max		
Rubinova Rannia	0.38±0.08	0.25	0.54	20.7	32.5
Valeriy Chkalov	0.53±0.10	0.31	0.72	19.7	23.6
Sweet Erliz	0.53±0.11	0.39	0.73	21.6	24.2
Merchant	0.37±0.07	0.29	0.54	20.1	28.5
Kazka	0.49±0.10	0.29	0.66	21.4	23.7
Bigaro Burlat	0.47±0.09	0.33	0.69	20.5	23.6
Zabuta	0.53±0.11	0.34	0.67	20.3	23.5
Average value	0.47±0.11	0.26	0.73	24.3	25.4
LSD_{05}	0.029	–	–	–	

ISSN-Internet 2197-411x OLCL 862804632

Table 3. Titrating acids content (TA) and sugar-acid index (SAI) in sweet cherry fruits of the varieties of a medium term of ripening, % (2008–2019), , n=5

Pomological variety	Average titrating acids content, %	Titrating acids content, %		Variation according to years, Vp, %	Sugar-acid index (SAI)
		min	max		
Vynka	0.67±0.13	0.50	0.89	19.7	18.3
Pervystok	0.64±0.13	0.47	0.80	20.1	19.4
Temp	0.57±0.12	0.40	0.67	21.3	23.9
Uliublenytsia Turovtseva	0.70±0.15	0.44	0.90	22.0	15.5
Talisman	0.70±0.13	0.47	0.87	19.7	20.8
Dilema	0.72±0.14	0.50	0.91	20.0	17.9
Melitopolska Chorna	0.63±0.13	0.41	0.81	20.6	17.7
Kordia	0.63±0.14	0.39	0.85	22.5	20.9
Oktavia	0.66±0.13	0.41	0.79	19.7	20.9
Orion	0.61±0.13	0.35	0.82	22.6	22.0
Chervneva Rannia	0.71±0.20	0.34	1.01	29.3	15.5
Dachnytsia	0.69±0.14	0.39	0.80	20.3	22.6
Prostir	0.66±0.13	0.43	0.80	19.74	19.2
Average value	0.66±0.14	0.34	1.00	20.7	19.5
LSD_{05}	0.038	–	–	–	

Table 4. Titrating acids content (TA) and sugar-acid index (SAI) in sweet cherry fruits of the varieties of a late term of ripening, % (2008–2019), , n=5

Pomological variety	Average titrating acids content, %	Titrating acids content, %		Variation according to years, Vp, %	Sugar-acid index (SAI), relative units
		min	max		
Krupnoplidna	0.72±0.139	0.41	0.86	19.2	19.9
Karina	0.65±0.116	0.39	0.79	17.7	18.9
Regina	0.67±0.134	0.34	0.81	20.1	17.3
Mirazh	0.68±0.132	0.40	0.86	19.3	20.1
Udivitelna	1.00±0.201	0.56	1.30	20.0	13.0
Zodiak	0.65±0.129	0.43	0.84	19.8	20.2
Surpryz	0.62±0.117	0.35	0.76	18.7	21.3
Kolhoznytsia	0.74±0.149	0.46	1.01	20.0	16.9
Kosmichna	0.63±0.123	0.42	0.81	19.4	21.2
Prazdnichna	0.59±0.114	0.37	0.71	19.2	21.6
Anons	0.66±0.138	0.32	0.81	20.7	18.5
Temporion	0.63±0.092	0.43	0.74	14.5	20.4
Meotyda	0.70±0.149	0.39	0.92	21.2	20.1
Average value	0.69±0.163	0.32	1.29	23.6	19.0
LSD_{05}	0.025	–	–	–	

Consumers evaluate the sweet taste of fruits which is emphasized by freshness due to the content of the organic acid (Takácsné Hájos et al., 2011). The best taste depends on harmony between a high sugar content and medium or high acid content. According to the data in tables 2-4, the rate of average values of SAI in the fruits of tested groups is within 13.0-25.4 r.u. As many as 31 sweet cherry cultivars of all terms of ripening with the range of the value within 16.9-28.5 r.u. have been determined by means of optimal SAI parameters. Udivitelna cultivar (SAI – 13.0 r.u.) and Rubinova Rannia cultivar (SAI – 32.5 r.u.) were an exception. There is an opinion that when the SAI value is higher than 30 r.u., the fruit flavour will be too sweet, and when the SAI value is lower than 15 r.u. – it will be too acidic (Serdyuk & Stepanenko, 2015). On the whole, the variation (as to TA content) of the group of cultivars of early, medium, and late-term ripening under the abiotic factors impact was high.

To determine the degree of weather factors impact and cultivar's particular qualities on the formation of titrating acids amount in sweet cherry fruits, a two-way analysis of variance was made (Table 5). The results of the experiment show that for all groups, irrespective of ripening term, the weather conditions which were during the period of 12 years of the experiment (Factor A) had a dominating impact on titrating acids formation. The degree of impact of Factor A for a group of an early term of ripening is 70.3%, for a group of medium-term ripening – 44.5%, and for a group of late-term ripening – 45.8%.

The effects of a cultivar's particular qualities (Factor B) were less substantial. An impact degree of a given factor was from 8.3% to 35.9% for a cultivar group that was analyzed. For a group of cultivars of medium and late terms of ripening the varietal features (Factor B) had a significant impact with a share of influence – 25.1 and 35.9% respectively. The influence of this factor on the fruits of an early term of ripening was low, with a share of influence of 8.3%. Thus, the experiment results show the expediency of titrating acids content prognostication in sweet cherry fruits by the medium values for a particular cultivars group, but not for each pomological cultivar.

Table 5. Results of two-factors dispersion analysis under titrating acids content fund formation in sweet cherry fruits

Source of variation	Sum of squares	Degree of freedom	Dispersion	F_{fact}	$F_{table\ 095}$	Impact, %
Sweet cherry varieties group of an early period of ripening						
Factor A (year)	2.020	11	0.184	594.0	1.8	70.3
Factor B (variety)	1.070	6	0.178	576.8	2.2	8.3
Interaction AB	0.253	66	0.004	12.4	1.4	19.5
Sweet cherry varieties group of a medium period of ripening						
Factor A (year)	6.955	11	0.632	1159.9	1.8	44.5
Factor B (variety)	0.823	12	0.069	125.8	1.8	25.1
Interaction AB	1.934	132	0.015	26.9	1.3	27.9
Sweet cherry varieties group of a late period of ripening						
Factor A (year)	5.738	11	0.522	2129.7	1.8	45.8
Factor B (variety)	4.504	12	0.375	1532.3	1.8	35.9
Interaction AB	2.166	132	0.016	66.9	1.3	17.3

ISSN-Internet 2197-411x OLCL 862804632

Weather factors ranking according to the degree of their impact on titrating acids accumulation in sweet cherry fruits cultivars of three terms of ripening has established that average monthly precipitation in May (X1) has a maximal impact and belongs to the 1st rank; for the cultivars of the medium term of ripening the average minimal relative air humidity in May (X3) are of the same importance. The analysis of weather conditions (factors) X_i impact on titrating acids index Y in sweet cherry fruits of early, medium and late ripening terms was done on the basis of calculated matching coefficients of correlation r_{YX_i} and on testing the meaningfulness of these correlation coefficients. In order to receive this target, Student's criteria were used and tested a statistical hypothesis $H_0: \rho = 0$ (ρ – correlation coefficient of entire assembly) when using an alternative hypothesis $H_1: \rho \neq 0$ under significance value $\alpha = 0{,}05$. As the calculations showed, significant correlation coefficients under the significant value $\alpha = 0{,}05$ and under the number of degrees of freedom $k = 10$ are within an interval [-0.55;0.55].

As a result, 11 factors that in a specified growing period may affect the titrating acids accumulation in sweet cherry fruits of the early, medium, and late ripening terms, were selected. These thermal air parameters (°C) are the difference between average, maximal, and minimal temperature in May (X_6), June (X_7), and during the period of fruit picking (X_9). Humidity indices (%, мм) are the average monthly precipitation amount in May (X_1); average monthly air humidity in May (X_2), the average minimal relative air humidity in May (X_3), in June (X_4), and during the period of fruits picking (X_{10}); a total amount of days with precipitation more than 1 mm in May (X_5); precipitation amount during the period of blooming and fruits ripening (X_8); average relative air humidity during the period of fruits picking (X_{11}). Further study is conducted according to the research design given above.

First step. Five principal components were selected by the Principal Components Method $(PC_i, i = 1..5)$. These 5 components ensured more than 95% of cumulative dispersion (Cumulative Proportion of Variance).

Second step. Regressive models of titrating acids index dependence on the principle components were designed for each cultivars group $(PC_i, i = 1..5)$ of a variety (2).

The regression equation for early cultivars looked like this:

$$\hat{Y}_1 = 0{,}4760 + 0{,}0288PC_1 + 0{,}0051PC_2 - 0{,}0195PC_3$$
$$-0{,}0467PC_4 + 0{,}0527PC_5$$

The regression equation for the medium cultivars group looked like this:

$$\hat{Y}_2 = 0{,}6664 + 0{,}0405PC_1 - 0.0186PC_2 - 0.0451PC_3$$
$$-0.0456PC_4 + 0.0057PC_5$$

The regression equation for the late cultivars group looked like this:

$$\hat{Y}_3 = 0{,}6918 + 0{,}0338PC_1 + 0{,}0132PC_2 - 0.0006PC_3$$
$$-0.0193PC_4 - 0.0807PC_5$$

The value of the determination coefficient (R – squared) for early cultivars amounted to 0.9181, for medium cultivars – 0.9199, and for late cultivars – 0.7156, which indicates a strong impact of independent variables on dependent variables. The values p-value < 0.05 for all regressive models indicate the validity of the models on the basis of Fisher criteria under the level of significance – 0.05.

Third step. After passing to base factors, the model looks like (3). This regressive model characterizes the dependence of the accumulation index of titrating acids (for $\hat{Y}_1, \hat{Y}_2, \hat{Y}_3$) on weather factors (in a standard form).

The regressive model of dependence of accumulation index of titrating acids on weather factors, expressed in a standard form is:

– for early cultivars it looks like this:

$$\hat{Y}_1 = 0{,}62875\tilde{X}_1 + 0{,}1820\tilde{X}_2 + 0{,}2612\tilde{X}_3 + 0{,}13290\tilde{X}_4$$
$$+0{,}490352\tilde{X}_5 - 0{,}17954\tilde{X}_6 - 0{,}0456\tilde{X}_7 + 0{,}19142\tilde{X}_8$$
$$+0{,}062705\tilde{X}_9 + 0{,}267523\tilde{X}_{10} + 0{,}12964\tilde{X}_{11}$$

– for medium cultivars it looks like this:

$$\hat{Y}_2 = 0{,}489599\tilde{X}_1 + 0{,}312162\tilde{X}_2 + 0{,}335628\tilde{X}_3$$
$$-0{,}0361\tilde{X}_4 + 0{,}335628\tilde{X}_5 - 0{,}19027\tilde{X}_6 + 0{,}066303\tilde{X}_7$$
$$+0{,}2263\tilde{X}_8 - 0{,}22744\tilde{X}_9 + 0{,}347166\tilde{X}_{10} + 0{,}30343\tilde{X}_{11}$$

– for late cultivars it looks like this:

$$\tilde{Y}_3 = 0{,}445998\tilde{X}_1 + 0{,}121565\tilde{X}_2 + 0{,}217837\tilde{X}_3$$
$$+0{,}28610\tilde{X}_4 + 0{,}428744\tilde{X}_5 - 0{,}26322\tilde{X}_6 - 0{,}26471\tilde{X}_7$$
$$+0{,}099087\tilde{X}_8 + 0{,}063256\tilde{X}_9 + 0{,}180767\tilde{X}_{10} + 0{,}053937\tilde{X}_{11}$$

On the basis of designed models, for each factor coefficients $\Delta_i, i = 1..14$ are calculated by the formula (3). Coefficients Δ_i determine the degree of each factor in total dispersion of the value of titrating acids content in sweet cherry fruits. On the basis of calculated indices $\Delta_i, i = 1.14$, all factors were ranked depending on the rate of their impact from the most significant (rank 1) to the least important (rank 14). Table 1 shows the indicator values $\Delta_i, \%$ and the rank of factors.

The varieties of the early, medium, and late periods of ripening Δ_i vary within 0.75-34.06 % (Table 6). For further analysis of research results all factors, depending on coefficient values $\Delta_i (i=1...11)$ were divided into 3 groups. The first group- factors that have a strong impact on titrating acids accumulation ($\Delta_i \geq 10{,}37\ \%$); second group – factors that have a medium impact on titrating acids accumulation (Δ_i from 3.00 to 9.31%); the third group – other factors which have little impact on titrating acids accumulation ($\Delta_i \leq 2{,}56\%$).

The first group of factors includes three factors that have a significant impact on titrating acids accumulation in sweet cherry fruits in an early term of ripening. They have a valuation Δ_i in the range of 10.44-34.06%. The factors which have a valuation Δ_i in the range of 11.52-18.33% belong to the first group of factors but are typical for sweet cherry fruits in the medium term of ripening. The experiment has detected some common impacts of three weather factors on titrating acids accumulation in sweet cherry fruits of early and medium terms of ripening. They are humidity indices in May: the average monthly precipitation (X_1), the average minimal relative air humidity (X_3), and the number of days with precipitation more than 1 mm (X_5). The humidity index in May (the average monthly humidity (X_2) also had a significant impact on titrating acids accumulation in sweet cherry fruits of a medium-term ripening.

The factors which have a valuation Δ_i in the range of 10.37-23.99 % belong to the first group of factors and are typical for the sweet cherry fruits of late-term ripening. They are – humidity indices and thermal parameters in May: the average monthly precipitation (X_1), the number of days with precipitation more than 1 mm (X_5), and the difference between average maximal and minimal air temperatures (X_6). The weather parameters in June also have an impact on titrating acids accumulation in sweet cherry fruits of a late-term of ripening: the average minimal relative air humidity (X_4) and the difference between average maximal and minimal air temperatures (X_7).

According to Table 6, the factors that have an average impact on titrating acids accumulation in sweet cherry fruits of early, medium and late terms of ripening with valuations Δ_i from 3.26 to 9.31% belong to the second group. To weather factors, which have an average impact on titrating acids, accumulation belongs:

– for cultivars groups of an early term of ripening: the average monthly relative air humidity (X_2) and the difference between average maximal and minimal air temperatures (X_6) in May; the average minimal relative air humidity (X_4) in June; the amount of precipitation in the period after blooming and before fruits ripening (X_8); the average minimal relative air humidity in the period of fruits picking (X_{10});

– for cultivars groups of medium-term ripening: the average minimal relative air humidity (X_4) and the difference between average maximal and minimal air temperatures (X_7) in June, the amount of precipitation in the period after blooming and before fruits ripening (X_8), the average minimal air humidity (X_{10}) and the average relative (X_{11}) air humidity in the period of fruits picking.

– for cultivars groups of late-term ripening: the average monthly relative air humidity (X_2) and the average minimal relative air humidity (X_3) in May, the amount of precipitation in the period after blooming and before fruits ripening (X_8), the average minimal relative air humidity (X_{10}) in the period of fruits picking.

In the second group of factors for sweet cherry fruits of three terms of ripening, there are two common weather factors, which have a significant impact on titrating acids accumulation in fruits of the early, medium, and late-term storage. They are the amount of precipitation after blooming before fruits ripening (X_8) and average minimal relative air humidity (X_{10}) in

ISSN-Internet 2197-411x OLCL 862804632

Table 6. Table of matching coefficients correlation , impact degree indices), ranks of weather factors (X_i,) on titrating acids content in sweet cherry fruits of early, medium, and late terms of ripening.

Factors (X_i)	Relative factors term (X_i)	Matching coefficients of correlation (), coefficients of factors' degree of impact (and indices of a rank of factors for the cultivars of early, medium, and late groups								
		early			medium			late		
		$r_{y_1x_i}$	Δ_i, %	rank	$r_{y_1x_i}$	Δ_i, %	rank	$r_{y_1x_i}$	Δ_i, %	rank
X_1	Average monthly amount of precipitation in May, mm	0.962	34.06	1	0.856	11.52	4	0.802	23.99	1
X_2	Average monthly relative air humidity in May, %	0.677	6.94	5	0.702	18.33	2	0.635	5.18	7
X_3	Average minimal relative air humidity in May, %	0.710	10.44	3	0.760	19.12	1	0.636	9.31	6
X_4	Average minimal relative air humidity in June, %	0.435	3.26	8	0.305	5.91	8	0.569	10.93	4
X_5	Total amount of days with precipitation more than 1 mm in May, %	0.797	22.02	2	0.724	15.07	3	0.672	19.33	2
X_6	Difference between average maximal and minimal temperatures in May, °C	-0.551	5.57	7	-0.609	0.85	10	-0.587	10.37	5
X_7	Difference between average maximal and minimal temperatures in June, °C	-0.430	1.11	10	-0.284	5.48	9	-0.649	11.54	3
X_8	Amount of precipitation in blooming period and in picking fruits period, %	0.569	6.13	6	0.524	7.15	7	0.503	3.35	9
X_9	Difference between average maximal and minimal temperatures in the period of fruit picking, °C	-0.255	0.90	11	-0.571	0.75	11	-0.207	0.88	11
X_{10}	Average minimal relative air humidity in the period of fruits picking, %	0.464	7.00	4	0.656	7.42	6	0.349	4.24	8
X_{11}	Average relative air humidity in the period of fruits picking, %	0.351	2.56	9	0.620	8.40	5	0.243	0.88	10

the period of fruit picking. The analysis of the ranking of weather factors, which belong to the second group as to their impact on the test index, confirms a mild impact of these factors on titrating acids accumulation in sweet cherry fruits.

Thus, in a cultivars group of an early term of fruits ripening factors (X_2, X_4, X_6X_8, X_{10}) take the fourth – eighth ranks; in a cultivars group of a medium-term of fruits ripening factors (X_2, X_4, X_6X_8, X_{10}) take the fifth – ninth ranks; in a cultivars group of a late-term of ripening factors (X_2, X_4, X_6X_8, X_{10}) take the third – ninth ranks in terms of the degree of their impact.

Other weather factors, which have an insignificant impact on titrating acids accumulation, belong to the third group. According to Table 6, valuations Δ_i for the cultivars of an early term of ripening are from 0.90 to 2.56%; for the cultivars of a medium-term of ripening $\Delta_i\ 0.75\% - 0.85\%$; for the cultivars of a late-term of ripening – 0.88%. A cumulative percentage of the impact of this group of factors for a cultivars group of an early term of ripening amounted to 4.57%, for a cultivars group of a medium-term of ripening it amounted to 1.60%, and for a cultivars group of a late-term of ripening – 1.76%. For all cultivars groups, there is a common weather factor which is 11th as to ranking and, according to the received data, it has an insignificant impact on titrating acids accumulation in fruits of the cultivars of three periods of ripening, This factor is the difference between average maximal and minimal temperatures in the period of fruits picking (X_9). Thus, weather conditions in May have the most significant impact on titrating acid accumulation in sweet cherry fruits irrespective of the period of ripening. These weather conditions are average monthly precipitation amounts (rank 1). For the cultivars of an early term of ripening, the most important are the weather conditions in May, and for the fruits of medium and late terms of ripening the most significant are weather conditions in May and June. It should provide a concise and precise description of the experimental results. All sections and subsections must be numbered.

4. Conclusions

Maximal values of titrating acids content have been established in Valeriy Chkalov, Dilema, and Udivitelna cultivars (0.53, 0.72, and 1.00% respectively) under Vp=19.7-20.0%.

Optimal parameters of the sugar-acid index were also established in the fruits of 31 sweet cherry cultivar samples with the range of the value within 16.9-28.5 r.u. For all groups of cultivars, irrespective of the term of ripening, the weather conditions during the period of research had dominating effects on the formation of titrating acids fund. The correlative analysis of weather conditions' impact on titrating acids amount in sweet cherry fruits of the early, medium, and late terms of ripening has been made. Medium and strong correlative dependences between 11 weather factors (X_i, i=1..11) and the amount of titrating acids for sweet cherry cultivars of early, medium, and late terms of ripening have been established ($\left|r_{Y_jX_i}\right| \geq 0.55$, $i = 1..11, j = 1..3$). The models of dependence of titrating acids accumulation on weather factors impact for cultivars groups of early, medium and late terms of ripening were developed on the basis of Principle Components Method and the Least Squares Method. The analysis of the degree of impact of each weather factor on the titrating acids accumulation index has been made. The calculated coefficients as to the impact of factors $\Delta_i, \%$ showed, that the group of temperature parameters and humidity indices had the most significant impact on the titrating acids accumulation in sweet cherry fruits with a maximal $\Delta_i \geq 10.37\%$ in the total factors impact. The ranges of the degrees of weather factors impact, which have the maximal effects on titrating acids accumulation in sweet cherry fruits (Δ_i 10.37% to 34,06%), have been established. The weather parameters which have the maximal impact on titrating acids accumulation in sweet cherry fruits have been established for the cultivars of three terms of ripening. Early and medium cultivars depend on three weather factors: average monthly precipitation, average minimal relative air humidity, and the total number of days with precipitation more than 1 mm in May. Late cultivars depend on average monthly precipitation, the total number of days with precipitation more than 1 mm, the difference between average maximal and minimal air temperatures in May, average minimal relative air humidity, and the difference between average maximal and minimal air temperatures in June. The weather factors ranking according to the degree of their impact on titrating acids accumulation in sweet cherry fruits of three terms of ripening showed, that average monthly precipitation in May (X_1) has the most significant impact and belongs to the first rank; for the cultivars of medium-term of ripening the average minimal relative air humidity in May (X_3) is the most important. On the basis of Regressive Analysis, it has been substantiated that the weather conditions in May have the most significant impact on titrating acids

ISSN-Internet 2197-411x OLCL 862804632

accumulation in sweet cherry fruits irrespective of the terms of ripening, in particular – the average monthly precipitation (rank 1); the weather conditions in May are the most significant for the cultivars of an early term of ripening; for the cultivars of medium and late terms of ripening the most important are the weather conditions in May and June.

Acknowledgements

The present study is the result of independent research and has not been done with organizational financial support.

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.

References

Antognoni, F., Potente, G., Mandrioli, R., Angeloni, C., Freschi, M., Malaguti, M., Hrelia, S., Lugli, S., Gennari, F., Muzzi, E., & Tartarini, S. (2020). Fruit quality characterization of new sweet cherry cultivars as a good source of bioactive phenolic compounds with antioxidant and neuroprotective potential. Antioxidants, 9(8), 677. doi: 10.3390/antiox9080677

Basanta, M. F., Ponce, N. M. A., Salum, M. L., Rafo, M. D., Vicento, A. R., Erra-Balsolls, R., & Stort, C. A. (2014). Compositional changes in cell wall polysaccharides from five sweet cherry (Prunus avium L.) cultivars during on-tree ripening. Journal of Agricultural and Food Chemistry, 62(51), 12418-12427. doi: 10.1021/jf504357u

Bieniek, A., Kawecki, Z., Kopytowski, J., & Zielenkiewicz, J. (2011). Yielding and fruit quality of Lithuanian sweet cherry cultivars grown under the climatic and soil conditions of Warmia. Folia Horticulturae, 23(2), 101-106. doi: 10.2478/v10245-011-0015-4

Borovinova, M., Tasseva, V., Domozetov, D., Christov, N., & Sredkov, I. (2008). Sweet cherry production in Bulgaria. Acta Horticulturae, 795, 545-550. doi: 10.17660/ActaHortic.2008.795.85

Cao, J., Jiang, Q., Lin, J., Li, X., Sun, C., & Chen, K. (2015). Physicochemical characterization of four cherry species (Prunus spp.) grown in China. Food Chemistry, 173, 855-863. doi: 10.1016/j.foodchem.2014.10.094

Corneanu, M., Iurea, E., & Sîrbu, S. (2020). Biological properties and fruit quality of sweet cherry (Prunus avium L.) cultivars from Romanian assortment. Agronomy Research, 18(4), 2353-2364. doi: 10.15159/AR.20.231

Dziedzic, E., Blaszczyk, J., & Kaczmarczyk, E. (2017). Postharvest properties of sweet cherry fruit depending on rootstock and conditions. Folia Horticulturae, 29(2), 113-121. doi: 10.1515/fhort-2017-0011

Einhorn, T. C., Wang, Y., & Turner, J. (2013). Sweet cherry fruit firmness and postharvest quality of late-maturing cultivars are improved with low-rate, single applications of gibberellic acid. American Society for Horticultural Science, 48(8), 1010-1018. doi: 10.21273/HORTSCI.48.8.1010

Faniadis, D., Drogoudi, P. D., & Vasilakakis, M., (2010). Effects of cultivar, orchard elevation, and storage on fruit quality characters of sweet cherry (Prunus avium L.). Scientia Horticulturae, 125(3), 301-304. doi: 10.1016/j.scienta.2010.04.013

Hajagos, A., Spornberger, A., Modl, P., & Vegvari, G. (2012). The effect of rootstocks on the development of fruit quality parameters of some sweet cherry (Prunus avium L.) cultivars, 'Regina' and 'Kordia', during the ripening process. Agriculture and Environment, 4, 59-70. Retrieved from http://www.acta.sapientia.ro/acta-agrenv/C4/agr4-7.pdf

Ivanova, I., Serdyuk, M., Kryvonos, I., Yeremenko, O., & Tymoshuk, T. (2020). Formation of flavoring qualities of sweet cherry fruits under the influence of weather factors. Scientific Horizons, 4(89). 72–81. doi: 10.31073/10.33249/2663-2144-2020-89-4-72-81

Ivanova, I., Serdyuk, M., Malkina, V., Priss, O., Herasko, T., & Tymoshchuk, T. (2021). Investigation into sugars accumulation in sweet cherry fruits under abiotic factors effects. Agronomy Research, 19(2), 44-457. doi: 10.15159/ar.21.004

Ivanova, I., Serdyuk, M., Malkina, V., Tymoshchuk, T., Vorovka, M., Mrynskyi, I., & Adamovych, A. (2022). Studies of the impact of environmental conditions and varietal features of sweet cherry on the accumulation of vitamin C in fruits by using the regression analysis method. Acta Agriculturae Slovenica, 118(2), 1-12. doi: 10.14720/aas.2022.118.2.2404

Jänes, H., Ardel, P., Kahu, K., Kelt, K., & Kikas, A. (2010). Some biological properties and fruit quality parameters of new sweet cherry cultivars and perspective selections. Agronomy Research, 8(Special Issue III), 583-588. Retrieved from https://agronomy.emu.ee/vol08Spec3/p08s309.pdf

Kask, K., Jänes, H., Libek, A., Arus, L., Kikas, A., Kaldmäe, H., Unive, N., & Univer, T. (2010). New cultivars and future perspectives in professional fruit breeding in Estonia. Agronomy Research, 8(Special Issue III), 603-614. Retrieved from https://agronomy.emu.ee/wp-content/uploads/2010/11/p08s312.pdf

Kelechi, A. C. (2012). Regression and principal component analyses: a comparison using few regressors. American Journal of Mathematics and Statistics, 2(1), 1-5. doi: 10.5923/j.ajms.20120201.01

Liu, Y., Liu, X., Zhong, F., Tian, R., Zhang, K., Zhang, X., & Li, T. (2011). Comparative study of phenolic compounds and antioxidant activity in different species of cherries. Journal Food Science, 76(4), C633–638. doi: 10.1111/j.1750-3841.2011.02150.x

Mahmood, T., Anwar, F., Abbas, M., Boyce, M. C., & Saari, N. (2012). Compositional variation in sugars and organic acids at different maturity stages in selected small fruits from Pakistan. International Journal Molecular Science, 13(2), 1380-1392. doi: 10.3390/ijms13021380

Malyuk, T., Pcholkina, N., & Pachev, I. (2014). Diagnostics of parameters of interrelations of mineral nutrition and formation of yield of fruit crops for intensive technologies of their cultivation. Banat's Journal of Biotechnology, 9, 41-44. doi: 10.7904/2068–4738–V(9)–41

Pereira, S., Silva, V., Bacelar, E., Guedes, F., Silva, A. P., Ribeiro, C., & Gonçalves, B. (2020). Cracking in sweet cherry cultivars early bigi and lapins: Correlation with quality attributes. Plants (Basel), 9(11), 1557. doi: 10.3390/plants9111557.

Sánchez, R. P., Gomez-Sánchez, M. A., & Morales-Corts, M. R. (2008). Agromorphological characterization of traditional Spanish sweet cherry (Prunus avium L.), sour cherry (Prunus cerasus L.) and duke cherry (Prunus × gondouinii Rehd.) cultivars. Spanish Journal of Agricultural Research, 6(1), 42-55. doi: 10.5424/sjar/2008061-293

Picariello, G., De-Vito, V., Ferranti, P., Paolucci, M., & Volpe, M. G. (2016). Species- and cultivardependent traits of Prunus avium and Prunus cerasus polyphenols. Journal of Food Composition and Analysis, 45, 50–57. doi: 10.1016/j.jfca.2015.10.002

Radicevic, S., Cerovic, R., Mitrovic, O., & Glisic, I. (2008). Pomological characteristic and biochemical fruit composition of some canadian sweet cherry cultivars. Acta Horticulturae, 795(1), 283-286. doi: 10.17660/ActaHortic.2008.795.39

Radunic, M., Spika, M. J., Strikic, F., Ugarkovic, J., & Cmelik, Z. (2014). Pomological and chemical characteristics of sweet cherry cultivars grown in Dalmatia, Croatia. Acta Horticulturae, 1020, 385-388. doi: 10.17660/ActaHortic.2014.1020.54

Savchovska, S., & Nesheva, M. (2021). Fruit quality characteristics of the Bulgarian sweet cherry cultivar 'Rozalina'. Romania Journal of Horticulture, 2, 93-98. doi: 10.51258/RJH.2021.12

Serdyuk, M., Ivanova, I., Malkina, V., Kryvonos, I., Tymoshchuk, T., & Ievstafiieva, K. (2020a). The formation of dry soluble substances in sweet cherry fruits under the influence of abiotic factors. Scientific Horizons, 3(88), 127-135. doi: 10.33249/2663-2144-2020-88-3-127-135

Serdiuk, M. E., Priss, O. P., Haprindashvili, N. A., & Ivanova, I. Ye. (2020b). Research methods of fruit, vegetable and berry products. Melitopol: Liuks.

Serdyuk, M. Y., & Stepanenko, D. S. (2015). Formation of the taste of plum fruits under the influence of abiotic factors. Eastern-European Journal of Enterprise Technologies, 4(10(76)), 55-60. doi: 10.15587/1729-4061.2015.46579

Serra, A. T., Duarte, R. O., Bronze, M. R., & Duarte, C. M. M. (2011). Identification of bioactive response in traditional cherries from Portugal. Food Chemistry, 125(2), 318–325. doi: 10.1016/j.foodchem.2010.07.088

Shaaban, F. K. M., El-Hadidy, G. A. M., & Mahmoud, T. S. M. (2020). Effects of salicylic acid, putrescine and moringa leaf extract application on storability, quality attributes and bioactive compounds of plum

ISSN-Internet 2197-411x OLCL 862804632

cv. 'Golden Japan'. Future of Food: Journal on Food, Agriculture & Society, 8(2), 1-14. doi: 10.17170/kobra-202007201466

Shubenko, L., Shokh, S., Fedoruk, Yu., Mykhailiuk, D., & Vuiko, A. (2021). The content of the main chemical elements in sweet cherry fruits of different ripening periods. Agrobiologiya, 1, 173-179. Retrieved from https://agrobiologiya.btsau.edu.ua/en/content/content-main-chemical-elements-sweet-cherry-fruits-different-ripening-periods

Sîrbu, S., Niculaua, M., & Chiriță, O. (2012). Physico-chemical and antioxidant properties of new sweet cherry cultivars from Iași, Romania. Agronomy Research, 10(1–2), 341-350. Retrieved from https://agronomy.emu.ee/wp-content/uploads/2012/12/p10108.pdf

Szpadzik, E., Krupa, T., Wojciech, N., & Jadczuk-Tobjasz, E. (2019). Yielding and fruit quality of selected sweet cherry (Prunus avium) cultivars in the conditions of central Poland. Acta Scientiarum Polonorum Hortorum Cultus, 18(3), 117-126. doi: 10.24326/asphc.2019.3.11

Takácsné-Hájos, M., Nyéki, J., Veres, E., Fieszl, C., & Szabó, Z. (2011). Organoleptic evaluation of sweet cherry varieties. International Journal of Horticultural Science, 17(4-5), 7–13. doi: 10.31421/IJHS/17/4-5/959

Usenik, V., Fabćić, J., & Štampar, F. (2008). Sugars, oganic acids, phenolic composition and antioxidant activity of sweet cherry (Prunus avium L.). Food Chemistry, 107(1), 185–192. doi: 10.1016/j.foodchem.2007.08.004

Usenik, V., Fajt, N., Mikulic-Petkovsek, M., Slatnar, A., Stampar, F., & Veberic, R. (2010). Sweet cherry pomological and biochemical characteristics influenced by rootstock. Journal of Agricultural and Food Chemistry, 58(8), 4928–4933. doi: 10.1021/jf903755b

Zeman, S., Jemric, T., Cmelik, Z., Fruk, G., Bujan, M., & Tompic, T. (2013). The effect of climatic conditions on sweet cherry fruit treated with plant growth regulators. Journal of Food, Agriculture and Environment, 11(2), 524-528. Retrieved from https://www.academia.edu/22383848/The_effect_of_climatic_conditions_on_sweet_cherry_fruit_treated_with_plant_growth_regulators