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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

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Abstract: The accumulation of vitamin C in sweet cherry fruits depends on the variety and environmental conditions. The aim of our research was to substantiate the rate of impact of weather factors as well as of varietal features on vitamin C accumulation in sweet cherry fruits. The varieties 'Kazka' and 'Zabuta', 'Kordia' and 'Mirazh' were chosen as the best ones from among 33 varieties of early, medium and late term of ripening (7.31–10.67 mg 100 g^{-1}) according to the average content of vitamin C in sweet cherry fruits. The studies found that the environmental conditions of the research years had the largest impact on the vitamin C content in the fruits of late and early ripening varieties, and in the fruits of medium ripening variety the vitamin C amount depended on the varietal features. The practicability of forecasting of vitamin C content in sweet cherry fruits on the average indices for a group of early and late maturity varieties, but not separately for every pomological variety, has been proven. For the medium ripening variety this index can be forecasted within each pomological variety. The models of dependence of vitamins C accumulation on the impact of meteorological parameters were evaluated on the basis of the principle components analysis and the least square method.

Key words: antioxidants; variety; terms of fruit ripening; vitamin C; weather conditions; principle components analysis

Preučevanje vpliva vremenskih dejavnikov in lastnosti sort na vsebnost vitamin C v plodovih češenj z metodo regresijske analize

Izvleček: Količina vitamin C v plodovih češenj je odvisna od sorte in okoljskih razmer. Namen te raziskave je bil ovrednotiti vpliv vremenskih dejavnikov in lastnosti sort na količino vitamina C v plodovih češenj. Izmed 33 zgodnjih, srednjih in poznih sort so bile izbrane najboljše sorte kot so 'Kazka','Zabuta', 'Kordia' in 'Mirazh' glede na poprečno vsebnost vitamin C (7,31–10,67 mg 100 g^{-1}) v plodovih. Raziskava je odkrila, da so imele na vsebnost vitamina C v plodovih zgodnjih in poznih sort češenj največji vpliv vremenske razmere posamezne rastne sezone, pri srednje dozorevajočih sortah pa so imele največji vpliv na vsebnost vitamina lastnosti sort. Dokazana je bila možnost napovedovanja vsebnosti vitamina C v plodovih zgodnjih in poznih sort na osnovi povprečnih indeksov, vendar ne za vsako sorto posebej. Za srednje dozorevajoče sorte bi lahko uporabili ta indeks za vsako sorto posebej. Model za ugotavljanje odvisnosti kopičenja vitamina C v odvisnosti od vremenskih dejavnikov je bil ovrednoten na osnovi analize glavnih komponent in metode najmanjšega kvadrata.

Ključne besede: antioksidanti; sorte; čas dozorevanja; vitamin C; vremenske razmere; analiza glavnih komponent

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1 INTRODUCTION

Sensible nutrition of people is one of the main priorities of the state policy of most countries. The fruits are considered as an essential element of good nutrition, as they are the source of a vitamin complex. Vitamins belong to a group of indispensable nutrients of organic nature, which facilitate metabolism. They are scarcely synthesized in an organism, so they should be in taken with food. The amount of vitamin C in fruits (Bastos et al., 2015; Hayaloglu & Demir, 2015) is an important characteristic of fruits for their consumption in raw condition, for processing and storing (Vasylyshyna, 2018). One of the directions of solving the defined problem is to provide the population with fruits with a high amount of biologically active substances which are essential for people (Dhandevi & Jeewon, 2015).

The sweet cherry fruits (*Prunus avium* L.) belong to the food stuff which contains digestible sugars, phenolic acids with a predominant amount of anthocyanins, mineral substances and vitamins (Leong & Oey, 2012; Pissard et al., 2016; Ivanova et al., 2021a, 2021b, 2021c). Biologically active substances represented by phyto-nutrients and antioxidants provide antioxidant, anti-cancerogenic and anti-phlogogenic action on human organism (Ballistreri et al., 2013; Popescu et al., 2014; Legua et al., 2017). Due to this, sweet cherry fruits reveal some preventive effect against cardiovascular diseases, diabetes, cancer, which is connected with an oxidative stress (He et al., 2007; Faniadis et al., 2008; Schmitz-Eiberger & Blanke, 2012). Sweet cherry fruits are characterized by a high amount of dietary medicative substances, which promote to organism functioning. Sweet cherry fruits contain water soluble (C, B) and fat soluble (A, E, K) vitamins (Antognoni et al., 2020). Vitamins take part in oxidation-reductions, respiration, nucleic acids formation and amino-acids exchange, protein secretion as well as improve carbohydrate digestion. Besides, they control cholesterol metabolism, prevent the accumulation of harmful free radicals in body tissues, improve the resistance to infectious diseases as well as to unfavorable environmental factors which cause overheating, excessive heat loss, hypoxia and improve person's performance (Bastos et al., 2015). Vitamin C or L-ascorbic acid is one of the most important phyto-nutrients, which determines the biological value of sweet cherry fruits. Vitamin C belongs to a group of water soluble vitamins (Antognoni et al., 2020). Vitamin C amount in sweet cherry fruits equals 7.26–10.78 mg 100 g^{-1} on the average. In living organisms, the ascorbic acid is an antioxidant, as it protects the organism against the oxidative stress and is a co-factor in essential vital enzyme reactions (Nowak et al., 2018; Antognoni et al., 2020). The immunity protection and the maintaining of psychical processes in a proper condition are the most important functions of vitamin C. Vitamin C is one of the regulators of reductive-oxidative processes in living cells. Vitamin C scarcity results in metabolic disorder in the whole organism (Prior, 2003). For a human an every-day need for vitamin C equals 50–100 mg. Vitamin C scarcity in a human diet can cause hypoavitaminosis and avitaminosis C, as this vitamin is not synthesized in an organism (Acero et al., 2019). Fresh fruits are the main source of vitamin C. This fact testifies to the expediency of prolonging the term of fruits consuming. Thus, it is important to retain this valuable nutritive constituent under sweet cherry fruits keeping and processing (Correia et al., 2017). Palatability traits and biochemical composition of sweet cherry fruits depend on the genetic traits of the variety (Serrano et al., 2005; Faniadis et al., 2008; Correia et al., 2020). The researchers have produced the varieties of stone fruits which meet modern requirements, but there are still some problems which are very topical (Correia et al., 2017; Grandi et al., 2017). The chemical composition of the fruits of any harvest, except varietal features, depend on the meteorological conditions of the growing period as well as of the zone of fruit growing (Hayaloglu & Demir, 2015; Luna-Vázquez et al., 2016).

The researchers of the subtropical regions of Brazil estimated the chemical composition, identificated the biologically active compounds and estimated the antioxidant activity of berries and fruits including sweet cherries. It was established that the amount of ascorbic acid in the fruits of the subtropical regions of Brazil is much higher than in the zone with moderate climate (Rios de Souza et al., 2014). The formation of the biochemical composition of sweet cherry fruits as well as of their consumption value depend on the temperature, light intensity, fruit ripeness (Martini et al., 2017; Acero et al., 2019). The dependence of vitamin C amount on the meteorological indicators within the period from blooming to stone fruit ripening was studied by many scientists. A higher concentration of vitamin C in fruits was registered in the years with sufficient water availability (Lakatos et al., 2010, 2014). The level of ascorbic acid content in fruits is formed genetically. But the weather factors during the growing period have great impact on the accumulation of vitamin C fund (Bieniek et al., 2011). The greatest amount of vitamin C is formed during the years with moderately warm and wet growing period. A sufficient fruits lightning is a very important factor which affects the process of ascorbic acid synthesis (Kevers et al., 2011). On the basis of literature sources it can be stated that there is a strong correlation between vitamin C amount and the environmental conditions of the region of fruit growing. Under conditions of climate changes, stress abiotic factors have negative impact on the formation of vitamin C fund in sweet cherry fruits under conditions of a Southern Steppe sub-zone of Ukraine. Therefore, there is a necessity to study the peculiarities of vitamin C accumulation in sweet cherry fruits of different terms of ripening under the influence of stress weather factors in order to single out the most suitable varieties for fruit storing and processing.

The aim of the study was to develop a model for vitamin C content forecasting in the fruits of early, medium and late terms of ripening depending on the environmental conditions. The received mathematic model is the basis for the forecasting of a test parameter of fruits quality in the regions with similar environmental conditions. The task of the research was to recommend the fruits of early, medium and late maturity varieties with a high amount of vitamin C for consuming fresh as well for fruit storing and processing.

To achieve the aim, it is necessary to:

- analyze the environmental conditions during the period of phenological stages of sweet cherry fruits growing and developing;
- estimate the vitamin C amount in fruits on the stage of their economic maturity and choose the best varieties;
- study the correlations between the accumulation of vitamin C and weather factors and to develop the mathematical models of their dependence;
- estimate the rate of impact of each weather factor on the formation of vitamin C fund in test varieties of three groups.

2 MATERIALS AND METHODS

The research was conducted during 2008–2019 in sweet cherry fruiteries in the Southern Steppe sub-zone of Ukraine. The region is characterized by insufficient water availability as to the amount of rainfalls. The climate is Atlantic-continental, dry with a high temperature regime. The dry winds are of Northeastern direction. According to the complex of climatic parameters, the test region is favorable for sweet cherry fruits growing (Table 1). The data of Melitopol meteorological station of the South of Ukraine (46° 49'N, 35° 22'E) were used for the calculation of the model of forecasting of vitamin C amount in sweet cherry fruits

The research areas have black southern loamy soil, which was formed on the loesses. The agrochemical characteristic of soil is given in Table 2.

The technology of sweet cherry growing in the experiment was standard for a given region. The scheme of trees planting in 2001 was – 5 × 3 m. The space between rows on the fruit plantation was kept under autumn fallow. All sweet cherry varieties on ‚Magalebska' cherry rootstock were divided into three groups according to the term of ripening (early, medium and late): early term of ripening 7 varieties, medium term of ripening 13 varieties, late term of ripening 13 varieties. The fruits of an early ripening term were harvested in the third decade of June and in the first decade of July. The fruits of a medium ripening term were harvested in the second decade of July. The fruits of a late ripening term were harvested in the third decade of July. To study the vitamin C amount, 100 fruits were chosen from 6 trees of each sweet cherry variety of the same age on the stage of heavy bearing with average intensity. There was a threefold frequency of variants in the experiment. The fruits of each variety were picked by hand from four different sides of the tree crown on

Table 1: Meteorological conditions of Southern Steppe sub-zone of Ukraine

Readings	Value
Average annual air temperatures, °C	9.1–9.9
Average monthly air temperatures in the warmest months, C	20.5–23.1
Sum of active temperatures higher than 10 C from April to October, C	3316
Average amount of rainfalls per year, mm	475
Average annual relative air humidity, %	73
Average annual air velocity, m s^{-1}	3
Hydrothermic coefficient	0.22–0.77

Table 2: Agrochemical characteristics of topsoil of tested soil

			Nutrient content, mg g^{-1} 100 of soil		
Depth of arable layer, cm	Humus content, %	pH_{kCl}	N	P_2O_5	K_2O
40.0	1.38	6.9	27.0	90.0	154.0

the stage of economic maturity. After harvesting the fruits, they were weighed and counted (Serdyuk et al., 2020). The sweet cherry fruits were transported to the laboratory for 2–3 hours after their harvesting to estimate the tested parameter. During the period of sweet cherry fruits harvesting, their economic maturity was estimated by visual and organoleptic examination. The fruit pulp was rather firm, color and flavor were typical for each pomological variety. The sweet cherry fruits were harvested with a fruit-stalk. The fruits transportation and storing were conducted under condition of preserving of the external appearance and flavor typical for a variety.

The restoring of Tilman's reagent (2.6-dichlorphenol-indophenol) was taken as the basis of the technique on the evaluation of a mass fraction of vitamin C. The amount of ascorbic acid in the extracts (Serdyuk et al., 2020) was evaluated in terms of the amount of the reagent which was used for titration.

The model of dependence of vitamin C amount in sweet cherry fruits on the weather factors was developed according to the schedule (Ivanova et al., 2021a, 2021b):

1. Evaluation of a mass fraction of ascorbic acid (AA).
2. Analysis of the weather factor during the years of the research.
3. Choosing the weather factor which show the correlation with vitamin C amount in fruits.
4. Developing the regression model of dependence of vitamin C amount in the fruits of sweet cherry varieties on the weather factor.
5. Evaluation and ranging of the rate of impact of each weather factor on the tested parameter of fruits quality.

The statistical analysis was made using modern computer technologies DataMining – software environment RStudio.

3 RESULTS AND DISCUSSION

For the sweet cherry fruits of three groups of ripening the average content of vitamin C equaled 8.17 mg 100 g^{-1} (Tables 3–5). The accumulation of vitamin C in the fruits of seven cultivars grown in Turkey was analyzed by Demir T. The average content of vitamin C in sweet cherry fruits varied between 4 and 7 g kg^{-1} of fresh mass (Demir, 2013). The ascorbate levels for 22 sweet cherry cultivars grown in southern of Italy was considerably lower – 0.034–0.260 g kg^{-1} of fresh mass (Matteo et al., 2016). The rate of accumulation of vitamin C fund in sweet cherry fruits of an early term of ripening equaled 7.10 mg 100 g^{-1}, which is by 13.1 % lower as compared with the average index for three groups.

In a group of an early term of ripening the varieties, 'Kazka' (7.36 ± 1.40 %) and 'Zabuta' (7.31 ± 1.49 %) had the largest vitamin C content on the average during the years of studies. In the fruits of 'Bigaro Burlat' variety vitamin C content was the lowest (6.84 ± 1.22 %). The fruits of 'Bigaro Burlat' (the early term ripening group) had the lowest content of vitamin C in 2018 – 5.02 mg 100 g^{-1}, which is for 26.6 % lower than the average varietal parameters. The fruits of 'Merchant' variety had a maximal accumulation of vitamin C (11.29 mg 100 g^{-1}) in 2019, which is for 63.6 % higher as compared with the average varietal parameters. The highest content of vitamin C during the years of research was in 'Kazka' and 'Zabuta' varieties, and the lowest – in 'Bigaro Burlat' variety (Table 3).

The average content of vitamin C in sweet cherry

Table 3: The accumulation of vitamin C in sweet cherry fruits of early term ripening varieties, mg 100 g^{-1} (2008–2019), $\overline{x} \pm S\overline{x}$, n = 5

Variety	Vitamin C content, %			Variation according to years, Vp, %
	average	min	max	
'Bigaro Burlat'	6.84 ± 1.22	5.02	9.83	17.9
'Zabuta'	7.31 ± 1.49	5.16	10.27	20.4
'Kazka'	7.36 ± 1.40	6.08	10.12	19.1
'Merchant'	6.90 ± 1.84	5.18	11.29	26.7
'Rubinova Rannia'	6.92 ± 1.28	5.12	9.03	18.5
'Sweet Erliz'	7.26 ± 1.68	5.17	11.00	23.1
'Valeriy Chkalov'	7.13 ± 1.54	5.19	10.12	21.5
Average value	7.10 ± 1.46	5.26	10.23	21.02
LSD_{05}	0.579	–	–	–

Table 4: Vitamin C content in sweet cherry fruits of medium term ripening varieties, mg 100 g^{-1} (2008–2019), $\overline{x} \pm s\overline{x}$, n=5

Variety	Vitamin C content, %			Variation according to years, Vp, %
	average	min	max	
'Chervneva Rannia'	5.95 ± 1.06	4.12	7.67	17.9
'Dachnytsia'	6.32 ± 1.11	5.01	7.88	17.5
'Dilema'	10.94 ± 2.20	8.19	14.51	20.1
'Kordia'	10.63 ± 1.81	8.01	13.85	17.1
'Oktavia'	10.11 ± 1.74	7.40	12.08	17.2
'Oktavia'	9.25 ± 2.25	5.12	12.47	24.3
'Orion'	10.46 ±1.83	7.51	12.82	17.8
'Pervystok'	9.05 ± 1.59	6.34	11.18	17.5
'Prostir'	7.73 ± 1.19	5.19	9.27	15.4
'Talisman'	10.48 ± 2.46	7.23	14.11	23.4
'Temp'	8.07 ± 1.49	5.89	9.85	18.5
'Uliublenytsia Turovtseva'	9.02 ± 1.60	6.11	11.91	17.7
'Vynka'	8.08 ± 1.51	6.23	10.14	18.7
Average value	8.93 ± 2.27	6.33	11.36	18.7
LSD_{05}	0.645	–	–	–

fruits of two varieties (medium and late terms of ripening) equals 8.93 ± 2.27 % and 8.48 ± 1.74 % respectively (Table 4, 5). The rate of formation of vitamin C fund in sweet cherry fruits of medium term of ripening exceeds the average varietal parameters by 3.8 % and in the fruits of late term of ripening by 9.3 %. It has been established that the fruits of a medium term of ripening had the maximal content of vitamin C.

In a medium term ripening group a minimal amount of vitamin C had the fruits of 'Dachnytsia',

Table 5: Vitamin C content in sweet cherry fruits of late ripening varieties, mg 100 g^{-1} (2008–2019), $\overline{x} \pm s\overline{x}$, n = 5

Variety	Vitamin C content, %			Variation according to years, Vp, %
	average	min	max	
'Anons'	8.20 ± 1.59	5.71	11.81	19.3
'Karina'	8.33 ± 1.48	5.78	10.28	17.7
'Kolhoznytsia'	7.85 ± 1.24	5.79	10.92	15.8
'Kosmichna'	8.95 ± 1.60	6.69	12.03	17.9
'Krupnoplidna'	7.74 ± 1.16	5.79	10.23	14.9
'Meotyda'	8.03 ± 1.45	5.61	10.72	18.1
'Mirazh'	10.67 ± 1.49	8.28	14.14	14.0
'Prazdnichna'	10.25 ± 2.02	7.61	13.08	19.7
'Regina'	7.29 ± 1.01	6.03	10.54	13.8
'Surpryz'	8.10 ± 1.47	5.65	11.01	18.2
'Temporion'	7.72 ± 1.44	5.01	9.76	18.7
'Udivitelna'	7.58 ± 1.31	5.41	9.23	17.3
'Zodiak'	9.60 ± 1.46	7.79	11.19	15.2
Average value	8.93 ± 2.27	6.33	11.36	18.7
LSD_{05}	0.645	–	–	–

′Temp′ and ′Chervneva Rannia′ varieties of 2008. Vitamin C content was lower than the average varietal parameter by 20.7 %, 27.0 % and 30.7 % respectively. A maximal amount of vitamin C was registered in the fruits of ′Talisman′ (14.11 %) and ′Dilema′ (14.51 %) of 2010 that is by 34.6 and 32.6 % higher than the average varietal parameter. The highest accumulation of an average content of vitamin C was registered in the fruits of ′Dilema′ (10.94 ± 2.20 %) and ′Kordia′ (10.63 ± 1.81 %) varieties.

In a late term ripening group a minimal amount of vitamin C had the fruits of ′Temporion′ variety (5.01 %) of 2008 (Table 5). The content of vitamin C was by 9.8 % lower than the average varietal parameter. The fruits of ′Mirazh′ (14.14 %) and ′Prazdnichna′ (13.08 %) of 2014 had a maximal amount of vitamin C that is by 34.9 and 27.6 % higher as compared with an average varietal parameter. A maximal accumulation of an average vitamin C content was registered in the fruits of ′Mirazh′ (10.67 ± 1.49 %) and ′Prazdnichna′ (10.25 ± 2.02 %). Especially valuable are the varieties whose fruits are characterized by a high and stable amount of vitamin C content (Leong & Oey, 2012).

Their variation parameter Vp can be used as an indicator of stability – of a variety in reference to the meteorological conditions of different years of fruits growing. The variation of sampling can be considered insignificant or low under the Vp lower than 10 %, average – under 10 – 20 % and high under 20 % and more. Therefore, the varieties whose fruits have a high and stable vitamin C content are of special value.

The variability of vitamin C content during the years of research in the sweet cherry fruits of an early and medium terms of ripening was in the range from 15,4 to 26,7 %. For a group of early ripening varieties (′Valeriy Chkalov′, ′Svit Earliz′, ′Merchant′ and ′Zabuta′) the variation parameter equaled 20.4–26.7 %, for a group of medium terms ripening varieties (′Talisman′, ′Dilema′, ′Oktavia′) Vp equaled 20.1–24.3 %. It testifies to a maximal impact of weather factors on vitamin C content in the sweet cherry fruits of these groups. The variation parameter for ′Prostir′ and ′Bigaro Burlat′ varieties equals 15.4 % and 17.9 % respectively that testifies to their resistance to stress factors.

The Vp range for the sweet cherry fruits of the late term of ripening varied within the average values 13.8–19.7 %. The lowest values of the variation parameter were registered in ′Regina′ and ′Mirazh′ varieties (Vp = 13.8–14.0 %). The highest vitamin C stability in a group of an early term of ripening is in ′Bigaro Burlat′ variety (Vp = 17.9 %). The varieties ′Kazka′ and ′Zabuta′ have the highest rate of vitamin C accumulation (7.36 ± 1.40 %) and (7.31 ± 1.49 %) respectively. The most perspective from the point of view of fruits storing and processing are ′Kordia′ (Vp = 17.1 %) of the medium term and ′Mirazh′ (Vp = 14.0 %) of the late term of ripening. These varieties are characterized by a high and nearly high content of vitamin C as well as by minimal variability as compared with other varieties. The received results of the research have been confirmed by literature data (Bieniek et al., 2011). The chemical composition analysis of fruit revealed significant differences both between the cultivars and between the years of the research.

Environmental conditions, Factor A (Table 6) had the greatest impact on vitamin C content in the fruits of

Table 6: The results of two factors dispersion analysis under the accumulation of vitamin C in sweet cherry fruits of different terms of ripening

Source of variation	Sum of squares	Degree of freedom	Dispersion	F_{fact}	$F_{table095}$	Impact, %
Group 1, early ripening sweet cherry varieties						
Factor A (year)	448.5	11	40.7	321.5	1.8	80.2
Factor B (cultivar)	9.9	6	1.6	13.0	2.2	1.7
Interaction AB	79.6	66	1.2	9.5	1.4	1.2
Group 2, medium term sweet cherry varieties						
Factor A (year)	998.05	11	90.7	577.7	1.8	39.1
Factor B (cultivar)	1266.13	12	105.5	671.9	1.8	49.6
Interaction AB	237.68	132	1.8	11.4	1.3	9.3
Group 3, late ripening sweet cherry varieties						
Factor A (year)	640.38	11	58.2	244.3	1.8	43.5
Factor B (cultivar)	513.89	12	42.8	179.7	1.8	34.9
Interaction AB	241.40	132	1.8	7.67	1.3	16.4

early and late terms of ripening. The rate of impact of the environmental conditions of the years of research (Factor A) for early ripening varieties equaled 80.2 %, for late ripening varieties only 43.5 %. The rate of impact on varietal features (Factor B) was significantly lower for these two groups of varieties in terms of ripeness rate. For early ripening varieties, it equaled 1.7 %, for late ripening varieties 34.9 %. It was established that the formation of vitamin C fund in the sweet cherry fruits of medium term of ripening depended on the varietal features (Factor B, 49.6 %). The impact of environmental conditions of the research years (Factor A) for this group of varieties equaled 39.1 %.

The research shows the practicability of forecasting of vitamin C accumulation in fruits of early and late ripening sweet cherry varieties in terms of average variety values but not for each pomological variety. The forecasting of accumulation of vitamin C fund in the fruits of medium ripening varieties is expedient to make in terms of average varietal parameters and rate of content for each pomological variety.

To establish the correlation relationships between vitamin C content in fruits of early (Y_1), medium (Y_2), late (Y_3) terms of ripening and the climatic factors, the following analysis was made. On the basis of the established matching coefficients of correlation r_{Y1Xi}, r_{Y2Xi}, r_{Y3Xi} were chosen the most significant factors. The significance of these correlation coefficients was established by checking a statistical hypothesis H_0: $p = 0$ (where p - is a correlation coefficient of general population) under the alternative hypothesis H_1: $p \neq 0$ under the reliability level $\alpha = 0{,}05$. Student's criteria was used to check the statistical hypothesis. It was established that significant correlation coefficients, under the significance level of 0.05 and the number of degrees of freedom $k = 10$, were within an interval [–0.55; 0.55].

Further experiments were conducted according to the schedule:

First step. On the basis of the principle components analysis we build a set of the principal components PC_i $(i = 1 \ldots n)$ represented by a liniar combination of weather factors:

$$PC_i = \sum_{j=1}^{m} p_{ij} X_j, \; i = 1 \ldots n \tag{1}$$

where X_j – weather factors parameters, $j = 1..m$

PC_i - principal components, $i = 1 \ldots n$

p_{ij} - coefficients, $i = 1 \ldots n$, $j = 1..m$.

We choose first five principal components (PC_i, $i = 1..5$), which provide more than 93,5 % of cumulative proportion of variance.

Second step. The development of the regression models of dependence of vitamin C value on the weather factors for each group of varieties from the principal components was as follows:

$$\hat{Y} = b_0 + \sum_{i=1}^{5} b_i \cdot PC_i \tag{2}$$

where $\hat{Y}$ – vitamin C content, mg 100 g^{-1}

PC_i - principal components, $i = 1 \ldots 5$

b_i - regression coefficients, $i = 1 \ldots 5$.

The regression equation for early ripening varieties is as follows:

$$\hat{Y}_1 = 7.10762 - 0.41631PC_1 + 0.13542PC_2 + 0.61543PC_3 + 0.13960PC_4 - 0.25401PC_5$$

The regression equation for medium ripening varieties is as follows:

$$\hat{Y}_2 = 8.9078 - 0.4252PC_1 + 0.1872PC_2 - 0.0064PC_3 + 0.7698PC_4 + 0.1628PC_5$$

The regression equation for late ripening varieties is as follows:

$$\hat{Y}_3 = 8.4881 - 0.3533PC_1 + 0.3044PC_2 - 0.0150PC_3 - 0.1113PC_4 - 0.0869PC_5$$

The value of the determination coefficient (R-squared) for early ripening varieties equals 0.9239, for medium –ripening, 0.7273, for late ripening varieties, 0.7069, it indicates that there is a strong impact of independent variables on the dependent variables.

The p-value is < 0.05 for F-statistic value for all regression models, it testifies to the adequacy of the models according to Fisher's criterion under the level of significance -0.05.

Third step. We proceed from the principal components to the initial factors by applying formula 1. We carry on the standardization process of variable models. We receive a regression model which characterizes the dependence of vitamin C value (for $\hat{Y}_1, \hat{Y}_2, \hat{Y}_3$) from weather factors.

$$\hat{Y} = \sum_{j=1}^{n} \tilde{a}_j \cdot \tilde{X}_j \tag{3}$$

where $\tilde{X}_j = \dfrac{X_j - \bar{X}_j}{\sigma_{X_j}}$ – values of weather and environmental factors in a standardized form $j = 1 \ldots n$

$\bar{X}_j$ - arithmetic mean of factors X_j, $j = 1 \ldots n$

σ_{X_j} - standard deviation of factors X_j, $j = 1 \ldots n$

$\tilde{a}_j$ - model coefficients, $j = 1 \ldots n$

$\hat{Y}$ - vitamin C content, mg 100 g^{-1}.

Table 7 presents the coefficients of model (3) for vitamin C content in sweet cherry fruits of early $(\hat{Y}_1)$, medium ($\hat{Y}_2$) and late ($\hat{Y}_3$) terms of ripening.

The coefficients $\Delta_i, (i = 1..12)$ were estimated by formula for each factor on the basis of the developed models:

$$\Delta_i = \left| \frac{\tilde{a}_i \cdot r_{yx_i}}{R^2} \right| \tag{4}$$

where $\tilde{a}_i$ - coefficients of a regression model (3)

r_{yx_i} - matching coefficients correlation

$R^2 -$ determination coefficients.

Twelve parameters of the climatic factors (X_i) which in a particular growing period could have a significant impact on the ascorbic acid content in the sweet cherry fruits of early (Y_1), medium (Y_2) and late (Y_3) ripening varieties were chosen (Table 8).

Ta**ble 7:** Coefficients of a regression model in standardized factors

	$\tilde{a}_1$	$\tilde{a}_2$	$\tilde{a}_3$	$\tilde{a}_4$	$\tilde{a}_5$	$\tilde{a}_6$
$\hat{Y}_1$	-0,529	-0,131	-0,207	-0,067	-0,234	-0,278
$\hat{Y}_2$	-0,420	-0,164	-0,225	-0,082	-0,167	-0,263
$\hat{Y}_3$	-0,360	-0,444	-0,478	0,070	-0,309	0,120
	$\tilde{a}_7$	$\tilde{a}_8$	$\tilde{a}_9$	$\tilde{a}_{10}$	$\tilde{a}_{11}$	$\tilde{a}_{12}$
$\hat{Y}_1$	-0,382	0,061	-0,021	-0,227	-0,183	0,101
$\hat{Y}_2$	-0,320	0,129	0,056	-0,184	-0,090	0,056
$\hat{Y}_3$	-0,166	0,477	0,147	0,004	0,380	0,064

These parameters are the following: air humidity; average monthly air humidity in May (X_2); average monthly precipitation amount in May (X_1) and in June (X_{11}); average number of days with precipitation amount more than 1 mm in May (X_5), June (X_6) and July (X_7); average minimal relative air humidity in May (X_3) and in June (X_4); the amount of precipitation during the period after blooming (X_{10}); hydrothermal coefficient (X_{12}). The parameters (X_8), the difference between the average maximal and minimal temperatures in May, and in June (X_9) were chosen from among the temperature air indicators (°C).

A complex of weather factors which have average and strong linear correlation dependence in terms of vitamin C content has been established for each group of varieties.

The factors of impact which are expedient to study from the point of view of the importance and the logicality of the experiment, despite the insignificance of their correlation coefficients, have been found.

The coefficients Δ_i estimate the rate of each factor in a total dispersion of vitamin C amount in sweet cherry fruits. On the basis of the estimated indices $\Delta_i, i=1..12$ we rank all the factors in terms of their impact from the most significant (rank 1) to the factor which has the lowest impact (rank 12). Table 7 represents the values of index $\Delta_i, \%$ and the rank of factors.

For the experimental groups of sweet cherry varieties of three terms of ripening, Δ_i varies in the range of 0.16 – 30.64 % (Table 7). According to the estimated indices $\Delta_i, (i=1..12)$ all the factors were divided into the ranks.

An average monthly amount of precipitation in May (X_1) had a maximal impact on vitamin C content in sweet cherry fruits of early and late ripening varieties. An average precipitation amount in June (X_{11}) had impact on the formation of vitamin C fund in sweet cherry fruits of late term of ripening. This parameter got the first rank and varied in the range of Δ_i indices from 14.92 % to 30.64 %. Air humidity indices had a significant impact on vitamin C content in sweet cherry fruits.

The parameters of the second rank are average monthly relative air humidity in May (X_2), late term of ripening, total number of days with precipitation amount more than 1 mm in June (X_6), medium term of ripening, total number of days with precipitation amount more than 1 mm in July (X_7), early term of ripening. The significance of the rate of impact of these factors, Δ_{X6}, Δ_{X7}, Δ_{X2}, was in the range of 11.57–18.57 %.

Weather factors which have a significant impact on vitamin C formation in sweet cherry fruits of three groups belong to the parameters of the third rank, they are: average minimal air humidity in May, % (X_3), a total number of days with precipitation amount more than 1mm in June (X_6). The rate of impact equaled Δ_{X7} = 18.57 % for the varieties of an early term of ripening, and for the varieties of medium and late terms of ripening the rate of impact equaled Δ_{X3} 11.38 % and 14.81 % respectively. The factors of the 1–7th ranks with the rates of impact Δ_i (6.09–30.64 %) had a maximal impact on vitamin C content for early ripening varieties of sweet cherry.

Table 8: The table of the coefficients of matching correlation $(r_{Y_j X_i})$, indices of the impact rate (Δ_i) and their ranks, which characterize the impact of factors (X_i) on vitamin C content in the sweet cherry fruits of three terms of ripening

Relative factors		Matching coefficients of correlation ($r_{Y_j X_i}$), indices of the impact rate of factors (Δ_i) and indices of the factors ranks for the varieties groups								
		early ripening			medium ripening			late ripening		
term (X_i)	Factors	$r_{y_1x_i}$	Δ_i	rank	$r_{y_2x_i}$	Δ_i	rank	$r_{y_3x_i}$	Δ_i	rank
X_1	Average monthly amount of precipitation in May, mm	0.889	30.64	1	0.651	23.86	1	0.535	13.45	4
X_2	Average monthly relative air humidity in May, %	0.712	6.09	7	0.575	8.22	7	0.479*	14.87	2
X_3	Average minimal relative air humidity in May, %	0.733	9.90	4	0.579	11.38	3	0.443*	14.81	3
X_4	Average minimal relative air humidity in June, %	0.201*	0.88	11	0.348*	2.49	10	0.476*	2.34	11
X_5	Total number of days with precipitation amount more than 1 mm in May, per day	0.531*	8.09	5	0.702	10.25	5	0.431*	9.29	5
X_6	Total number of days with precipitation amount more than 1 mm in June, per day	0.604	10.97	3	0.503*	11.57	2	0.719	6.03	8
X_7	Total number of days with precipitation amount more than 1 mm in July, per day	0.745	18.57	2	0.368*	10.28	4	0.634	7.37	7
X_8	Difference between average maximal and minimal temperatures in May, °C	−0.52*	2.07	9	−0.29*	3.35	9	−0.24*	8.24	6
X_9	Difference between average maximal and minimal temperatures in June, °C	−0.27*	0.36	12	−0.27*	1.35	12	−0.541	5.56	9
X_{10}	Amount of precipitation in blooming period, mm	0.498*	7.37	6	0.631	10.13	6	0.528	0.16	12
X_{11}	Average monthly amount of precipitation in June, mm	0.159*	1.90	10	0.683	5.38	8	0.563	14.92	1
X_{12}	Hydrothermical coefficient	0.480*	3.15	8	0.452	1.74	11	0.661	2.97	10

*some important factors which must be studied in the experiment as expedient and logical ones, though their correlation coefficients are not significant

Some additional impact on vitamin C content had the following parameters: average minimal relative air humidity in June (X_4); the difference between average maximal and minimal temperatures in May (X_8); the difference between average maximal and minimal temperatures in June (X_9); average monthly precipitation amount in June (X_{11}); hydrothermical coefficient (X_{12}). The overall value of index Δ_i for factors X_{12}, X_8 and X_{11}, X_4, X_9 equaled 8.36 %.

Factors of 1–8 ranks had a maximal impact on vitamin C content for medium ripening varieties. The range of Δ_i for them was in the range of 5.38–23.86 %. A less significant impact on the formation of vitamin C content in sweet cherry fruits of a medium term of ripening had the climatic parameters like: average minimal relative air humidity in June (X_4), the difference between average maximal and minimal temperatures in May (X_8); the difference between average maximal and minimal temperatures in June (X_9); hydrothermical coefficient (X_{11}). The overall value of index Δ_i for factors X_4, X_8, X_9, X_{11}, which belong to ranks 9–12 within the given group of sweet cherry varieties, equaled 8.93 %.

All factors in a group of late ripening sweet cherry varieties (Δ_i – 5.56–14.92 %) had a largest impact on the formation of vitamin C content. The factors of 10–12 ranks (X_{10}, X_{11}, X_{12}) had a less significant impact on vitamin C content in sweet cherry fruits of a given group. The overall value of index Δ_i for them equaled 5.47 %.

The analysis of the rate of impact of weather factors on vitamin C content in sweet cherry fruits of three terms of ripening testifies to the fact that the most significant climatic parameters are: humidity indices in May and June (the last months of fruits formation), the average monthly precipitation amount in May (X_1) for early ripening and medium ripening varieties, and the precipitation depth in June (X_{11}) for late ripening varieties respectively.

4 CONCLUSIONS

1. The varieties 'Kazka' (7.36 mg 100 g^{-1}), 'Zabuta' (7.31 mg 100 g^{-1}) have been chosen in terms of vitamin C content for the group of an early term of ripening. 'Bugaro Burlat' variety (with a minimal variability parameter Vp = 17.9 %) has been chosen in terms of minimal variability parameter during the years of research.

2. A medium ripening variety 'Kordia' (10.63 mg 100 g^{-1} under Vp = 17.1 %) and late ripening variety 'Mirazh' (10.67 mg 100 g^{-1} under Vp = 14.0 %) were chosen as the most perspective from the point of view of fruit storing and processing in terms of vitamin C content. The variation parameters of vitamin C content in sweet cherry fruits of three terms of ripening ranged from 13,8% to 26,7%.

3. The environmental conditions of the years of research (Factor A) – 43.5 % and 80.2 % respectively, had a dominating impact on vitamin C content in the fruits of late and early ripening varieties.

4. The impact of varietal features (Factor B) was dominating (49.6 %) in terms of vitamin C content in the sweet cherry fruits of medium term of ripening.

5. The models of dependence of vitamin C content on the impact of climatic conditions for three groups of varieties were developed by using the method of the principle components and the method of least squares.

6. The analysis of the rate of impact of each meteorological parameter on vitamin C content in sweet cherry fruits was made by using the developed regression models. The range of impact of the meteorological parameters in the formation of vitamin C fund has been established and their maximal values (Δ_i 14.92 % to 30.6 %) for the groups of three-term ripening varieties have been estimated.

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