Effect of temperature and humidity on quality score of sour cherry fruits *(Prunus cerasus* L.)

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Abstract

Vasilishina, O. (2017). Effect of temperature and humidity on quality score of sour cherry fruits (Prunus cerasus L.). *Rastenievadni nauki*, *54*(6), 35–40

The article presents the effect of climate conditions during the growing season of sour cherry on the chemical composition of fruits. It is established that the chemical composition of sour cherry fruits formed during ripening, 15 days before harvesting. The content of soluble substances and sugars in fruits significantly increased with the rise of the sum of effective temperatures with almost no rainfall (12.8 mm). The same conditions help to reduce the acidity of the fruit and increased sugar-acid index to 10. The content of tannins and coloring substances in fruits of sour cherry is consistently high regardless of weather conditions (1.00-1.04%). It is found a strong correlation dependence between hydrothermal coefficient and content of dry soluble substances and deduced regression equation.

Key words: sour cherry; fruits; chemical composition; weather conditions

INTRODUCTION

Formation of the chemical composition of fruits, including cherries, depending on the species, variety, degree of ripeness, growing area, weather conditions and so on (Sahno, 2001; Kawecki et al., 2006). To a large extent this changes the quality of food and dietary value products (Caprio and Quamme, 2006; Xu et al., 2007).

Fruit sugars in an amount of 6.5-21.5% are glucose (3.8-5.3%), fructose (3.3-4.4%) and sucrose (0.8%). Acids in them are 0.7-3.0%, mainly found in apple and lemon, and a small amount – formic acid and traces of salicylic acid. In relation to the sugars they determine the sweet and sour taste of cherry fruits (Zheng et al., 2009a; Zheng et al., 2009b; Wani et al., 2014). Fruits contain vitamin C (10-50 mg/100 g), and vitamins B_1, B_2, B_9, PP. Tannins in an amount of 0.05-0.34% provide the tartness of the fruits. However, the number of useful substances in the fruits is 0.8% (Skurikhin, 1978; Naychenko and Osadchy, 1999; Kolesnikov, 2003).

Daily moisturizing, minimum and maximum temperatures at different periods of growth of the tree are the main factors that determine the yield of cherries. The terms of ripening of fruits depend on the cultivation characteristics. For example, warm weather in June and July contributes to early ripening, and low temperatures with heavy rains cause late ripening of fruits (Kawecki et al., 2006; Crespo et al., 2010; Kaldmae et al., 2013).

Weather conditions, especially before harvesting, affect cultivation of cherries. Warm weather during flowering with temperatures above 16°C ensures good pollination of the flowers (Caprio and Quamme, 2006). Low temperature during flowering causes a decrease in performance grade (Bublyk et al., 2002). High rainfall reduces productivity due to cracking of the fruits. High daytime temperatures above 33°C during the harvest is disastrous (Caprio and Quamme, 2006).

Quality of cherry fruits is a varietal character and changes during the growing season (Bublyk, 2002). Different varieties of sour cherries have different reactions to changing weather conditions, including changes in the hydrothermal coefficient (HTC), especially in the last period of ripening – 10-15 days before harvesting (Chernozubenko, 1993).

High temperatures and reduced humidity increase the content of soluble dry substances, including sugars (Shyrko and Yaroshevich, 1991; Kanhina et al., 1992). In years with high temperatures and minimal rainfall during ripening their acidity is reduced. In years with a cool and humid weather in this period – conversely, the acidity is increased (Yushev and Sharova, 1976).

Rainfall, temperature and humidity affect accumulation of ascorbic acid in fruits. Cool weather, with lots of rainfall, is one of the positive factors for accumulation of ascorbic acid in the fruits (Chernozubenko, 1993; Kaldmae et al., 2013). Low temperature during the development of sour cherry increases its content in the friuts (Shyrko and Yaroshevich, 1991).

Content of tannins in the fruit sour cherries varies depending on weather conditions, but less than ascorbic acid (Chernozubenko, 1993). The total content of phenolic compounds depends on the temperature of growing fruit. Strawberries grown at a temperature of 25-30°C, has a higher content of anthocyanins and phenols. The formation of basic phenols (anthocyanins) observed in the last few weeks before harvest, contributing to the antioxidant activity (Wani et al., 2014).

According to Kaldmae et al. (2013), the average temperature in July is negatively correlated with the content of ascorbic acid, and positively with content of dry soluble substances and organic acids. Rainfall in July is negatively correlated with total sugar content and the ratio of sugar to acid with a correlation coefficient $r = -0.82$ and $r = -0.75$, accordingly.

The purpose of this research is to study the formation of sour cherry fruit quality indicators, depending on the length of the growing season and weather conditions.

MATERIAL AND METHODS

The study was conducted at the Department of Technology of storage and processing of fruits and vegetables at Uman National University of Horticulture.

The sour cherry harvesting was carried out in the plantations of the Uman region with Lotovka variety. The scheme of trees was 5x3 m. The intersection is held under the black steam, the slope strips under the herbicide ferry. The soil is typical for the forest-steppe zone: medium-humus podzolized chernozem.

One sample of 2 kg of fully ripe sour cherries per cultivar was collected from each plot in the middle of the harvesting season. Fruit harvesting took place before noon. The sample of 2 kg fruits was homogenized using a kitchen blender and analyzed within the same day for content of soluble solids, organic acids, ascorbic acid, tannins and coloring substances. Dry soluble solids were analyzed by the digital refractometer RPL (GOST 28562-90) at 20°C. The ferri-cyanide method was used for total sugar content analysis (Naychenko, 2001). Organic acids were determined by titration with 0.1 NaOH (GOST 25555.0-82). The content of tannins and coloring substances was analyzed by the method of Neubauer and Leventhal (Naychenko, 2001). Ascorbic acid was determined using the modified Tillman's method, it was titrated with 2,6-dichloroindophenol under acid conditions (Naychenko, 2001). Experiments were triple three times and then the mean values of all results were calculated.

The data were statistically processed using one and two factor analysis of variance (ANOVA) at significance level $P < 0.05$ on the PC program Statistica.

RESULTS AND DISCUSSION

A significant difference in the length of the growing season sour cherries in 2013 has been established compared to other years of studies (Table 1). It was, probably, due to hydrothermal conditions during the ripening of fruits 15 days before harvest. In particular, in the last 15 days of ripening in 2013 the amount of effective temperature was 318.3°C, while in 2014 and 2015 it was 49.3°C and 31.5°C lower, respectively, and in 2016 it was 174.7°C. At the same time, the amount of rainfall was reduced in 2014 to 8.7 mm and in 2015 and 2016 respectively to 39.8 and 21.9 mm with increased HTC 5.5. These conditions contributed to the longer ripening of fruits.

Obviously, total rainfall has a stronger impact on sour cherry fruit during the growth season than the temperature. Specifically, compared with hydrothermal conditions in 2013, the sum of effective temperatures during the growing season in 2016 was lower - 174.7°C, and in 2014 and 2015 years it was 49.3°C and 31.5°C, respectively. But rainfall in 2016 was only 8.7 mm less than in 2013, while rainfall for the 15-day period of maturation in 2015 was 39.8 mm, in 2016 – 21.9 mm, respectively, with HTC 5.5 in 2013 and HTC 4.1 and 4.8 in 2015 and 2016, respectively. With lower rainfall and lower temperatures the fruits have ripened longer at 2015 year. Thus, reduced amount of effective temperatures and increased precipitation in the final stage prolongs the period of ripening.

Chemical composition of sour cherry fruits (Table 2) depend on climatic parameters in the last 15 days of maturation.

The content of dry soluble matter (17.4%) was higher in the sour cherry fruits accumulated at 2015. This is due to the high temperature and almost no rain during the last 15 days of ripening. For these 15 days the sum of effective temperatures amounted to 286.8°C, 17.8°C more than 2014, and the rainfall were small (12.8 mm).

Significant reduction of dry soluble substances (14.8%) was recorded in sour cherry fruits harvested at 2014 and 2016 years, which were characterized by low amount of effective temperatures, especially in the last 15 days of ripening, while rainfall were up to 43.9 and 30.7 mm. This is confirmed by the increasing value of HTC 2.1 to 1.6 in the last 15 days of maturation.

The level of generalized indicator of fruit quality – dry soluble substances significantly increased with increasing the amounts of effective temperatures to 286.8°C and reducing the rainfall to 12.8 mm in the last 15 days of maturation at 2015 year.

According to Table 2 majority (63-68%) of dry soluble substances in sour cherry fruits occupy sugars. Their content in the fruits ranges from 10 to 14%. The high level of sugars (14.0%) in the fruits harvested at 2015 coincides with their natural ac-

Table 1. Agroclimatic performance during the growing season of sour cherry fruits (according to Uman weather station)

Year	Growing season, days	Sum of effective temperatures, °C		Rainfall, mm		HTC	
		growing season	phase of ripening 15 days	growing season	phase of ripening 15 days	growing season	phase of ripening 15 days
2013	80	710.3	318.3	191.9	52.6	2.7	1.7
2014	84	546.1	269.0	298.5	43.9	5.5	1.6
2015	89	564.2	286.8	233.9	12.8	4.1	0.4
2016	80	398.2	143.6	191.1	30.7	4.8	2.1

Table 2. Content of some components of the chemical composition of sour cherry fruits

Year	Dry soluble substances, %	Sugars, %	Acid (in terms of malic), %	Sugar-acid index	Tannins and coloring substances, %	Ascorbic acid, mg/100g
2013	15.0±0.31	10.1±0.19	1.50±0.09	6.7	1.04±0.17	20.0±0.33
2014	14.8±0.23	10.0±0.18	1.40±0.08	7.1	1.00±0.14	22.0±0.23
2015	17.4±0.29	14.0±0.23	0.84±0.08	16.6	1.03±0.16	13.2±0.32
2016	14.8±0.21	10.1±0.20	0.90±0.06	11.2	1.04±0.17	22.0±0.34
NSD	0.5	0.2	0.70	0.7	0.50	0.7

cumulation as dry soluble substances. Increased sugar content of the fruits at 2015 to 40% is due exclusively to high temperatures without effective amount of rainfall in the last 15 days of maturation. This is confirmed by the results of Chernozubenko (1993) and Kaldmae et al. (2013), according to whom the warm weather in June and July contributes to early ripening of fruits and sugar accumulation. Since the difference in sugar content in the sour cherry fruits over the years of research is minimal, it is believed that thermal resources and almost no precipitation in the last 15 days of maturation had a significant impact on the synthesis of sugars.

Acid content is an important component of the chemical composition of the fruits. Its level in sour cherry fruits is 0.9-1.5%. However, the level of fruit acid depends on environmental factors. Given that there is no significant difference between the acid content in the fruits at 2014 and 2013 (1.4% and 1.5%), the decreased acid content in the fruits harvested at 2015 and 2016 years (0.84% and 0.9%) can be explained by its own lows of synthesis and accumulation. In dry and hot weather conditions during ripening more fruit acid rapidly accumulated, its content increased by 6.7% and 44% in 2014 and 2015 compared with 2013 year. Conversely, the significant reduction in the content of fruit acid in 2015 and 2016 is due to the increase in rainfall and the temperature decrease.

This confirms the results obtained from Chernozubenko (1993) and Kaldmae et al. (2013), according to whom the longer ripening of the fruits and accumulating the higher levels of fruit acid is a result of low temperatures and adequate humidity.

The fruit sugar content is expressed by sugar-acid index, which in sour cherry varies over the years. The sour cherry fruits can be classified as moderately acidic with sugar-acid index 6.7-16.6.

Biologically active substances of sour cherry fruits are submitted by polyphenolic substances and ascorbic acid. The total content of tannins and coloring substances in fruits is consistently high - average 1.00-1.04%. Weather conditions had no significant effect on its level.

The content of ascorbic acid in sour cherry fruit was quite labile, its size – 13.2-22% mg/100g changed under the influence of weather conditions during the growing season, especially during the 15-day period of maturation. The concentrations of ascorbic acid was high - 22 mg/100g in 2014 and 2016, 13.2 mg/100g in 2015 and 20.0 mg/100g in 2013. In 2014 and 2016 the amount of effective temperature decreases 1.1 and 2.3 times, the rainfall increases 3.4 and 2.0 times, respectively, compared to 2015 year, and HTC reaches 1.6 and 2.1. In 2013 and 2015 years the amount of effective temperatures was highest, and precipitation is practically absent in 2015 year. Thus, the high content of ascorbic acid in sour cherry fruits correlated with weather conditions during ripening. In the most extreme conditions of 2015, characterized by dry weather during ripening, the content of ascorbic acid in fruits was lowest − 13.2 mg/100g. This confirmed the results obtained by Zheng et al. (2009a, 2009b) and Kaldmae et al. (2013).

Since the weather conditions during the growing season and 15 days before harvesting significantly affect the chemical composition of the sour cherry fruits, we have established a correlation relationship between these parameters (Table. 3).

There is a strong correlation between air temperature during the growing season and acids (r = 0.99), and between air temperature and tannins and coloring substances (r = 0.98). The fruit quality was less influenced by the rainfall. There is a strong correlation dependence between the content of soluble dry matter and hydrothermal coefficient

Table 3. Correlations between weather conditions and parameters of the chemical composition in sour cherry fruits

Weather conditions	Dry soluble substances	Sugars	Acids	Tannins and coloring substances	Ascorbic acid
Temperature	0.31	0.28	0.99	0.98	-0.43
Rainfall	-0.83	-0.86	0.28	0.99	0.74
SCC	-0.96	-0.95	-0.50	-0.61	0.95

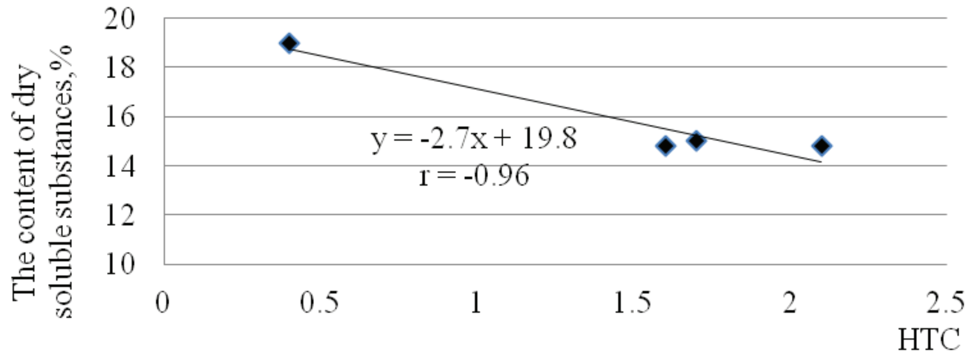

Figure 1. Dynamics of the content of dry soluble substances in sour cherry fruits according to the hydrothermal coefficient (HTC)

(r = -0.96). Kaldmae et al. (2013) found a similar correlation.

On the basis of this index a regression equation is derived (Figure 1), by which we can predict the content of dry soluble substances in sour cherry fruits depending on weather conditions 15 days before harvest.

CONCLUSIONS

The final chemical composition of the sour cherry fruits formed during ripening, 15 days before harvesting. The content of soluble dry matter, sugars in fruits significantly increased with increasing the amount of effective temperatures and decreasing of rainfall. The same conditions help to reduce the acidity of the fruit and increased sugar-acid index to 10. The content of tannins and coloring substances in fruits of sour cherry was consistently high regardless of weather conditions – 1.00-1.04%.

It is found a strong correlation dependence between hydrothermal coefficient and content of dry soluble substances and an equation of regression was received.

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