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Cooling sweet cherry fruits prolongs their use value

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Abstract

Sweet cherry (*Prunus avium* L.) fruits are characterised by a short shelf life. To extend the shelf life, pre-storage hydrocooling is carried out to reduce their temperature before storing them in the cold storage. During 2015 and 2016, hydrocooling treatment on fruits of two sweet cherry cultivars, 'Kordia' and 'Regina', from orchards on the locality of Trebinje, was performed. Samples of both cultivars were subjected to hydrocooling treatment in an automatic hydrocooling system at a temperature of 0.9 ºC for 10 minutes. The treated fruits were subjected to a cooling process before being placed in the cold storage, and the control fruits were put into the cold storage without hydrocooling. The fruits were placed for 15 days in NA cold storage at a temperature of 1 ºC and humidity of 85-95%. Analysis of fruit mass, colour, and firmness was performed on fruits after harvest and after storage. The results showed a significant positive effect of hydrocooling on fruit mass, i.e., treated fruits had less loss compared to the control fruits. The same fruits had higher fruit flesh firmness during cold storage. The fruit skin had the highest intensity of red colour in the harvesting time, while in treatment and control fruits in both years the intensity of the colour decreased during the cold storage. The year showed to have an impact on all examined characteristics of fruits of both cherry cultivars.

Key words: hydrocooling, cold storage, fruit firmness, skin colour, fruit mass

Introduction

The picky market is looking for large cherry fruits, firm, bright red in colour, and with crispy flesh of the fruit (Mićić et al., 2017). The goal of modern cherry production systems is, among other things, an adequate way to extend the shelf life of freshly picked fruits. The ability to store fruit to have a longer presence on the market and/or reach remote consumer centres is one of the main challenges for cherry producers. In modern world different postharvest strategy treatments are applied on fruits, such as heat treatment (Pašalić et al., 2010), and modified atmosphere packaging - MAP (Kurubas et al., 2018). To extend the life cycle of cherries, various techniques are used to cool fruits immediately after harvest, and the most common method is cooling fruits with cold water. By applying a fruit cooling treatment, fruits can be available on the market for a significantly longer period of time (Tsado & Aghotor, 2012). Cherries belong to non-climacteric fruit, which means that the fruits cannot ripen after the harvest. For that reason, determining the optimal time of harvest is extremely important because it directly affects the quality and durability of fruits (Sahin et al., 2018). Physiological and full maturity in cherries practically coincide (Mratinić & Đurović, 2015). Fruit mass and size are very important characteristics for the market value of cherry fruits and consumers prefer larger fruits with higher mass because they have a better visual appeal, better fruit yield, and higher share of fruit flesh (Milatović et al., 2013). The increase in the mass of cherry fruits mostly occurs just before harvest. Analyses have shown that cherry fruits reach up to 25% of the mass in the last week before harvest, although the mass of cherry fruits largely depends on the cultivar itself (Radičević et al., 2011).

Firmness is an important characteristic because it directly affects the transportability of the fruits. Modern methods enable successful measurement of the firmness of cherry fruits and thus the optimal degree of ripeness (Pašalić, 2006; Meland, 2018). Firmness is also one of the attributes of cherry fruit quality that is most sensitive to changes at the time after the harvest. Loss of firmness, which is softening of the fruit flesh, is a key attribute not only for the sensory quality of the fruit but also for further handling and eventual transport. The mechanical properties of the fruit are a good indicator for determining the quality of commercial cherry cultivars (Alique et al., 2006). Analyses have shown that about 30% of fruits are mechanically damaged upon arrival at the storage, and damage occurs during harvest and other field operations (Kader, 2010). The 'Kordia' and 'Regina' cultivars are characterized by high values of fruit firmness, which is very good for long-distance transportation (San Martino et al., 2008).

Along with other sensory characteristics, colour is a very important factor in consumer choice. Colour is generally an indicator of fruit quality and serves to determine the moment of full fruit maturity (Pedisić et al., 2009). By measuring the intensity of fruit colour, the content of coloured pigments or anthocyanins can be determined, which further represents an indicator of the maturity and quality of the fruit itself (Pedisić et al., 2009).

The objective of this study was to examine the effects of hydrocooling treatment before storage on the fruit mass, fruit flesh firmness, and fruit skin colour of two cherry cultivars, 'Regina' and 'Kordia', from orchards in Trebinje, after 15 days of cold storage with regulated temperature and humidity.

Material and Methods

The influence of post-harvest fruit cooling treatment on pomological properties of fruits after storage was monitored in two leading cherry cultivars 'Kordia' and 'Regina', during 2015 and 2016 from orchards in the area of Trebinje (Veličani location, Popovo Polje). The temperature of the fruits at the time of the harvest and before treatment was around 25-30 °C. Fruit cooling was performed by inserting plastic crates with sampled fruits into a hydro cooler (Hydrocoler, Eho, Slovenia) in which the water temperature was 0.9 °C, and in which chlorine was dissolved to prevent the development of pathogens. The hydro cooling treatment lasted 10 minutes, i.e., until the fruits reached a temperature of 6 - 9 °C. Fruit temperature was measured with a thermometer (DoltaTRAK, 11063).

Fruit sampling in this study was performed at the time of regular harvesting, as requested by the orchard manager. The 'Kordia' cultivar fruits of were sampled on 16 June in 2015 and on 25 June in 2016. Fruits of the 'Regina' cultivar were sampled on 19 June in 2015 and on 27 June in 2016. The part of fruits (treated fruits) was subjected to cooling process before being placed in the cold storage, and the other part (control fruits) was put into the cold storage without cooling. The fruits were placed in cold storage with normal atmosphere, where the temperature was automatically maintained at 1 °C and the humidity between 85-95%, for a period of 15 days.

Analysis of fruit mass, fruit flesh firmness, and fruit skin colour was performed on a representative sample of 30 fruits after harvesting and after storage of both stored fruit groups. Fruit mass was determined by weighing the fruits on a digital scale type KERN EMB 600-2 measuring range 0-600 ± 0.01g (KERN & SOHN, Germany). The firmness of the fruit flesh was determined using a table penetrometer type PCE-FM200 (STEP Systems GmbH, Germany) with piston diameter of 3 mm with measuring scale on which the penetration force in kg cm^{-2} was read. The colour of the fruit skin was measured with a colorimeter type Konica Minolta CR 400 (Konica Minolta, Japan), in the "Lab" colorimetric system of digital colour positioning, and colour quantification and data processing were performed using software Spectromagic CR (Konica Minolta, Japan). The indicator "L" indicates the amount of light in colour, i.e., its limit values are black and white. The indicator "a" represents the intensity of blue and yellow, and indicator "b" the intensity of green and red. The value of "L" ranges from 0 to 100, with 0 indicating complete black (absence of light) and 100 completely white. Values "a" and "b" can have the sign + and -, and range from - 60 to + 60.

All measured data was processed by standard descriptive statistical methods using the statistical software package SPSS Statistics 22 (IBM 2013). Fruit characteristics were analysed in detail by fitting appropriate linear models. All observed differences were analysed from the point of view of statistical significance. Differences were considered statistically significant at $p < 0.05$.

The analysis of climatic factors in the area where the research was done was performed based on the data obtained from the Republic Hydro-Meteorological Institute of the Republic of Srpska.

Tab. 1. Medium annual and medium monthly air temperatures (ºC) for the area of Trebinje in 2015 and 2016.

Month Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual average
2015	6.0	6.6	9.3	12.4	18.9	22.8	28.4	26.2	21.4	15.5	12.1	7.6	15.6
2016	6.2	10.1	9.8	15.1	16.4	22.4	26.4	24.5	19.7	14.4	10.2	5.8	15.1

Tab. 2. Total monthly and annual precipitation (mm) for Trebinje in 2015 and 2016.

Month Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual sum	March-June sum
2015.	278.4	129.4	212.1	54.6	23.6	43.0	1.7	164.0	66.2	250.4	81.9	0.0	1,305.3	333.3
2016.	199.7	154.0	249.8	124.0	130.6	81.9	18.0	1.6	86.3	304.1	186.8	1.9	1,538.7	586.3

According to the data from Table 1 and Table 2, it can be concluded that there were differences between the two years of research. When comparing the temperature conditions in the research years (Table 1), it can be concluded that 2016 was on average slightly colder compared to 2015 (15.1 ºC and 15.6 ºC, respectively). When analysing the average monthly temperatures, however, it can be noticed that in 2016, compared to 2015, warmer months were February, March, and April, while May and June were slightly colder on average.

The analysis of precipitation data in these years (Table 2) showed that 2016 was rainier compared to 2015 (1,538.7 mm and 1,305.3 mm, respectively). However, in the period from March to June (cherry blossoms and ripening) in 2016, there was almost twice as much rainfall compared to 2015.

This resulted in a later harvest of both varieties in 2016, by almost 10 days. These different climatic conditions and time of harvesting could affect the pomological characteristics of ripe cherry fruits.

Results and Discussion

Fruit mass

The average fruit mass of the examined cherry cultivars on two localities in two years of research is shown in Table 3. Both cultivars had the highest average fruit mass in the harvesting time in 2015 ('Kordia' 10.64 g and 'Regina' 10.87 g). The lowest average fruit mass was found in the control fruits of both cultivars, 'Kordia' 8.89 g in 2016 and 'Regina' 9.13 g in 2015. The obtained results on the average fruit mass of cherry fruits are similar to the results of other researchers (Milatović et al., 2013, San Martino et al., 2008), who conducted research in Serbia and South Patagonia in Chile, in which the average mass of the 'Kordia' cultivar was 9.1 g and 9.54 g, respectively. The average fruit mass in the treatment with hydrocooling compared to the control fruits after storage in this research was significantly higher in both cultivars. The treated fruits of 'Kordia' weighed 10.15 g in 2015 and 9.65 g in 2016, while control fruits had fruit mass of 9.53 g in 2015 and 8.89 g in 2016. The treated fruits of 'Regina' had fruit mass of 10.21 g in 2015 and 10.05 g in 2016, while control fruits weighed 9.13 g in 2015 and 9.26 g in 2016. There were no significant differences between the fruit mass in 2015 and 2016, although there was a tendency of smaller fruits in 2016, except the treated fruits of 'Regina'. The tendency of smaller fruits in 2016 could be explained by climate conditions that year (a colder and rainier year and later harvest).

Tab. 3. The mass fruit (g) of the 'Kordia' and 'Regina' cultivars in 2015 and 2016 at harvest time and after 15 d storage at 1 °C temperature

Cultivar	Treatment/Year	2015		2016		
		$\bar{X} \pm S_{\bar{x}}$	Fruit loss (%)	$\bar{X} \pm S_{\bar{x}}$	Fruit loss (%)	t $_{(2016-2015)}$
'Kordia'	Time of harvest	10.64 ± 0.349^{a}		9.83 ± 0.143^{a}		1.285
	Hydrocooling	10.15 ± 0.296^{a}	4.6	9.65 ± 0.134^{ac}	1.83	0.479
	Control	9.53 ± 0.383^{b}	10.43	8.89 ± 0.162^{b}	9.56	0.340
'Regina'	Time of harvest	10.87 ± 0.337^{a}		10.32 ± 0.264^{a}		1.882
	Hydrocooling	10.21 ± 0.279^{a}	6.07	10.05 ± 0.183^{a}	2.62	1.539
	Control	9.13 ± 0.332^{b}	16.01	9.26 ± 0.203^{bc}	10.27	1.539
$\bar{X}_{year}$	'Kordia'	10.11		9.46		
	'Regina'	10.07		9.88		

The various lowercase letters in respective columns indicate significant differences at P ≤ 0.05 according to the t-test. The differences between years are not significantly different according to the t-test.

The highest fruit mass in both cultivars was at the time of harvest, which is justified, bearing in mind that after the harvest, there was a continuation of biochemical processes in the fruit and mass loss. Fruit weight loss in control fruit was less than in the treatment fruit with cold water (Wang & Long, 2015), indicating a positive effect of hydrocooling treatment on fruit mass.

Fruit firmness

The average firmness values of the fruit flesh of the 'Kordia' and 'Regina' cherry cultivars during two years of research are given in Table 4.

Table 4. The firmness of fruit flesh (kg cm^{-2}) of the 'Kordia' and 'Regina' cultivars in 2015 and 2016 at harvest time and after 15 d storage at 1 °C temperature

Cultivar	Treatment / Year	2015	2016	$t_{(2016-2015)}$
		X ± Sx	X ± Sx	
'Kordia'	Time of harvest	0.99 ± 0.03^{a}	0.78 ± 0.04^{c}	2.828**
	Hydrocooling	0.95 ± 0.02^{ab}	0.75 ± 0.03^{c}	2.343*
	Control	0.90 ± 0.03^{b}	0.71 ± 0.04^{c}	4.772**
'Regina'	Time of harvest	$1.12 \pm 0.04_{a}$	0.93 ± 0.04^{d}	2.400*
	Hydrocooling	1.08 ± 0.05^{a}	0.85 ± 0.04^{d}	5.547**
	Control	0.99 ± 0.04^{a}	0.83 ± 0.04^{d}	5.600**
$\bar{X}_{year}$	'Kordia'	0.95	0.75	
	'Regina'	1.06	0.87	

The various lowercase letters in respective columns indicate significant differences at $P \leq 0.05$ according to the t - test;
** - significant differences.

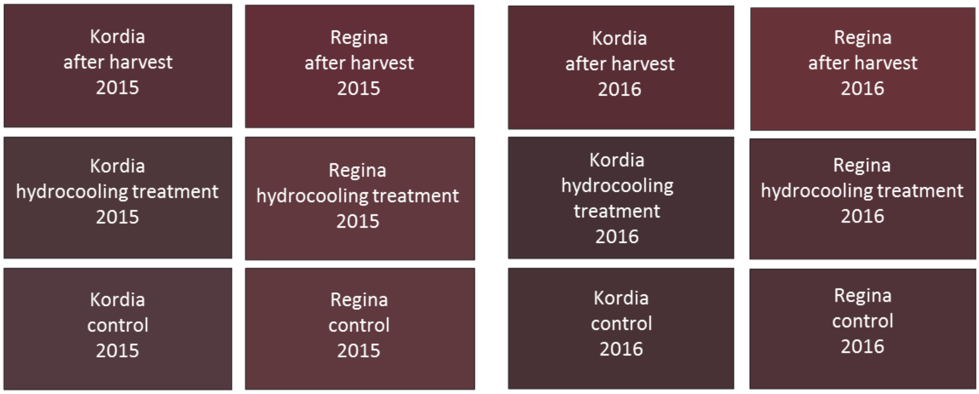
'Kordia' showed the highest average firmness in 2015 at harvest time (0.99 kg cm^{-2}), while the lowest average firmness was found in the control fruits in 2016 (0.71 kg cm^{-2}). 'Regina' showed the highest average fruit firmness at harvest time in 2015 also (1.12 kg cm^{-2}), and the lowest in the control fruits in 2016 (0.83 kg cm^{-2}). Both cultivars had higher fruit firmness in 2015 compared to 2016, i.e., the average fruit flesh firmness of 'Kordia' was 0.95 kg cm^{-2} and 0.75 kg cm^{-2}, respectively, while the average fruit flesh firmness of 'Regina' was 1,06 kg cm^{-2} and 0.87 kg cm^{-2}, respectively. The treated fruits of the 'Kordia' cultivar compared to the control fruits had slightly harder fruits after storage in both years (0.95 kg cm^{-2} and 0.9 kg cm^{-2} in 2015; 0.75 kg cm^{-2} a 0.71 kg cm^{-2} in 2016, respectively). Similar results were obtained for 'Regina', whose treated fruits compared to the control ones after storage, had harder fruits in both years, although slightly higher in 2015 (1.08 kg cm^{-2} and 0.99 kg cm^{-2}) than in 2016 (0.85 kg cm^{-2} and 0.83 kg cm^{-2}, respectively). Although there is a tendency for higher fruit flesh firmness in treated fruits (Sena at al., 2019), these differences were not statistically significant. The only significant differences were manifested at the level of the year, i.e., in 2016 all fruits of both cultivars had significantly lower firmness than in 2015. When comparing these results with the results of other researchers (Harb et al., 2003) who claimed that cherry fruit flesh firmness was at the level of 315.1 g mm^{-2} at harvest time and after storage 343.4 g mm^{-2}, it can be concluded that the fruits of both varieties were probably harvested at a high degree of maturity, i.e., before storage they had a higher degree of maturity and lower firmness of fruit flesh, which was especially pronounced in 2016 in which the harvest, due to the rainier period at the time of ripening, was delayed by 10 days compared to 2015.

Fruit skin colour

The average skin colour of the fruit of examined cherry cultivars on two localities in two years of research is shown in Table 5 and the graphical presentation is presented in Graph 1.

Table 5. The fruit skin colour of the 'Kordia' and 'Regina' cultivars in 2015 and 2016 at harvest time and after 15 d storage at 1 ºC temperature

Cultivar	'Kordia'	'Regina'	'Kordia'	'Regina'
Year	2015		2016	
Treatment	$\overline{X} \pm S_{\overline{X}}$	$\overline{X} \pm S_{\overline{X}}$	$\overline{X} \pm S_{\overline{X}}$	$\overline{X} \pm S_{\overline{X}}$
Time of harvest	L: 26.33± 0.35 a: 17.49 ± 0.67 b: 3.46 ± 0.22	L: 27.78 ± 0.51 a: 23.83 ± 1.09 b: 5.992 ± 0.59	L: 25.736 ± 0.43 a: 19.26 ± 1.04 b: 5.30 ± 0.41	L: 29.07 ± 0.33 a: 23.88 ± 0.69 b: 8.04 ± 0.36
Hydrocooling	L: 26.46 ± 0.89 a: 10.88 ± 0.64 b: 2.31 ± 0.19	L: 29. 38 ± 0.46 a: 18.12 ± 1.32 b: 4.94 ± 0.57	L: 23.82 ± 0.19 a: 9.11 ± 0.57 b: 1.65 ± 0.14	L: 25.91 ± 0.30 a: 15.71 ± 0.72 b: 3.63 ± 0.22
Control	L: 28.02 ±0.18 a: 11.05 ± 0.56 b: 1.95 ± 0.18	L: 29.75 ± 0.41 a: 17.94 ± 1.52 b: 4.72 ± 0.56	L: 24.70 ± 0.19 a: 10.85 ± 0.64 b: 2.17 ± 0.19	L: 25.05 ± 0.22 a: 13.67 ± 0.76 b: 2.84 ± 0.22



Graph 1. Colour representation of the intensity of fruit skin colour of two cherry cultivars in 2015 and 2016 in different treatments

Colour analysis in the examined cultivars showed that the 'Regina' cultivar had significantly higher red colour intensity compared to 'Kordia'. The analysis showed that there was a significant difference between the fruits at the time of the harvest compared to the treated and control fruits. Based on the data from the second year of study, it can be said that generally higher intensity of red skin colour was recorded on the fruits in 2016, which could be explained by the harvesting time in this year. The 'Kordia' cultivar showed that fruits analysed after the harvest had the highest colour intensity, while after storage the treatment and control fruits showed a significantly lower red colour intensity in both years.

Conclusion

- The year showed to have an impact on the examined characteristics of fruits of both cherry varieties.
- The hydrocooling treatment prevented fruit weight losses and had a positive effect on fruit flesh firmness of the 'Kordia' and 'Regina' cherry cultivars after cold storage.
- The cherry fruit skin had the highest intensity of red colour at harvest, while in the treatment and control fruits in both years the intensity of the colour decreased during the cold storage.

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References

Alique, R., Martinez, M. A., & Alonso, J. (2006). Metabolic response to two hydrocooling temperatures in sweet cherries cv Lapins and cv Sunburst. *Journal of the Science of Food and Agriculture (86),* 1847-1854. doi:10.1002/jsfa.2516

Harb, J., Streif, J., & Saquet, A. (2003). Impact of controlled atmosphere storage conditions on storability and consumer acceptability of sweet cherries "'Regina'". *The Journal of Horticultural Science and Biotechnology 78 (4),* 574-579. doi: 10.1080/14620316.2003.11511666

Kader, A. (2010). *Postharvest Technology of Horticultural Crops*. University of California. Agricultural and Natural Resources. *Publication 3311*, 97-113.

Kurubas, M. S., Ozalp, G. S., & Erkan, M. (2018). Impact of modified atmosphere packaging on fruit quality and postharvest life of '0900 Ziraat' cherries. *Derim 35(1),* 19-26. doi:10.16882/derim.2018.314511

Meland, M. (2018). High density sweet cherry production in Norway. *Fructus 3(2),* 7-13.

Mićić, N., Đurić, G., & Mićić, G. (2017). Uzgojne forme za trešnju - formiranje i održavanje. *Fructus 2*, 3-19.

Milatović, D., Đurović, D., Đorđević, B., Vulić, T., & Zec., G. (2013). Pomološke osobine novijih sorti trešanje na podlozi Colt. *Journal of Agricultural Sciences 58,* 61-72. doi: 10.2298/JAS1301061M

Mratinić, E., & Đurović, D. (2015). *Biološke osnove čuvanja voća*. Partenon, Beograd, 257-421.

Pašalić, B. (2006). Berba, pakovanje i skladištenje plodova voćaka. *GrafoMark*, Banja Luka.

Pašalić, B., Grubačić, M., & Gračanin, S. (2010). Influence of thermotherapy on the physiological constitution of Granny Smith apple fruits. *Agroknowledge 11 (4),* 41-54.

Pedisić, S., Levaj, B., Dragović-Uzelac, V., Škevin, D., & Skenderović-Babojelić, M. (2009). Color parameters and total anthocyanins of Sour Cherries (*Prunus cerasus* L.) during ripening. *Agriculturae Conspectus Scientificus 74,* 259-262.

Radičević, S., Cerović, R., Mitrović, M., Mitrović, O., Lukić, M., & Marić, S., Milošević, N. (2011). Biološke osobine introdukovanih sorti trešnje (*Prunus avium* L.). *Zbornik radova III savjetovanja "Inovacije u voćarstvu" Beograd,* 2011.

Sahin, T., Kasim, R., & Kasim, M. U. (2018). Postharvest Practices for the Preservation of Sweet Cherry Fruit Quality. *7th International Vocational Schools Symposium*, 160-167.

San Martino, L., Manavella, F. A., Garcia, D. A., & Salato, G. (2008). Phenology and fruit quality of nine sweet cherry cultivars in South Patagonia. *Acta Horticulturae 795*, 841-848. doi:10.17660/ActaHortic.2008.795.136

Sena, E. D. O. A., da Silva, P. S. O., de Araujo, H. G. S., de Aragao Batista, M. C., Matos, P. N., & Sargent, S. A. (2019). Postharvest quality of cashew apple after hydrocooling and coold room. *Postharvest Biology and Technology 155*, 65-71. doi: 10.1016/j.postharvbio.2019.05.002

Tsado, E. K., & Aghotor, P. (2012). Effect of pre-transport cold water treatment on postharvest quality of pawpaw fruits. Journal of Biology, *Agriculture and Healthcare 2,* 52-59.

Wang, Y., & Long, L. E. (2015). Physiological and biochemical changes relating to postharvest splitting of sweet cherries affected by calcium application in hydrocooling water. *Food Chemistry 181*, 241-247. doi: 10.1016/j.foodchem.2015.02.100

Хлађење плодова трешње продужује њихову употребну вриједност

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Сажетак

Плодове трешње карактерише кратак рок трајања. Како би се продужио вијек трајања, врши се расхлађивање плодова прије складиштења ради смањења њихове температуре прије уношења у хладњачу. Током 2015. и 2016. године извршен је хладни третман плодова двије сорте трешње, Регина и Кордиа, из воћњака на локалитету Требиње. Узорци обе сорте подвргнути су обради хидрохлађења у аутоматском систему хидрохлађења при температури од 0,9 ºC током 10 минута. Третманска група плодова подвргнута је поступку хлађења прије уношења у хладњачу а контролна група је унесена у хладњачу без хлађења. Плодови су држани 15 дана у НА хладњачи при температури од 1 ºC и релативној влажности од 85-95%. Анализа масе, боје покожице и тврдоће меса плода извршена је на плодовима након бербе и након складиштења. Резултати су показали значајан позитиван ефекат хидрохлађења на масу плода, тј. третмански плодови су имали мањи губитак масе у односу на контролне плодове. Исти плодови су имали већу тврдоћу плода током складиштења. Покожица плода имала је највећи интензитет црвене боје у вријеме бербе, док је код третманских и контролних плодова у обе године интензитет боје опадао током складиштења. Година је показала утицај на све испитиване карактеристике плодова обе сорте трешње.

Кључне ријечи: хидрохлађење, хладњача, тврдоћа плода, боја покожице, маса плода

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