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DINAMICA INDICATORILOR BIOCHIMICI AI AFINELOR ÎN TIMPUL DEPOZITĂRII POSTRECOLTĂ

DYNAMICS OF BIOCHEMICAL INDICATORS OF HIGHBUSH BLUEBERRIES DURING POSTHARVEST STORAGE

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Abstract

Blueberries, considered non-climacteric fruits, must be harvested at optimal ripeness for consumption. Due to the high water content, the storage life of the fruit is very short. The loss of water accelerates the senescence of the fruits, simultaneously with the deterioration of the biochemical quality of the fruits. This study provides a systematic evaluation of the observed changes in water content, total dry matter, sugars, organic acids and vitamin C in blueberries, under refrigerated conditions at 4°C, starting at the time of fruit harvesting and continuing in the interval 7, 14, 30, 45 days after harvesting. The study was conducted on two blueberry varieties Delicia and Bluecrop. The loss of water content observed and through the weight loss of the fruit caused the increase in the level of sugars and total dry matter per mass unit. The degradation of organic acids and vitamin C in fruits was influenced by the duration of storage. The obtained results were also significantly influenced by the genetic characteristics of the variety or the year of the study.

Cuvinte cheie: *Vaccinium corymbosum*, păstrare, calitate fructe.
Keywords: *Vaccinium corymbosum,* postharvest storage, fruits quality.

1. Introduction

Blueberry (*Vaccinium corymbosum* L.) is a species native to the high alpine areas of North America. This terrestrial shrub belongs to the family *Ericaceae*, genus *Vaccinium*, subgenus *Cyanococcus* (Ștefănescu et al., 2019) and is currently widely cultivated throughout the world. In 2020, it was estimated that world production reached 850,886 thousand tons harvested from an area of 126,144 ha. The largest blueberry producer in the world is the USA (294,000 thousand tons), followed by Peru (180,300 thousand tons) and Canada (146,370 thousand tons) (FAO Date, 2022).

In Romania, the cultivation of highbush blueberry dated from 1968. The first plantations were established in a mountainous region - at the Bilcești Fruit Growing Research Station and in an area positioned between the plateau and the mountains - at the Fruit Growing Research and Development Institute , Mărăcineni (Asănică et al., 2016). In 2020, Romania reached a production of 1,170 thousand tons of blueberries on an area of 400 ha (FAO Data, 2022). In our country, blueberry culture is spread mainly in Transylvania, Muntenia and Maramureș, the rest in Moldova, Crisana, Banat, Oltenia and a small part in Bucovina (Asănică et al., 2016).

The blueberry fruit is a berry of about 2 cm, with several seeds (15-60), spherical or flattened, colored light blue or bright dark blue, covered with pruin. This layer is easily damaged or removed during fruit harvesting and post-harvest handling. Cuticular wax plays an important role in maintaining post-harvest quality and delaying fruit senescence. Removing it from fruit accelerates water loss and degradation after harvest, reduces sensory and nutritional qualities, and shortens shelf life.

Immature fruits may have a longer storage capacity, but are unlikely to develop adequate organoleptic characteristics, while the shelf life of overripe fruits is generally very short, as susceptibility to decay increases {García, 2001}. Being non-climacteric fruits, very perishable, with a short shelf life, the maturity of the fruit at harvest is one of the main factors that contribute and determine their quality (Kruger, et al. 2003). At optimum harvest maturity, the water content of the fruit is approximately 85%. The sugar content varies from 7% in green fruit to 15% in ripe fruit. Accumulation of sugars occurs during ripening. Due to the low starch content, the berries do not become sweeter after harvesting. It is recommended to keep the fruits on the plant to increase the quality until they are technically ripe for consumption. In this regard, the UNECE Standard FFV-57 {UNECE, 2011} on the marketing and commercial quality control of berries states that "The berries must be sufficiently developed and show a satisfactory maturity according to the species, but must not to be overripe" emphasizing the need to harvest at the appropriate stage of ripening for each type of fruit.

Pre-harvest field conditions, harvesting methods, genetic characteristics of the cultivar, stage of fruit ripening, storage conditions (temperature, relative humidity and atmosphere), can influence the

shelf life of blueberries for 1 to a maximum of 8 weeks (Hancock et al., 2008). Improper handling during pre-harvest, harvest, selection, packaging, transport, preservation and marketing operations; affect the quality of blueberry fruits, causing deformation, mechanical damage, water loss, fermentation and fungal decay [Sánchez, et al., 2012]. To avoid excessive handling and fruit damage, berries for the fresh market must be hand-harvested, sorted, graded and packed in the field, directly into the final container. Ideally, the fruit should be harvested early in the morning after the dew has cleared from the berries or in the evening when temperatures are cooler.

Cold storage is the main method used to maintain the quality and commercial value of fresh fruit after harvest. Temperature is the most important environmental factor affecting blueberry post-harvest quality. Fresh blueberries are recommended to be stored at temperatures close to 0 °C and 90–95% RH to achieve maximum post-harvest shelf life (Perkins-Veazie et al., 2008). Dropping the temperature to 0–1°C is an effective storage technique for up to 3 weeks for blueberries (Sanford et al., 1991; Harb and Streif, 2004). Loyola et al. (1993) stated that fruit of 'Bluecrop' blueberry cultivars were cold stored for 21 days without loss of fresh export quality. At the end of the storage period Borecka and Pliszka (1985) reported an increased incidence of caries and weight loss; Sanford et al. (1991) reported weight loss and firming effects and Nunes et al. (2004) found effects only for degradation, while Forney et al. (1999) found no significant difference in caries incidence, weight loss or firmness for a 3°C storage difference after 3 weeks of storage.

Higher temperatures accelerate the metabolism of blueberries and pathogens and are likely to increase moisture loss, leading to greater decay, softening and weight loss during storage. Low postharvest temperatures slow down respiration rate of horticultural products, water losses, delay ripening and senescence processes, reduce fungal decays (Oliveira et al., 2013). In a controlled atmosphere, blueberries can be stored longer. Fungal growth and fungal spore germination are delayed by limited O_2 and elevated CO_2 levels (Day et al., 1990; Beaudry, 1999), while fruit firmness and sensory quality are maintained. Controlled atmospheres of 8-15% CO_2 and above 1% O_2 are commonly used to extend the post-harvest shelf life of fresh blueberries (Alsmairat et al., 2011). However, CO_2 concentrations greater than 12% have very different effects on flavor, firmness and acidity depending on the variety (Harb and Streif, 2004). The quality of fruit for marketing is largely determined by physicochemical parameters such as size, color, brightness, firmness, absence of wounds, rot, a balance between sweetness and acidity, and typical aroma (Horvitz et al., 2017).

The aim of the present study was to evaluate the biochemical composition of blueberries refrigerated at 4°C and 75% humidity for 45 days.

2. Material and methods

Experiment location and plant material

The experiment was carried out in Research Institute for Fruit Growing, Pitesti (RIFG) in South of Romania 44°54’12” Northern latitude, and 24°52’18” Eastern longitude, 284 m altitude, in the experimental field of shrubs for a period of 2 consecutive years (2021 - 2022). There were studied 2 blueberry cultivars: one of Romanian origin ('Delicia') and one from America ('Bluecrop'), planted at a distance of 1 x 3 m. The plants were placed on billets covered with black polyethylene. Blueberry were harvested in stage I of maturation, on the beginning of July, morning time at technical fruits maturity. The fruit samples were harvested in three repetitions manually, at the tehnical harvest maturity and were sorted, classified and packed in the field, directly in the final container (vented plastic containers). Undamaged samples were selected. After harvesting, the blueberries were immediately brought to the laboratory where they were refrigerated 4°C and 75% humidity for 45 days.

Soil Description

The plantation was organized on an alluviosol from the phreatic protisols class, formed on illuvial deposits with a clay-sandy granulometric composition. Soil samples were collected from the row of plants with an agrochemical probe, from a depth of 0- 20 cm and 20-40 cm). The soil samples were then air-dried and analyzed in the agrochemical laboratory. The soil is characterized by a strong-moderatelybacidic reaction, a low humus content and a poor supply of nitrogen phosphorus.

Climatic conditions

The studied area has a humid temperature continental climate, with average annual temperatures between 8-10°C. In the years 2021 and 2022, the average temperatures between budding and fruit harvesting in the blueberry species were 8.6-10.9°C at 22.4-23.5°C, with minimum and maximum averages in the ranges of 2,3-3,2°C (at the beginning of the vegetation period) and 15,0-29,2°C (at fruit ripening). It is considered that for the development of all the biological processes of plants, the optimal temperature must be within the range of 8-20°C (Zydlik et al., 2019). The character of precipitation, in the study area, is extremely heterogeneous with a rain season especially in the months May-June, reduced in the year 2021 and also poor in precipitation in 2022. The crop

benefited from an additional supply of water, during the period of study, through a sprinkler irrigation system.

Fruit quality parameters

The following blueberry quality parameters were determined in this study: total water content, total dry matter, organic acids, total sugar and ascorbic acid. The determinations were made starting from the time of fruit harvesting and continuing in the interval of 7, 14, 30, 45 days after harvesting. Each test was performed three times.

Fruits weight

The mass of fruits represents the mass of 100 fruits chosen randomly from the shoots of the shrubs. A Kern analytical balance with a precision of 0.01 g was used for the determination.

Fruit weight loss

Fruit weight loss was calculated according to the relationship: Weight loss = ((Weight of fresh fruit – Weight after duration)/ (Weight of fresh fruit)) x 100.

Weight loss of blueberry samples during storage was measured by weighting fruits in containers before storage and at every day of analysis.

Total dry weight content (DW)

The total dry matter content was determined by a gravimetric method (drying 10 g of fruit tissue at 105°C to constant weight) according to AOAC International (2002).

Titratable acidity (TA)

The organic acid content of blueberry fruit was determined by the titrimetric method, using 25 ml of aqueous fruit extract neutralized with a 0.1N NaOH solution in the presence of phenolphthalein as an indicator (AOAC, 2000).

Total sugar content

The total sugar content was estimated by the Fehling-Soxhlet method, 1968 (JAOAC, 1968). The principle of the method is based on the oxidation reaction between the copper in the copper alcoholate of sodium and potassium tartrate and the aldehyde and ketone grouping 50 of the reducing sugars. This method determines the amount of reducing sugar which reduces a certain volume of Fehling's reagent. Total sugar content was expressed as a percentage (%).

Vitamin C content

The vitamin C (ascorbic acid) content of fruit expressed in mg/100 g fresh weight (FW) was analyzed according to the method based on the oxidation of L-ascorbic acid to dehydroascorbic acid in an acid medium with a blue dye of 2.6- dichloroindophenol, followed by the reduction of the dye to the colorless form, which turns red at pH 4.2 (PN-A-04019: 1998).

Statistical analysis

Statistical analysis was performed using an IBM SPSS 20 program (SPSS Inc., Chicago, IL, USA). All results were analyzed by unidirectional analysis of variance (ANOVA) and using the Duncan Multiple Range test. The differences were considered statistically significant at $p < 0.05$.

3. Results and discussions

In this study, the evaluation of blueberry fruits during the refrigeration period for years 2021 and 2022 showed that the storage time (ST) and interactions between cultival x ST, cultivar x year, ST x year and cultivar x ST x year had a significant impact on majority determined parameters (Table 1).

Table 2 presents measures of central tendency (mean and median) and measures of variability (standard deviation, minimum and maximum absolute variables) of the data set regarding fruit weight, weight loss during storage, DW, organic acids, total sugar and vitamin C content from the fruits of 'Delicia' and 'Bluecrop' cultivars separately or taken together. For the two cultivars taken togheter, blueberries had a content of 15.51 ± 2.77% DW (with a minimum of 12.05 and a maximum of 23.79%). The average mass of the 100 fruits weighed was 173.33 ± 36.55 g (with a variation between 127.60 and 249.00 g), and the percentage of weight loss showed a value of 2.30 ± 1.61% (spread between a minimum of 0.18% and a maximum of 8.03%). The average TA counted 0.90 ± 0.29% (with 0.43 – 1.32%), 6.81 ± 1.30% for total sugar content (4.49 – 8.84%) and 19.35 ± 9.55 mg/100 g FW for vitamin C (5.89 – 39.82 mg/100 g FW).

Fruits weight and fruit weight loss

At harvest (Fig.1), the maximum value of the mass of 100 fruits in the period 2021-2022 was obtained for the 'Bluecrop' variety (191.32 g), superior to the 'Delicia' variety (168.02 g). After 45 days of storage, fruit weight decreased significantly in both cultivars. Fruit weight loss is primarily the result of respiration, transpiration and metabolic activities that occur in the post-harvest period (Fatima et al., 2022). Fruit weight loss caused by moisture loss, is also manifested by changes in fruit texture, flavor and appearance (Sanford et al., 1991). The influence of storage time was very significant (p=0.000) (Table 1), and the highest weight loss rate of blueberries was observed after 30 days of storage (Fig. 2). At 14 days after harvest, fruit weight loss was 1.97% in the 'Delicia' variety and 1.43% in the

'Bluecrop' variety. Jackson et al. (1999) reported a weight loss of about 2% in blueberry fruit after 14 days of storage at 0°C. At 45 days after harvest, weight loss was 4.83% in the 'Delicia' variety and only 2.31% in the 'Bluecrop' variety. The rate of weight loss was also greatly influenced by the genetic background according to the analysis of variance (ANOVA) test, a fact also confirmed by Leisso et al. (2021). According to the literature, the maximum weight loss before blueberries become unmarketable is approximately 5% to 8% (Sanford et al., 1991). After 45 days at 4°C storage, blueberries lost less than 5% of their initial weight. And storage temperature can have a significant role in fruit weight loss. Fruit respiration rates increase with storage temperature (Kader, 2002). To prevent the migration of water from the fruit into the environment during storage at the reception, various coatings with edible layers have been tried. Also, using non-vented containers can provide better protection (Duan et al., 2011).

Total dry weight content

Blueberries contain on average 84-88% water, the rest is DW. It consists of carbohydrates, proteins, lipids, minerals, organic acids, vitamins, phenolic compounds (Kader, 2002). Essentially, total dry matter reflects the quality of the fruit at harvest. DW content showed significant increases during fruit storage at 4°C and 75% humidity. Fruit moisture loss causes weight loss and increased DW content. According to the results of the ANOVA analysis, DW content was significantly influenced by the effect of all experimental factors (cultivator, ST and year of study) but also by the effect of their interaction (p=0.000) (Table1). The fruits had maximum DW at the end of the refrigeration period: 18.79% - 'Delicia' variety and 17.67% - 'Bluecrop' variety (Fig. 3). Due to the moisture loss of the fruits, the content of DW in the fruits was higher by 5.78, respectively 4.10% in the two blueberry varieties analyzed. Due to the high water content, blueberries are perishable fruits with poor storage capacity and an accelerated deterioration of quality.

Titratable acidity

TA is directly related to the dominant organic acid concentration, which is an important parameter in maintaining fruit quality. Genetic background, storage time, year of study and the interaction cultivar x year and ST x year significantly influenced the TA of blueberries (Table 1). The effect of storage time, in the two years of the study, revealed that the maximum titratable acidity was recorded in freshly harvested fruits and 14 days after harvest (Fig. 4). If in the first 7 days after harvesting a slight significant decrease of 0.04 percent was observed in both varieties, in the period 7 to 14 days TA had an increasing tendency. The tendency to increase TA occurs with the onset of breakdown of total sugars. The greatest decrease in TA was observed in both cultivars in the period between 14-30 days (from 1.17 to 0.94% in 'Delicia' cultivar and from 1.02 to 0.95% in 'Bluecrop' cultivar). According to previous studies, fruit acidity reduction occurs due to the use of acid as an energy source that converts organic acid into sugar (Karadeniz, 2004). The degradation of organic acids continued during the 30-45 days but with a lower intensity, TA reaching the value of 0.78% in the 'Delicia' cultivar and 0.52% in the 'Bluecrop' cultivar. Based on the obtained data, the TA of blueberries decreases with increasing storage time. Since organic acids are used as substrates for respiration in enzymatic reactions, TA is expected to decrease during postharvest (Shokrollahfam et al., 2012 cited by Zeraatgar et al.,2018).

Total sugar content

In blueberries, the sugar content contributes to determining the organoleptic quality of the fruit (Li et al., 2020). With refrigeration, total sugars decrease although initially show an increasing trend. During the first 7 days of storage in both varieties, a slight (insignificant) increase in the total sugar content was recorded (from 7.83 to 7.86% in the 'Delicia' cultivar, respectively from 7.32 to 7.35% in the 'Bluecrop' cultivar) (Fig. 5). Being non-climacteric fruits, the tendency of sugar content to increase during the storage period is due to the loss of moisture in the fruit. The results are also confirmed by previous studies that fruits can gain sweetness through weight loss during storage (Pareek, 2001 cited by Singh, et al., 2013). Between 7-14 days after harvesting, the sugar content drops slightly. A drastic reduction of them was observed during the period of 14-30 days of refrigeration at a temperature of 4°C, in the 'Bluecrop' cultivar their drastic reduction continues during the period of 30-45 days. The initial increase in the level of total sugars in fruits followed by the subsequent decrease was also observed in other studies (Singh et al., 2013). Fruit sugars can be used in respiration (Öztürk et Ağlar, 2019) by reducing into pyruvic acid, citric acid. As can be seen from table 1, the total sugar content of blueberries during the storage period can be influenced very significantly by the genetic background of the cultivar, by ST and interactions between cultivar x year, ST x year (p=0.000) and significantly by the interaction of the three factors cultivar x ST x year (p=0.034).

Vitamin C content

Vitamin C is one of the most abundant antioxidants found in fruits. The vitamin C content of blueberries showed a gradual decreasing trend during storage, the results showed. If the level of ascorbic acid at harvest recorded the values of 10 mg /100 g FW in the 'Delicia' cultivar and 9.70 mg /100 g FW in the 'Bluecrop' cultivar at the end of the refrigeration period, it reaches the values of 7.83

mg /100 g FW respectively 7.32 mg /100 g FW (Fig. 6). Ascorbic acid shows sensitivity to destruction when fruits are subjected to unfavorable storage conditions after harvest (Lee and Kader, 2000). The decrease in vitamin C during storage can be attributed to the oxygen released in ascorbic acid, dehydroascorbic acid conversion (Sumnu & Bayindirli, 1995). Higher storage temperature could be responsible for higher oxidation resulting in higher level of dehydroascorbic acid (Lee & Kader 2000).

Comparison between the two cultivars of blueberries

Although no statistical comparison was made between the two blueberry varieties, differences were observed between them in terms of post-harvest quality. 'Delicia' was obtained by free hybridization of the variety 'Patriot', at the Pitesti-Mărăcineni Research-Development Institute for Fruit Growing (Romania), approved in 2001, with large blue berries, firm, mid-late ripening period and 'Bluecrop' (Jersey X Pioneer) X (Stanley X June) was obtained in the USA, put into production in 1952, with large fruit, very light blue, very firm, medium ripening period under the conditions of the Argeș meadow. 'Delicia' fruit had higher mass, DW, TA, total sugar and vitamin C compared to 'Bluecrop' at harvest. However, after 45 days of refrigeration, fruit weight, weight loss and sugar reduction were superior in Delicia cultivar, while organic acid and vitamin C contents degraded faster in 'Bluecrop' cultivar. Fig. 7 and fig. 8 show the influence of the storage period on the main biochemical indicators studied in the analized 'Delicia' and 'Bluecrop' cultivars.

Following the determinations made on the fruits of the two blueberry varieties regarding the quality characteristics, the existence of positive or negative correlations, statistically significant between most of the studiied compounds, was found (Table 3). The obtained results indicated a positive linear interdependence, distinctly significant, between fruit weight and TA ($r=0.369$), between fruit weight loss and DW content ($r=0.348$) and between TA and total sugar content ($r=0.535$; $p<0.01$) and a positive linear interdependence of lower intensity between total sugar content and vitamin C ($r=0.369$; $p<0.05$). A linear negative relationship was obtained between fruit weight and fruit weight loss, DW content of high intensity and vitamin C of very high intensity ($r=-0.362$, $r=-0.466$ and $r=-0.802$; $p<0.01$). The relationship between fruit weight loss and total sugar content is negative, distinctly significant ($r=-0.529$) as is the relationship between DW content and total sugar content ($r=-0.580$; $p<0.01$).

4. Conclusions

After 7 days of blueberry storage at 4°C and 70% humidity in open containers, the biochemical indicators of fruit quality fall on a downward trend that is maintained up to 45 days.

Prolonged storage of blueberries at a temperature of 4°C significantly reduced the biochemical quality of the fruits. This storage method is indicated for a short period of time.

References

1. Alsmairat N., Contreras C., Hancock J., Callow P., & Beaudry R., 2011. Use of combinations of commercially relevant O2 and CO2 partial pressures to evaluate the sensitivity of nine highbush blueberry fruit cultivars to controlled atmospheres. HortScience, 46(1): 74-79.
2. Asănică A., Bădescu A., Bădescu C., 2016, April. Blueberries in Romania: past, present and future perspective. In XI International Vaccinium Symposium 1180: 293-298.
3. Beaudry R. M., 1999. Effect of O2 and CO2 partial pressure on selected phenomena affecting fruit and vegetable quality. Postharvest Biology and Technology, 15(3): 293-303.
4. Borecka H. W., & Pliszka K., 1985. Quality of blueberry fruit (*Vaccinium corymbosum* L.)stored under lps, ca, and normal air storage. In III International Symposium on Vaccinium Culture 165: 241-250.
5. Day N. B., Skura B. J., & Powrie W. D., 1990. Modified atmosphere packaging of blueberries: microbiological changes. Canadian Institute of Food Science and Technology Journal, 23(1): 59-65.
6. Duan, J., Wu, R., Strik B. C., & Zhao Y., 2011. Effect of edible coatings on the quality of fresh blueberries (Duke and Elliott) under commercial storage conditions. Postharvest biology and technology, 59(1), 71-79.
7. Fatima F., Basit A., Ahmad A., Sajid M., Faiza A. M. A. N., Mohamed H. I. & Elhakem A., 2022. Enhancement of the fruit quality and postharvest life expectancy of mango fruit (Mangifera indica L.) applying ecofriendly bio-coatings. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 50(4): 12917-12917
8. Forney C. F., Nicholas K. U. & Jordan M. A., 1999. Firmness of blueberry fruit following storage in air or controlled atmospheres. HortScience, 34(3): 538F-539.
9. García M. C., 2001. La agroindustria de la mora. Alternativas viables para los fruticultores. Tecnología para el Agro, 1(2): 15-17.

10. Hancock J., Callow P., Serçe S., Hanson E. & Beaudry R., 2008. Effect of cultivar, controlled atmosphere storage, and fruit ripeness on the long-term storage of highbush blueberries. HortTechnology, 18(2): 199-205.
11. Harb J.Y., Streif J., 2004. Controlled atmosphere storage of highbush blueberries cv.'Duke'. Europ. J. Hort. Sci., 69 (2): 66–72.
12. Horvitz S., Chanaguano D. & Arozarena I., 2017. Andean blackberries (*Rubus glaucus* Benth) quality as affected by harvest maturity and storage conditions. Scientia Horticulturae, 226: 293-301.
13. Jackson E. D., Sanford K. A., Lawrence R. A., McRae K. B. & Stark R., 1999. Lowbush blueberry quality changes in response to prepacking delays and holding temperatures. Postharvest Biology and Technology, 15(2): 117-126.
14. Kader A. A., 2002. Methods of gas mixing, sampling and analysis. Postharvest technology of horticultural crops, 3: 145-148.
15. Karadeniz F., 2004. Main organic acid distribution of authentic citrus juices in Turkey. Turkish Journal of Agriculture and Forestry, 28(4): 267-271.
16. Kruger E., Schopplein E., Rasim S., Cocca G. & Fischer H., 2003. Effects of ripening stage and storage time on quality parameters of red raspberry fruit. European Journal of Horticultural Science, 68(4): 176-182.
17. Lee S. K. & Kader A. A., 2000. Preharvest and postharvest factors influencing vitamin C content of horticultural crops. Postharvest biology and technology, 20(3): 207-220.
18. Leisso R., Jarrett B., Richter R. & Miller Z., 2021. Fresh haskap berry postharvest quality characteristics and storage life. Canadian Journal of Plant Science, 101(6), 1051-1063.
19. Li X., Li C., Sun J., Jackson A., 2020. Dynamic changes of enzymes involved in sugar and organic acid level modification during blueberry fruit maturation. Food chemistry, 309: 125617.
20. Loyola L., Georgi J., Andrade S. & Teixido M. 1993. Behaviour of blueberry, cultivated blackberry and wild blackberry in cold storage and its effect on quality. Agro-Sur, 21: 59-69.
21. Nunes M. C. N., Emond J. P. & Brecht J. K. 2004. Quality curves for highbush blueberries as a function of the storage temperature. Small Fruits Review, 3(3-4): 423-440.
22. Oliveira D. M., Rosa C. I. L. F., Kwiatkowski A. & Clemente E., 2013. Biodegradable coatings on the postharvest of blackberry stored under refrigeration. Revista Ciência Agronômica, 44: 302-309.
23. Öztürk B., & Ağlar E. 2019. Effects of modified atmosphere packaging (MAP) and Aloe vera treatments on quality characteristics of cornelian cherry fruits during cold storage. Akademik Ziraat Dergisi, 8(1): 1-8.
24. Perkins-Veazie P., Collins J. K. & Howard L., 2008. Blueberry fruit response to postharvest application of ultraviolet radiation. Postharvest Biology and Technology, 47(3): 280-285.
25. Sánchez M. T., De la Haba M. J., Benítez-López M., Fernández-Novales J., Garrido-Varo A. & Pérez-Marín D., 2012. Non-destructive characterization and quality control of intact strawberries based on NIR spectral data. Journal of Food engineering, 110(1): 102-108.
26. Sanford K.A., Lidster P.D., McRae K.B., Jackson E.D., Lawrence R.A., Stark R., Prange R.K., 1991. Lowbush blueberry quality changes in response to mechanical damage and storage temperature. J. Am. Soc. Hort. Sci. 116: 47–51.
27. Singh S. K., Singh R. S. & Awasthi O. P., 2013. Influence of pre-and post-harvest treatments on shelf-life and quality attributes of ber fruits. Indian J. Hort. 70(4): 610-613.
28. Sumnu, G., Bayindirli, L., 1995. Effects of coatings on fruit quality of amasya apples. Food Science and Technology, 28(5): 501-505.
29. Ștefănescu B. E., Szabo K., Mocan A., Crişan G., 2019. Phenolic compounds from five Ericaceae species leaves and their related bioavailability and health benefits. Molecules, 24(11): 2046.
30. Zeraatgar H., Davarynejad G. H., Moradinezhad F. & Abedi B., 2018. Effect of salicylic acid and calcium nitrate spraying on qualitative properties and storability of fresh jujube fruit (*Ziziphus jujube* Mill.). Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 46(1), 138-147.
31. Zydlik Z., Cieśliński S., Kafkas N. E., Morkunas I., 2019. Soil preparation, running highbush blueberry *(Vaccinium corymbosum L.)* plantation and biological properties of fruits. In Modern Fruit Industry. IntechOpen., pg. 1-11.
32. AOAC, 2000. Official Methods of Analysis. Association of Official Analytical Chemist. EUA, Gaithersburg, Maryland.
33. AOAC International, 2002. Official methods of analysis (OMA) of AOAC International 17th Edition, USA. Method number: 920.15. Available at: http://www.eoma.aoac. org/.
34. JAOAC, 1968. Journal of Association of Official Analytical Chemists, Volume 51, Issue 4, 1 July 1968, pp. 755–761.
35. PN-A-04019, 1998. Produkty spożywcze – Oznaczanie zawartości witaminy C (Food products – Determination of vitamin C content).

36. UNECE (United Nations Economic Commission for Europe). UNECE STANDARD FFV-57 Concerning the Marketing and Commercial Quality Control of Berry Fruits; United Nations. New York and Geneva. 2011.
37. ***2022. FAO Statistic Division (accesat la 08.2022).

Tables and Figures

Table 1. Main effects of cultivar, storage time (ST) and year and significance of interaction effect cultivar x ST, Cultivar x year, ST x year, cultivar x ST x year, over fruit weight loss, dry weight (DW), titratable acidity (TA), total sugar and vitamin C content of fruits on blueberry cultivars 'Delicia' and 'Bluecrop'

	Experimental factor	Fruits weight	Fruit weight loss	DW content	TA	Total sugar content	Vitamin C
Significance	Cultivar	*** p=0.000	*** p=0.000	*** p=0.000	*** p=0.000	*** p=0.000	*** p=0.000
	Storage time (ST)	n.s. p=0.413	*** p=0.000	*** p=0.000	*** p=0.000	*** p=0.000	*** p=0.000
	Year	*** p=0.000	*** p=0.000	*** p=0.000	*** p=0.000	n.s. p=0.688	*** p=0.000
	Cultivar x ST	n.s. p=0.986	*** p=0.000	*** p=0.000	n.s. p=0.081	n.s. p=0.081	*** p=0.000
	Cultivar x Year	* p=0.014	*** p=0.000	*** p=0.000	*** p=0.000	*** p=0.000	*** p=0.000
	ST x Year	n.s. p=0.928	*** p=0.000	*** p=0.000	*** p=0.000	*** p=0.000	*** p=0.000
	Cultivar x ST x Year	n.s. p=0.961	*** p=0.000	*** p=0.000	n.s. p=0.386	* p=0.034	*** p=0.000

*Significance symbols and letters refer to cultivar, storage time (ST), year and cultivar x ST, cultivar x year, ST x year, cultivar x ST x year interaction efects: n.s. = non significant; * = significant (at p ≤ 0.05), ** = highly significant (at p ≤ 0.01), and *** = very significant (at p ≤ 0.001, respectively).

Table 2. Statistical descriptors (mean, median, standard deviation, minimum absolute and maximum absolute) for fruits weight, fruit weight loss, DW, TA, total sugar and vitamin C content on blueberry fruits 'Delicia' and 'Bluecrop' cultivars

Cultivar	Statistical descriptors	Fruits weight (g)	Fruit weight loss (%)	DW content (%)	TA (%)	Total sugar content (%)	Vitamin C (mg/100g FW)
'Delicia'	Mean	182.89	2.84	15.30	1.01	6.99	18.70
	Median	160.50	2.01	15.13	1.07	7.17	18.91
	Std. deviation	38.72	2.04	1.88	0.18	1.20	8.32
	Minimum absolute	137.88	1.32	12.05	0.56	5.03	5.89
	Maximum absolute	249.00	8.03	18.67	1.27	8.84	31.07
'Bluecrop'	Mean	163.46	1.73	15.72	0.79	6.62	20.01
	Median	138.71	1.88	14.02	0.75	6.91	17.25
	Std. deviation	31.85	0.65	3.46	0.26	1.04	10.75
	Minimum absolute	127.60	0.18	12.05	0.43	4.49	7.26
	Maximum absolute	211.02	2.55	23.79	1.32	8.04	39.82
'Delicia' and 'Bluecrop'	Mean	173.33	2.30	15.51	0.90	6.81	19.35
	Median	155.01	1.98	14.58	0.95	6.95	18.91
	Std. deviation	36.55	1.61	2.77	0.29	1.13	9.55
	Minimum absolute	127.60	0.18	12.05	0.43	4.49	5.89
	Maximum absolute	249.00	8.03	23.79	1.32	8.84	39.82

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Table 3. Correlation between the values of the quality indicators studied in the fruits of the 'Delicia' and 'Bluecrop' blueberry cultivars during the storage period

	Fruits weight (g)	Fruit weight loss (%)	DW content (%)	TA (%)	Total sugar content (%)	Vitamin C (mg/100g FW)
Fruits weight	1					
Fruit weight loss	-0.362(**)	1				
DW content	-0.466(**)	0.348(**)	1			
TA	0.369(**)	0.100	-0.329(*)	1		
Total sugar content	0.115	-0.529(**)	-0.580(**)	0.535(**)	1	
Vitamin C	-0.802(**)	-0.160	-0.689(**)	-0.079	0.326(*)	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Fig. 1. Influence of storage period on fruits weight (g) of blueberries by cultivar

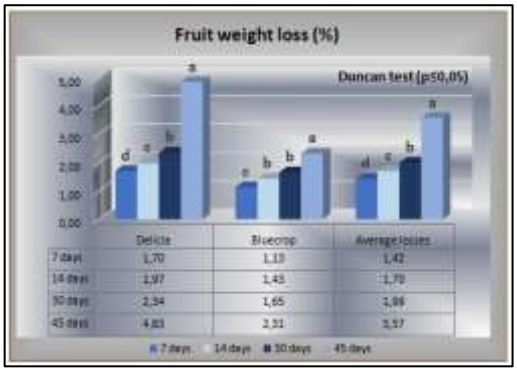

Fig. 2. Influence of storage period on weight loss (%) of blueberries by cultivar

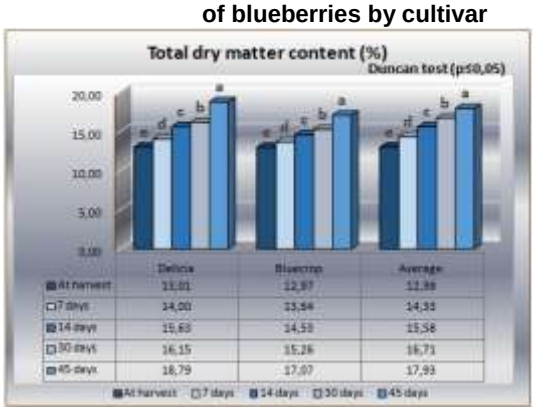

Fig. 3. Influence of storage period on total dry matter content (%) according to cultivar

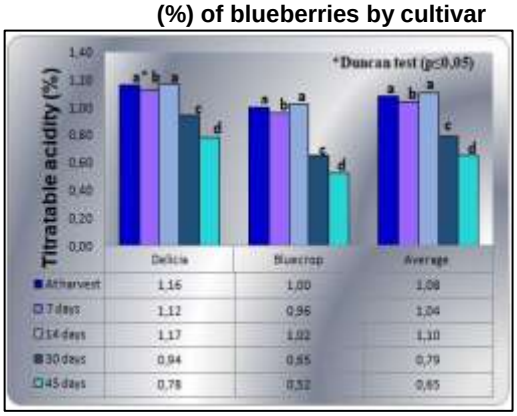

Fig. 4. The influence of the storage period on the content of organic acids (%) in blueberries according to the variety

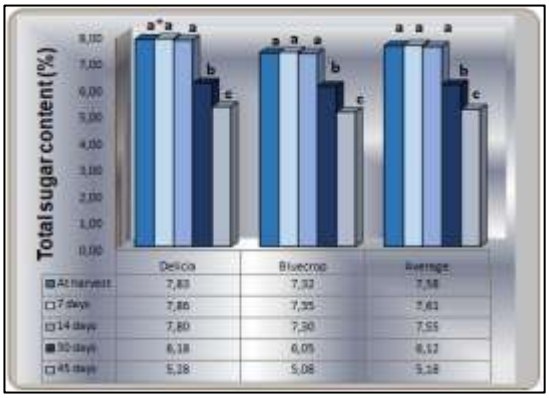

Fig. 5. Influence of storage period on total sugar content (%) of blueberries by cultivar

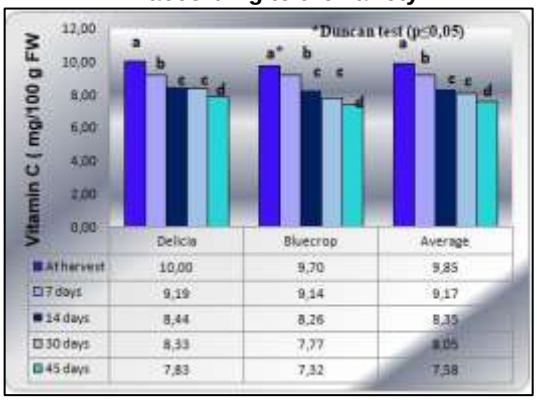

Fig. 6. Influence of storage period on vitamin C content (mg/100g FW) of blueberries according to cultivar

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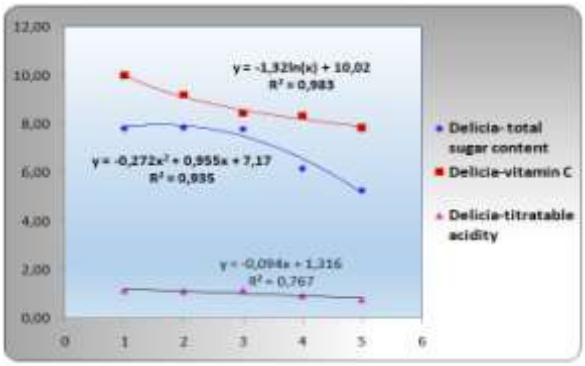

Fig. 7. Influence of storage period on TA, total sugar content and vitamin C

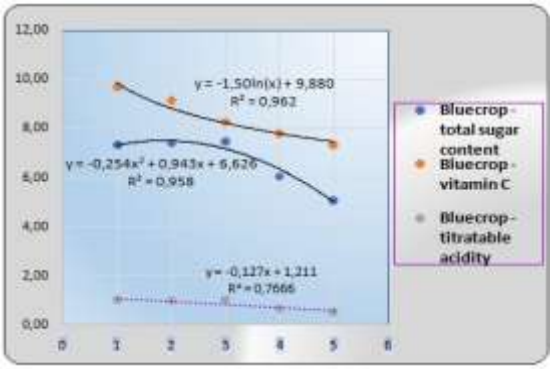

Fig. 8. Influence of storage period on TA, total sugar content and vitamin C in Bluecrop cultivar in Delicia cultivar