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Physical-chemical properties of blueberry as influenced by production and conservation processes

Christophe F. Gonçalves - christopheferreira2009@hotmail.com
ESAV, Instituto Politécnico de Viseu
Raquel P. F. Guiné - raquelguine@esav.ipv.pt
CI&DETS/ESAV - Instituto Politécnico de Viseu
Fernando Gonçalves - fgoncalves@esav.ipv.pt
CI&DETS/ESAV, Instituto Politécnico de Viseu
Daniela V. T. A. Costa - dvtacosta@gmail.com
ESAV, IPV / UC-ESB

Abstract
In this study was evaluated the effect of production mode (organic versus conventional) on some physical-chemical properties of three blueberry cultivars (Duke, Bluecrop, Ozarkblue). The properties evaluated were caliber, moisture content, total soluble solids, acidity, color and texture. The effect of storage on these properties was also evaluated. For this, samples were analyzed at harvest and after 7 and 14 days of storage. This work showed that Duke blueberries had a higher diameter and a more intense coloration. It was also found that the Duke blueberries presented a harder and more elastic texture, when compared with the other cultivars at study.Cultivar Ozarkblue from conventional production mode showed at harvest the higher sugar content and for cv. Ozarkblue a trend for decreasing acidity along storage time, was further noticed. In respect to the production mode it was detected that the blueberries produced in organic farming were less acid and less sweet, but had a more intense blue color and were less elastic when compared with blueberries produced in conventional mode. The blueberry storage temperature (cold or at room temperature) did not meaningfully influence the chemical properties of blueberry, but influenced the physical properties, namely colour and texture.

Keywords
Blueberry, Conservation, Color, Organic Farming, Texture.

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1. Introduction

Native from North America the blueberry has been used by man since the sixteenth century, and is popularly known as longevity fruit. The fruit is a berry with bluish color, which has relatively small dimensions and weight, being very much appreciated for its exotic flavor.
Among fruits, blueberries are considered as one of the richest sources of bioactive compounds that impart healthy properties and exert a protective effect against many disorders, and particularly degenerative diseases, such as memory loss, cancer, heart disease, vision problems and ageing [1].
Blueberry crop has suffered a marked expansion, mainly due to a greater fruit demand, and arouses the interest of producers and researchers because of the beneficial health characteristics that are valued by consumers. Hence, in the last two decades, the worldwide area planted with blueberries has largely increased, also possible due to the greater availability of genetic material, which has allowed the diversification of the geographical zones suitable for the cultivation of this crop [2].
It has been shown that yield is greater when the harvest is carried out with the fruit completely blue, i.e., at full maturation, instead of being harvested at an early ripening stage suitable for export. In fact, when the fruit is allowed to mature on the bush its diameter and weight are increased [3,4].
Conventional agriculture includes practices such as burning of crop residues, the reversal of topsoil, mobilization for weed control and preparation of the seedbed. These techniques promote soil compaction, erosion, increased carbon dioxide and contamination of waterways with sediment, fertilizers and pesticides. Conventional agriculture practices have led to environmental damage and degradation of ecosystems, which poses a serious threat to the quality of life of all living beings [5]. Organic farming aims to introduce external elements in the agro system in order to avoid the indiscriminate use of pesticides, which are destabilizing factors of the ecosystem. Hence, in recent years, there has been a significant increase in consumer demand for foods produced in organic farming in opposition to conventional farming. On the basis of this demand are aspects related to the quality of the food produced using less aggressive cultivation techniques and on the other hand greater awareness of the general public about environmental issues and care in preserving ecosystems [6].
Blueberries are commercialized in different ways and food preparations, apart from the fresh form. However, fresh fruits quickly deteriorate after they are picked and have a shelf life of less than 2 weeks at 0 C and 90–95% humidity after harvesting [7]. Hence the conservation is of the utmost importance.
This work intended to evaluate the effect of production mode (organic or conventional) in three blueberry cultivars (Duke, Bluecrop and Ozarkblue) with respect to some biometric attributes (size and weight), some physical properties (color and texture) and some chemical components (moisture content, total soluble solids and acidity. Furthermore, this study was also complemented with the evaluation of the change along storage (up to 14 days) in some of the properties analyzed.

2. Experimental Procedure

2.1. Sampling

For this work were evaluated three varieties of Northern Highbush blueberries (Duke, Bluecrop, Ozarkblue), all from farms located in the North-Centre region of Portugal. The blueberries were original from conventional production mode and also from organic farming.
The fruits were harvested in full maturity state, as the berries are normally marketed, corresponding to complete color development and without loss of turgor. For each cultivar were collected approximately 500 g of berries, selected randomly from several plants in different parts of the same field.

2.2. Handling and conservation

After harvesting, the samples were transported to the laboratory in appropriate plastic cuvettes protected from light and refrigerated.
The properties were then evaluated in the fresh samples and also after 7 and 14 days of storage under refrigeration at a temperature of 4 ºC and 85 to 90% relative humidity (RH).
In addition, for the cultivar Duke produced in conventional mode, were also evaluated the changes in the blueberries when stored at room temperature (around 15 to 25 ºC and 30 to 60% RH).

2.3. Biometric characteristics

For the assessment of biometric characteristics, weight and size, 30 berries were randomly selected as representative of each sample. The size of each berry was measured with the aid of an automated caliper rule and the weight was determined through a precision scale.

2.4. Chemical analysis

Moisture content was determined by a Halogen Moisture Analyzer HG53 from mettle Toledo. The operating conditions were as follows: heat source - halogen lamp; drying temperature - 120 °C; speed of drying - 3 (intermediate). The number of repetitions for each sample was 8 independent measurements.
For the determination of acidity, the sample preparation followed the Portuguese Standard NP-783, 1985 [7] and the acidity determination was carried out according to the NP-1421, 1977 [8].
For the determination of total sugars the sample was prepared by the same procedure as for acidity. Total sugars were determined as total soluble solids by refractometry and the Brix graduation was measured using a refractometer Atago 3T. In all cases three replicates were made.

2.5. Color measurement

The color of blueberries was determined with a colorimeter (Chroma Meter - CR-400, Konica Minolta) in the CIE Lab color space, though the Cartesian coordinates L*, a* and b*. The L* axis represents Lightness and varies from 0 (corresponding to no lightness, i.e., absolute black), to 100 which is maximum lightness (i.e. absolute white). The other axes are represented by a* and b* and they are at right angles to each other. The a* axis varies from green at one extremity (represented by -a) to red at the other (+a), whereas the b* axis varies from blue at one end (-b), to yellow (+b) at the other. Although in theory there are no extreme values of a* and b*, in practice they can be numbered from -128 to +127.
For each sample were examined 55 berries.

2.6. Texture analysis

To determine the texture attributes (strength and elasticity) were randomly selected also 55 representative berries of each sample. The analyzes were performed with a texturometer TA.XT Plus , from Stable Micro Systems, with the following test conditions: pre-test speed = 1.50 mm/s, test-speed = 1.00 mm/s, post-test speed = 10.00 mm/s, distance = 6 mm, trigger force = 0.05 mm and a load cell of 50 kg. The results were treated with Exponent software TEE (Stable Micro Systems) and from the obtained texture profile (Figure 1) was determined firmness (strength on the highest peak) and elasticity (distance at the highest point).

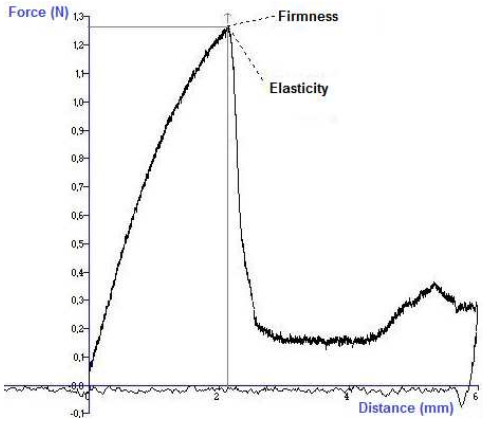

Figure 1 – Texture profile analysis for blueberry.

3. Results and Discussion

3.1. Biometric characteristics

The results showed that the mass of blueberries varied depending on the cultivar and production mode. At harvest, the berries from cv. Ozarkblue were heavier than the other cultivars, and particularly when produced in conventional mode (Figure 2). This trend for the products being lighter when produced in organic production was observed for the other two varieties studied, although the differences were less significant, particularly in Bluecrop, where the difference was minimal.

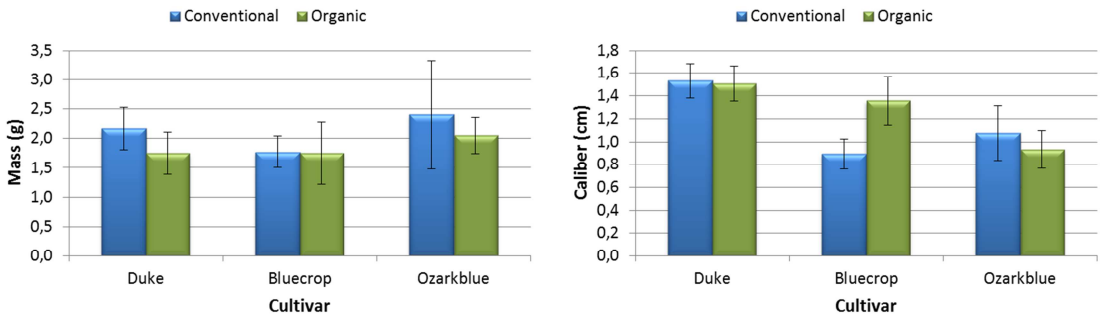

Figure 2 – Mass (left) and caliber (right) of the blueberries evaluated.

When harvested, the blueberries of cultivar Duke had higher average caliber when compared to the other cultivars (Figure 2) either in organic farming or conventional production mode. The cultivar that showed a lower average caliber was Bluecrop grown in conventional production. For variety Ozarkblue, blueberries in conventional production had a higher caliber. The size of the berries obtained for Ozarkblue was 0.93 cm and 1.07 cm, which are

values lower than the results of 1.60 cm obtained by Machado and Jesus [9] for the same cultivar. However, the harvest blueberry gauge values obtained in cultivars were similar to values obtained by Sousa [10] (range 1.01 to 2.25 cm).

3.2. Chemical analysis

The moisture content at harvest was very similar for both production modes, varying slightly among varieties (Figure 3(a)). The value obtained for cultivar Bluecrop at harvest (around 75% corresponding to 25% of dry matter) is higher than that reported by Skupien [11] (16% dry matter). In the study of Kalt and McDonald [12], dry matter values obtained in the blueberry at harvest were around 13.8%. The results in Figure 3(b) show that the effect of room temperature storage was not much different to cold storage in respect to the variation of the moisture content along conservation. Furthermore, in most cases a loss in moisture was observed along time.

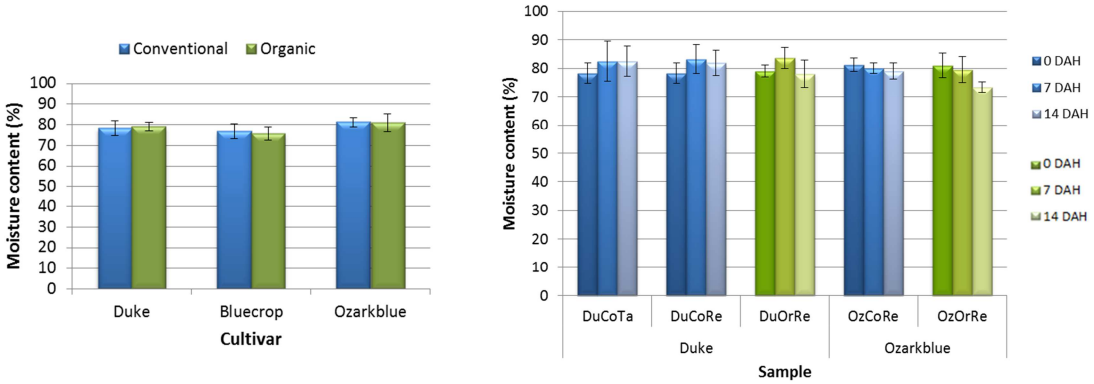

Figure 3 – (Left) Moisture content of the fresh blueberries. (Right) Moisture content of the blueberries upon harvesting and along conservation (Coding: Cultivar: Du=Duke, Bl=Bluecrop, Oz=Ozarkblue; Production mode: Co=conventional, Or=organic; Conservation: Re=refrigeration, Ta=ambient temperature; DAH=days after harvest).

Figure 4(a) shows the concentration in °Brix of soluble solids (expressed in g sucrose per 100 g sample) for the different samples analyzed right after harvest. The cultivar that showed the larger amount of soluble solids was cv. Ozarkblue produced in conventional mode (15.39%). For the cv. Duke the major difference was observed between both production modes, being 6.86% for organic farming and 11.26% for conventional mode. Figure 4(b) shows the evolution of total soluble solids content during the storage. Again in this case the trends are contradictory. Still, for cv. Ozarkblue a decreasing trend was observed during storage, as suggested by Zheng et al. [13].

The results of the acidity obtained for the different samples analyzed are shown in Figure 5. The mean values of acidity at harvesting varied between 0.04 and 0.10 mg citric/100 g acid (Figure 5(a)). Kalt and McDonald [12] obtained at harvest for blueberries of cv. Duke 0.05 mg citric acid/100g, which is similar to the results obtained in this study for the same cultivar. Also Zheng et al. [13], found acidity values around 0.08 mg citric acid/100g for blueberries at harvest. As regards the effect on the acidity of conservation (Figure 5(b)) blueberry cultivar Ozarkblue appeared to exhibit a tendency of decreasing acidity along storage time. The same trend was observed by Zheng et al. [13], which revealed a reduction in the acidity over the 35 days of storage after harvest.

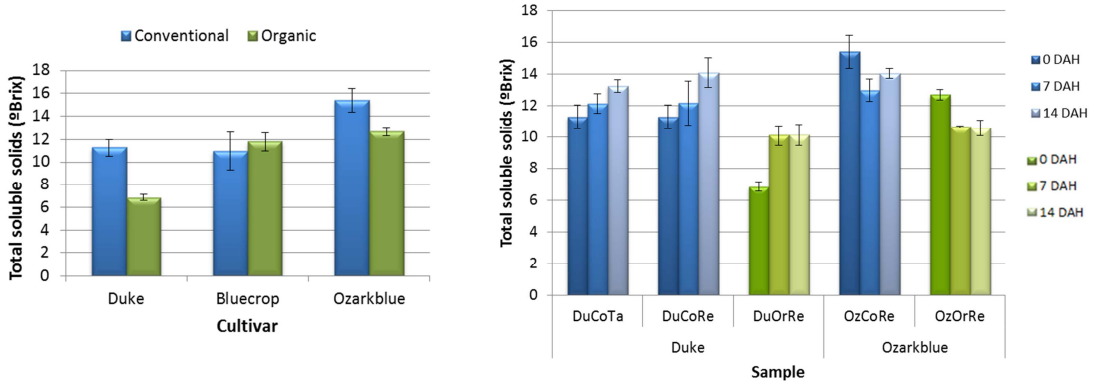

Figure 4 – (Left) Total soluble solids of the fresh blueberries. (Right) Total soluble solids of the blueberries upon harvesting and along conservation (Coding: Cultivar: Du=Duke, Bl=Bluecrop, Oz=Ozarkblue; Production mode: Co=conventional, Or=organic; Conservation: Re=refrigeration, Ta=ambient temperature; DAH=days after harvest).

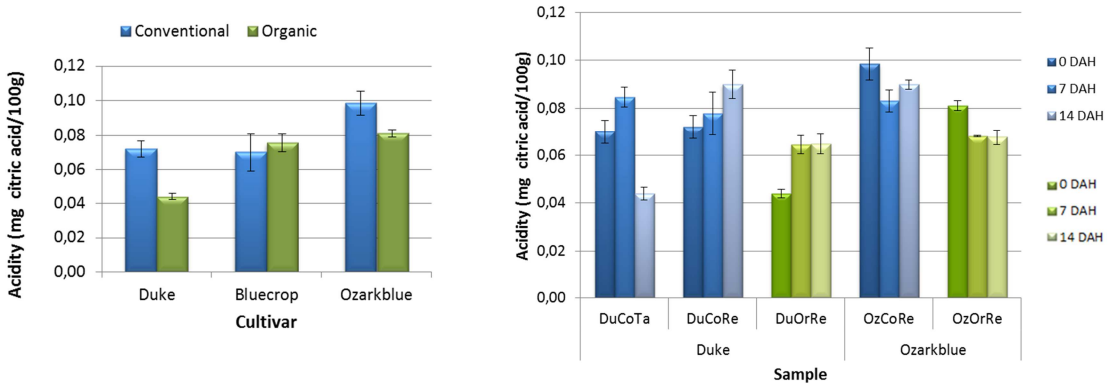

Figure 5 – (Left) Acidity of the fresh blueberries. (Right) Acidity of the blueberries upon harvesting and along conservation (Coding: Cultivar: Du=Duke, Bl=Bluecrop, Oz=Ozarkblue; Production mode: Co=conventional, Or=organic; Conservation: Re=refrigeration, Ta=ambient temperature; DAH=days after harvest).

3.3. Color

Table 1 lists the values for the color coordinate L*, lightness, at harvest and after 7 and 14 days of storage. At harvest, samples Ozarkblue were less dark, with higher values of L* (around 40), while cultivars Duke and Bluecrop exhibited similar values of L* (around 35). Along storage, lightness tends to decrease slightly, indicating that the blueberries became darker. The values of L* obtained by Zheng et al. [13] and Rocha [14], ranged from 31 at harvesting and 28.5 after 30 days of storage, thus confirming a tendency for decrease along time.

The color coordinate a* shows in the present case values very close to zero, either positive or negative but around zero (Table 2), thus indicating that there is neither a predominance of green nor of red. Because all values are very similar and the standard deviations are of the same magnitude of the value itself (as a consequence of having positive and negative values), no comparisons could be made among the cultivars or along drying, because the results are similar in all cases. In the study by Zheng et al. [13] the values of a* coordinate were as follows: 0.46 at harvesting; -1.85 at 7 days after harvest; and -1.62 at 14 days after harvest, thus confirming that the balance between greenness/redness is not significant for blueberry color.

Table 1 – Lightness (L*) of the blueberries upon harvesting and along conservation.

Sample [1]	L* along time [2]		
	0 DAH	7 DAH	14 DAH
DuCoRe	33.15 ± 2.69	30.64 ± 2.04	31.08 ± 2.77
DuCoTa	33.15 ± 2.69	31.58± 2.28	31.78 ± 2.26
DuOrRe	34.39 ± 2.07	36.02 ± 2.29	35.74 ± 4.79
BlCo	33.82 ± 4.19	-	-
BlOr	35.59 ± 1.88	-	-
OzCoRe	38.56 ± 2.50	35.40 ± 2.86	34.17 ± 3.07
OzOrRe	39.66 ± 2.05	37.10 ± 3.37	35.85 ± 3.27

[1]Cultivar: Du=Duke, Bl=Bluecrop, Oz=Ozarkblue; Production mode: Co=conventional, Or=organic; Conservation: Re=refrigeration, Ta=ambient temperature.
[2]DAH=days after harvest.

Table 2 – Color coordinate a* of the blueberries upon harvesting and along conservation.

Sample [1]	a* along time [2]		
	0 DAH	7 DAH	14 DAH
DuCoRe	0.54 ± 1.33	0.39 ± 0.61	0.73 ± 1.59
DuCoTa	0.54 ± 1.33	0.00 ± 0.40	0.08 ± 0.53
DuOrRe	-0.21 ± 0.29	-0.56 ± 0.24	-0.11 ± 1.46
BlCo	0.53 ± 0.94	-	-
BlOr	0.60 ± 1.18	-	-
OzCoRe	0.34 ± 0.52	0.60 ± 0.74	-0.05 ± 0.58
OzOrRe	-0.05 ± 0.52	1.95 ± 2.43	1.27 ± 1.40

[1]Cultivar: Du=Duke, Bl=Bluecrop, Oz=Ozarkblue; Production mode: Co=conventional, Or=organic; Conservation: Re=refrigeration, Ta=ambient temperature.
[2]DAH=days after harvest.

Table 3 shows the values for color coordinate b*, which represents blue color when negative and yellow when positive. In the present case the values are negative, confirming the blue color of the berries. At harvest, the intensity of blue is higher for cultivar Bluecrop in organic farming (-8.21) and Ozarkblue in conventional mode (-8.01). Cultivar Duke showed less intense blue coloration. Regarding the effect of storage, a slight trend to diminish the blue color was observed in most cases. In a study by Rocha [14], the author concluded that, under similar conditions, the coordinate b* values were 0.36 and 2.23. Zheng et al. [2013] found at harvest values of b* of 4.68, a result similar to the values observed in this study.

Table 3 – Color coordinate b* of the blueberries upon harvesting and along conservation.

Sample [1]	b* along time [2]		
	0 DAH	7 DAH	14 DAH
DuCoRe	-5.84 ± 1.27	-4.70 ± 1.01	-5.04 ± 1.42
DuCoTa	-5.84 ± 1.27	-4.93 ± 1.34	-4.80 ± 1.06
DuOrRe	-6.61 ± 0.89	-7.31 ± 1.02	-7.43 ± 2.08
BlCo	-6.16 ± 1.87	-	-
BlOr	-8.21 ± 0.90	-	-
OzCoRe	-8.01 ± 0.88	-7.14 ± 1.20	-6.31 ± 1.31
OzOrRe	-7.01 ± 0.87	-6.35 ± 1.83	-6.65 ± 0.98

[1]Cultivar: Du=Duke, Bl=Bluecrop, Oz=Ozarkblue; Production mode: Co=conventional, Or=organic; Conservation: Re=refrigeration, Ta=ambient temperature.
[2]DAH=days after harvest.

3.4. Texture

At harvest the values of firmness range between 1.31 and 1.70 N (Table 4), which are similar to those found in the study by Kalt and McDonald [12] for mature blueberries, about 2 N. Although the differences are very small, cv. Duke presents higher values for firmness, indicating that these berries were slightly harder. As to the effect of storage, increasing storage time increased firmness in all cases.

Table 4 – Firmness of the blueberries upon harvesting and along conservation.

Sample [1]	Firmness (N) along time [2]		
	0 DAH	7 DAH	14 DAH
DuCoRe	1.70 ± 0.16	1.90 ± 0.20	1.99 ± 0.28
DuCoTa	1.70 ± 0.17	1.31± 0.32	1.34 ± 0.37
DuOrRe	1.63 ± 0.25	1.86 ± 0.26	1.89 ± 0.44
BlCo	1.46 ± 0.23	-	-
BlOr	1.31 ± 0.22	-	-
OzCoRe	1.40 ± 0.25	1.53 ± 0.34	1.50 ± 0.45
OzOrRe	1.36 ± 0.17	1.71 ± 0.33	1.57 ± 0.48

[1]Cultivar: Du=Duke, Bl=Bluecrop, Oz=Ozarkblue; Production mode: Co=conventional, Or=organic; Conservation: Re=refrigeration, Ta=ambient temperature.
[2]DAH=days after harvest.

Table 5 shows the elasticity of the blueberries evaluated at harvest and after storage. Once again the differences seem quite small, but a trend for less elasticity was still observed for cultivar Ozarkblue (2.02 and 2.19 mm, respectively for organic or conventional production modes). Elasticity seems to increase along storage, being this rend observed for all samples at study.

Table 5 – Elasticity of the blueberries upon harvesting and along conservation.

Sample [1]	Elasticity (mm) along time [2]		
	0 DAH	7 DAH	14 DAH
DuCoRe	2.89 ± 0.42	3.15 ± 0.45	3.15 ± 0.68
DuCoTa	2.89 ± 0.42	2.83± 0.50	2.99 ± 0.77
DuOrRe	2.44 ± 0.38	3.04± 0.46	4.08 ± 0.63
BlCo	2.49 ± 0.46	-	-
BlOr	2.93 ± 0.42	-	-
OzCoRe	2.19 ± 0.45	2.32 ± 0.39	2.99 ± 0.71
OzOrRe	2.02 ± 0.36	1.97 ± 0.26	2.43 ± 0.61

[1]Cultivar: Du=Duke, Bl=Bluecrop, Oz=Ozarkblue; Production mode: Co=conventional, Or=organic; Conservation: Re=refrigeration, Ta=ambient temperature.
[2]DAH=days after harvest.

4. Conclusions

This study allowed concluding that the berries from cultivar Duke presented an average caliber higher when compared to the other cultivars, and that they also had a more intense blue color and were darker. Regarding texture, the Duke blueberries presented a harder and more elastic texture.
The cultivar that showed at harvest the larger amount of soluble solids was cv. Ozarkblue produced in conventional mode. The acidity showed for cv. Ozarkblue a trend for decreasing along storage time.
With regard to the production mode it was observed that the blueberries produced in organic farming had lower levels of acidity and total soluble solids, a more intense blue color and were less elastic when compared with blueberries produced in conventional mode.
The blueberry storage temperature (cold or at room temperature) did not meaningfully influence the chemical properties of blueberry, but influenced the physical properties, so that the blueberries stored under refrigeration had a less intense color (lighter and less blue) and a firmer and less elastic texture. It was also found that the firmness higher in Duke berries and lowest in Ozarkblue berries.

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