COLOR AND HEAT STABILITY CHANGES OF ANTHOCYANINS IN WILD BERRY (BILBERRY AND STRAWBERRY) JUICES

Mariya G. Georgieva

Institute of Mineralogy and Crystallography "Acad. Ivan Kostov", Bulgarian Academy of Sciences, Acad. G Bonchev Str., bl. 107, 1113 Sofia, Bulgaria

Abstract

Color degradation, anthocyanins, and antioxidant activity were determined spectrophotometrically in wild strawberry and bilberry juices. The structure of anthocyanins influences pigment stability and color variation. Anthocyanins made up 43-49% of the content of total phenols in bilberry juices at the beginning of the heat test. The effects of the temperature on the degradation of anthocyanins in strawberry juices were determined at 85 ºC and respectively for bilberry juices at 95 ºC. Color and anthocyanins in juices were thermally degraded in a first-order kinetic degradation. Total anthocyanin degradation had a strong positive connection with chroma value (C). The findings are part of a study that used CIELCH and CIELAB color coordinates to characterize the quality of heat-treated bilberry and wild strawberry juices.*

Keywords: *anthocyanins, color, degradation, kinetic, wild berry species - bilberry and strawberry*

1. INTRODUCTION

Anthocyanins are pigments giving the colors – red, blue, and purple- to fruits, vegetables, and other foods (Khoo et al., 2017). They are mostly found in the glycosylated form in nature, and less frequently as acyl glycosides of anthocyanidins. Anthocyanidins possess flavylium structures, which are made up of two aromatic rings connected by a three-carbon heterocyclic ring containing the anthocyanidin moiety's conjugated double bonds forming the chromophore (Rodriguez-Amaya, 2019). Anthocyanins are responsible for the taste, and flavour of fresh fruits, as well as the red color and its different hues in many fruits and berries.

Color quality is a very important sensory characteristic of fruits, vegetables, and processed foods (Garzón and Wrolstad, 2002). It is the first criterion that buyers review (Holzwarth et al., 2012), and is a crucial criterion wanted to determine if food and beverages are acceptable (Le et al., 2019***).***

Anthocyanin pigment intensity and stability are influenced by a variety of elements such as pH, chemical structure, temperature, light, oxygen, ascorbic acid, sulfur dioxide, and metal ions during food processing and storage (Mazza and Miniati, 1993; Nakamura et al., 1999; Schwartz et al., 2008).

The antioxidant activity of berries varies by species, and wild berries, for example, are known to have a higher total antioxidant capacity than farmed berries. (Wu et al., 2004). Large differences in phenolic content have been detected in different wild berry populations (Yoncheva et al., 2010; Lätti et al., 2008, Gajdoš Kljusurić et al., 2016), showing that environmental factors, particularly the effect of processing and subsequent storage, have a significant impact.

Anthocyanins have been discovered to have potentially beneficial effects on cancer, inflammation, cardiovascular diseases, and obesity (Chen et al., 2018; Saulite et al., 2019; Thilavech, et al. 2018).

A pleasing color is not only a key sensory feature of fruit, but it also has a link to nutritional quality. The amount of anthocyanin in food is also a good predictor of its nutritional value. Anthocyanins, on the opposite hand, are unstable and simply degraded (White et al., 2011; Laokuldilok and Kanha, 2017). In general, berry juice processing modifies the color and amount of bioactive chemicals in the juice (Hager et al., 2008). Storage can cause anthocyanins to deteriorate even further, reducing the antioxidant capacity of juice (Brownmiller et al. 2009, Hellstrom et al. 2013, Qiu et al. 2018).

This study aims to evaluate the presence and antioxidant activity of phenols and anthocyanins in bilberries and wild strawberries were hand-picked from their natural habitats in two different regions of Bulgaria, Velingrad, and Troyan. The approach involved figuring out the effects of temperature treatment during food processing of bilberry and wild strawberry, specifically color stability in relation to the time of exposure. Anthocyanins' deterioration can be predicted based on visual color during thermal processing.

2. MATERIALS AND METHODS

2.1. Materials

Ripe fruit samples of bilberry (*Vaccinium myrtillus* L.) and strawberry (*Fragaria vesca* L.) were delivered from forest plantations in Troyan and Velingrad. Immediately after harvesting, fruits were frozen and stored at – 20 ºC until analysis.

2.2. Methods

2.2.1. Obtaining fruit juice and conducting a heat test

Frozen bilberries and wild strawberries are thawed at room temperature, after which the juice is used for extraction.

The juice (100 g) was pasteurized for 1 minute at 2450 Hz in a microwave oven and filtered. The samples were subjected to a heat stability test with warm-up times of 0, 30, 60, 90, and 120 minutes, and the temperature for bilberry juice was 95 ºC and 85 ºC for strawberry juice. Before determining the chromatic indices and measuring the color, the samples were diluted with McIlvaine buffer (0.1 M, pH 3.0) prepared according to Elving et al. (1956), to a total anthocyanin content of approximately 10 mg CGE / L (for heat-untreated samples) and allowed to equilibrate for 30 min. The same dilution factors were used after each heating step.

2.2.2. Determination of total polyphenols (TPP)

TPP were determined by the Folin-Ciocalteau method and were expressed as mg Gallic acid equivalents (GAE) per 100 g of frozen fruits. The Folin-Ciocalteau method was used to measure total polyphenols, which were represented as mg Gallic acid equivalents (GAE) per gram of frozen fruits (Current protocols in Food Analytical Chemistry, 2011).

2.2.3. Determination of total monomeric anthocyanins (TMA)

TMA were determined by a pH-differential method (Current protocols in Food Analytical Chemistry, 2011). The results were calculated using a molar absorptivity of 26900 L/(mol cm) and a molecular weight of 449.2 g/mol and expressed as equivalents of cyanidin 3–glucoside (CGE) in mg per 100 g of the lyophilized fruits.

2.2.4. Antioxidant activity

The antioxidant activity of fruit juices was measured spectrophotometrically with the UV-VIS spectrophotometer Helios Omega (Thermo Scientific) using the DPPH assay (Brand-Williams et al., 1995).

2.2.5. Measurement of color and determination of chromatic indices

The color of bilberry and strawberry juice is determined spectrophotometrically with a Helios Omega UV-Vis spectrophotometer, with ColorCalc Basic software installed (all elements of the equipment are from Thermo Fisher Scientific, Madison, WI, USA), using a1 cm path length cuvettes in the CIELCh system, CIELab (X-Rite Incorporated). The color spectra were registered at transmission in the region of 380-780 nm, at illuminant D65, and a viewing angle of 10º.

Absorption at λ = 420 nm, λ = 520 nm, and λ = 620 nm was used to determine the chromatic indices giving information about the color due to the different structural forms of anthocyanins. According to

the method proposed by Glories (1984 a, b) for wine and modified by Azar et al.1990 for bilberry juice.

$$d420\ \% = \frac{A420}{A420 + A520 + A620} \times 100$$

$$d520\ \% = \frac{A520}{A420 + A520 + A620} \times 100$$

$$d620\ \% = \frac{A620}{A420 + A520 + A620} \times 100$$

$$dA\ (\%) = (1 - \frac{A_{420} - A_{620}}{2\ x\ A_{520}})\ x\ 100,$$

Whereas:

A_{420}, A_{520}, A_{620} are the absorbance measured at λ = 420 nm, λ = 520 nm и λ = 620 nm;

d420 % provides information on the degradation products of most condensed anthocyanins and partially oxidized tannins;

d520 % due to the flavylium ion of free and condensed anthocyanins;

d620 % due to the quinoid structure of condensed anthocyanins;

dA (%) – to calculate the amount of red color due to the flavylium ion.

3. RESULTS AND DISCUSSION

The heat test is used to predict the stability during the processing and storage of fruits in terms of their chemical composition and quality characteristics.

Data on the content of total polyphenols, total monomeric anthocyanins, and the antioxidant capacity of berry juices subjected to a heat test for stability are presented in Table 1.

There were no statistically significant differences in the number of total polyphenols in bilberry juice with increased heating time but decreased antioxidant capacity. This can be explained by the significant reduction in anthocyanins, which make up 43–49% of the total polyphenol content of the juice at the beginning of the heat test.

In strawberry juice, the total polyphenols decrease and the antioxidant capacity (for the Troyan sample) increases until the 90th minute, after which it decreases. The results obtained are probably due to the presence of ellagic acid derivatives in the phenolic composition of strawberries. The decomposition of such components during heat treatment leads to an initial increase in antioxidant capacity as a result of the accumulation of ellagic acid. Degradation of free ellagic acid with prolonged heating may explain the decrease in antioxidant capacity.

Table 1. Content of total phenols (TPP), total monomeric anthocyanins (TMA), and antioxidant capacity (DPPH-test) of wild berry juice, subjected to a thermal stability test (95/85 ºC – bilberry/strawberry juice).

Warm-up time (min)	Type of juice and region of origin of the fruit			
	Bilberry		Strawberry	
	Velingrad	Troyan	Velingrad	Troyan
	TPP[a,d] (mg GAE/L[e])			
0	982.1 ± 48.1	1104.0 ± 48.6	1337.0 ± 28.1	1776.7 ± 23.1
30	905.8 ± 15.4	1130.0 ± 40.7	1236.0 ± 40.8	1712.5 ± 3.4
60	962.3 ± 47.2	1178.0 ± 23.6	1279.0 ± 42.2	1747.9 ± 14.0
90	967.6 ± 29.0	1112.3 ± 43.4	1259.5 ± 25.2	1590.6 ± 38.2
120	996.7 ± 48.8	1128.3 ± 27.1	1306.7 ± 35.3	1802.5 ± 39.7
	TMA[b,d] (mg CGE/L[e])			
0	419.0 ± 15.9	545.6 ± 1.1	87.1 ± 3.2	54.8 ± 0.4
30	338.9 ± 2.7	294.7 ± 12.3	71.3 ± 2.0	37.8 ± 0.7
60	299.9 ± 4.2	212.1 ± 10.4	61.9 ± 0.1	29.5 ± 1.4
90	228.5 ± 11.2	178.7 ± 2.2	50.3 ± 0.5	26.8 ± 1.3
120	157.3 ± 2.2	135.7 ± 3.5	40.5 ± 1.6	14.9 ± 0.2
	DPPH[c,d] (µmol TE/100 mL[e])			
0	573.9 ± 14.3	352.5 ± 17.3	1865.0 ± 91.4	2468.8 ± 121.0
30	525.8 ± 24.7	332.5 ± 16.3	1726.7 ± 15.5	3012.5 ± 105.4
60	475.8 ± 23.3	297.5 ± 14.6	3320.0 ± 162.7	4218.8 ± 206.7
90	371.6 ± 11.1	275.0 ± 13.5	3640.0 ± 178.4	5768.8 ± 80.8
120	239.8 ± 11.8	220.0 ± 10.8	2730.0 ± 43.7	4268.8 ± 183.6

The thermal degradation of total anthocyanins, which is shown in Figure 1, proceeds via a first-order reaction. These results are consistent with previous research, both in model systems (Sadilova et al., 2009; Mollov et al., 2007; Tanchev and Yoncheva, 1974; Tanchev and Yoncheva, 1975; Yoncheva and Tanchev, 1972) and in real food matrices (Garzón and Wrolstad, 2002; Cemeroglu et al., 1994; Skrede et al., 1992).

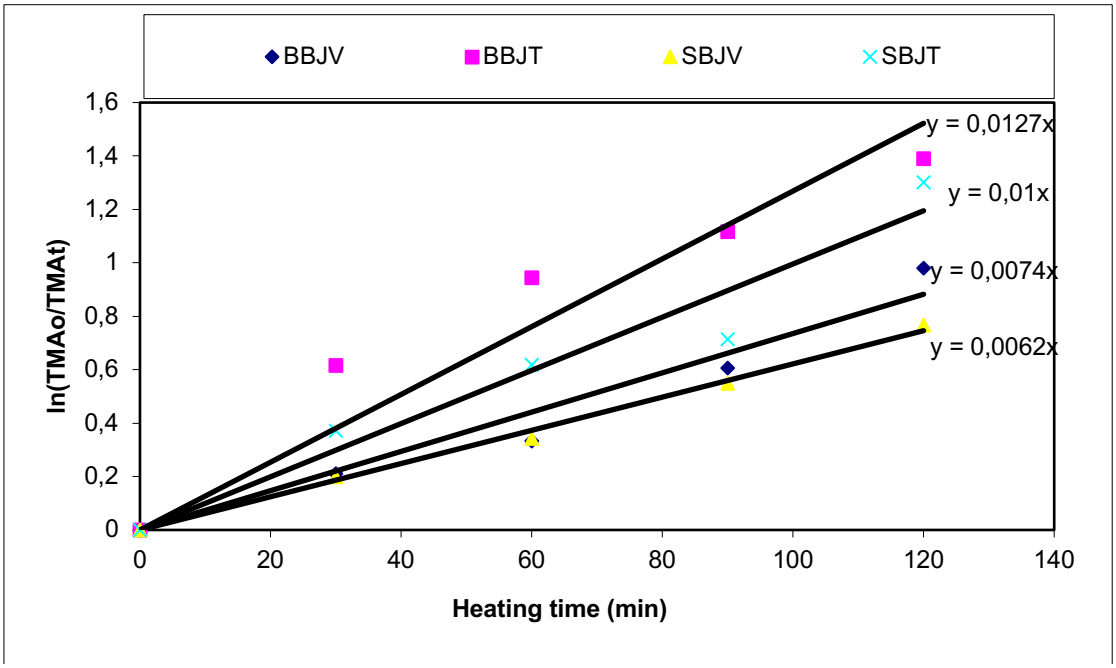

Figure 1. Kinetics of thermal degradation of anthocyanins when heating bilberry juice (95ºC) and wild strawberry (85ºC): TMA_o – initial concentration of anthocyanins (mg CGE/L); TMA_t – concentration of anthocyanins, respectively 30, 60, 90, and 120 min after heating; BBJV – bilberry juice from the Velingrad region; BBJT – bilberry juice from the Troyan region; SBJV – juice of wild strawberries from the region of Velingrad; SBJT – juice of wild strawberries from the region of Troyan.

The half-lifetime values of anthocyanins are given in Table 2. The slope of the line (Figure 1) and half-lifetime of anthocyanins indicate that the juices of strawberries and bilberries originating from Velingrad are more stable compared to the same juices obtained from the fruits of Troyan. This can be explained by the composition of the fruit, depending on the region of origin. Another study of Bulgarian bilberries and cranberries from the region of Velingrad found a reduction in bioactive components - amino acids and flavoring substances that determine the taste of the product (compote of them) in heat-treatment sterilization (Yocheva et al., 1987).

Table 2. Half-life time values ($T_{1/2}$, min) of anthocyanins in the juice of wild berries depend on the region of origin of the fruit.

Type of juice	**Region of origin of the fruit**	
	Velingrad	**Troyan**
Bilberry	93.7 (0.98[c])	54.6 (0.97[c])
Strawberry[b]	111.8 (0.99[c])	69.3 (0.97[c])

[a] Heat juice at 95 ºC.

[b] Heat juice at 85 ºC.

[c] Correlation coefficient.

The results obtained for the CIELab and CIELCh color indices of bilberry and wild strawberry juices subjected to a heat stability test are presented in Table 3.

The content of anthocyanins was standardized before colorimetric measurements. The values of the brightness (lightness, L*) of the berry juices from the region of Troyan are higher than those of the juices from the region of Velingrad. This is probably due to the transformations that occur with anthocyanins depending on the pH of the medium.

The results in Table 3 are estimated to significantly reduce the values of a* and b* and may be associated with the degradation of bilberry anthocyanins. The increase in the value b* and hue (h°) of wild strawberry juice indicates the formation of more yellow-brown components.

The values of chroma C (saturation of color) depend on the values of a* and b*. In bilberry juices, they decrease with increasing heating time. While those characterizing strawberry juices in the samples from Velingrad increased until the 60th minute of heating and then decreased again. The saturation of strawberry juices originating from Troyan increases until the 90th minute of heating and then decreases. This is probably due to the formation of more yellow-brown pigments in strawberry juice.

Table 3. Color indices by CIEL*ab* and CIEL*C*h of wild berry juice were subjected to a heat stability test (95/85 ºC – bilberry/strawberry juice).

Warm-up time (min)	Color indices				
	L^*	a^*	b^*	C^*	h
	Bilberry juice - Velingrad				
0	72.8	51.4	9.0	51.7	9.7
30	74.3	41.3	4.7	41.5	6.5
60	74.7	34.4	3.4	34.6	5.6
90	77.1	26.2	2.9	26.3	6.4
120	76.9	20.2	2.6	20.0	7.5
	Bilberry juice - Troyan				
0	71.7	48.7	8.0	50.0	9.7
30	77.0	38.3	4.2	38.0	6.4
60	83.3	23.5	2.1	23.6	5.1
90	84.7	19.0	2.7	19.2	8.1
120	84.1	16.7	2.9	16.4	9.0
	Strawberry juice - Velingrad				
0	68.4	35.6	31.1	46.9	41.1
30	68.0	31.5	33.2	47.8	46.4
60	64.3	29.8	35.2	49.1	49.3
90	64.8	28.5	37.2	46.8	52.5
120	62.5	27.6	38.6	47.5	54.5
	Strawberry juice - Troyan				
0	61.0	15.3	22.3	29.4	56.3
30	73.0	16.0	27.7	30.7	59.8
60	72.0	13.8	27.9	33.7	65.1

90	74.0	14.3	31.3	34.4	65.5
120	63.8	13.3	30.2	32.4	66.6

The absorption spectrum of bilberry juice in the visible region is determined by the equilibrium in a solution of the three forms of anthocyanins (flavylium cation, condensed anthocyanins, and partially oxidized tannins, quinoid structure).

Table 4. Chromatic index values (at λ = 420 nm, λ = 520 nm и λ = 620 nm) of wild berry juice subjected to a heat stability test (95/85 ºC – bilberry/strawberry juice).

Warm-up time (min)	Chromatic indices			
	420%	**520%**	**620%**	**dA%**
	Bilberry juice - Velingrad			
0	24.7	73.2	2.1	86
30	28.2	66.6	5.2	91
60	30.6	60.2	9.2	93
90	33.8	54.6	11.6	95
120	35.6	48.7	15.7	96
	Bilberry juice - Troyan			
0	25.2	71.2	3.6	87
30	28.4	65.3	6.3	93
60	31.1	60.5	8.4	97
90	34.5	55.1	10.4	98
120	35.8	50.6	13.6	98
	Strawberry juice - Velingrad			
0	52.0	42.1	5.9	66
30	54.2	38.5	7.3	63
60	56.9	35.1	8.0	59
90	55.5	35.4	9.2	62
120	56.1	34.4	9.5	61
	Strawberry juice - Troyan			
0	48.1	33.5	18.4	76
30	55.7	32.4	11.9	81
60	55.8	31.7	12.5	83
90	58.3	30.7	11.0	82
120	56.1	34.4	9.5	61

Absorption at 420 nm is due to partially oxidized condensed anthocyanins and tannins. Absorption at 520 nm is due to the flavylium ion of free and condensed anthocyanins. Absorption at 620 nm is due

to the quinoid structure of anthocyanins. The contribution of the flavylium cation of free and condensed anthocyanins (A_{520}) to the red color of the juice was estimated by dA(%) (Azar et al.1990).

The information in Table 4 appears that as the heating time increases, the values of the chromatic indices change, which shows that the different structural forms of anthocyanins change. The relative share of flavylium cation (520%) decreases, while that of oxidized (420%) and quinoidal (620%) forms of condensed anthocyanins increases. Chromatic indices show that anthocyanins, in their form of flavylium cation (520%), contribute the most to the red color of the juice, which is not heated. With increasing heating time, the color of the juice is determined mainly by the quinoid form (620%) of anthocyanins.

4. CONCLUSIONS

The analysis of the results obtained by studying the stability of phenolic antioxidants and the color of berry juices allows the formulation of the following conclusions:

- The rate of thermal degradation of anthocyanins in the juices of wild berries (bilberries, strawberries) from the region of Velingrad is lower than those of the region of Troyan.
- Color loss in the heat treatment of bilberry juice is measured by reducing the values of a* in the range of 61 - 86% for bilberries and 23 - 38% for wild strawberries.
- Bilberry juices lose between 33 and 39% of their original color saturation at 120 minutes of heating.

REFERENCES

1. Azar M, Verette E, Brun S 1990, Comparative study of fresh and fermented bilberry juices – state and modification of the coloring pigments. Journal of Food Science, 55, 164-166.
2. Brand-Williams W, Cuvelier M, Berset C 1995, Use of a free radical method to evaluate antioxidant activity. *Lebensmittel Wissenschaft und Technologie, 28:25-30*
3. Brownmiller C, Howard LR, Prior RL 2009, Processing and Storage Effects on Procyanidin Composition and Concentration of Processed Blueberry Products.J. Agr. Food Chem. 57, 1896–1902. DOI:10.1021/jf803015s.
4. Cemeroglu B, Velioglu S, Isik S 1994, Degradation kinetics of anthocyanins in sour cherry juice and concentrate. Journal of Food Science, 59, 1216-1218.
5. Chen, X, McClements, DJ, Zhu, Y, Chen, Y, Zou, L, Liu, W, Liu, C 2018, Enhancement of the solubility, stability and bioaccessibility of quercetin using protein-based excipient emulsions. Food Research International, 114, 30–37. https://doi.org/10.1016/J.FOODRES.2018.07.062.
6. Current Protocols in Food Analytical Chemistry 2011 John Wiley & Sons, Inc., F1.2.1-F1.2.13.
7. Elving P, Markowitz J, Rosenthal I 1956, Preparation of buffer systems of constant ionic strength. Analytical Chemistry, 28, 1179-1180.
8. Garzón, G, Wrolstad, R 2002, Comparison of the stability of pelargonidin-based anthocyanins in strawberry juice and concentrate. Journal of Food Science, 67, 1288-1299.
9. Glories Y 1984 a, La couleur des vins rouges. 1ère partie. Les équilibres des anthocyanes et des tanins. Connaissance de la Vigne et du Vin, 18, 195-217.
10. Glories Y 1984 b, La couleur des vins rouges. 2ème partie. Mesure, origine et interprétation. Connaissance de la Vigne et du Vin, 18, 253-271.

11. Hager TJ, Howard LR, Prior RL 2008, Processing and Storage Effects on Monomeric Anthocyanins, Percent Polymeric Color, and Antioxidant Capacity of Processed Blackberry Products.J. Agr. Food Chem. 56, 689–695. DOI:10.1021/jf071994g.
12. Hellstrom J, Mattila P, Karjalainen R 2013, Stability of Anthocyanins in Berry Juices Stored at Different Temperatures.J. Food Compos. Anal. 31, 12–19. DOI:10.1016/j.jfca.2013.02.010.
13. Holzwarth, M, Korhummel, S, Kammerer, DR, Carle, R 2012, Thermal inactivation of strawberry polyphenoloxidase and its impact on anthocyanin and color retention in strawberry (Fragaria x ananassa Duch.) purées. Eur. Food Res. Technol. 235, 1171–1180.
14. Gajdoš Kljusurić J, Mihalev K, Bečić I, Polović I, Georgieva M, Djaković S, Kurtanjek Ž 2016, NIR Analysis of Berry Fruit Extracts, Food Technol. Biotechnol. 54(2) 236–242 doi: 10.17113/ftb.54.02.16.4095
15. Khoo, HE, Azlan, A, Tang, ST, Lim, SM 2017, Anthocyanidins and anthocyanins: Colored pigments as food, pharmaceutical ingredients, and the potential health benefits. Food & Nutrition Research, 61(1), 1361779. https://doi.org/10.1080/16546628.2017.1361779.
16. Laokuldilok T, Kanha N 2017, Microencapsulation of Black Glutinous Rice Anthocyanins Using Maltodextrins Produced from Broken Rice Fraction as Wall Material by Spray Drying and Freeze Drying.J. Food Process. Pres. 41. DOI: 10.1111/jfpp.12877.
17. Lätti AK, Riihinen KR, Kainulainen PS 2008, Analysis of anthocyanin variation in wild populations of bilberry (*Vaccinium myrtillus* L.) in Finland. J Agric Food Chem. 56: 190–6. http://dx.doi.org/10.1021/jf072857m
18. Le, XT, Huynh, MT, Pham, TN, Than, VT, Toan, TQ, Bach, LG, Trung, NQ 2019, Optimization of total anthocyanin content, stability and antioxidant evaluation of the anthocyanin extract from Vietnamese Carissa carandas L. fruits. Processes 7, 468. https://doi.org/10.3390/pr7070468.
19. Mazza G, Miniati E 1993, Introduction. In Anthocyanin in Fruits, Vegetables, and Grains. CRC Press, Boca Raton, FL, USA. p 1-28.
20. Mollov, P., Mihalev, K., Shikov, V., Yoncheva, N., Karagyozov, V., 2007.Colour stability improvement of strawberry beverage by fortification with polyphenolic copigments naturally occurring in rose petals. Innov. Food Sci. Emerg. Technol. 8, 318–321.
21. Nakamura M, Takeuchi Y, Miyanaga K, Seki M, Furusaki S 1999, High anthocyanin accumulation in the dark by strawberry (Fragaria ananassa) callus. Biotechnol Lett 21: 695-699.
22. Qiu G, Wang D, Song X, Deng Y, Zhao, Y 2018, Degradation Kinetics and Antioxidant Capacity of Anthocyanins in Air-Impingement Jet Dried Purple Potato Slices. Food Res. Int.2018, 105, 121–128. DOI:10.1016/j.foodres.2017.10.050
23. Rodriguez-Amaya, DB 2019, Update on natural food pigments - A mini-review on carotenoids, anthocyanins, and betalains. Food Research International, 124, 200–205. https://doi.org/10.1016/j.foodres.2018.05.028.
24. Sadilova E, Stintzing FC, Kammerer DR, Carle R 2009, Matrix dependent impact of sugar and ascorbic acid addition on color and anthocyanin stability of black carrot, elderberry and strawberry single strength and from concentrate juices upon thermal treatment. Food Res. Int. 42, 1023–1033
25. Saulite L, Jekabsons K, Klavins M, Muceniece R, Riekstina U 2019, Effects of malvidin, cyanidin and delphinidin on human adipose mesenchymal stem cell differentiation into adipocytes, chondrocytes and osteocytes. Phytomedicine, 53, 86–95.
26. Schwartz SJ, von Elbe JH, Giusti MM 2008, Colorants. In Fennema's Food Chemistry. 4th ed. Damodaran S, Parkin KL, Fennema OR, eds. CRC Press, Boca Raton, FL, USA. p 571- 638.

27. Skrede G, Wrolstad R, Durst R (2000, Changes in anthocyanins and polyphenolics during juice processing of highbush blueberries (*Vaccinium corymbosum* L.). Journal of Food Science, 65, 357-364.
28. Tanchev S, Yoncheva N 1974, Kinetics of Thermal Degradation of the Anthocyanins Delphinidin-3-rutinoside and Malvidin-3-glucoside. Nahrung, 18, 747-752.
29. Tanchev, S., Yontcheva N 1975, Kinetik des termischen Abbaues der Anthocyane Pelargonidin-3-Glucosid und Cyanidin-3-Glucosid. Nahrung, 19, 629-633.
30. Thilavech T, Abeywardena MY, Dallimore J, Adams M, Adisakwattana, S 2018, Cyanidin-3-rutinoside alleviates methylglyoxal-induced cardiovascular abnormalities in the rat. Journal of Functional Foods, 49, 258–266. https://doi.org/10.1016/J.JFF. 2018.08.034.
31. White BL, Howard LR, Prior RL 2011, Impact of Different Stages of Juice Processing on the Anthocyanin, Flavonol, and Procyanidin Contents of Cranberries. J. Agr. Food Chem. 59, 4692–4698. DOI:10.1021/jf200149a.
32. Wu X, Beecher GR, Holden JM, Haytowitz DB, Gebhardt SE, Prior RL 2004, Lipophilic and hydrophilic antioxidant capacities of common foods in the United States. J Agric Food Chem. 52:4026–37.
33. Yocheva N, Katsarova S, Grigorova S 1987, Alteration of amino acids and aromatic substances during sterilization of bilberries and cranberries. Food-industry science, 3, 72-76 (in Bulgarian).
34. Yoncheva N, Georgieva M, Ivanov G, Mihalev K, Kondakova V 2010, Antioxidant capacity profile of fruits from different wild berry species. J Mount Agri Balkans, 13:1475–81.
35. Yoncheva N, Tanchev St 1972, Kinetik des thermischen Abbaues von Pelargonidin-3-sophorosid. Zeitschrift für Lebensmittel Untersuchung und Forschung, 150, 31-37.