Thesis of PhD dissertation

LILLA SZALÓKI-DORKÓ

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SZENT ISTVÁN UNIVERSITY

Department of Applied Chemistry

Department of Food Preservation

ANALYTICAL STUDY OF ELDERBERRY ANTHOCYANINS DURING FOOD TECHNOLOGY

LILLA SZALÓKI-DORKÓ

Budapest

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PhD School

Name: PhD School of Food Science

Field : Food Science

Head: Gyula Vatai
Professor, DSc
Szent István University, Faculty of Food Science
Department of Food Engineering

Supervisor: László Abrankó
Associate professor, PhD
Szent István University, Faculty of Food Science
Department of Applied Chemistry

Supervisor: Mónika Stéger-Máté
Associate professor, PhD
Szent István University, Faculty of Food Science
Department of Food Preservation

The appliant met the requirement of the PhD regulations of the Szent István University and the thesis is accepted for the defence process.

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Head of PhD School Supervisor

1. INTRODUCTION AND OBJECTIVE

In recent days, market for the application of synthetic colourants has decreased in favour of natural colourants, especially since the human safety of synthetic food dyes has been legally questioned. The regulation of the European Commission 1333/2008/EC states that foods containing certain artificial colouring material must be labelled with the following phrase: 'may have an adverse effect on activity and attention in children' [1333/2008 EC REGULATION]. Based on the above regulation along with the strengthening consumer demand, food producers tend to make efforts to replace their synthetic food colouring agents with natural food colourants [WROLSTAD & CULVER, 2012]. Food colourants from natural sources with high pigment content are becoming more preferred as alternatives of synthetic food agents to adjust food colour. Among them, elderberry (*Sambucus nigra* L.) may be an excellent and preferred source of natural food colourant in food industry due to high anthocyanin content [BRONNUM-HANSEN *et al.*, 1985; JAKOBEK *et al.*, 2007; LEE & FINN, 2007; VEBERIC *et al.*, 2009, 2015].

However colouring potential of concentrate is influenced by several factors therefore, studying anthocyanins only in elderberry fruit is not sufficient to evaluate colouring potential and colour stability in a food product. Therefore, the aim of my PhD work was to comprehensively evaluate food colouring properties of elderberry varieties grown in Hungary .

The study was divided into three parts:

- At first, effects of vintages and growing areas on anthocyanins profiles and total water soluble solid contents were evaluated during ripening to estimate optimal conditions of harvest.
- The aim of the second part was to investigate the effects of industrial concentrate production technology on individual and total anthocyanin content of elderberry juice. Qualitative and quantitative changes in elderberry anthocyanins were investigated in process samples obtained from various steps of concentrate production.
- Finally, the colour stability of elderberry juice concentrates in strawberry yoghurts was investigated during a storage experiment.

2. MATERIAL AND METHOD

2.1. Investigated elderberry varieties

Five different elderberry [*S. nigra* (L.) subsp. *nigra*, Adoxaceae] varieties, namely Haschberg, which is the only state-recognized variety in Hungary, and Samocco, Samident, Samyl and Sampo were collected in two different growing locations in Hungary: Vál (47°21'N, 18°40'E) and Nagyvenyim (46°57'N, 18°51'E).

2.2. Experimental sections

2.2.1. Collection of elderberry samples

Elderberry fruits were harvested in summer of 2012 and 2013. Collected samples were classified according to different ripening stages (1 to 6) based on harvest date and visual judgement in case of each variety.

2.2.2. Production of elderberry concentrate

Elderberry juice concentrates from Haschberg and Samocco varieties were prepared according to industrial protocols under laboratory conditions. Samples were collected after each processing step (Figure 1.).

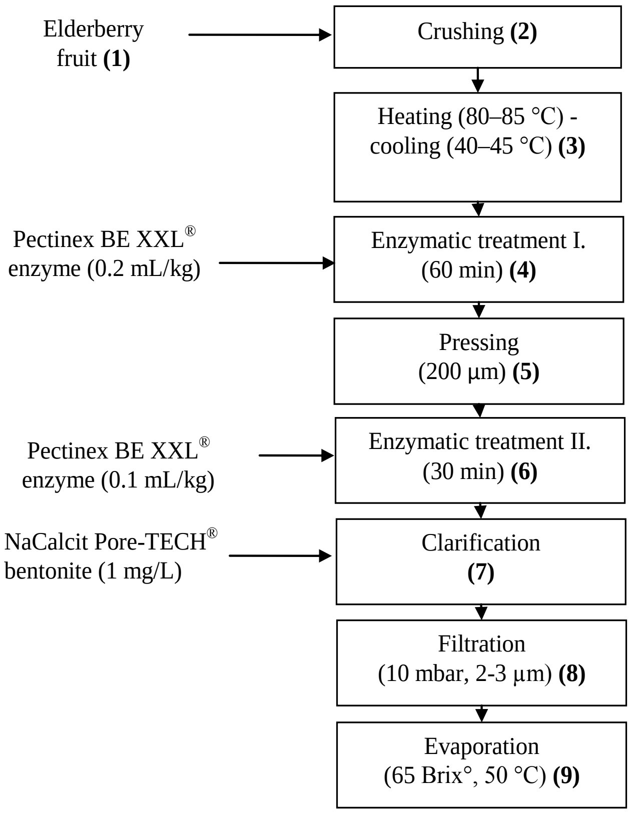


Figure 1. Production scheme of elderberry concentrate processing with sampling points (1–9)

2.2.3. Stability of coloured yoghurts during storage

Haschberg and Samocco colouring concentrates were used to replace carminic acid (E120, animal origin) in a strawberry yoghurt product. Test samples coloured with elderberry concentrates were prepared in the laboratory of Sole-Mizo diary company (Szeged) applying the recipe and ingredients routinely used in their commercially available strawberry yoghurt. The required quantity of elderberry concentrates was determined based on preliminary colour measurement (data are not shown) and visual judgement to reach the colour of the original strawberry yoghurt. Yoghurt samples (pH 4.6) were made in the following combination:

- yoghurt with uncoloured strawberry puree (No. 0);
- yoghurt with carminic-coloured strawberry puree (No. 1);
- yoghurt with strawberry puree coloured only by Haschberg (0.5 m/m%) concentrate (No. 2);
- yoghurt with strawberry puree coloured only by Samocco (0.4 m/m%) concentrate (No. 3).

Yoghurt samples consisted of 42.5 natural yoghurt and 7.5 g fruit preparation plus 0.5 m/m% Haschberg and 0.4 m/m% Samocco concentrates in case of samples No. 2 and 3, respectively. Each sample was stored at 5 °C for 6 week in the absence of light.

2.3. Sample preparations

In case of ripening and technology studies, sample preparation was adopted from LIN & HARNLY (2007) and applied with slight modifications. Extracts were made from lyophilized and homogenized sample with methanol/water/formic acid 60:39:1 (v/v) extraction solution using an ultrasonic bath (<35 °C).

Sample preparation of yoghurt products was carried out according to the method of NAGY *et al*. (2009) with slight modifications.

2.4. Analytical methods

2.4.1. Determination of anthocyanins

Determination of anthocyanin profile was carried out on an Agilent 1200 HPLC system (Agilent Technologies, Waldbronn, Germany) coupled to an Agilent 6350 Accurate-Mass (Q-TOF-MS) (quadruple – time-of-flight) tandem mass spectrometer (Agilent Technologies, Santa Clara, CA USA) equipped with a Dual-Spray ESI source using the mass range of 50–1100 *m/z*. Chromatographic separation of anthocyanin components was performed using a 125 × 4 mm, Hypersil ODS (C18), 3 μm particle size column (Dr. Maisch GmbH, Ammerbuch-Entringen, Germany). For the elution, 0.5% (v/v) formic acid in high purity water (mobile phase A) and 0.5% (v/v) formic acid in acetonitrile (mobile phase B) were used as solvents at a flow rate of 0.5 mL min^{-1}. Samples were analysed at 520 nm, which is the maximum absorption of cyanidin-based anthocyanins.

Concentrations of each anthocyanin compounds were assessed from peak areas and are given as cyanidin- 3-*O*-glucoside equivalent (CGE) per 100 g of dry weight (DW) elderberry fruit. The amount of total anthocyanins (TA) was expressed as sum of individual anthocyanin concentrations.

2.5. Statistical analysis

T-test was used for the analysis of the effect of vintages on anthocyanin content at optimum ripening stage and effect of technology steps on anthocyanin content in case of Haschberg and Samocco variety (SPSS 13.0, SPPS Inc., Chicago, USA). Significant differences between groups were considered when P value was <0.05. Normality was confirmed by Kolmogorov-Smirnov probe and the homogeneity of variance was confirmed by Levene-test.

3. RESULTS AND DISCUSSION

3.1. Changes in composition of elderberry varieties during ripening

3.1.1. Anthocyanin profile

3.1.1.1. Identification of anthocyanins

Based on the UV/Vis chromatogram at 520 nm, the following three anthocyanin compounds were identified in elderberry fruit extracts independently of varieties and ripening stages: cyanidin-3-*O*-glucoside (CyG), cyanidin-3-*O*-sambubioside (Cy2G) and cyanidin-3-*O*-sambubiosie-5-*O*-glucoside (Cy3G) (Figure 2.).

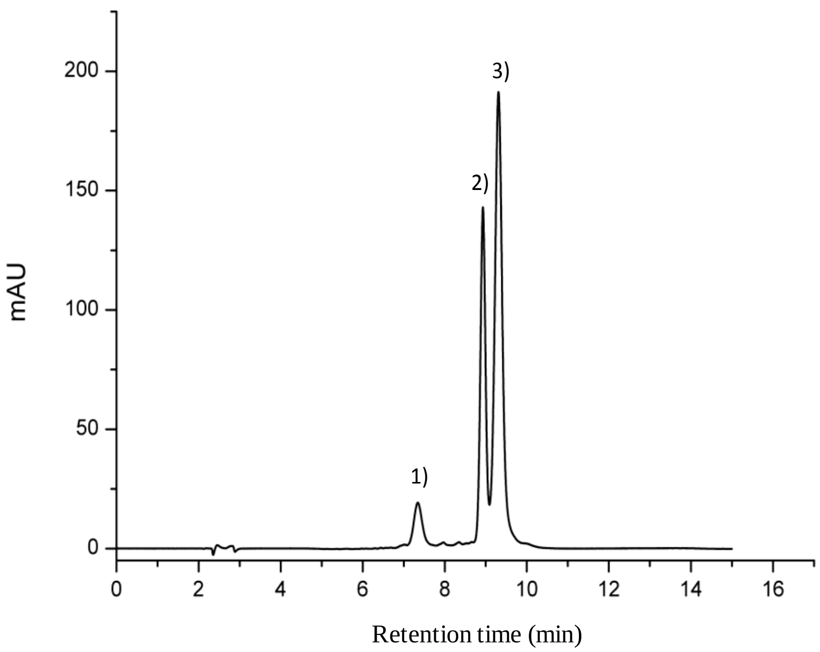


Figure 2. Representative chromatogram of elderberry samples monitored at 520 nm by HPLC-UV/Vis-TOFMS system. 1) cyanidin-3-*O*-sambubiosie-5-*O*-glucoside, 2) cyanidin-3-*O*-sambubioside, 3) cyanidin-3-*O*-glucoside. Chromatogram of 3rd ripening stage of Sampo from Vál is shown.

In some cases, the distribution pattern of anthocyanin compounds was variety and maturity stage dependent. As can be seen in Figure 3., Cy2G (eluting at 8.91 min) is the dominant anthocyanin in Haschberg in the 2nd maturity stage (chromatogram A), whereas in Sampo in the same 2nd maturity stage Cy2G and CyG (eluting at 9.27 min) are present in almost equal amounts (chromatogram C). However, this ratio changes in Sampo during ripening and in the following (3rd) maturity stage, CyG becomes more abundant (chromatogram B).

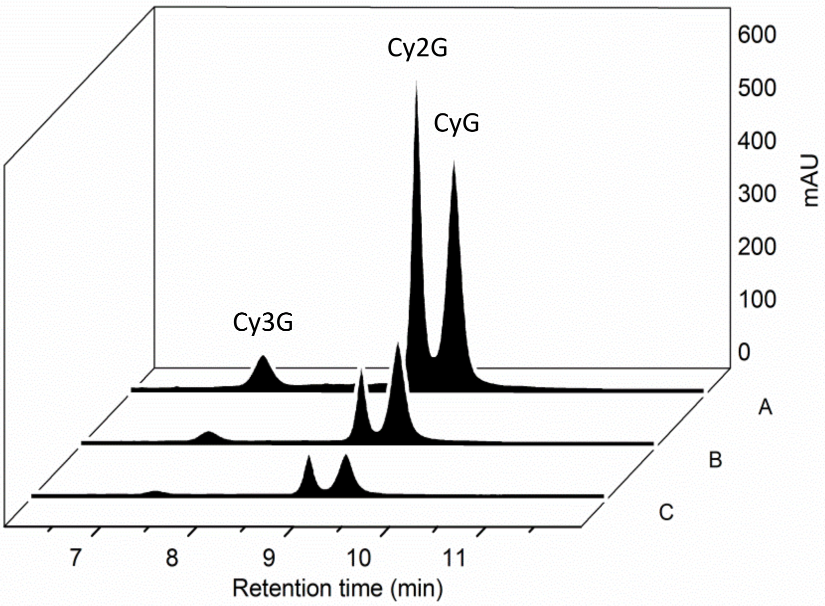


Figure 3. Three different anthocyanin profiles of elderberry varieties from the same growing area of Vál in the harvest year of 2012. Chromatogram 'A' shows the 2nd maturity stage of Haschberg variety, whereas chromatograms 'B' and 'C' show the 3rd and 2nd maturity stages of Sampo, respectively. Cy3G: cyanidin-3-*O*-sambubioside-5-*O*-glucoside, Cy2G: cyanidin-3-*O*-sambubioside, CyG: cyanidin-3-*O*-glucoside.

3.1.1.2. Quantitative analysis of anthocyanin content in elderberries

The most abundant anthocyanin molecule in most samples was CyG that accounted for approximately the half of all determined anthocyanins. The only exception was Samocco where Cy2G accounted for more than 50% of all analysed anthocyanins. This property can be used for the identification of variety. Cy3G component was present in the smallest concentration in elderberry fruits that is consistent with the findings of another study on European elderberries [HONG & WROLSTAD, 1990; KAACK & AUSTED, 1998; WU *et al.*, 2004; VEBERIC *et al.*, 2009].

Results show that elderberry cultivars have a maximum point in their anthocyanin contents during ripening. This was observed for all investigated samples; however, the maximum was reached at different dates for each variety. In some cases continuously increasing ripening curve was detected, which means collected samples did not reach the maximum anthocyanin concentration in the investigated period.

Table 1. Anthocyanin concentration in optimum maturity stages of five elderberry varieties from different growing areas in mg CGE per 100 g DW

Variety	Growing area	Optimum maturity stage		Cy3G		Cy2G		CyG		TA	
		2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Samocco	V	5	6	604±95.4	455±64.8	3942±606	3118±439	2432±355	1801±248	6979±1056	5373±751*
	NV	5	6	535±86.8	393±105	3833±609	1372±339	2645±429	877±222	7013±1125	2641±666*
Samident	V	5	5	252±42.6	246±50.3	1196±206	1590±309	1263±224	1863±359	2711±472.6	3699±718*
	NV	3	5	300±23.4	390±85.4	2051±119	2102±435	2457±122	1676±355	4809±264.4	4168±875*
Haschberg	V	6	6	333±63.8	142±23.8	1369±265	747±119	1107±217	991±158	2809±545.8	1880±300
	NV	4	6	358±35.2	249±11.6	1984±188	1679±61.0	2378±222	1553±47.0	4720±445.2	3282±119*
Sampo	V	5	5	258±10.4	269±52.9	1348±47.6	1280±254	1759 ±81.4	1395±281	3365±139.4	2943±587*
	NV	5	6	402±37.2	248±54.2	1933±176	1203±274	2242 ±202	2065±478	4577±415.2	3516±806
Samyl	V	6	5	282±113	185±67.5	1155±464	871±311	1184±468	925±336	2621±1045	1981±714
	NV	6	6	364±61.8	193±47.5	2282±379	886±218	1513±252	747±183	4159±692.8	1826±448*

Average values of five replicates ($n = 5$) ± standard errors are presented. Cy3G: cyanidin-3-*O*-sambubioside-5-*O*-glucoside; Cy2G: cyanidin-3-*O*-sambubioside; CyG: cyanidin-3-*O*-glucoside; NV: Nagyvenyim; TA: total anthocyanin content; V: Vál, DW: dry weight. *Represents significant differences in anthocyanin content between the two vintages ($P < 0.05$).

Evaluation of colouring potential of the investigated elderberry varieties was based upon the measured total anthocyanin contents in the optimum maturity stage (maturity stage with the highest total anthocyanin value). Total anthocyanin (TA) concentrations of each studied variety ranged from 2621 mg CGE per 100 g DW to 7013 mg CGE per 100 g DW in 2012 and from 1826 mg CGE per 100 g DW to 5373 mg CGE per 100 g DW in 2013 (Table 1). These results are in accordance with previous investigations [BRONNUM-HANSEN & FLINK, 1985; KAACK & AUSTED, 1998; KAACK *et al.*, 2008; VEBERIC *et al.*, 2009].

Considerable difference (19–66%) in TA content between the studied 2 years hindered the possibility to set up an unequivocal ranking of the remaining varieties, however Samocco had the highest pigment concentration in both of studied years and growing areas. With respect to the vintage effect, significant differences ($P < 0.05$) were observed for most elderberry varieties between the two studied years (Table 1.). The highest dissimilarity between two harvest years was observed for Samocco and Samyl from Nagyvenyim growing area. The average TA content in 2013 was 4007 mg CGE per 100 g DW in Samocco and 1906 mg CGE per 100 g DW in ‘Samyl’ that are less than the two-third of the amount observed in 2012.

3.1.2. Total water soluble solid content

In addition to anthocyanin content estimated on a dry weigh basis, water content of the harvested fruit samples has to be considered when the potential of these varieties as source of natural food colourants are evaluated. Therefore, total soluble solid contents of samples were also determined in all studied samples and in all maturity stages. In order to be able to realistically assess the usability of Samocco variety with the highest anthocyanin content as raw material for processing colouring concentrate, TA content was normalised to total soluble solids and value of Samocco was compared to the other varieties (Table 2). In terms of TA/Brix value still Samocco comes out as having the most anthocyanins relative to the other elderberry varieties in the optimum maturity stage.

Table 2. Comparing the total anthocyanin content (mg CGE per 100 g fresh weight) and the Brix° value of elderberry varieties to Samocco in optimum maturity stage in two harvest years

TA/BRIX	2012	2013	2012	2013	2012	2013	2012	2013
	Samocco/Haschberg		Samocco/Sampo		Samocco/Samident		Samocco/Samyl	
NV	1.53	1.38	1.44	1.24	1.26	0.77	1.46	2.12
V	2.38	2.04	2.28	1.97	2.62	1.30	2.77	2.74

CGE: cyanidin-3-*O*-glucoside equivalent, NV: Nagyvenyim, V: Vál; TA: total anthocyanin content; Brix: Brix°

3.2. Anthocyanin concentration during concentrate production

3.2.1. Identification of anthocyanin molecules

Samples from each step of the processing technology (see Figure 1.) were analysed by HPLC-UV/Vis-TOFMS system. Chromatogram at 520 nm revealed, in addition to the previously identified three anthocyanins (peak 1,4–5) two new pigment components appeared at 7.91 min (2nd peak) and 8.23 min (3rd peak) in the applied gradient program (Figure 4.). These new compounds were present in all samples taken after step 3. In order to identify these two anthocyanin-related components (compound 2 and 3) which most probably formed as a result of heat treatment of the crushed fruit, HPLC-Q/TOFMS experiments were performed.

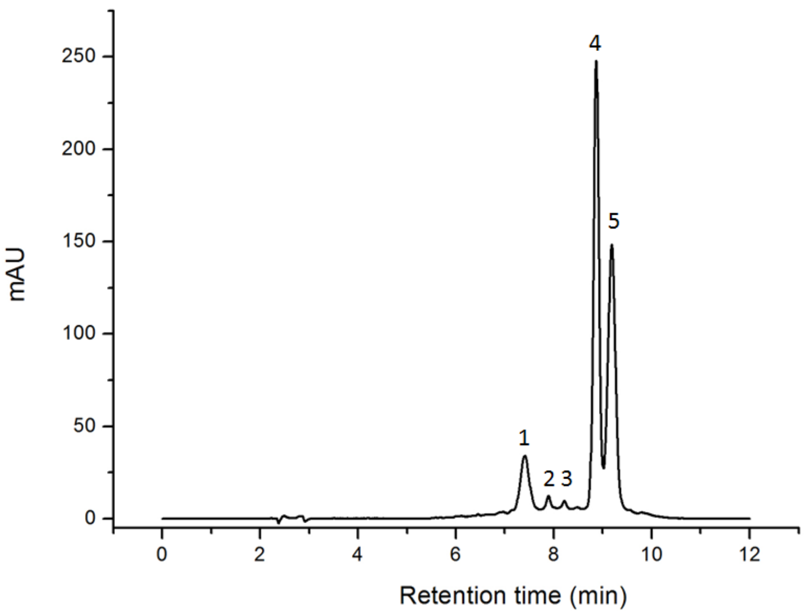
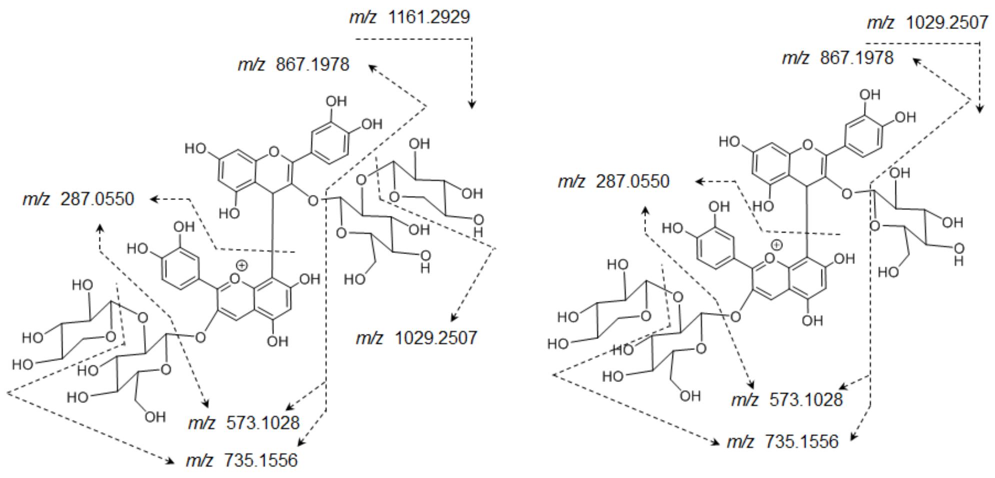


Figure 4. Chromatogram of elderberry anthocyanins monitored at 520 nm by HPLC-UV/Vis-TOFMS system in the extract of Samocco sample after heating-cooling (step 3).1) cyanidin-3-*O*-sambubioside-5-*O*-glucoside, 2-3) new components, 4) cyanidin-3-*O*-sambubioside, 5) cyanidin-3-*O*-glucoside.

Based on acquired MS and MS/MS mass spectra in combination with the obtained UV/Vis signal at 520 nm, this anthocyanin compound eluting at 7.91 min was assigned as a condensed dimeric Cy2G product formed most probably by nucleophilic condensation of two Cy2G molecules during the heating step of the processing technology. The compound eluting at 8.23 min was also presumed to be a condensation product formed of a Cy2G and a CyG. In Figure 5, the hypothesised structures of these condensation products are outlined along with their proposed MS fragmentation schemes.



Compound 2 Compound 3

Figure 5. Hypothesised structure of dimeric condensation products formed during the heating step of the processing technology and their proposed MS fragmentation schemes. ‘Compound 2’ eluted at 7.91 min and ‘Compound 3’ at 8.23 min.

3.2.2. Quantitative analysis of anthocyanin content in elderberries

Industrial concentrate production technology resulted qualitative and quantitative changes in anthocyanins of elderberry samples in both varieties (Figure 6.). Processing steps such as crushing, pectolytic enzymatic treatments, mash pressing either enriched anthocyanin content of the product or left it unaffected. Increase of anthocyanins was due to the fact that more molecules released from the plant matrix and got solubilized. Generally applied purification steps such as clarification and filtration resulted in a decrease in anthocyanin content of the total dry matter content of the processed juice, which observation can be explained by the degradation of anthocyanins.

In case of Samocco significant (P<0.05) loss (26%) in TA was observed after filtration step, while in Haschberg samples, the second pectolytic enzymatic treatment (step 6) caused a significant (P<0.05) increase (~38%) in average TA content of Haschberg, but practically unaffected the TA content of Samocco.

It was also established that endogenous anthocyanidin-saccharide conjugates with more complex saccharide moieties, are more stable during processing. Namely cyanidin-3-*O*-sambubioside-5-*O*-glucoside was the most robust component, while cyanidin-3-*O*-glucoside the less stable one.

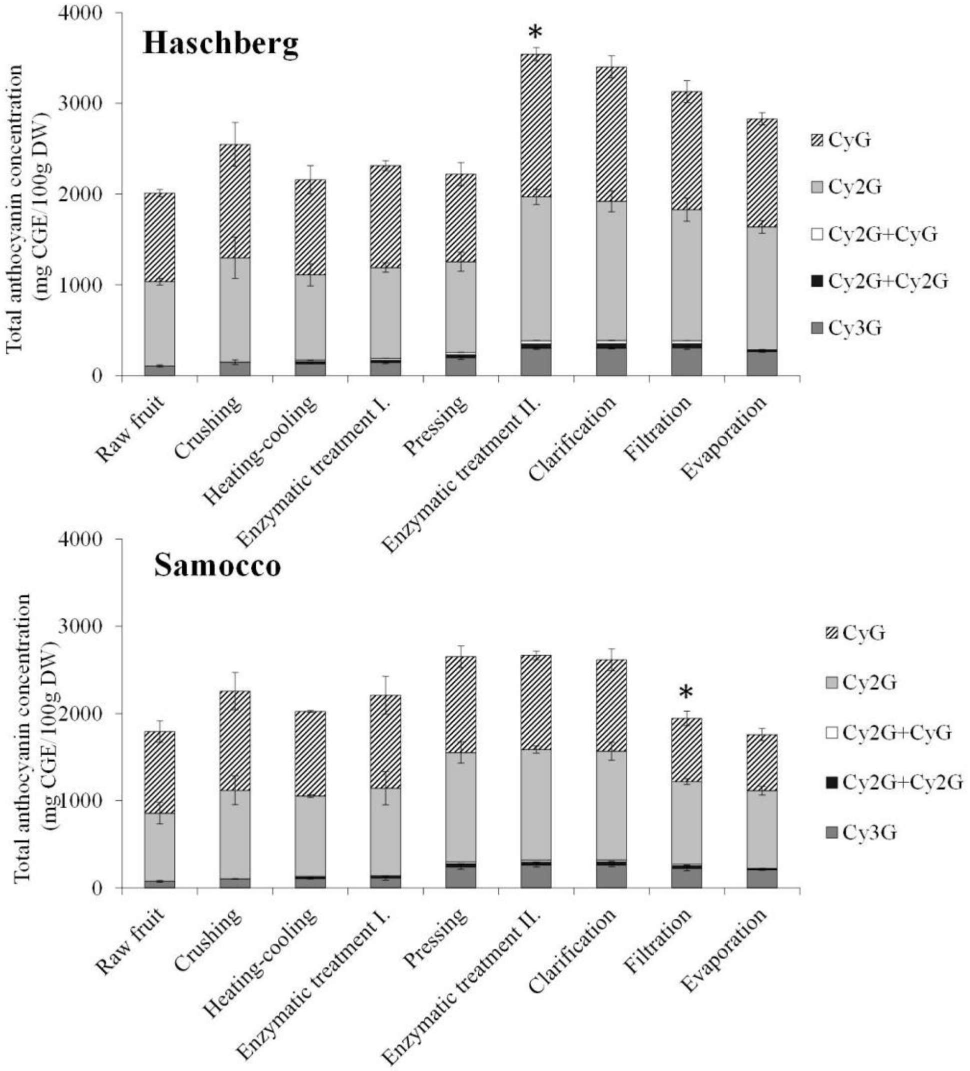


Figure 6. Anthocyanin concentration of Haschberg and Samocco samples during concentrate production technology. CyG: cyanidin -3-*O*-glucoside, Cy2G: cyanidin-3-*O*-sambubioside, Cy3G: cyanidin-3-*O*-sambubioside-5-*O*-glucoside, DW: dry weight. *Representing significant difference (P<0.05) in total anthocyanin concentration compared to previous processing step.

3.3. Evaluation of elderberry concentrate in strawberry yoghurts

Degradation of total cyanidin-based anthocyanins was 38% in case of Haschberg-coloured yoghurts, while ca. 12% decrease of anthocyanin content was observed in Samocco coloured-sample after storage (Figure 7.). This reduction was lower than was detected in Haschberg-coloured yoghurt, despite of the fact that Samocco concentrate was used at 0.1% (w/w) lower concentration to colour samples. This means pigments of Samocco-coloured yoghurts proved to be more stable during experiment. This difference probably comes from the characteristics of the variety because the same medium was investigated (yoghurt).

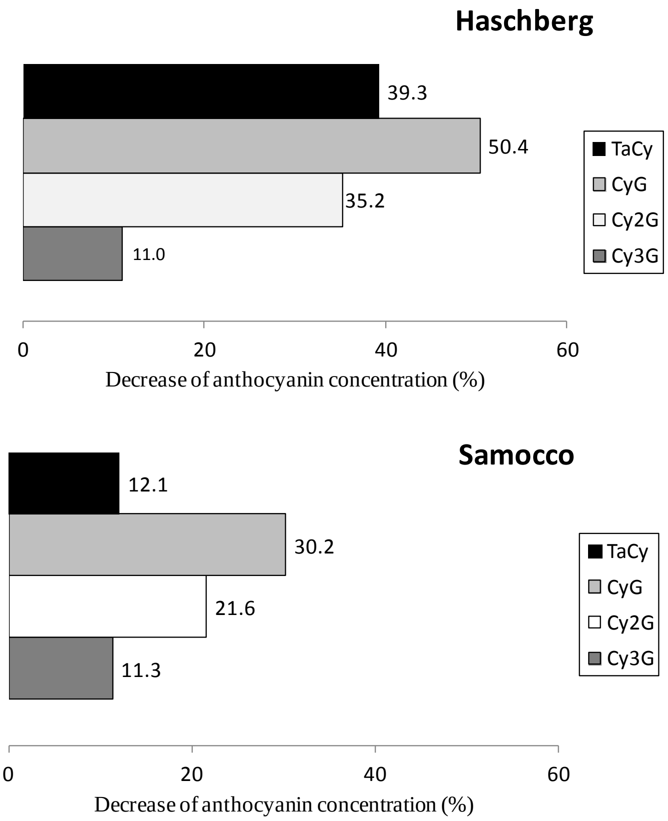


Figure 7. Degradation of anthocyanin concentration of Haschberg- and Samocco-coloured yoghurts after storage experiment. TaCy: total cyanidin-based anthocyanin content; CyG: cyanidin-3-*O*-glucoside; Cy2G: cyanidin-3-*O*-sambubioside; Cy3G: cyanidin-3-*O*-sambubioside-5-*O*-glucoside.

Regarding the anthocyanin stability in elderberry concentrate coloured-yoghurts, Cy3G was the most robust pigment molecule during storage, while concentration of CyG decreased the most in both elderberry varieties. The second most stable anthocyanin component was Cy2G. This observation is in agreement with the result of technology study that anthocyanin conjugates with more complex saccharide moieties are more robust during storage and processing conditions. The explanation of this phenomenon is probably due to chemical structure of cyanidin molecules. If more sugar molecules are attached to the cyanidin aglycone, less phenolic hydroxyl groups remain free, so anthocyanin saccharide conjugate become more resistant to the hydrolysis process. Therefore Cy3G is more stable than CyG. The difference in stability between Cy2G and CyG can be explained with the higher resistance of sambubioside disaccharide molecule against hydrolysis compared to that of glucose.

In order to better understand the differences occurring during storage, aqueous buffer solutions (pH 4.6) were prepared with adequate amounts of Haschberg (0.5% w/w) and Samocco

(0.4% w/w) concentrates also used for yoghurt colouring. Total anthocyanin content of Haschberg concentrate decreased by 10% after 3-week storage, while pigment degradation of Samocco-coloured samples was 35%. Cy3G content did not change practically in Haschberg, while 7% decrease was detected in case of Samocco. Reductions of Cy2G content were 12% and 30%, CyG degradations were 20% and 60%. These data suggest, that the matrix plays a key role in terms of both colouring ability and stability of elderberry anthocyanins.

It might be explained by the anthocyanin stabilising properties of milk proteins in yoghurt [CHUNG *et al.*, 2015]. The number of sugar moieties linked to the aglycone can also play an active role in the interaction between anthocyanins and protein. Therefore Cy3G and Cy2G are more stable than CyG. Consequently, high Cy2G content anthocyanin profile ensures more robustness in case of Samocco.

3.4. Novel scientific results

1) Profiling and quantitative analysis of anthocyanins in five Hungary grown elderberry (*Sambucus nigra* L.) varieties were performed in six different maturity stages from two consecutive years and from two growing areas. Based on the results, I concluded that Samocco variety has an individual anthocyanin profile, which is different from that of the other studied samples. Outstandingly high cyanidin-3-*O*-sambubioside concentration was detected, whereas cyanidin-3-*O*-glucoside was the major species in the other investigated varieties. Consequently, the anthocyanin-species ratio is variety dependent characteristic.

2) I identified two condensed dimeric anthocyanin species generated after heat treatment in elderberry juice. The exact structure of conjugates is not known, however based on high mass resolution and accurate mass spectrometry measurements, these components can be presumably dimeric products of i) cyanidin-3-*O*-sambubioside and ii) dimeric product of cyanidin-3-*O*-sambubioside and cyanidin-3-*O*-glucoside. Their elemental formula could be elucidated as [$C_{52}H_{57}O_{30}^{+}$] and [$C_{47}H_{49}O_{26}^{+}$].

3) I proved that the more complex the glycan part of an anthocyanin conjugate, the more stable the molecule gets against processing technology and storage time. Cyanidin-3-*O*-sambubioside-5-*O*-glucoside is the most stable pigment component, while cyanidin-3-*O*-glucoside is the less robust one.

4) I concluded that industrial fruit juice concentrate production technology modified differently the anthocyanin concentration of two investigated elderberry varieties. The second enzymatic treatment caused significant increase in pigment content of Haschberg, while filtration step resulted significant anthocyanin decrease of Samocco. Consequently, variety dependent characteristics of processing technology should be considered.

5) Samocco proved to be the most suitable elderberry variety among the investigated ones for colouring food of yoghurt products. Samocco had the highest anthocyanin concentration with high water soluble solid content in both studied years. In concentrate form it preserved total pigment concentration better in strawberry yoghurts during 42-days storage than Haschberg concentrate. This latter finding is probably due to different anthocyanin profile.

4. CONCLUSIONS AND SUGGESTIONS

Based on my PhD work, Samocco grown in Hungary, might be a promising variety for growing as raw material for natural food colourant processing industry. The raw fruit had high anthocyanin concentration with high water soluble solid content in both studied years. Furthermore, Samocco has an outstanding anthocyanin profile due to its high cyanidin-3-*O*-sambubioside concentration, which accounted for more than 50% of all analysed anthocyanins in optimum maturity stage. This property can be used to identification of variety.

Samocco is able to provide more colour stability than Haschberg variety against the effects of industrial juice concentrate production technology and storage conditions. This can be probably due to the above mentioned high cyanidin-3-*O*-sambubioside concentration, because the stability of cyanidin-compounds in elderberry seems to be positively correlated to the complexity/ number of sugar derivatives attached to the cyanidin aglycone. The explanation of this difference is probably due to difference of chemical structure of cyanidin anthocyanins. Namely, the more complex the glycan part of an anthocyanin conjugate, the less phenolic hydroxyl groups remain free. This leads to more stability against processing technology and storage. Consequently, cyandin-3-*O*-glucoside is the least stable pigment component, which is detected in higher amount in Haschberg.

In summary based on my results, exclusively evaluation in terms of colouring potential of investigated elderberries, Danish varieties are suitable for cultivation in Hungary. One of them, Samocco has outstanding anthocyanin content, so it can be a promising alternative of synthetic food colourants and carminic acid in food industry. However, further research is needed to confirm that.

5. LIST OF PUBLICATION RELATED TO THE DISSERTATION

<u>Articles in journals</u>

Journals with impact factor

Szalóki-Dorkó, L., Stéger-Máté, M., Abrankó, L. (2016): Effects of fruit juice concentrate production on individual anthocyanin species in elderberry. *International Journal of Food Science & Technology*, 51 (3) 641–648. p., doi:10.1111/ijfs.13031 (IF 1.358)

Szalóki-Dorkó, L., Stéger-Máté, M., Abrankó, L. (2015): Evaluation of colouring ability of main European elderberry (Sambucus nigra L.) varieties as potential resources of natural food colourants. *International Journal of Food Science & Technology*, 50 (6) 1317–1323. p., doi:10.1111/ijfs.12773 (IF 1.354)

Szalóki-Dorkó, L., Végvári, Gy., Ladányi, M., Ficzek, G., Stéger-Máté, M. (2015): Degradation of Anthocyanin Content in Sour Cherry Juice During Heat Treatment: Thermal degradation of Sour Cherry Anthocyanins. *Food Technology & Biotechnology*, 53 (3) 354–360. p., doi: 10.17113/ftb.53.03.15. 3931 (IF 0.977)

Journals without impact factor, foreign language

Szalóki-Dorkó, L., Csizmadia, G., Abrankó, L., Stéger-Máté, M. (2015): Examination of anthocyanin content of some elderberry cultivars grown in Hungary. *Acta Horticulturae*, 1061 (1) 79–86. p., ISBN 978-94-62610-54-5

Szalóki-Dorkó, L., Légrádi, F., Abrankó, L., Stéger-Máté, M. (2014): Effects of food processing technology on valuable compounds in elderberry (*Sambucus nigra* L.) varieties, *Acta Biologica Szegediensis*, 58 (1) 45–48. p. ISSN: 1588-385X

Journals without impact factor, Hungarian language

Szalóki-Dorkó, L., Zöldy, A. B., Abrankó, L., Stégerné Máté, M. (2015): Enzimkezelések hatásának vizsgálata fekete bodzalé (*Sambucus nigra* L.) beltartalmi paramétereire. *Élelmiszer Tudomány technológia*, 69 (3) 1–8.p., ISSN: 2061-3954

<u>Conferences</u>

Hungarian conference, proceeding

Dorkó, L., Ménesi, L. M., Stégerné Máté, M. (2013): Fekete bodza (*Sambucus nigra* L.) fajták színstabilitásának vizsgálata a pH és a hőmérséklet függvényében, „Fiatal kutatók az egészséges élelmiszerért” conference, University of Debrecen, Proceeding: 15–22.p. ISBN 978-963-473-601-1

International conference, proceedings

Szalóki-Dorkó, L., Abrankó, L., Stéger-Máté, M. (2015): Colour stability of elderberry concentrates in natural yoghurt. Food Science Conference 2015, Proceeding: 229–232. p., ISBN 978-963-503-603-5

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