

Influence of different extracts addition on total phenols, anthocyanin content and antioxidant activity of blackberry juice during storage

Kopjar, Mirela; Bilić, Blanka; Piližota, Vlasta

Source / Izvornik: **Croatian journal of food science and technology, 2011, 3, 9 - 15**

Journal article, Published version

Rad u časopisu, Objavljena verzija rada (izdavačev PDF)

Permanent link / Trajna poveznica: <https://urn.nsk.hr/urn:nbn:hr:109:317766>

Rights / Prava: [Attribution-NoDerivatives 4.0 International/Imenovanje-Bez prerada 4.0 međunarodna](#)

Download date / Datum preuzimanja: **2025-04-02**

REPOZITORIJ

PTFS

PREHRAMBENO-TEHNOLOŠKI FAKULTET OSIJEK

dabar
DIGITALNI AKADEMSKI ARHIVI I REPOZITORIJI

Repository / Repozitorij:

[Repository of the Faculty of Food Technology Osijek](#)



Influence of different extracts addition on total phenols, anthocyanin content and antioxidant activity of blackberry juice during storage

Mirela Kopjar*, Blanka Bilić, Vlasta Piližota

University of Josip Juraj Strossmayer in Osijek, Faculty of Food Technology Osijek, Franje Kuhača 20, 31000 Osijek, Croatia

original scientific paper

Summary

The aim of this study was investigation of influence of different extracts addition on total phenols, anthocyanin content, antioxidant activity and percent of polymeric colour of blackberry juice during storage of 52 days at 4 °C. Anthocyanin content of control sample (blackberry juice without extracts addition) was 149.91 mg/L. Samples with addition of extracts (olive leaf, pine bark PE 5:1, pine bark PE 95 %, green tea, red wine PE 30 %, red wine PE 4:1 and bioflavonoids) had higher anthocyanin content (from 152.42 to 161.19 mg/L) in comparison to control sample. Sample with addition of bioflavonoids had the highest anthocyanin content. Samples with addition of extracts had much higher total phenol content and antioxidant activity than control sample, what was expected since extracts are rich in phenols. During storage decrease of phenols, anthocyanins and antioxidant activity occurred in higher or lesser extent, depending on extract type addition. Anthocyanin content in control sample was 119.85 mg/L. Samples with addition of bioflavonoids, olive leaf, pine bark PE 5:1 and red wine PE 4:1 had lower (from 103.44 to 118.84 mg/L), while other samples had higher (from 131.99 to 135.57 mg/L) anthocyanin content than control sample. After storage, decrease of anthocyanins was followed with increase of percent of polymeric colour, with exception of samples with addition of green tea.

Keywords: anthocyanins, phenols, crude extracts, polymeric colour, antioxidant activity

Introduction

Colour is, next to texture and aroma, one of the most important quality properties of food products. Anthocyanins have a crucial role in the colour quality of many fresh and processed fruits. They are a good source of natural antioxidants, however, they are quite unstable during processing and storage (Artes, 2002; Stintzing and Carle, 2004). The temperature, pH, oxygen, and water activity are considered to be important factors influencing their stability (Tsai and Huang, 2004). It is well known that copigmentation has been suggested as a main colour stabilising mechanism in plants protecting the coloured flavylium cation from the nucleophilic attack of the water molecule (Mazza and Brouillard, 1987; Baranac et al., 1997). The attack by water converts the flavylium ion to colourless pseudobase resulting in colour loss. Formation of complex between the pigment and copigment causes a hyperchromic effect (ΔA) and a bathochromic shift ($\Delta \lambda$). While hypochromic effect means an increase in colour intensity, the bathochromic shift presents shift of the maximum absorbance wavelength (Chen and Hrazdina, 1981; Mazza and Miniati, 1993).

Phenolic compounds, which are present naturally in vegetables, fruits and grains exhibit wide range

of physiological properties and possess the ability to reduce oxidative damage associated with many diseases, including cancer, cardiovascular diseases, cataracts, atherosclerosis, diabetes, asthma, hepatitis, liver injury, arthritis, immune deficiency diseases and ageing (Pietta et al., 1998; Lee et al., 2003; Middleton et al., 2000). The oxidative stress, defined as “the imbalance between oxidants and antioxidants in favour of the oxidants potentially leading to damage”, has been suggested to be the cause of aging and various disease in humans. In modern western medicine, the balance between antioxidation and oxidation is believed to be a critical concept maintaining a healthy biological system (Davies, 2000; Tiwari, 2001; Katalinić et al., 2006).

It is possible to fortify food products with addition of extracts rich in phenolic compounds and through that increase nutritional and health-promoting value of food products. Consequently, in this study influence of addition of different plant extracts which are rich in phenolics to blackberry juice on total phenol content, anthocyanin content, antioxidant activity and formation of polymeric colour was investigated. Those parameters were also monitored during 52 days of storage at 4 °C.

*Corresponding author: University of Josip Juraj Strossmayer in Osijek, Faculty of Food Technology Osijek, Franje Kuhača 20, 31000 Osijek, Croatia; Mirela.Kopjar@ptfos.hr

Materials and methods

Materials

Blackberry was bought at local market in Osijek, Croatia and kept at $-20\text{ }^{\circ}\text{C}$ before sample preparation. Crude extracts were from Naturex (France) and obtained from Vitis d.o.o. (Croatia). Potassium chloride, sodium acetate, hydrochloric acid, methanol, sodium carbonate, sodium disulfite, Folin-Ciocalteu reagents were bought from Kemika (Zagreb, Croatia). Trolox was obtained from Sigma (Germany). 2,2'-azinobis-(3-ethylbenzthiazoline-6-sulphonic acid) (ABTS) and 2,2-diphenyl-1-picrylhydrazyl (DPPH) were obtained from Fluka.

Blackberry juice preparation

Blackberry juice was prepared by fruit pressing through cheese cloth and centrifuged, shortly heated at $90\text{ }^{\circ}\text{C}$ for enzyme inactivation. Samples of juice were prepared without and with addition of selected extracts (0.1 %), namely olive leaf, green tea, pine bark PE 95 %, pine bark PE 5:1, red wine PE 30 %, red wine PE 4:1 and bioflavonoids. After preparation, samples were kept in dark at $4\text{ }^{\circ}\text{C}$ for 24 hours for stabilization and after that all measurements were conducted. Samples were stored for 52 days at $4\text{ }^{\circ}\text{C}$ and all measurements were conducted.

Determination of total phenol content

The Folin-Ciocalteu method (Ough and Amerine, 1988) was used to determine total phenol content. Gallic acid was used as standard to produce the calibration curve. Total phenol content was expressed in g of gallic acid equivalents (GAE)/L of sample. Measurements were done in duplicates.

Determination of antioxidant activity

Antioxidant activity was determined using ABTS and DPPH method. The ABTS assay followed the method of Arnao et al. (2001) with some modifications. The results were expressed in mmol trolox equivalents (TE)/100 mL of sample. Additional dilution was needed if the ABTS value was over the linear range of the standard curve. For DPPH assay 0.2 mL of the sample was diluted with methanol and 1 mL of DPPH solution was added. After 15 minutes absorbance was read at 517 nm. The results were expressed in mmol trolox equivalents (TE)/100 mL of sample. Additional dilution was needed if the DPPH value was over the linear range of the standard curve. Measurements were done in duplicates.

Determination of monomeric anthocyanins

Determination of monomeric anthocyanins was conducted by pH-differential method (Giusti and Wrolstad, 2001). Total monomeric anthocyanins were expressed as cyanidin-3-glucoside. Sample absorbance was read against a blank cell containing distilled water using spectrophotometer (Jenway 6300 Spectrophotometer). The absorbance (A) of the sample was then calculated according the following formula:

$$A = (A_{\lambda_{\text{vis}}} - A_{700})_{\text{pH } 1.0} - (A_{\lambda_{\text{vis max}}} - A_{700})_{\text{pH } 4.5}$$

where $A_{\lambda_{\text{vis max}}}$ was wavelength at which maximal absorbance of samples was achieved.

The monomeric anthocyanin pigment content in the sample was calculated according the following formula:

$$\text{Anthocyanin content (mg/L)} = (A \times \text{MW} \times \text{DF} \times 1000) / (\epsilon \times l)$$

where DF was dilution factor, MW cyanidin-3-glucoside molecular weight (449.2) and ϵ molar absorptivity (26,900). Measurements were done in duplicates.

Determination of percent of polymeric colour

Percent of polymeric colour was determined using the method described by Giusti and Wrolstad (2001). For analysis, 0.2 mL of sodium bisulfite was added to 2.8 mL diluted sample and 0.2 mL of water was added to 2.8 mL diluted sample. After equilibrating for 15 min, samples were evaluated at $\lambda_{\text{vis max}}$, 700 and 420 nm. Colour density was calculated using the control sample according to the following formula:

$$\text{Colour density} = [(A_{420} - A_{700}) + (A_{\lambda_{\text{vis max}}} - A_{700})] \times \text{DF}$$

Polymeric colour was determined using the bisulfite-bleached sample using the following formula:

$$\text{Polymeric colour} = [(A_{420} - A_{700}) + (A_{\lambda_{\text{vis max}}} - A_{700})] \times \text{DF}$$

Percent polymeric colour was calculated using the formula:

$$\% \text{ PC} = (\text{polymeric colour} / \text{colour density}) \times 100$$

Statistical analysis

Anthocyanin content was analyzed by the analysis of variance (ANOVA) and Fisher's least significant difference (LSD) with significance defined at $P < 0.05$. All statistical analyses were carried out using the software

program STATISTICA 8 (StatSoft, Inc, USA). The results were expressed as means \pm standard deviation.

Results and discussion

Total phenol content

In Table 1 results of total phenol content of blackberry juice are presented. Total phenol content in control sample was 0.52 g GAE/L. All samples with addition of extracts had much higher values, from 1.13 to 1.59 g GAE/L, with blackberry juice with addition of pine bark 95 % having the highest total phenol content. Used extracts are rich in phenols thus that tendency was expected (Kopjar et al., 2009a). During storage decrease of total phenol occurred. Control sample had the lowest total phenol content, 0.38 g GAE/L, while all other samples had higher values, from 0.71 to 1.13 g GAE/L.

Table 1. Total phenol content (g GAE/L) of blackberry juice without and with addition of extracts during 52 days of storage at 4 °C

Sample	Total phenol content (g GAE/L)	
	Storage (days)	
	"0"	52 days
BJ	0.52 \pm 0.039 ^a	0.38 \pm 0.005 ^a
BJ + olive leaf	1.13 \pm 0.099 ^b	0.77 \pm 0.011 ^c
BJ + pine bark PE 95 %	1.59 \pm 0.088 ^e	1.13 \pm 0.004 ^e
BJ + green tea	1.57 \pm 0.011 ^e	1.03 \pm 0.010 ^d
BJ + pine bark PE 5:1	1.17 \pm 0.094 ^{b,c}	0.72 \pm 0.023 ^b
BJ + red wine PE 30 %	1.35 \pm 0.024 ^d	1.02 \pm 0.041 ^d
BJ + red wine PE 4:1	1.19 \pm 0.037 ^c	0.75 \pm 0.048 ^c
BJ + bioflavonoides	1.14 \pm 0.050 ^b	0.71 \pm 0.010 ^b

BJ – blackberry juice

Values in the same column with different superscripts (a-e) are significantly different ($P < 0.05$) by analysis of variance (ANOVA) and Fisher's least significant difference (LSD).

Antioxidant activity

Results of determination of antioxidant activity of blackberry juice without and with addition of extracts during storage at 4 °C are presented in Table 2. The lowest antioxidant activity had control sample (0.46 and 0.52 mmol TE/100 mL, determined by DPPH and ABTS method, respectively), while samples with addition of extracts had higher antioxidant activity since extracts are rich in phenolics. The highest antioxidant activity had samples with green tea (1.21 and 1.38 mmol TE/100 mL, determined by DPPH and ABTS method, respectively). During storage decrease of antioxidant activity occurred, in higher or lesser extent. In some samples there was very low decrease of antioxidant activity, probably due to formation of Maillard reaction products (Yilmaz and Toledo, 2005), or the formation of anthocyanin polymers (Brownmiller et al., 2008). Results of antioxidant activity determination by ABTS were higher than results obtained by DPPH method. Depending on applied method for determination of antioxidant activity different results could be obtained since different agents were used for determination of antioxidant activity. Various responses of various phenolic compounds in different assays (different agents used) can be obtained depending on the number of phenolic groups they have (Singleton and Rossi, 1965). Kopjar et al. (2009a) reported antioxidant activity of water plant extracts using different methods showing that same extract reacted differently with different reagents depending on used method.

Table 2. Antioxidant activity (mmol TE/100 mL) of blackberry juice without and with addition of extracts during 52 days of storage at 4 °C

Sample	Antioxidant activity (mmol TE/100 mL)			
	DPPH method		ABTS method	
	"0"	52 days	"0"	52 days
BJ	0.46 \pm 0.010 ^a	0.39 \pm 0.014 ^a	0.52 \pm 0.004 ^a	0.49 \pm 0.003 ^a
BJ + olive leaf	0.88 \pm 0.016 ^b	0.81 \pm 0.052 ^b	1.05 \pm 0.024 ^b	1.01 \pm 0.010 ^b
BJ + pine bark PE 95 %	1.07 \pm 0.004 ^c	1.01 \pm 0.013 ^c	1.28 \pm 0.006 ^c	1.15 \pm 0.010 ^c
BJ + green tea	1.21 \pm 0.073 ^d	1.06 \pm 0.021 ^c	1.38 \pm 0.004 ^d	1.27 \pm 0.004 ^d
BJ + pine bark PE 5:1	1.00 \pm 0.006 ^{c,e}	0.78 \pm 0.021 ^d	1.15 \pm 0.004 ^e	0.94 \pm 0.004 ^e
BJ + red wine PE 30 %	1.04 \pm 0.038 ^c	0.99 \pm 0.038 ^c	1.23 \pm 0.006 ^c	1.22 \pm 0.006 ^d
BJ + red wine PE 4:1	0.95 \pm 0.008 ^c	0.81 \pm 0.014 ^b	1.15 \pm 0.017 ^e	1.06 \pm 0.026 ^b
BJ + bioflavonoides	1.01 \pm 0.042 ^c	0.71 \pm 0.010 ^d	1.23 \pm 0.034 ^c	1.05 \pm 0.003 ^b

BJ – blackberry juice

Values in the same column with different superscripts (a-e) are significantly different ($P < 0.05$) by analysis of variance (ANOVA) and Fisher's least significant difference (LSD).

Monomeric anthocyanin content and percent of polymeric colour

Results of determination of monomeric anthocyanins are presented in Table 3. Anthocyanin content of control sample (blackberry juice without extracts addition) was 149.91 mg/L. Samples with addition of extracts had higher anthocyanin content in comparison to control sample. Anthocyanin content in samples with addition of extract was from 152.42 to 161.19 mg/L. Sample with addition of bioflavonoids extract had the highest anthocyanin content. During 52 days of storage at 4 °C degradation of anthocyanins occurred. Since extracts are rich in phenols, copigmentation effect was most likely reason for this increase of anthocyanin content in samples with addition of extracts. It is well known that phenolic compounds act as copigments and through copigmentation effect improve anthocyanin stability. The attack by water converts the flavylum ion to colourless pseudobase resulting in colour loss. Several factors influence copigmentation, among which copigment type is the most important one (Mazza and Brouillard, 1990; Dimitrović-Marković et al., 2000; Bąkowska et al., 2003). Blackberry juice without addition of extracts had A_{\max} at 510 nm, while samples with addition of extracts had A_{\max} at higher λ . The difference in increase of λ ($\Delta\lambda$), i.e. bathochromic shift for different extracts was different. $\Delta\lambda$ were 3 nm for pine bark PE 5:1 and bioflavonoides, and 2 nm for all other extracts. In red current juice increases of λ was 3 nm for catechol and 4-methyl catechol, 4 nm for gallic acid and 5 nm for catechin and chlorogenic acid (Kopjar and Piližota, 2009; Kopjar et al., 2009b). Mollov et al. (2007) found out that addition of polyphenolic copigments extracted from distilled rose petals to strawberry anthocyanins caused $\Delta\lambda$ of 6 nm. Bąkowska et al. (2003) reported that shift of λ of cyanidin were 21.4, 14.9, 5.5, 3.8 and 2.5 nm after addition of flavones of *Scutellaria baicalensis* Georgi, quercetin-5'-sulphonic acid, sodium salt of morin-5'-sulphonic acid, tannic acid and chlorogenic acid, respectively. Also they reported that absorbance i.e. hyperchromic effect increased with addition of copigments in higher or lesser extent. Copigmentation phenomenon is not always predictable, and it is not well understood how different factors enhance or reduce this phenomenon. The structure of the anthocyanin aglycone seems to significantly affect rate and degree of copigmentation (Mazzaracchio et al., 2004), probably by influencing the degree of intramolecular copigmentation, as well as the hydration efficiency of the pyranic ring. Other important factors that

influence the degree of copigmentation include pH, ionic strength of solution, temperature and pigment to copigment molar ratio (Davies and Mazza, 1993).

After storage, anthocyanin content of control sample was 119.85 mg/L. In samples with addition of olive leaf, pine bark PE 5:1, red wine PE 4:1 and bioflavonoides extracts, anthocyanin content was lower than in control sample, from 103.44 to 118.84 mg/L. In other samples, juices with addition of pine bark PE 95 %, green tea and red wine PE 30 %, anthocyanin content was higher than in control sample, from 131.99 to 135.57 mg/L, with sample with addition of pine bark PE 95 % having the highest anthocyanin content after storage.

Values of polymeric colour are represented in Table 3. Control sample had 31.91 % of polymeric colour. With addition of extracts that value increased ranging from 32.76 to 38.42 %, with an exception of sample with addition of green tea (31.9 %). During storage percent of polymeric colour increased, except in the case of samples with addition pine bark PE 95 % and red wine PE 30 %. It is possible to make correlation between anthocyanin content and % of polymeric colour after storage. With increased anthocyanin content lower % of polymeric colour was observed, with exception of sample with addition of green tea extract.

The $A_{440}/A_{\text{vis max}}$ ratio values were calculated for each sample since it can be used as indicator of substitution in C-3 position of flavilium ring (Giusti et al., 1999; Longo and Vasapollo, 2005; Longo et al., 2005). After preparation there was no big difference in that ratio between samples no matter of addition of extracts (Table 3). After storage, increase of ratio was observed in all samples but the lowest increase was observed in samples with addition of pine bark PE 95 % and red wine PE 30 %. This change can be indicator of change in anthocyanin structure, thus we can assume that the smallest change of anthocyanin structure was observed in samples with addition of pine bark PE 95 % and red wine PE 30 %. Those two samples were also the samples with the highest anthocyanin content after storage. It can be observed that after storage samples with addition of pine bark PE 95 % and red wine PE 30 % had the highest anthocyanin content, the lowest percent of polymeric colour and the lowest ratio $A_{440}/A_{\text{vis max}}$ indicating that there was slight polymerization observed in those samples, and that there was slight change in anthocyanin structure (substitution in C-3 position of flavilium ring). Sample with addition of green tea showed different tendency. In that sample high anthocyanin content was observed, but also there was high percent of polymeric colour and high change of ratio $A_{440}/A_{\text{vis max}}$.

Table 3. Anthocyanin content (AC), percent of polymeric colour (PC) and ratio A440/A_{vis max} of blackberry juice without and with addition of extracts during 52 days of storage at 4 °C

Sample	Storage (days)					
	0			52		
	AC (mg/L)	PC (%)	A440/A _{vis max}	AC (mg/L)	PC (%)	A440/A _{vis max}
BJ	149.91±0.86 ^a	31.91	0.764	119.85±0.35 ^a	40.04	1.001
BJ + olive leaf	154.55±0.35 ^b	32.76	0.748	114.21±0.18 ^b	41.33	1.078
BJ + pine bark PE 95%	152.66±0.18 ^c	34.27	0.777	135.57±0.53 ^c	35.34	0.822
BJ + green tea	152.29±0.35 ^c	31.90	0.741	131.99±0.18 ^d	43.08	1.050
BJ + pine bark PE 5:1	152.42±0.18 ^c	38.42	0.799	112.21±0.53 ^b	43.30	1.065
BJ + red wine PE 30 %	153.55±0.35 ^b	34.25	0.757	133.45±0.35 ^e	34.98	0.828
BJ + red wine PE 4:1	158.56±0.71 ^e	32.99	0.754	118.84±0.35 ^a	40.04	0.991
BJ + bioflavonoides	161.19±0.53 ^f	34.39	0.766	103.44±0.18 ^f	44.45	1.081

BJ – blackberry juice

Values in the same column with different superscripts (a-f) are significantly different (P<0.05) by analysis of variance (ANOVA) and Fisher's least significant difference (LSD).

Probably different mechanism was involved in anthocyanin retention in sample with addition of green tea, pine bark PE 95 % and red wine PE 30 %. In samples with pine bark PE 95 % and red wine PE 30 % addition there was slight polymerisation and change in structure at C-3 position in flavilium ring involved, while in sample with green tea addition polymerisation and change in structure probably caused retention of anthocyanins.

In all other samples, the losses of monomeric anthocyanins were most likely due to the formation of anthocyanin polymers during storage. Several authors reported the same tendency. Brownmiller et al. (2008) investigated processing and storage effect on monomeric anthocyanins and percent of polymeric colour of processed blueberry products and observed that the losses of monomeric anthocyanins were most likely due to the formation of anthocyanin polymers during the juice processing. Hager et al. (2008) investigated processing and storage effect on monomeric anthocyanins and percent of polymeric colour of processed black raspberry products. During storage anthocyanin content decreased while polymeric colour increased. Anthocyanin losses were also accompanied by increased percent polymeric colour values in raspberry pulp stored at different temperatures (Ochoa et al., 1999). Chaovanalikit and Wrolstad (2004) also observed that with decrease of anthocyanin content increase of polymeric colour occurred during storage of fresh and processed cherries. Potential mechanism for polymerization involves condensation reactions of anthocyanins with other phenolic compounds, including flavan-3-ols or polyflavan-3-ols that can be mediated by acetaldehyde (Es-Safi et al., 1999) and furfural (Es-Safi et al., 2000), or via direct anthocyanin-tannin reactions (Reed et al., 2005; Remy et al., 2000; Brownmiller et al., 2008; Hager et al., 2008).

Conclusions

In this study influence of different extracts on total phenol content, anthocyanin content, antioxidant activity and formation of polymeric colour of blackberry juice was investigated. After preparation of samples increase of anthocyanin content was observed when extract were added, probably due to copigmentation effect. During storage degradation of phenols and anthocyanins occurred. Loss of anthocyanins was followed by formation of polymeric colour, with exception of sample with addition of green tea. That sample had higher anthocyanin content than control sample, but also high percent of polymeric colour. This research could be benefit from nutritional point, but also from the technological point of view. These findings could be useful for development of functional food products and improvement of nutritional and health-promoting values of food products, since food products with higher anthocyanins and phenolic compounds content could be more effective against oxidative stress in human body.

Acknowledgment

This work was supported by the Ministry of Science, Education and Sports of the Republic of Croatia.

References

- Arnao, M.B., Cano, A., Acosta, M. (2001): The hydrophilic and lipophilic contribution to total antioxidant activity, *Food Chem.* 73 (2), 239-244.
- Artes, F. (2002): *Colour in Food Improving Quality*. Woodhead Publishing, Cambridge.
- Bąkowska, A., Kucharska, A.Z., Oszmiański J. (2003): The effects of heating, UV irradiation, and storage on stability of the anthocyanin-polyphenol copigment complex, *Food Chem.* 81 (3), 349-355.

- Baranac, J.M., Petranović, N.A., Dimitrić-Marković, J.M. (1997): Spectrophotometric study of anthocyan copigmentation reactions 2. Malvin and the nonglycosidized flavone quercetin, *J. Agr. Food Chem.* 45 (5), 1694-1697.
- Brownmiller, C., Howard, L.R., Prior, R.L. (2008): Processing and Storage Effects on Monomeric Anthocyanins, Percent Polymeric Color, and Antioxidant Capacity of Processed Blueberry Products, *J. Food Sci.* 73 (5), H72-H79.
- Chaovanalikit, A., Wrolstad, R.E. (2004): Total Anthocyanins and Total Phenolics of Fresh and Processed Cherries and Their Antioxidant Properties, *J. Food Sci.* 69 (1), FCT67-FCT72.
- Chen, L.J., Hrazdina, G. (1981): Structural aspects of anthocyanin-flavonoid complex formation and its role in plant colour, *Phytochem.* 20 (2), 297-303.
- Davies, K.J.A. (2000): Oxidative stress, antioxidant defences, and damage removal, repair, and replacement systems, *IUBMB Life* 50 (4-5), 279-289.
- Davies A. J., Mazza G. (1993): Copigmentation of simple and acylated anthocyanins with colorless phenolic compounds. *J. Agric. Food Chem.* 41 (5), 716-720.
- Dimitrović-Marković, J.M., Petranović, N.A., Baranac, J.M. (2000): A spectrophotometric study of the copigmentation of malvin with caffeic and ferulic acids, *J. Agric. Food Chem.* 48 (11), 5530-5536.
- Es-Safi, N., Fulcrand, H., Cheynier, V., Moutounet, M. (1999): Studies on acetaldehyde induced condensation of (-)-epicatechin and malvidin-3-O-glucoside in a model solution system, *J. Agric. Food Chem.* 47 (5), 2096-102.
- Es-Safi, N., Cheynier, V., Moutounet, M. (2000): Study of the reactions between (+)-catechin and furfural derivatives in the presence or absence of anthocyanins and their implication in food color change, *J. Agric. Food Chem.* 48 (12), 5946-54.
- Giusti, M. M., Rodríguez-Saona, L. E., Wrolstad, R. E. (1999): Molar absorptivity and color characteristics of acylated and non-acylated pelargonidin-based anthocyanins, *J. Agric. Food Chem.* 47 (11), 4631-4637.
- Giusti, M.M., Wrolstad, R.E. (2001): Characterization and measurement of anthocyanins by UV-visible spectroscopy. Unit F1.2. In *Current Protocols in Food Analytical Chemistry*. New York: John Wiley and Sons, Inc.
- Hager, A., Howard, L.R., Prior, R.L., Brownmiller, C. (2008): Processing and Storage Effects on Monomeric Anthocyanins, Percent Polymeric Color, and Antioxidant Capacity of Processed Black Raspberry Products, *J. Food Sci.* 73 (6), H134-H140.
- Katalinić, V., Milos, M., Kulisic, T., Jukic, M. (2006): Screening of 70 medicinal plant extracts for antioxidant capacity and total phenols, *Food Chem.* 94 (4), 550-557.
- Kopjar, M., Piližota, V. (2009): Copigmentation effect of phenolic compounds on red currant juice anthocyanins during storage, *Croat. J. Food Sci. Technol.* 1 (2), 16-20.
- Kopjar, M., Piližota, V., Hribar, J., Simčič, M. (2009a): Total phenol content and antioxidant activity of water solutions of plant extracts, *Croat. J. Food Sci. Technol.* 1 (1), 1-7.
- Kopjar, M., Piližota, V., Šubarić, D., Babić, J. (2009b): Prevention of thermal degradation of red currant juice anthocyanins by phenolic compounds addition, *Croat. J. Food Sci. Technol.* 1 (1), 24-30.
- Lee, M. H. (2003): Free radical-scavenging activity of Taiwanese native plants, *Phytomed.* 10 (2-3), 170-175.
- Longo, L., Vasapollo, G. (2005): Anthocyanins from Bay (*Laurus nobilis* L.) Berries, *J. Agric. Food Chem.* 53 (20), 8063-8067.
- Longo, L., Vasapollo, G., Rescio, L. (2005): Identification of Anthocyanins in *Rhamnus alaternus* L. Berries, *J. Agric. Food Chem.* 53 (5), 1723-1727.
- Mazza, G., Brouillard, R. (1987): Recent developments in the stabilization of anthocyanins in food products, *Food Chem.* 25 (3), 207-225.
- Mazza, G., Brouillard, R. (1990): The mechanism of copigmentation of anthocyanins in aqueous solutions, *Phytochem.* 29, 1097-1102.
- Mazza, G., Miniati, E. (1993): Anthocyanins in fruits, vegetables and grains. Boca Raton, CRC Press.
- Mazzaracchio, P., Pifferi, P., Kindt, M., Munyaneza, A., Barbiroli, G. (2004): Interactions between anthocyanins and organic food molecules in model systems, *Int. J. Food Sci. Techn.* 39 (1), 53-59.
- Middleton, E., Kandaswamy, C., Theoharides, T.C. (2000): The effects of plant flavonoids on mammalian cells: Implications for inflammation, heart disease, and cancer. *Pharm. Rev.* 52 (4), 673-751.
- 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 (3), 318-321.
- Ochoa, M.R., Kessler, A.G., Vulllioud, M.B., Lozano, J.E. (1999): Physical and Chemical Characteristics of Raspberry Pulp: Storage Effect on Composition and Color. *LWT*, 32 (3), 149-153.
- Ough, C.S., Amerine, M.A. (1988): Phenolic compounds, In: *Methods for analysis of musts and wines*, John Wiley and Sons, Inc., New York, USA.
- Pietta, P., Simonetti, P., Mauri, P. (1998). Antioxidant activity of selected medicinal plants, *J. Agr. Food Chem.* 46 (11), 4487-4490.
- Reed, J.D., Krueger, C.G., Vestling, M.M. (2005): MALDI-TOF mass spectrometry of oligomeric food polyphenols, *Phytochem.* 66 (19), 2248-2263.
- Remy, S., Fulcrand, H., Labarbe, B., Cheynier, V., Moutounet, M. (2000): First confirmation in red wine of products resulting from direct anthocyanin-tannin reactions, *J. Sci. Food Agric.* 80 (6), 745-751.
- Singleton, V.L., Rossi, J.A. (1965): Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *Am. J. Enol. Viticul.* 16 (3), 144-158.

Stintzing, F.C., Carle, R. (2004): Functional properties of anthocyanins and betalains in plants, food, and in human nutrition, *Trends Food Sci. Techn.* 15 (1), 19-38.

Tiwari, A.K. (2001): Imbalance in antioxidant defense and human diseases: Multiple approach of natural antioxidant therapy. *Current Sci.* 81 (9), 1179-1187.

Tsai, P.J., Huang, H.P. (2004): Effect of polymerization on the antioxidant capacity of anthocyanins in roselle, *Food Res. Int.* 37 (4), 313-318.

Yilmaz, Y, Toledo, R. (2005): Antioxidant activity of water-soluble Maillard reaction products, *Food Chem.* 93 (2), 273-278.

Received: April 12, 2011

Accepted: July 11, 2011