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Influences of organically and conventionally grown strawberry cultivars on anthocyanins content and color in purees and low-sugar jams

Danijela Bursać Kovačević [a], Predrag Putnik [a,*], Verica Dragović-Uzelac [a], Nada Vahčić [a], Martina Skendrović Babojelić [b], Branka Levaj [a]

[a] Faculty of Food Technology and Biotechnology, University of Zagreb, Pierottijeva 6, 10000 Zagreb, Croatia
[b] Faculty of Agriculture, University of Zagreb, Svetošimunska cesta 25, 10000 Zagreb, Croatia

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ABSTRACT

The objective of this study was to detect influences of cultivar, cultivation and processing on anthocyanin content and color in purees and low-sugar jams produced from strawberry cultivars (Elsanta, Maya, Marmolada, Queen Elisa), grown under conventional and organic cultivation. Color was determined by CIELab values while anthocyanins were quantified by HPLC-UV/VIS-PDA. Queen Elisa was the best cultivar for processing as it had highest total anthocyanin content (TAC) that was well preserved in processing. On average, processing purees to jams decreased TAC for 28% where pelargonidin-3-glucoside revealed most noticeable loss (53%) and cyanidin-3-rutinoside was best preserved in processing. Obtained results indicated that measurement of colorimetric parameters are strongly correlated with content of anthocyanins. In other words, loss of anthocyanins during processing was accompanied by noticeable decrease in lightness, red/yellow color and total color change. Results showed that change of color is useful predictor for estimating anthocyanins in strawberry purees and jams.

1. Introduction

Strawberries (*Fragaria x ananassa* Duch.) are a commercially important food commodity, commonly consumed fresh or processed worldwide. Among many strawberry products, jams are highly appreciated for their fruity taste and aroma. Due to their natural chemical composition, strawberries are a sensitive fruit and there are many challenges associated with the preservation of their natural quality. One of them is preservation of their attractive red color during processing, as that is a very important jam characteristic.

Anthocyanins are the most abundant flavonoid compounds in strawberries (see Fig. 1) that are responsible for the red color of this fruit (Aaby, Mazur, Nes, & Skrede, 2012). Their content is affected by many factors such as strawberry cultivar, postharvest performance, cultivation practice and processing (Amaro et al., 2013; Fernandes, Domingues, de Freitas, Delerue-Matos, & Mateus, 2012; Holzwarth, Korhummel, Carle, & Kammerer, 2012a; Levaj, Bursać Kovačević, Bituh, & Dragović-Uzelac, 2012; Mazur et al., 2014; Pincemail, Kevers, Tabart, Defraigne, & Dommes, 2012). It is well known that anthocyanins are highly unstable and easily susceptible to degradation. Thus, processing of strawberries into jam may result in loss of up to 70% of the initial anthocyanin content (Garcia-Viguera et al., 1999), which has strong influence over the red color in strawberry jams (Amaro, Soares, Almeida, Ferreira, & Pinho, 2012; Amaro et al., 2013). Pelargonidin-3-glucoside is the dominant anthocyanin in strawberries regardless of genetic and environmental factors, followed by derivatives of pelargonidin and cyanidin, but in considerably smaller amounts (Crecente-Campo, Nunes-Damaceno, Romero-Rodriguez, & Vazquez-Oderiz, 2012). It was reported that cyanidin-3-glucoside and pelargonidin-3-glucoside in blackberry and strawberry purees are thermally less stable than other anthocyanins (Patras, Brunton, Da Pieve, & Butler, 2009), therefore it is important to preserve their maximum amounts during processing.

Many health-promoting benefits have been attributed to strawberry anthocyanins (Alvarez-Suarez et al., 2014). Studies shown that in comparison to fresh strawberry fruit, their products contained remarkable amounts of phenolics and therefore have considerable antioxidant capacity (Amaro et al., 2013; Patras, Brunton, Tiwari, & Butler, 2011). Over the last decade increased risk for obesity (associated with high glucose index) steered classic industrial jam manufacturing towards low-sugar production with natural flavoring and color, similar to those of traditional products (Figuerola, 2007). Low-sugar jams usually consist of maximum 45%

* Corresponding author. Tel.: +385 (1) 460 5036; fax: +385 (1) 460 5072.
E-mail address: pputnik@alumni.uconn.edu (P. Putnik).

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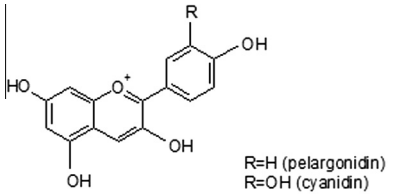

Fig. 1. Basic structure of strawberry anthocyanidins. R = H; pelargonidin; R = OH, cyanidin.

soluble solids that is considerably lower than usual 60% in traditional products. Therefore, low-sugar jams can offer substantial marketing potential as this product has increased nutritive and decreased caloric value (Masmoudi, Besbes, Blecker, & Attia, 2010).

Presently, many consumers are attracted to organic approaches due to observed improvements in food and environmental safety. Frequently studies determine anthocyanins as part of phenolic content that is measure of nutritional quality i.e. antioxidant activity, and compare it among organic and conventional cultivation (Crecente-Campo et al., 2012; Faller & Fialho, 2010; Jin, Wang, Wang, & Zheng, 2011). These studies demonstrated that crops produced using organic production might benefit human health better than corresponding conventionally grown produce. Contrarily, other authors showed similar or lower contents of polyphenolics in organic vs. conventional products (Vrcek, Bojic, Žuntar, Mendaš, & Medic-Šaric, 2011). Aside from environmental factors and cultivation practices, genetic background greatly affects strawberry characteristics. For instance content of micronutrients and phytochemicals may significantly vary among different cultivars grown under the same type of cultivation (Tulipani et al., 2008).

In order to systematically correlate color with pigment in food, one has to objectively evaluate color and determine pigment concentrations (Ngo, Wrolstad, & Zhao, 2007). Literature indicated that colorimetric values of C^* and H^* are closely correlated with color evaluation and anthocyanins levels during storage, and that color measurements can be used to monitor anthocyanin contents in sweet cherry cultivars (Goncalves et al., 2007). The color of strawberry puree is highly associated with anthocyanin content where anthocyanin loss during storage was accompanied by increased L^* and H^* values and decreased C^* values (Howard, Brownmiller, & Prior, 2014). In conclusion, optimal selection of raw materials for strawberry jam production should account for the type of cultivar and cultivation as such parameters affect the color and content of anthocyanins. That is directly related with product's acceptance and health benefits (nutritional value) of such foods.

Currently, strawberry jam is popular product that is available in both, sugar and low-sugar forms and is made from conventional or organic strawberries. No information is available on how cultivar, cultivation and processing of low-sugar jams influence on retention of anthocyanins and color parameters in strawberries. Therefore, the objectives in this study were: (a) to identify anthocyanins present in strawberry cultivars and their products under various cultivations; (b) to objectively measure color of strawberry cultivars and their products under various cultivations; (c) to detect influences of cultivar, cultivation and product type on anthocyanin content and color, and (d) to show a relationship among anthocyanin content and color parameters.

2. Materials and methods

2.1. Chemicals and standards

Anthocyanin standards (cyanidin 3-glucoside chloride and pelargonidin 3-glucoside chloride) were purchased from Fluka (Neu-Ulm, Germany). HPLC-grade acetonitrile, acetone, chloroform, hydrochloric acid, and acetic acid were obtained from Merck (Darmstad, Germany).

2.2. Samples

Strawberry fruits (*Fragaria x ananassa* Duch., cvs. Elsanta, Maya, Marmolada and Queen Elisa) grown conventionally (Belovar/Croatia, latitude 45°53′54″N; longitude 16°10′53″E) and organically (Horvati/Croatia, latitude 45°43′17.97″N; longitude 15°48′41.15″E) at cultivation sites were hand-harvested at full maturity (7.25 ± 0.25 °Brix and 5.50 ± 0.15 °Brix; for conventional and organic, respectively). All cultivars from both cultivations (conventional and organic) were grown in a pseudogley soil with pH = 6.40–6.45. Row planting distance was 0.3 m and space between rows was 1.2 m. Distance between two growing fields was 500 m. Used fertilizer for conventional cultivation consisted of N:P:K = 5:20:30 with trace elements and micronutrients applied at 40t/ha of N. Fertilization for organic cultivation was conducted in accordance with national regulations where no synthetic herbicides or insecticides were used. Fruit samples were selected based on uniform size, color and absence of mechanical damage. After harvesting, approximately 15 kg of each cultivar was packed in wooden boxes and immediately transported to research facility. Sepals were removed upon arrival, and fruits were manually washed, dried, then homogenized in purees with blender (Mixy, Zepter International, Switzerland), and used for experiments (assessment of anthocyanins content, colorimetric measurements, and jams preparation).

Low-sugar jams were prepared under vacuum (Vacuum Cooking Equipment; Pecon, Croatia) with formulation of: 10% fruit dry matter content in jam, 35% sugar and 0.6% pectin with soluble solids content (SSC) being 45 °Brix. Fruit purees were blended with sugar (commercial sucrose), placed in a vacuum cooker, then stirred and boiled. Cooking temperature was $T < 80$ °C and vacuum pressure was $p < 0.8$ bar. The mixture was allowed to boil for $t = 20$ min after SSC was measured with hand-type refractometer (LEICA 7531L). Close to the end of cooking, pectin solutions (Grinsted TM Pectin LA 410, Danisco Ingredients, Denmark) were added to the cooking mass in the amounts required to reach 45 °Brix. When cooking was finalized, jams were filled into hot glass jars, immediately capped and pasteurized at $T = 80$ °C for $t = 10$ min. Finally, jams were cooled at room temperature and stored until analysis in dark space at $T = 4$ °C.

2.3. Analysis of anthocyanins

2.3.1. Extraction procedure

Anthocyanins were extracted according to modified method from literature (Chaovanalikit & Wrolstad, 2004b). Either, strawberry puree or jam ($m = 20$ g) were mixed in capped Erlenmeyer flask with $V = 20$ cm^3 of acetone then sonicated for $t = 10$ min at $T = 20$ °C, with frequency of 35 kHz by using ultrasonic device (Transsonic T460, Elma, Germany). All samples were continuously protected from interference with light, and then filtered on Büchner funnel using Watmann No. 1 paper. Filter cake was re-extracted twice with $V = 10$ cm^3 of acetone/water (70:30 v/v). Filtrates were combined and mixed with $V = 80$ cm^3 of chloroform, then centrifuged at 5000 rpm for $t = 10$ min (Hettich Centrifuge,Rotofix 32, Germany). The upper aqueous phase was collected and evaporated in rotavapor R-215 (Büchi, Switzerland) at $T = 40$ °C. The fraction was made up to $V = 25$ cm^3 with acidified water (0.01% aqueous HCl, by volume).

2.3.2. Purification procedure

Prior chromatography, extracts were purified by solid phase extraction (SPE) (Chaovanalikit & Wrolstad, 2004a) with slight modifications. An aliquot ($V = 2$ cm^3) of the aqueous extract was