THE EFFECT OF THERMAL PROCESSING ON THE CONTENT OF BIOACTIVE COMPOUNDS IN CRANBERRY (Vaccinium macrocarpon) FRUITS

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INTRODUCTION

The American cranberry (Vaccinium macrocarpon Ait.), with an attractive bright red appearance and distinctive flavor, is recognized as a concentrated source of dietary flavonoids, including anthocyanins, flavonol glycosides, and proanthocyanidins (condensed tannins) as well as various phenolic acids (Cailliet et al., 2011; Blumberg et al., 2013). This plant has been known and cultivated for a long time and in comparison to other, its fruits are highly appreciated by the people. Their special benefits come from many health-promoting properties which include antioxidant (Lacombe et al., 2010; Côté et al., 2011), antifungal (McKenna et al., 2002), anti-inflammatory, antioxidant (Sun et al., 2002), antiproliferative (Seeram et al., 2004), antiedema, diuretic, antipyretic (Blumberg et al., 2013).

Quercetin, possibly the most powerful phytonutrient of the cranberry, has been reported to be a growth inhibitor of primary bladder transitional cell cancers in humans (Lavigne et al., 2007; Pappas and Schaiach, 2009; Gryszywajska, 2010). These benefits appear to be principally due to the ability of cranberries to interfere with the adhesion of some bacteria to select cell types and surfaces, i.e. P-fimbriated Escherichia coli from adhering to uroepithelial cells, Helicobacter pylori, the causative agent of most gastric and duodenal ulcers, to gastrointestinal mucosa, as well as oral pathogens such as Streptococcus mutans to tooth hydroxypatite (Lacombe et al., 2010; Côté et al., 2011). Recently, research on the effects of cranberries and their components has also been focused on their use in the prevention and treatment of cardiovascular disease (CVD) (McKay and Blumberg, 2007; Dohadwala et al., 2011).

Due to the presence of benzoic and cistic acids, cranberry belongs to the fruit of high durability, but with additional fusing process (drying, freezing, candying) the period of its shelf life can be more extended (Blumberg et al., 2013). Moreover, fresh cranberries fruits have pungent taste, which is not desirable by consumers, therefore different processing methods lead to increasing their eligible (Pappas and Schaiach, 2009). Cranberries can be processed into fresh fruit concentrate, sauce products, and juice drinks. The single-strength juice is very acidic (pH 2.5) and unpalatable. So that, since 1930, cranberry juice cocktail, comprising a mixture of cranberry juice (33%), sweeterener, water, and added vitamin C, was introduced. Dried cranberry powder formulated in capsules or tablets is also available (Dorofejeva et al., 2011).

The aim of the study was to investigate the effect of drying and freezing process on the chemical composition of cranberry fruits available on the Polish market.
Cranberry extract preparation

For the other determinations cranberry extracts (10% w/v) were used. Cranberry samples (2 g of fresh and frozen and converted into FW amounts of dried cranberries samples) were dipped in 20 mL of distilled water. The obtained solutions were stirred for 20h at room temperature using a shaker and then filtered through syringe filter with a diameter of 0.2 μm.

Anthocyanins

The content of anthocyanins was determined spectrophotometrically at various pH (AOAC Method 2005; Kaniewska et al., 2013). The determination principle consists in measurement the difference in absorbance at pH=1 and pH=4.5 at the wavelength λ = 510 nm and λ = 800 nm. Anthocyanins at pH = 1 exist in the form of red flavylum cation, and at pH 4.5 are converted into the form of a colorless pseudo-alkali. As a blank distilled water was used. The content of anthocyanins was calculated by special formula and expressed as % of DW based on cyanidin-3-glucoside (main anthocyanin component of cranberry).

Total content of phenolic compounds (Folin-Ciocalteau)

To 100 μL of obtained extracts, 500μL of Folin-Ciocalteau reagent (Merck, Germany; diluted in the volume ratio 1:10 with distilled water) and 400 μL of 7.5% Na2CO3 were added. The resulting solutions were allowed to stand for 90 minutes at room temperature and then the absorbance at the wavelength λ = 760 nm were measured according to the blank. The content of phenolic compounds were calculated using the prepared calibration curve and expressed in mg gallic acid (GAE)/100 g DW (Pijiac-Żegara et al., 2009).

Antioxidant activity (FRAP)

The FRAP reagent contained 10 mM TPTZ (Sigma, USA) solution in 40 mM HCl, 20 mM FeCl3, and 0.3 M acetate buffer pH 3.6 (POCh, Poland), in volume ratio 1:1:10 (Çelik et al., 2008). Aliquots of 200 μL of cranberry extracts (0.1g FW/1mL) were mixed with 1.8 mL of FRAP reagent and the absorbance of the reaction mixture was measured spectrophotometrically at λ = 593 nm after incubation at 37°C for 10 min against blank. 1 mM Trolox (Sigma-Aldrich, USA) was used for the calibration curves and the results were expressed as mM of Trolox equivalent (TE) per 100 g of fruits (DW).

Acidity

Five grams of the shredded fresh, frozen and dried cranberries samples (converted into fresh weight amounts) were heated to boil with 20 mL of water. The whole material was transferred to volumetric flask and made up to 50 mL with distilled water. After 15 min solution was filtered and 10 mL of the filtrate was titrated with 0.1 M NaOH to pH = 8 (measured by pH-meter). Results were calculated for citric acid and showed as g/100 g of DW.

Statistical analysis

Statistical calculations were performed using StatSoft Statistica, 9.0. Pearson’s correlation coefficients to assess interaction between tested parameters were calculated.

RESULTS AND DISCUSSION

The antioxidant activity, and phenolic compounds as well as vitamin C contents in fresh and processed cranberries were determined (Table 2). Fresh fruits were the richest source of vitamin C and polyphenols, both created their antioxidant activity. Freezing decreased the level of vitamin C by 25%, whereas the phenolic compounds were not changed and antioxidant activity was surprisingly improved by 41%. During convective drying, intensive losses of studied parameters were observed, especially when higher temperature was applied. The vitamin C level was strongly reduced by 62 and 87% during processing in 59 and 65°C, respectively. Meanwhile the phenolic compounds losses amounted from 9 to 26%, and antioxidant activity was reduced by 2-21%. In comparison sweetened dried cranberries (commercial) were dipped in 20 mL of distilled water containing significantly lower concentration of studied compounds, 5-fold, 3-fold and 3-fold lower for vitamin C, antioxidant activity and phenolic compounds, respectively.

Table 2 Content of bioactive compounds in tested samples (per 100 g dry weight)

<table>
<thead>
<tr>
<th>Thermal processing</th>
<th>Vitamin C [mg/g100g DW]</th>
<th>FRAP [mmol TE/100g DW]</th>
<th>Phenolic compounds [mg GAE/100g DW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh</td>
<td>208.60±50.51</td>
<td>101.30±0.27</td>
<td>634.94±78.86</td>
</tr>
<tr>
<td>Frozen</td>
<td>156.03±2.67</td>
<td>143.21±2.50</td>
<td>6420.10±0.00</td>
</tr>
<tr>
<td>Dried I</td>
<td>78.95±51.90</td>
<td>98.88±5.37</td>
<td>5874.38±50.15</td>
</tr>
<tr>
<td>Dried II</td>
<td>26.32±0.00</td>
<td>79.98±2.81</td>
<td>4743.50±115.66</td>
</tr>
<tr>
<td>Dried sweetened</td>
<td>41.36±5.32</td>
<td>31.22±0.53</td>
<td>2234.20±31.54</td>
</tr>
</tbody>
</table>

The obtained results confirmed negative impact of drying in high temperature on the levels of vitamin C in cranberry fruits and are in agreement with other authors findings. Del Caro et al. (2004), who studied the effects of drying parameters on two varieties of plums also showed detrimental impact of high temperature on the level of vitamin C. According to Świderski and Waszkiewicz-Robak (2005) losses of vitamin C as a result of the high temperature application are around 80%. On the other hand, Pobereźny and Wszelczakiszynia (2013) studied the effects of fixation methods on the quality of fruit and demonstrated that freezing is a good way to keep the high content of vitamin C in fruits.

The total phenolics content in studied fresh cranberry reached 865.5 ± 10.6 mg GAE / 100 g FW (6434.94 ± 78.86 mg of GAE / 100 g DW) and slightly decreased during thermal processing. However, research conducted by Witkowska and Zajko (2009) showed significantly lower levels of polyphenols in Polish small cranberries (Oxyccoccus palustris Pers.) fruits (2440 ± 521 mg / 100 g DW) in comparison to our results. Fabišak et al. (2005) in the studies on the effect of the drying method and temperature on the level of polyphenols in apples have shown that drying at 60 and 70°C resulted in a 35% decrease in the polyphenolic compounds while drying at low temperatures, especially with the use of freeze-drying method, led to significantly lower losses of the tested compounds.

In studies conducted on Polish small cranberry by Witkowska and Zajko (2009), the antioxidant activity of cranberry fruits tested by FRAP method was on the lower level (23.63 ± 3.62 mmol TE / 100 g DW) as compared to our findings. However, the confirmation of adverse effects of high temperature on antioxidant property of fruits were also obtained by Rutkowska et al. (2012). During studies on the level of bioactive compounds in wild rose fruits dried by a conventional and a freeze-dried methods they showed that the method of air chilling drying (72°C) caused a greater decrease in bioactive compounds (lower % of DPPH radical inhibition) than in freeze-drying method (Rutkowska et al., 2012).

Total acidity of fresh and dried fruits were analyzed by titration (Figure 1). In order to compare the result, all values were calculated to the dry weight (DW), taking into account the water content of the fruit (approx. 87%). The highest total acidity expressed as citric acid equivalent for fresh cranberry (2.21 g / 100 g of FW = 16.5 g / 100 g DW) was observed. The acidity of the fruit in the gentle drying (59°C, 144h) was reduced by 24.6%. Dried sweetened cranberries contained the least amount of organic acids. The acidity of the different varieties of ripe American cranberry fruits identified in a study conducted by Teleszkoo (2011) was at the same level as in the presented study (2.18-2.66 g of citric acid / 100 g FW). Freezing is one of the best ways of fusing fruit which is confirmed by the results of anthocyanin content (Figure 2). Fruit subjected to freezing have up to 4% more of these compounds than fresh cranberries. This may indicate that even short-term storage of fruits in the refrigerator caused small losses of such dye compounds, as compared to fruit preserved by freezing. The content of anthocyanins in dried fruits cranberries is about 38 to 90.3% lower than in fresh, the higher the drying temperature the more drastic decrease in the level of anthocyanins was observed. Anthocyanins are labile compounds that are not very resistant to the action of high temperatures. According to literature data, under the influence of heat glycosidic bonds in dye molecules undergo hydrolysis leading to unstable aglycones, which easily oxidize forming brown, high molecular weight compounds (Krucnar et al., 2014), who reported anthocyanin losses of 61% caused by 60 s heating at 115°C of highbush blueberries. The obtained results on the level of anthocyanins in fresh cranberry fruits (0.841g/100g FW) indicated that the domestic fruits are more abundant source of these colored compounds as compared to Pappas and Schaich (2009) findings, who indicated the contents of anthocyanin in American cranberries at the level 0.013-0.171 mg / 100 g of FW.
The comparison of nutritional properties of experimentally processed cranberry fruits and commercial sweetened dried fruits showed that the conventionally dried products have better nutritional properties than commercial one, which was however less acidic. High calorific value of sweetened cranberries and lower antioxidant capacity of commercial sweetened dried fruits were found. The obtained results indicate that the fresh cranberries have better nutritional properties and ascorbic acid content than commercial sweetened dried fruits.

Among studied parameters significant correlation was observed (Table 3). The total antioxidant activity was positively and significantly correlated with the content of phenolic compounds, anthocyanins and vitamin C, indicating that those compounds are responsible for the antioxidant properties of cranberry fruits. The highest correlation (r=0.943) was observed for anthocyanins and vitamin C content in Latvian cranberry dried in convective and microwave vacuum driers. 

Table 3 The Pearson’s correlation coefficient (r) between analyzed parameters

<table>
<thead>
<tr>
<th></th>
<th>FRAP</th>
<th>Phenolic compounds</th>
<th>Acidity</th>
<th>Anthocyanins</th>
<th>Vitamin C</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRAP</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phenolic compounds</td>
<td>0.922</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acidity</td>
<td>0.985</td>
<td>0.964</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anthocyanins</td>
<td>0.824</td>
<td>0.833</td>
<td>0.943</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Vitamin C</td>
<td>0.724</td>
<td>0.649</td>
<td>0.862</td>
<td>0.955</td>
<td>1</td>
</tr>
</tbody>
</table>

CONCLUSION

Fresh cranberries contains large amounts of bioactive ingredients (vitamin C, polyphenols, anthocyanins), but their contents were reduced during drying process directly proportional to the applied temperature. The best method of cranberry fruits preservation is freezing which does not significantly change their chemical composition. Convective dried fruits possess greater nutritional value than commercial sweetened dried fruits, due to higher content of bioactive compounds as well as lower calorific value.

REFERENCES


