Physico-chemical and antioxidant properties of six apple cultivars (Malus domestica) grown in Slavonia

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Sekcija: Analiza hrane / *Topic: Food analysis*

PHYSICO-CHEMICAL AND ANTIOXIDANT PROPERTIES OF SIX APPLE CULTIVARS (*MALUS DOMESTICA*) GROWN IN SLAVONIA

UDC: 634.11(497.54)

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original scientific paper

Summary

The aim of this study was to compare the physico-chemical properties and antioxidant activity of six apple cultivars grown in Slavonia (Croatia). Apple firmness, total soluble solids (TSS), pH, total acid content (TAC), total phenolics (TP), anthocyanins (A) and antioxidant activity (AA) were measured in the apple cultivars Idared, Fuji, Gala, Granny Smith, Jonagold and Top Red Delicious. The TP, A and AA were measured in peel, flesh+peel and flesh tissues from the apple cultivars. The results showed significant differences in the composition of the apple cultivars. Firmness of Fuji apple was the highest and Jonagold was the lowest. The TSS varied from 10.95% (Gala) to 15.20% (Fuji), pH value was between 3.63 (Granny Smith) and 4.33 (Gala), and the TAC ranged from 0.10 (Gala) to 0.33 (Granny Smith). Within each cultivar, the TP, A content and AA were the highest in the peel, followed by the flesh+peel and the flesh. Apple peel had from 2.4 to 3.8 times greater AA and from 4.7 to 9.8 times greater TP compared with flesh, with lower values found in Gala and Top Red Delicious, and higher in Idared, respectively. The TP (g GAE/kg fresh matter) observed in the apple cultivars was between 0.54 (Jonagold) and 6.56 (Idared). The values of the A (mg/L) ranged from 0 (Granny Smith) to 166.70 (Idared). The highest AA (mmol TE/100mL) was observed in Top Red Delicious peel (7.54), while the lowest value was found in the flesh of Jonagold (1.32). The Pearson correlation analysis showed positively correlation between TP in peel, flesh+peel, and flesh tissues with their AA ($r=0.891$, $\alpha<0.05$). These results can be of great value to geneticists, producers, food processing industry and consumers.

Keywords: apple, physico-chemical properties, antioxidant activity

Introduction

Apple is known as one of the most consumed fruits due to availability during the whole year, pleasant taste and rich source of dietary fibre and phytochemicals, including antioxidants. Apple firmness is used worldwide as a measure of ripeness and "condition" of the fruit. Firmness of apples as measured by instrumental methods is frequently used to determine their maturity and ripeness, which is important in handling, storing and processing procedures. The compression and the penetration tests are reliable and traditional methods used to estimate fruit firmness (Nabil et al., 2012). The firmness is

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negatively proportional to the maturity of the fruit and can be used as an alternative indicator to maturity in fruit grading and sorting (Jarén and Garczia-Pardo, 2002). Furthermore, firmness is an important quality attribute and a component of texture influencing sensory perception of fruit by consumers (García-Ramos et al., 2005).

The consumption of apples has been linked to the prevention of degenerative diseases; a reduction in the risk of lung cancer, asthma, type-2 diabetes, thrombotic stroke, ischemic heart disease, and antiproliferative activities (Knekt et al., 2002; Hyson et al., 2000; Giomaro et al., 2014). Apples are an important source of polyphenolics which are responsible for most of the antioxidant activities of the fruit, far over the amount explained by the presence of ascorbic acid (Eberhardt et al., 2000). Many studies show that the concentration of phenolic compounds, such as flavanols and anthocyanins in apple differ with cultivar, maturity stage, environmental conditions and the part of the fruit (Wolfe et al., 2003). Apple peel, in general, had a 2-9 times higher content level of both individual phenolics and total phenolics. These quantitative differences occurred mainly because of flavonol glycosides as well as high levels of catechins and chlorogenic acid in the peel (Mikulič Petkovšek et al., 2007). In particular, phenolics in apple skin showed a much higher contribution to the total antioxidant and antiproliferative activity of the whole apple than those in apple flesh (Wolfe et al., 2003; Drogoudi et al., 2008). Interestingly is the real proportion of peel of the apple fruit (based on its weight) to the whole apple quantity, especially as this part of fruit is frequently discarded as a waste product during apple manufacturing or before eating (Lata and Tomala, 2007). One way of increasing the intake of phytochemicals from fruit and vegetable is restoration and enrichment of food products with by-products obtained from fruits and vegetables processing industry (Lončarić and Piližota, 2014).

In this context, the aim of this work was to compare the physico-chemical properties and antioxidant activity of six apple cultivars grown in Slavonia.

Materials and methods

Apple cultivars Idared, Fuji, Gala, Granny Smith, Jonagold and Top Red Delicious were obtained from a commercial orchard in Slavonia County (Croatia) and stored at 4 °C in air, before they were used for trials. Bioyield force and fruit firmness were measured on using a texture analyser (TA.XT 2, Stable Micro Systems, UK) fitted with a 2 mm diameter probe. The penetration depth was 5 mm and the cross-head speed was 1.5 mm s^{-1}. Apple fruit firmness was measured on pared surfaces on opposite sides of fruit using a penetrometer (McCormick, USA) with an 8 mm diameter tip. Ten replicates were performed for texture measurements.

Total soluble solids were determined at 20 °C by means of a refractometer (Carl Zeiss, Germany). The pH was measured by using a pH meter (Mettler Toledo, Switzerland). Total acid content was measured by titration with 0.1 N NaOH, and given in g/100 g, calculated as malic acid (AOAC, 1980). The measurements were performed in duplicates for each cultivar. Total phenolics (TP), anthocyanins (A) and antioxidant activity (AA) of the apple peels, flesh+peel and flesh tissues from the apple cultivars were evaluated immediately after harvesting. For each cultivar, extractions from peel, flesh+peel and peel were carried out using 1 g of composite fruit tissue samples prepared from five randomly selected apples to minimise variation. The extractions were performed with 10 mL acidified methanol for 1 hr at the ambient temperature. After 1 h mixture was filtered through pleated filter paper. The extracts were used for the determination of TP, A and AA. Total phenol content was determined using the Folin-Ciocalteu colorimetric method described by Ough and Amerine (Ough and Amerine, 1988). The measurements were performed in triplicates for each sample and the average value was interpolated on a gallic acid calibration curve and expressed as g of gallic acid equivalents (g GAE)/kg of fresh matter. Determination of monomeric anthocyanins was conducted by pH-differential method (Giusti and Wrolstad, 2001). The results were expressed as mg cyanidin-3-glucoside. Antioxidant activity was determined by DPPH assay (Arnao et al., 2001). Three replicates were performed for each sample. The results were expressed as mmol trolox equivalents (TE)/100 mL of sample.

Statistical analysis

Pearson's correlation coefficients (α=0.05) were used to assess the strength and direction of the linear relationships between total phenol content and antioxidant activity in investigated apple cultivars (XL stat ver. 2009 3.02, Addinsoft, Inc. Brooklyn, New York, USA).

Results and discussion

The mechanical properties of apples, such as the firmness, are an indication of the apple's quality. Some specific forces corresponding to penetration such as yield and maximum point was selected as the firmness index. Table 1 shows the results measuring of bioyield force by texturometer and firmness of whole apples by texturometer and penetrometer. The obtained values were within the limits of literature data on the same cultivars (Bai et al., 2005; Iglesias et al., 2008; Calu et al., 2009; Jan and Rab, 2012). Of all the cultivars, firmness of Fuji apple was the highest and Jonagold was the lowest.

Table 1. Bioyield force and firmness of six apple cultivars measured by texturometer and penetrometer

Cultivar	BF (g)/CV (%)	F-T (g)/CV (%)	F-P (kg/cm^2)
Top Red Delicious	608.83 / 8.53	103.99 / 10.38	7.11 ± 0.62
Jonagold	600.58 / 8.23	101.55 / 10.81	6.01 ± 0.78
Fuji	861.12 / 4.58	136.98 / 9.41	8.28 ± 0.74
Gala	616.05 / 6.19	110.83 / 11.71	6.95 ± 1.00
Granny Smith	706.99 / 7.13	121.59 / 9.01	7.98 ± 0.70
Idared	688.03 / 5.11	119.88 / 8.03	7.65 ± 0.81

BF - bioyield force
CV - coefficient of variation
F-T - firmness measured by texturometer
F-P - firmness measured by penetrometer

In Table 2 total soluble solids (TSS), pH and total acid content (TAC) of investigated apple cultivars are given. The results showed significant differences in the composition of the apple cultivars. The TSS varied from 10.95% (Gala) to 15.20% (Fuji), pH value was between 3.63 (Granny Smith) and 4.33 (Gala), and the TAC ranged from 0.10 (Gala) to 0.33 (Granny Smith). Results of composition parameters are in accordance with the results of other authors (McCracken et al., 1994; Bai et al., 2005; Drogoudi et al., 2008; Calu et al., 2009; Mikulič Petkovšek et al., 2009).

Table 2. Total soluble solids (TSS), pH and total acid content (TAC) of apple cultivars

Cultivar	TSS (%)	pH	TAC (%)
Top Red Delicious	13.05 ± 0.49	4.32 ± 0.04	0.12 ± 0.01
Jonagold	13.30 ± 0.42	3.73 ± 0.03	0.29 ± 0.05
Fuji	15.20 ± 0.00	3.94 ± 0.05	0.28 ± 0.01
Gala	10.95 ± 0.07	4.33 ± 0.01	0.10 ± 0.01
Granny Smith	13.45 ± 0.07	3.63 ± 0.01	0.33 ± 0.00
Idared	13.45 ± 0.07	3.65 ± 0.01	0.31 ± 0.00

In Figs. 1-3 the values of total phenolics, anthocyanins and antioxidant activity in the peels to those of the flesh and flesh+peel parameters of the apples were compared. Within each cultivar, the AA and TP contents were the highest in the peels, followed by the flesh+peel and the flesh. The Pearson correlation analysis showed positive correlation between TP in peel, flesh+peel, and flesh tissues with their AA ($r=0.891$, $\alpha=0.05$). The results of the correlation analysis were to be expected and similar findings have been reported by other researchers (Drogoudi et al., 2008; Vieira et al., 2009). Apple peel had from 2.4 to 3.8 times greater AA and from 4.7 to 9.8 times greater TP compared with flesh, with lower values found in Gala and Top Red Delicious, and higher in Idared, respectively. The TP (g GAE/kg fresh matter) observed in the apple cultivars was between 0.54 (Jonagold) and 6.56 (Idared). The highest AA (mmol TE/100mL) was observed in Top Red Delicious peel (7.54), while the lowest value was found in the flesh tissue of Jonagold (1.32). The values of the A (mg/L) ranged from 0 (Granny Smith) to 166.70 (Idared). Anthocyanins were detected only in the flesh Top Red Delicious.
These results can be of great value to geneticists, producers, food processing industry and consumers.

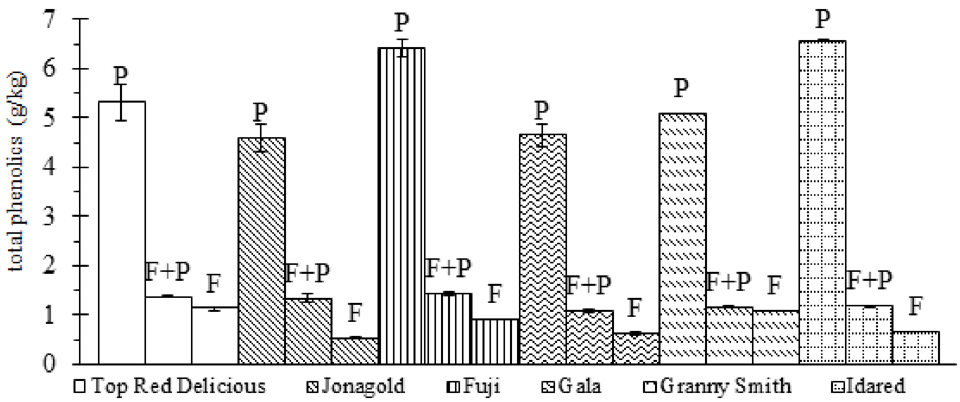

Fig. 1. Total phenolics in different parts of apple cultivars
(P - peel; F+P - flesh+peel; F - flesh)

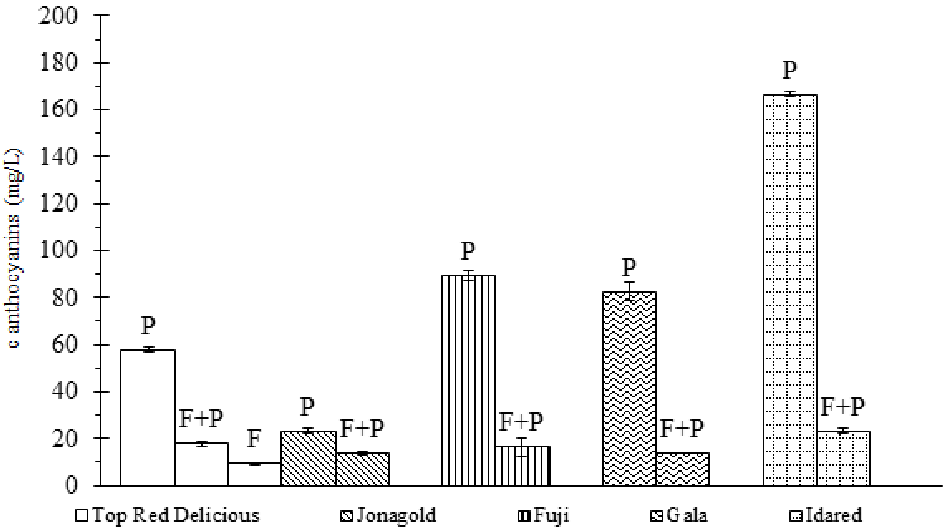

Fig. 2. Anthocyanins in different parts of apple cultivars
(P - peel; F+P - flesh+peel; F - flesh)

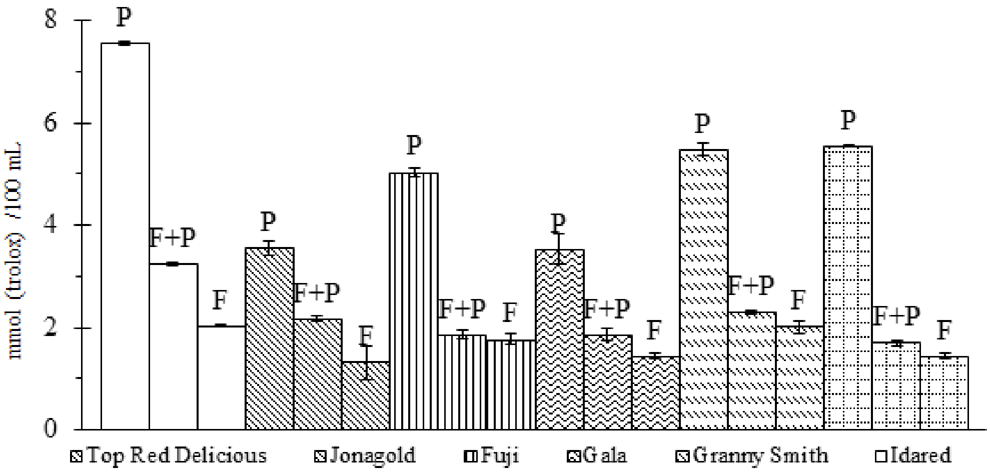

Fig. 3. Antioxidant activity in different parts of apple cultivars
(P - peel; F+P - flesh+peel; F - flesh)

Conclusions

The investigated apple cultivars showed differences in the physico-chemical properties and antioxidant activity of six apple cultivars grown in Slavonia. Cultivar Fuji had the highest values of firmness and total soluble solids. Gala had the lowest values of total soluble solids and total acid content. Cultivar Granny Smith had the highest total acid content and the lowest pH value. Within each cultivar, the total phenolics, anthocyanins and antioxidant activity were the highest in the peel, followed by the flesh+peel and the flesh. Apple peel had from 2.4 to 3.8 times greater antioxidant activity and from 4.7 to 9.8 times greater total phenolics compared with flesh tissue, with lower values found in Gala and Top Red Delicious, and higher in Idared, respectively. The highest peel contribution to antioxidant activity and total phenolics in comparison with flesh+peel tissue was observed in Idared.

The results indicated that the consumption of antioxidant polyphenols from apples can be increased simply by the appropriate choice of cultivar. Thus, this information can be useful to both consumers, who are interested in knowing which variety can have a greater beneficial effect on their health. Producers can also use this information for production and marketing purposes.

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