Chemical composition, nutritional value and antioxidant properties of crabapples

Srđan Ljubojević[1], Goran Vučić[2], Ladislav Vasilišin[2], Nataša Lakić-Karalić[2], Ana Velimir[2], Ivan Samelak[3]

[1]The Independent University of Banja Luka, Faculty for Ecology & Institute for Scientific Research
[2]University of Banja Luka, Faculty of Technology
3University of Banja Luka, Faculty of Science
Bosnia and Herzegovina

Abstract

The aim of this study was to determine the chemical composition, nutritional value and antioxidant properties of three crabapples: *Malus* `Pink Perfection` *Malus* `Royalti` and *Malus* x *zumi* `Golden Hornet`, with distinctive appearance characteristics. Subjects of the analysis were fresh fruits and juice obtained from the last one by steam extractor. Crabapples were taken from an urban garden. Chemical analysis includes the following parameters: macro- and microelements (As, Ca, Cu, Fe, K, Mg, Mn, N, Na, P, Se, Zn), water, dry matter, ash, proteins, sugars, total acidity, pectin, minerals, pH, vitamin C, anthocyanins, phenolic compounds, nonflavonoids, flavonols and free radical scavenging capacity (applying DPPH and ABTS tests). Basic phenotypic and morphometric characteristics of the fruits were observed as well. Results obtained from the research have shown that *M.* 'Pink Prefection' and *M.* x *zumi* 'Golden Hornet' have a fairly similar chemical composition. *M.* `Royalti contains significantly more vitamin C and a little more sugar but is also poorer in pectin and has much greater acidity. Compared to commercial apples, crabapples do not lag behind in sugar content, but they have significantly higher acidity and half the amount of vitamins C. The elemental composition of crabapples is also fairly uniform. When it comes to phytochemicals, *M.* 'Royalti is particularly prominent by the high content of anthocyanins, flavonols and phenols. The ABTS test showed that *M.* x *zumi* 'Golden Hornet' has the strongest antioxidant capacity. We have reached the same result by applying the DPPH method.

Crabapples, chemical composition, nutritional value, antioxidant properties

Introduction

Crabapple is rather loosely defined term in a different connotation. Its origin was believed to come from Scandinavia at the beginning of the 18th century, with meaning - "fruit of the wild apple tree" (Anon 2017). Jefferson (1970) indicates that any tree or shrub of genus *Malus* whose fruit diameter does not exceed 5.2 cm (2 inches), whether it is ornamental or economical plant implies under crabapple. From our point of view this term implies decorative (horticultural) apples, which are introduced into urban and peri-urban gardens and other horticultural facilities primarily due to their aesthetic values: the color of leaves, flowers and fruits, the abundance and duration of flowering, the abundance of fruiting and prolonged fruits retention. These characteristics do not exclude or neglect their other useful properties, such as: pollinizers in apple orchards, raw materials for the production of vinegar, jams, juices, then rootstocks in the production of grafted seedlings, bonsai cultures, etc., not to forget their role as a habitat and a shelter for wildlife, especially birds.

About the names of crabapples there are certain dilemmas and doubts, most often when it comes to the categories hybrid and cultivar. The assignment of names within the first category is governed by the International Code of Nomenclature for algae fungi and plants (earlier International Code of Botanical Nomenclature) and within the second category through the International Code of Nomenclature for Cultivated Plants. According to Jefferson (1970), referring to Wyman (1955), cit.: "Crab apples hybridize very freely, and because of this, much controversy has resulted in their proper identification. Seed has been gathered in large collections, grown and seedlings were named after the trees from which the seed was collected. Frequently, such seed has produced plants with totally different characteristics from the parent plant, and once this has become evident, it has

Address for correspondence:
Prof. Dr. Srđan Ljubojević
The Independent University of Banja Luka, Faculty for Ecology &
Institute for Scientific Research
e-mail: ljuboje@blic.net
www.maso-international.cz

caused much confusion." The native (indigenous) apple in Europe is considered a wild (forest) apple *Malus sylvestris* (L.) Mill., although many orchard apples actually derived from Asian apple *M. pumila* (Mabberley et al. 2001).

This paper analyzes the chemical composition, the nutritional value and the antioxidant properties of three taxa of crabapples, one hybrid and two cultivars. The obtained results were compared with the values of the most common sort of apple (*Malus domestica* Borkh.) in South East Serbia: `Fuji` (hybrid), `Golden Delicious` (cultivar), `Granny Smith` (cultivar), `Idared` (cultivar) and `Mutsu` (cultivar), presented by Stojanović (2014); it is undivided opinion that apples are delicious and nutritous fruits, which, in addition, possess a high antioxidative capacity (Lotito and Frei 2004). Morphometric parameters of the fruit, such as diameter and weight (*id est* mass), are also measured.

Materials and methods

The subject of our research are three taxa of crabapples that grow in an urban garden in the city of Banja Luka in Bosnia and Herzegovina. These are two cultivated varieties: *Malus* `Pink Perfection` and *Malus* `Royalty`, and hybrid cultivar *Malus* x *zumi* `Golden Hornet`. The trees were purchased from garden center "Flora" in Busovača small town in Bosnoa and Herzegovina (B&H), previously imported from Italy. At the time of planting, in the spring of 2013, each tree was five years old. Material for analysis was collected during year 2017.

Malus 'Pink Perfection' was selected by W. Flemer III (1960), at Princeton Nurseries, USA. Seed was taken from *Malus* 'Katherine' and the male parent was *Malus* 'Almey' (Hebb 1970). The main characteristic of this crabapple is blossom. It is made of clusters of lightly fragrant, double, light pink and white flowers (Plate XI, Fig. 1). Fruits from this apple also have a beautiful appearance and may be used in nutrition (Plate XI, Fig. 2). Research by Matsumoto et al. (2015) have shown that *Malus* 'Pink Perfection' is among the most superior pollinators and can be a useful pollinator for all domestic cultivars.

Malus 'Royalty' was selected by W. L. Kerr in 1958. in Canada (Saskatchewan), using many open pollinated rosy bloom seedlings he found growing there. As a rootstock he used wild apples of small fruits - *M. baccata* (L.) Borkh. Crabapple *M*. 'Royalty' is recognizable by the purple-red pigmentation of foliage, flowers and fruits (Plate XI, Fig. 3 & 4), and was the first crabapple with this feature, which was until then unique to plums. Purple pigmentation comes from the presence of anthocyanins. These compounds are powerful antioxidants in vitro and are widely believed to contribute to human health (van Nocker et al., 2012). However, due to very low mass and hardness, the fruits are not yet used in the nutrition.

Malus x *zumi* 'Golden Hornet' originates from the United Kingdom, created in the first half of the 20th century. It is thought to be a natural cross hybrid between two other crabapple species, *Malus sieboldii calocarpa* and *Malus prunifolia coccinea*. Its main characteristic is lush pink-white flowers, also from which numerous butter yellow fruits occur, which remain on the tree for long (Plate XI, Fig. 5). The leaves also turn yellow and become attractive in autumn. Unlike the previous taxon, the fruits are used in culinary art, preparation of jams and jellies, juices and vinegar.

Thus, all three observed trees are of the same age and grow under the same agro-environmental regime. This prevents bias in terms of fruit acidity and some other features, considering that many agronomic studies have shown the impact of cultural practices on these characteristics (Etienne et al. 2013).

Methods

Fresh samples of crabapples were collected at the moment of optimal ripeness. This stage was visually evaluated on the basis of daily monitoring. The harvest was carried out at the time when participation of the immature or overripe fruits compared to mature ones, was minimal. Namely, it has been known for a long time that the total acid content of apples is directly related to the ripening processes (Nybom 1959). In addition to fresh fruits, a sample of *Malus* x *zumi* 'Golden Hornet' juice was taken, using a simple steam extraction, simple household utensil, without any additives (sugar, preservatives, etc.).

After harvesting and before the seeds were extracted from the fruits. It is known that seeds of crabapples contain trace amounts of amygdalin, which is under stomach acid transformed into toxic compound. Before homogenization the samples were ground with a knife and then chipped in the laboratory mill (Tecator Kniefetec 109/, Foss), according to Vasilišin et al. (2017). At the same time, it is known that apple seed is a rich source of selenium, which is an antioxidant and important element for enzymatic activity of liver (Stojanović 2014). From the homogenised material, 5 g of fruits of each taxon was extracted with 80% ethanol, twice at 25 ml. The solutions were refilled with 80 % ethanol in volumetric flasks of 50 mL volume.

Thus, 100 mg/mL concentrations were obtained and further used to determine total phenols, flavonoids, flavonols, neutralization of 2.2-diphenyl-1-picrylhydrazyl radical (DPPH) and 2,2'-azinobis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS +) radicals. To determine a total and monomeric anthocyanins, 20 g of samples was extracted with a 20 mL solution (85 ml of 95 % ethanol solution in 15 ml of 1.5 mol/L HCl solution) at 0° C for 24 hours. After being left to stand, resulting mixture was filtered through a quantitative filter paper, and the filtrates were used for further analysis. The content of dry matter, ash, total acidity and vitamin C were determined by standard AOAC methods (Anon 2000). Total phenol content was determined by the modified Folin-Ciocalteu method (Wolfe et al. 2003). Gallic acid was used as the standard compound and the results were expressed as phenol equivalent to gallic acid (GAE), *i.e.* μg GAE/g_{FW}. The total flavonoids are determined by the method of Kumaran and Karunakaran (Kumaran 2007), and the total flavonols according to the method of Ordoñez et al. (2006). Quercetin was used as the standard compound, and the results were expressed as μg Quercetine (Qc) /g_{FW}. The antioxidant activity in relation to the DPPH radical was determined by the method of Liyana-Pathirana and Shahidi (Liyana-Pathirana 2005). The modified method of Re et al. (1999) was used fot the ABTS radical. The results were presented with the TEAC value (Trolox equivalent of antioxidant activity), *i.e.* as μg Trolox/g_{FW}. Total and monomeric anthocyanins were determined by the spectrophotometrically modified "single" pH and by the pH differential method. The overall experiments were performed in three parallel repetitions.

Five hundred healthy, undamaged fruits were collected from each taxon. In a random manner 120 fruits were further taken from each set. They are given an average diameter in millimeters, as the mean of two cross-measurements. Also, their weight (mass) was measured with accuracy of 0.01 g. In this way, a better insight into the morphometric characteristics of the observed fruits was obtained.

Descriptive statistical analysis was performed and the results were presented by the mean of n repetitions with standard deviation using Statgraphic 5 Plus program. Statistically significant differences were proved by analysis of variance (ANOVA).

Results

The chemical composition of *Malus* 'Pink Prefection' and *M.* x *zumi* 'Golden Hornet' is quite similar (Tab. 1). *M.* 'Royalti' contains considerably more vitamin C and a little more sugars, but is also poorer in pectin and has much higher acidity. The relationship between increased

Table 1. Chemical composition of fresh fruit and juice of crabapples

Components	Unit	*M.* 'Pink Prefection'	*M.* 'Royalti '	*M.* x *zumi* 'Golden Hornet'	Crabapple juice
		Mean value (Sx)			
Invert sugars	%	9.99 ± 1.4	11.19 ± 1.7	9.17 ± 1.4	3.71 ± 1.4
Pectin	%	0.48 ± 0.09	0.35 ± 0.08	0.56 ± 0.07	0.43 ± 0.05
Proteins	%	0.37 ± 1.3	0.37 ± 1.2	0.37 ± 1.4	-
Total acidity (as malic acid)	%	1.11 ± 0.6	2.75 ± 0.8	1.12 ± 0.09	0.56 ± 0.08
Total ash	%	0.48 ± 0.04	0.78 ± 0.06	0.35 ± 0.09	-
Vitamin C (Tillmans)	mg/100 g	2.45 ± 1.4	0.94 ± 1.4	1.19 ± 1.4	2.07 ± 1.4
pH		3.28 ± 0.2	3.02 ± 0.4	3.17 ± 0.2	-
Sugar-acid Ratio	Invert sugars / Total acidity	9.0 ± 1.1	4.33 ± 1.2	8.19 ± 1.1	6.62 ± 1.3

vitamin C concentration and total acidity, among the first was observed by Nybom (1959), in soft apples. However, the same author finds that sometimes sweet fruits have a rather high vitamin C content.

Compared to commercial apples (Campeanu et al. 2009, Stojanović 2014), crabapples do not lag behind sugar content, but they have significantly higher acidity and double less vitamin C (Tab. 2). Difference in malic acid concentration between cultivated and wild apple fruits was also noted by Ma et al. (2015). The same source emphasizes that the major components of soluble sugars (fructose, glucose and sucrose) are different between cultivated and wild fruits.

Table 2. Comparative overview of fresh fruits of crabapples and commercial apples

Components	Unit (Stojanović 2014)	Crabapples differences	Comercial apples	Statistical
		Mean value & range		
Sugars content	% (9.17 - 11.19)	10.12 (9.53 - 12.34)	10.62	statisticlly random
Water content	% (70.97 - 82.26)	78.27 (76.69 - 88.37)	83.75	statisticlly random
Vitamin C	mg/100 g (2.45 - 5.94)	3.19 (7.19 - 7.89)	7.51	statisticlly significant
Ash content	% (0.35 - 0.78)	1.61 (1.63 - 2.77)	2.18	statisticlly significant
Total acidity	% (1.11 - 2.75)	1.66 (0.127 - 0.345)	0.2	statisticlly highly significant

By variance analysis, a statistically significant difference was found between Ca, P, Mn and Se content in crabapples fruits and juice (Tab. 3). Crabapples on average have significantly lower Na and Fe content compared to the average for five varieties of commercial apples from Southeast Serbia - 11.31 mg/100 g and 0.41 mg/100 g, respectively, and slightly lower content of Ca - 87.62 mg/100 g (Stojanovic 2014). However, crabapples have significantly higher content of K and Mn compared to orchard apples from Southeast Serbia, where K takes values from 57.25 to 98.23 mg/100 g, Mn - 0.05 mg/100 g, then Mg - 6.44 mg/100 g, Cu - 0.09 mg/100 g and Zn - 0.04 mg/100 g (Stojanović 2014). The

Table 3. Macro- and microelements in fresh fruits and juice of crabapples (mg/100g)

Elements	Unit	*M.* 'Pink Prefection'	*M.* 'Royalti '	*M.* x *zumi* Golden Hornet'	Crabapple juice
			Mean value		
Na	mg/100 g	1.15 ± 0.56	1.11 ± 0.62	1.07 ± 0.58	1.07 ± 0.42
K	mg/100 g	161.92 ± 10.65	161 ± 12.85	160.45 ± 13.42	160.45 ± 10.47
Ca	mg/100 g	8.28 ± 1.67	8.27 ± 2.37	8.35 ± 1.95	10.03 ± 2.12
Mg	mg/100 g	10.05 ± 1.05	9.99 ± 1.95	9.58 ± 1.69	9.83 ± 1.59
P	mg/100 g	17.02 ± 2.53	17.42 ± 2.58	17.67 ± 3.64	13.42 ± 3.11
Fe	mg/100 g	0.21 ± 0.09	0.20 ± 0.08	0.20 ± 0.06	0.19 ± 0.07
Cu	mg/100 g	0.11 ± 0.05	0.11 ± 0.03	0.12 ± 0.08	0.09 ± 0.002
Mn	mg/100 g	0.39 ± 0.03	0.38 ± 0.04	0.34 ± 0.07	0.46 ± 0.06
Zn	mg/100 g	0.13 ± 0.05	0.12 ± 0.06	0.12 ± 0.05	0.10 ± 0.06
Se	μg/100 g	0.73 ± 0.09	0.68 ± 0.07	0.62 ± 0.08	0.82 ± 0.05

average selenium content in apple peel is also lower in relation to fresh fruits of crabapples - 0.62 µg/100g (Stojanović 2014), taking note that peel is considered as a better source of minerals in comparison to apple flesh.

When it comes to phytochemicals, *M*. 'Royalti is particularly prominent in the high content of anthocyanins, flavonols and phenols, compared to the other two taxa. The ABTS test showed that the strongest antioxidant capacity has *M*. x *zum*i 'Golden Hornet'. We obtained the same results using the DPPH method (Tab. 4).

Table 4: Phytocemicals and antioxidant activity of fresh fruits and juice of crabapples

Components	Unit	*M*. 'Pink Prefection'	*M*. 'Royalti '	*M*. x *zumi* Golden Hornet'	Crabapple juice
			Mean value		
Anthocyanins	mg/L	0.09	2.77	0.04	0.02
Monomeric anthocyanins	mg/L	0.02	2.01	-	-
Flavonols	mgQcE/g	0.65	1.21	0.62	0.24
Phenols	mg GAE/g	7.99	42.46	5.86	4.21
Flavonoids	mgQcE/g	7.39	42.12	5.36	3.74
Nonflavonoids	mgQcE/g	0.60	0.34	0.50	0.47
ABTS	mg Trolox /mL	0.08	0.04	0.13	0.39
DPPH	mg Trolox /mL	0.46	0.18	0.70	1.21

Table 5: Morphometric features of crabapple fruit

Crabapple	Diameter (mm)			Weight (g)			$r_{d.w}$
	M_d	S_x	Range	M_w	S_x	Range	
*M*alus 'Pink Prefection'	22.87	± 2.23	14 – 33	7.03	± 1.23	4.8 – 9.5	0.54
Malus 'Royalti'	17.19	± 1.58	14 - 20	2.97	± 0.67	1.7 - 4.5	0.82
Malus x *zumi*	24.92	± 3.17	15 - 30	9.06	± 2.00	3.4 - 13.8	0.52

'Golden Hornet' Notice: Ni = 120, number of fruits, M_d – diameter (mm), M_w – weight (g), $r_{d.w}$ - Coefficient of correlation between diameter (d - diameter) and weight (w - weight)

Among the observed crabapples *Malus* x *zumi* 'Golden Hornet' has the largest and heaviest fruits (Tab. 5). An ocular estimation suggests that this apple yields the highest fruit yield per tree, under the same other conditions.

All observed species possess high aesthetic properties (Fig. 1-5) throughout the vegetation period and even afterwards in the first winter months. In this context, the crabapple *M*. x *zumi* 'Golden Hornet' is particularly remarkable, which keeps the fruits many months during the winter and can serve as Christmas or New Year decoration.

Conclusions

The analyzed crabapples have a fairly similar chemical composition, with *M*. 'Royalti' predominating in the vitamin C content and hold a slightly higher sugar content but are also poorer in pectin content and contain much greater acidity. Compared to commercial apples, crabapples do not lag behind in sugar content but are inferior to vitamin C and have significantly higher acidity. The elemental composition of crabapples is also fairly uniform. Compared to commercial apples, they have lower sodium and iron content and

a partially lower amount of calcium. On the other hand, they have significantly higher quantity of potassium and manganese, and some higher content of magnesium, copper, zinc and selenium. Crabapple *Malu*s 'Royalti' predominates in the amount of anthocyanins, flavonols and phenols versus *M*. 'Pink Prefection' and *M.* x *zumi* 'Golden Hornet', while the ABTS test showed that the strongest antioxidant capacity has *M*. x *zum*i 'Golden Hornet'. We came to the same conclusion by applying the DPPH method. Crabapple *Malus* x *zumi* 'Golden Hornet' has the largest and the heaviest fruits and gives the highest fruit yield per tree, under the same other conditions. All observed species have high aesthetic properties throughout the vegetation period and even during the winter period.

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