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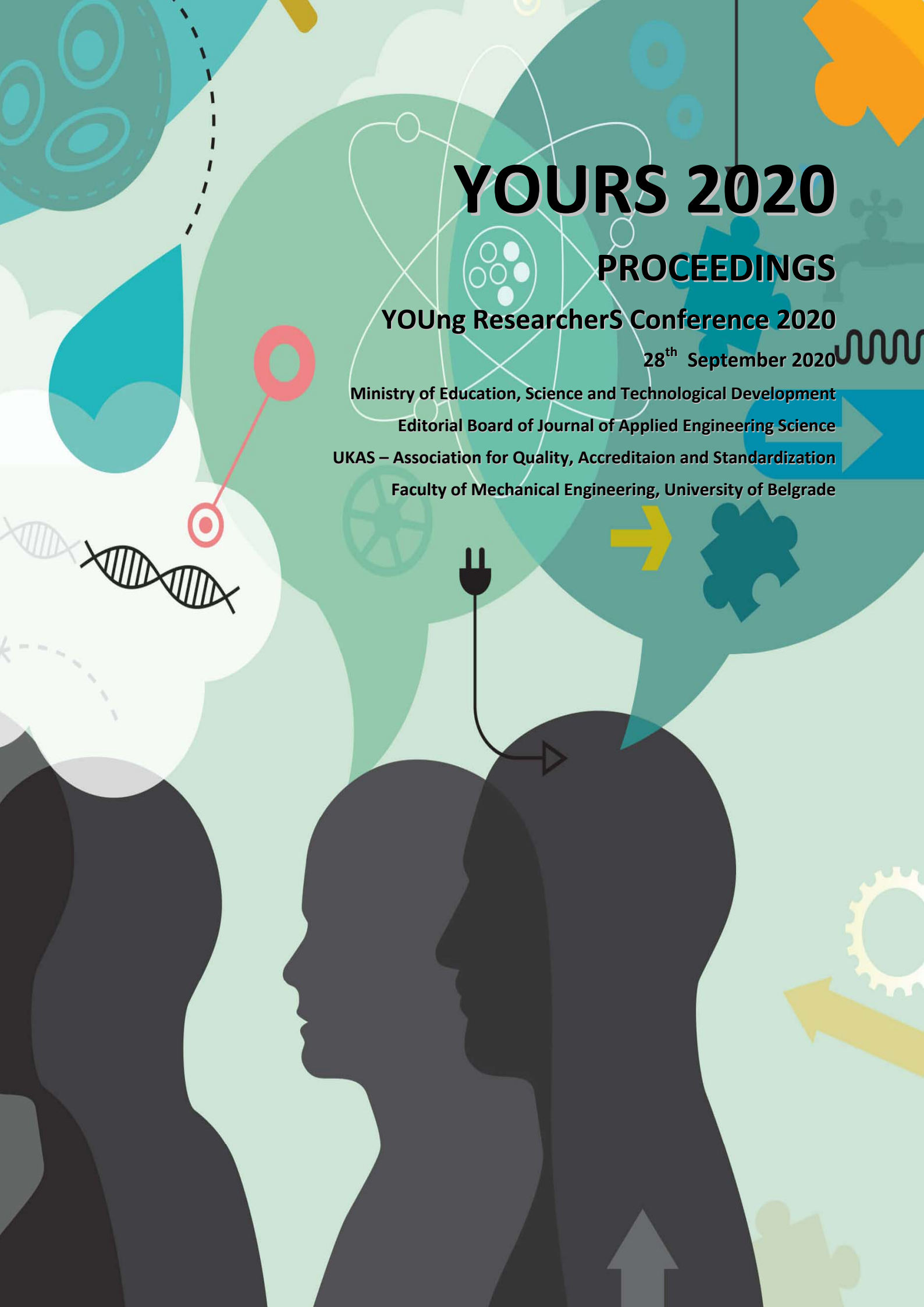
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TABLE OF CONTENT

YOUNG RESEARCHERS CONFERENCE 2020

APPLICATION OF GRASSHOPPER OPTIMIZATION ALGORITHM IN MECHANICAL ENGINEERING	1
Đorđe Jovanović, Branislav Milenković, Mladen Krstić	
THE INFLUENCE OF LONG-RANGE CORRELATED GROWTH SIGNALSON THE EVOLVING COMPLEX NETWORK STRUCTURES	6
Ana Vranić, Marija Mitrović Dankulov	
AN IMPROVED LAPLACE TRANSFORM METHOD FOR THE CALCULATION OF THE LIGHTNING CHANNEL RETURN STROKE PARAMETERS	13
Dragan Pavlović, Tomislav Šekara, Jovan Cvetić	
RESILIENCE AS A MEASURE FOR RISK ASSESSMENT OF THE WATER SYSTEMS: REVIEW OF EXISTING CONCEPTS	19
Lazar Ignjatović, Milan Stojković, Nikola Milivojević	
EFFICIENT LARGE-SCALE OPTIMIZATION IN THE CONTAINERIZED ENVIRONMENT	28
Nikola Andrijević, Višnja Simić, Miloš Ivanović	
EXPERIMENT PLANNING FOR PRELIMINARY ASSESSMENT OF THE MATHEMATICAL MODEL OF AN UNPOWERED AIR GLIDER BOMB	36
Goran R. Petrović, Milan R. Ristanović, Goran Memon, Dragan V. Lazić, Radoslav D. Radulović	
ADJUSTING PH PZC VALUE DURING AND AFTER ADSORBENT PREPARATION.....	46
Mladen Bugarčić, Dragana Milošević, Milica Spasojević, Dunja Marunčić, Jovanka Kovačina, Milan Milivojević.....	46
METHOD FOR ACQUISITION AND ANALYSIS OF OPERATING PARAMETERS OF A SUPERCAPACITOR ELECTRIC BUS.....	52
Miloš Maljković, Branko Miličić, Milena Žunjić, Ivan Blagojević	
EFFECT OF PATIENT SPECIFIC YOUNG'S MODULUS ON MECHANICAL BEHAVIOUR OF CORTICAL FEMORAL BONE – A FINITE ELEMENT STUDY	60
Aleksandra Vulović, Nenad Filipović	
APPLICATION OF UAS IN LAND COVER DETECTION AND CLASSIFICATION IN RURAL AREAS	65
Nenad Šurjanac, Natalija Momirović, Sanja Jovanović, Branka Spasojević, Ljubinko Rakonjac, Aleksandar Lučić, Marija Milosavljević	
DIGITAL AGRICULTURE AS A FACTOR OF ENERGY EFFICIENCY AND ENVIRONMENTAL PROTECTION	72
Zoran Brljak, Jelena Ješić, Zlatica Miladinov	
EVALUATION OF FRUIT QUALITY OF TWO AUTOCHTHONOUS APPLE CULTIVARS SUITABLE FOR WIDESPREAD PRODUCTION	81
Aleksandra Korićanac, Milan Lukić, Boris Rilak, Branko Popović, Olga Mitrović, Slađana Marić	
REVIEW, SYSTEMATIZATION AND APPLICATION OF THE STANDARDS FOR ASSESSMENT OF STATIC AND FATIGUE STRENGTH OF METAL CRANE STRUCTURES	87
Lidija Jelić, Nikola Jović, Vladimir Milovanović, Miroslav Živković, Jelena Živković	
USING DIFFERENT TYPES OF FINITE ELEMENTS FOR NUMERICAL SIMULATIONS OF BUFFING IMPACT TESTS OF FREIGHT WAGONS.....	93
Nikola Jović, Lidija Jelić, Miroslav Živković, Vladimir Milovanović, Aleksandar Dišić	
SOME ASPECTS ON THE DESIGN APPROACHES FOR BOLTED MOMENT CONNECTIONS IN FRAMES.....	98
Aleksandra Arsić, Vlada Gašić, Nenad Zrnić	
TOPSIS MULTI-CRITERIA DECISION MAKING METHOD FOR PELLETIZED FLY ASH PARAMETERS SELECTION.....	105
Marina S. Blagojev, Rudolf A. Tomanec, Slavica R. Mihajlović, Miroslav D. Sokić, Slavomír Hredzák	
COMPARISON OF STANDARD, SLIM AND ROLL-YOUR-OWN CIGARETTES BY MEASURING LEVELS OF POLYCYCLIC AROMATIC HYDROCARBONS (PAHS) IN MAINSTREAM CIGARETTE SMOKE WITH GAS CHROMATOGRAPHY–MASS SPECTROMETRY	110
Tatjana Taušanović, Marijana Apić, Nataša Stojić, Mira Pucarević	

EVALUATION OF FRUIT QUALITY OF TWO AUTOCHTHONOUS APPLE CULTIVARS SUITABLE FOR WIDESPREAD PRODUCTION

Aleksandra Korićanac, Milan Lukić, Boris Rilak, Branko Popović, Olga Mitrović, Slađana Marić

Fruit Research Institute, Čačak, Serbia

Summary: Autochthonous apple cultivars are mainly grown in extensive orchards. Due to their resistance to pathogens, frost and summer droughts, they should be considered for more intensive organic and integrated production. Since autochthonous cultivars represent valuable source of genetic variability, they contribute to biodiversity and stability of ecosystems. Nevertheless, fruit of autochthonous cultivars is abundant in health-protecting compounds. Thus, the objective of this study was to analyze the fruit quality of two autochthonous apple cultivars, 'Bobovec' and 'Kolačara', in comparison to 'Morrens Jonagored', one of the most commercially important cultivar. The obtained results indicate that examined autochthonous cultivars contained higher amount of soluble solids, total acids and total phenolics. Although 'Bobovec' had the smallest fruit, it exhibited the highest antioxidant capacity and contained the highest concentration of health-beneficial phenolic compounds.

Keywords: 'Bobovec', 'Kolačara', pomological characteristics, chemical properties, bioactive compounds.

INTRODUCTION

Permanently increasing apple production ought to be in compliance with criteria of food safety, environmental protection and variable market's demands. Although intensive production enables high yields and fruit quality, it also requires high investments, particularly in chemical control, mainly performed for the purpose of suppressing some economically most significant diseases [1]. Evans et al. [2] reported that more than 30 fungicide treatments against apple diseases were conducted in some European regions. By using of resistant apple cultivars, many toxicological and environmental problems, primarily caused by excessive application of pesticide, could be avoided. According to Parisi et al. [3] fungicide treatments required on a plantation of resistant apple cultivars could be one fourth of those needed to protect susceptible cultivars. As opposed to modern assortment, autochthonous apple cultivars are resistant to pathogens, frost and summer droughts. Thus, they require less care [4] and can be produced organically [5, 6].

Jemrić et al. [7] noted that the range of apple cultivars in the European market was significantly reduced to no more than 12 cultivars. Since planting a small number of apple cultivars could endanger the biodiversity and lead to worldwide epidemics of certain pests and pathogens [8], growing of autochthonous cultivars is a key way for preserving biodiversity and protection of environment. In addition, indigenous genotypes represent a good source of genetic variability and can be used as parents in the apple breeding programmes.

Fruit of autochthonous cultivars is often commercially unattractive, due to its shape, size or discoloration. However, there is a change in the concept of food quality. The nutritional value of fruit and health-beneficial properties are becoming more important determinants of consumers' demand and choice.

Bioactive compounds of apple have substantial role in the human diet. Epidemiological studies have linked the consumption of apples with reduced risk of many chronic diseases, such as cancer, cardiovascular disease, asthma and diabetes [9]. Apple phenolics possess significant antioxidant potential and they prevent oxidative damage caused by free radicals [10]. The phenolic content in apples depends on genotype [11], maturation stage [12], part of the fruit [13], applied storage technique and shelf-life [14]. According to Sun et al. [15], apples more abundant in phenolic compounds expressed a higher antioxidant activity. Therefore, it is crucial to select apple genotypes with the highest phenolics content. Lončarić et al. [16] found significantly higher content of phenolic compounds in autochthonous apple cultivars comparing to the commercial ones.

'Jonagold' and its clones, due to their high yields, easy cultivation and popularity among consumers, represent economically important cultivars grown in Europe [17, 18]. Thus, the objective of this study was to analyze fruit quality of two autochthonous apple cultivars, 'Bobovec' and 'Kolačara', and compare to 'Morrens Jonagored', the most popular clone of 'Jonagold'. The study evaluated pomological (morphometric and chemical) properties of examined cultivars, including the content of bioactive compounds in different fruit's tissues. Although 'Bobovec' and 'Kolačara' are resistant and moderately resistant to powdery mildew and scab, respectively [1], these cultivars can be found only in extensive orchards. Since this type of growing is questionable for survival of these cultivars, new knowledge about their characteristics could help to preserve biodiversity and offer consumers fruits with different organoleptic traits and high content of health-promoting compounds.

MATERIALS AND METHODS

Plant material

Fruits of the two autochthonous apple cultivars 'Bobovec' and 'Kolačara' (also known as 'Božićnica'), and one commercial cultivar 'Morrens Jonagored', were harvested at the optimal maturity stage. Harvest dates in 2019 for examined cultivars, grown in the region of Čačak, were as follows: 'Morrens Jonagored' 23rd September, 'Kolačara' 15th October, 'Bobovec' 6th November.

Fruit weight, fruit dimension, soluble solids content (SSC), titratable acidity (TA)

The fruits were transported to the laboratory of Fruit Research Institute, Čačak where morphometric characteristics were measured on the aforementioned date. Twenty fruits from each cultivar were used for measurements of fruit weight and dimensions. Fruit weight (g) was measured using an Ohaus Adventurer technical scale (Parsippany, NJ, USA). Fruit length (mm) and width (mm) were measured using the digital caliper. Digital refractometer (Hanna Instruments, Germany) was used for measurements of SSC in the fruit. Titratable acidity (TA) was determined by neutralization with 0.1 N NaOH to pH 8.2, using phenolphthalein as indicator. The results were expressed as a percentage (%) of malic acid.

Determination of total phenolics (TPC) and antioxidant capacity (AC)

In order to compare the differences in phenolic contents and antioxidant activity between different fruit's tissues, the analyses were performed for the whole apple fruit (wf), flesh (f) and peel (p) separately. Five apples from each cultivar were cut, and the core and seeds were removed in order to prepare extract of whole fruit. For preparation of peel and flesh extracts another five apples were carefully peeled using stainless steel knife, thus, the peel and flesh were separated. The extraction procedure were conducted in the following way: the tissue of samples was frozen in liquid nitrogen and ground using electric mill; the ground sample (3 g) was stirred with 30 mL of extraction solution (80% aqueous methanol); after 30 min of ultrasonic extraction, supernatant was filtered and obtained extracts were used for analyses.

The total phenolic content (TPC) was determined according to modified Folin-Ciocalteu colorimetric procedure [19]. The changes in the colour of the radical were measured after 30 min at 765 nm using UV-VIS spectrophotometer (Beckman, model 25, CA, USA). TPC was expressed as milligrams of gallic acid equivalents per 100 g fresh weight (mg GAE/100 g fw). Antioxidant capacity (AC) was determined by the ABTS assay. ABTS•+ radical cation scavenging activity was determined according to the method described by Re et al. [20]. The results were expressed as millimoles of Trolox equivalents per 100 g of fresh weight (mmol TE/100 g fw). All analyses were performed in three replicates.

Statistical analysis

The obtained data were subjected to the one-way analysis of variance (ANOVA, F test) in order to examine differences among the cultivars. Multiple comparisons of means was performed by Tukey test ($p = 0.05$) using STATISTICA 7.0 software (Statsoft Inc., Tulsa, OK, USA). All data were reported as mean \pm standard deviation (S.D.).

RESULTS AND DISCUSSION

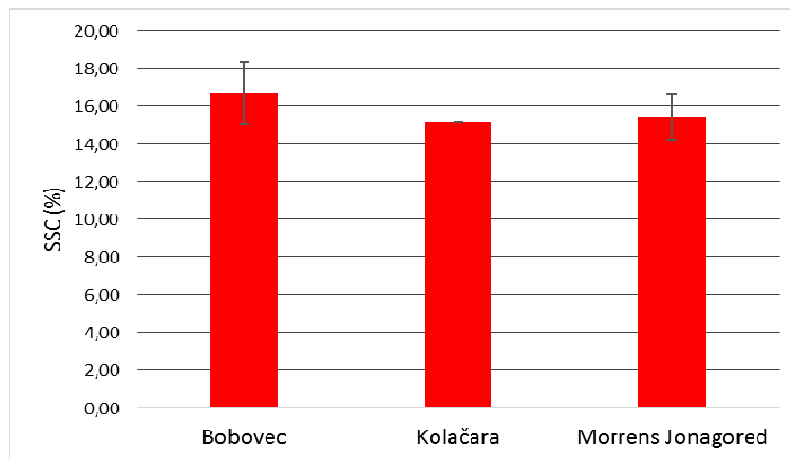
Fruit size and weight are generally the most important determinants for consumers' acceptance. Salkić et al. [21] stated that market criterion for the first class fruit regarding the weight is from 160 to 180 g. Considering the obtained results presented in Table 1, both, 'Morrens Jonagored' and 'Kolačara' can be marked as the first class fruit according to the previously mentioned criterion. Nevertheless, there was no statistically significant difference in the term of fruit width between 'Kolačara' and 'Morrens Jonagored'. In contrast, 'Bobovec' had the smallest fruit. The mean values of fruit dimensions and weight of examined cultivars are in compliance with the previously reported data [16, 22]. However, Kulina et al. [23] reported significantly higher fruit weight for 'Bobovec' (162.1 g). Since numerous factors affect fruit weight and dimensions, distinctions in the obtained and reported results could be the consequence of different environmental conditions in the regions of Čačak and Majevica.

Table 1: Fruit weight and dimensions of examined apple cultivars

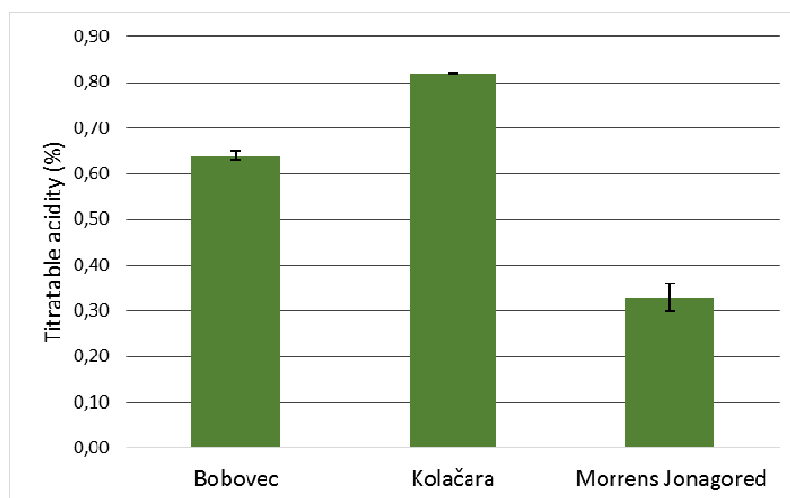
Parameter	Cultivar		
	'Bobovec'	'Kolačara'	'Morrens Jonagored'
Fruit weight (g)	70.17 ± 12.71 c	160.98 ± 35.15 b	228.53 ± 37.04 a
Fruit height (mm)	55.09 ± 4.54 b	56.76 ± 5.40 b	70.80 ± 5.49 a
Fruit width (mm)	53.65 ± 3.54 b	77.48 ± 5.70 a	80.58 ± 4.81 a

Each value is expressed as mean ± standard deviation (n = 20). The presence of equal letters in the same row indicates that there is no significant difference according to the Tukey test.

SSC and TA are crucial properties for consumers' perception of inner apple quality [24]. All examined cultivars had high content of SSC, above 15% (Figure 1). The highest content of SSC was observed in 'Bobovec'.

**Figure 1:** SSC in the fruit of examined apple cultivars

The content of total acids differs significantly among examined cultivars. It was highest in 'Kolačara' and the lowest in 'Morrens Jonagored' (Figure 2). Both observed parameters, SSC and TA, were higher in autochthonous cultivars comparing to the commercial one and were in agreement with the findings of Lončarić et al. [16] and Kulina et al. [23].

**Figure 2:** Titratable acidity in the fruit of examined apple cultivars

Phenolic compounds are naturally occurring plant secondary metabolites which determine quality parameters of fruit such as appearance, flavour and health-promoting properties [25]. Since apples are widespread and available in the market all year around, they represent one of the major source of phenolic compounds. Determination of total

phenolics and antioxidant capacity in autochthonous cultivars is crucial for recognition of these apples as highly valuable source of health-promoting compounds. Nevertheless, it is reported that phenolics of plant tissue can determine the level of susceptibility to fungal infections [26]. Thus, our study evaluated TPC and AC not only in fruit, but also in the peel and flesh. The obtained results are shown in Table 2.

The analysis of variance showed significant effect of cultivar on total phenolics and antioxidant capacity in fruit. High amount of accumulated phenolic compounds, particularly in the peel of autochthonous cultivars could be linked with their resistance to pathogens. Liu et al. [27] noted that phenolic compounds accumulate in dermal plant's tissue because of their protective role against ultraviolet radiation and diseases. The highest TPC and AC were detected in 'Bobovec', regardless of the part of the fruit. Similar results were reported by Djapo et al. [28], who analyzed TPC in the peel and flesh of five autochthonous and two commercial cultivars. Lončarić et al. [16] noted that all examined autochthonous cultivars, including 'Bobovec' and 'Kolačara' ('Božićnica'), had higher TPC than commercial ones. Interestingly, they also found significantly higher TPC and AC in 'Jonagold' apples compared to the results of the present study.

Table 2: Total phenolics and antioxidant capacity in different fruit's parts of examined apple cultivars

Parameter	Cultivar		
	'Bobovec'	'Kolačara'	'Morrens Jonagored'
Total phenolics, wf (mg GAE/100 g fw)	239.29 ± 1.43 a	150.71 ± 5.15 b	58.81 ± 3.60 c
Total phenolics, p (mg GAE/100 g fw)	405.95 ± 0.82 a	369.29 ± 8.92 b	176.90 ± 6.75 c
Total phenolics, f (mg GAE/100 g fw)	150.71 ± 2.86 a	81.67 ± 2.18 b	13.10 ± 2.18 c
Antioxidant capacity, wf (mmol TE/100 g fw)	3.41 ± 0.04 a	2.32 ± 0.02 b	1.27 ± 0.01 c
Antioxidant capacity, p (mmol TE/100 g fw)	5.60 ± 0.09 a	4.90 ± 0.01 b	2.58 ± 0.02 c
Antioxidant capacity, f (mmol TE/100 g fw)	2.84 ± 0.05 a	1.67 ± 0.02 b	0.70 ± 0.02 c

Each value is expressed as mean ± standard deviation (n = 3). The presence of equal letters in the same row indicates that there is no significant difference according to the Tukey test. wf – whole fruit, p – peel, f – flesh

Study of Lončarić et al. [29] evaluated individual phenolics and AC in peel of twelve autochthonous and eight commercial apple cultivars. 'Bobovec' had the highest amount of procyanidin A2 and B2, quercetin, quercetin-3-glucoside and epicatechin, whereas 'Kolačara' contained the highest amount of phloridizin and quercetin-3-rutinoside. Additionally, 'Bobovec' exhibited the highest AC, which is in compliance with our findings. Accordingly, 'Bobovec' could be considered a rich source of health-promoting compounds.

CONCLUSION

Despite the fact that examined autochthonous cultivars had smaller fruits in comparison to 'Morrens Jonagored', they possessed a high content of SSC, total phenolics and exhibited great antioxidant activity. Since the peel of examined traditional cultivars contains significant amounts of potentially health bioactive compounds, it is recommended to consume whole fruit in order to increase the daily polyphenol intake. The obtained results showed that 'Bobovec' and 'Kolačara' do not lag behind commercial cultivars in their fruit quality characteristics. Nevertheless, their cultivation could help in preserving biodiversity, suppressing the usage of chemicals in orchards and diversification of the market.

ACKNOWLEDGMENTS

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