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THE EVALUATION OF SELECTED QUALITATIVE PARAMETERS OF SWEET POTATO (*IPOMOEA BATATAS* L.) IN DEPENDENCE ON ITS CULTIVAR

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ABSTRACT

The sweet potato (*Ipomoea batatas* L.) is relatively known vegetable species, but it is grown only on small area in the Middle European region. Its cultivars are characterized by different colour of tuber flesh which can be white, beige, yellow, orange and purple. The aim of this study was to determine and compare selected qualitative parameters of tubers (total carotenoids, vitamin C and total soluble solids) among orange, white and purple sweet potato cultivars. The field experiments were established at Slovak University of Agriculture in Nitra in 2016 and 2017. Sweet potatoes were grown by hillock system with using of black non-woven textile for soil mulching. The tuber harvest was realised on the 6th October 2016 and 13rd September 2017. The highest content of total carotenoids was found in orange sweet potato cultivars (78.47 – 122.89 $mg.kg^{-1}$ fresh weight) and its values were multiple-fold higher in comparison with purple (4.22 $mg.kg^{-1}$ f. w.) and white (10.71 $mg.kg^{-1}$ f. w.) cultivars. Orange cultivars were also richer source of vitamin C (246.31 – 325.99 $mg.kg^{-1}$ f. w.) compared to white (179.66 $mg.kg^{-1}$ f. w.) and purple (187.75 $mg.kg^{-1}$ f. w.) cultivars of sweet potatoes. The total soluble solids, expressing mainly sugar content, was higher in purple (10.13 °BRIX) cultivar of sweet potatoes, followed by cultivars with orange (8.52 – 9.72 °BRIX) and white (5.57 °BRIX) tuber flesh. Obtained results showed the significant effect of cultivar, characterized by different tuber flesh colour, on the composition and contribution of sweet potatoes for human health.

Keywords: sweet potato; quality; carotenoids; vitamin C; total soluble solids

INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) belongs to the family *Convolvulaceae* and genus *Ipomoea* **(Firon et al., 2009)**. **Loebenstein (2009)** indicate, that sweet potatoes (syn. batatas) were domesticated before more than 5000 years in tropical America. According to the database **FAOSTAT (2019)**, world sweet potato production within period 2007 – 2016 was ranged from 101,3 to 105,4 mil. tonnes. **Musilová et al. (2017)** state that sweet potatoes are grown in Slovak republic only by small growers.

Sweet potatoes are universal and delicious vegetable species with high nutritional value because of many medicinally valuable compounds with anticarcinogenic, antidiabetic and anti-inflammatory activity **(Mohanraj and Sivasankar, 2014)**. According to the database **USDA (2019)**, sweet potato tubers are characterized by higher energetic value in comparison with classical potatoes (*Solanum tuberosum* L.). Sweet potatoes have higher ratio amylose to the amylopectin compared to the potatoes. The amylose increases the sugar level in blood more slowly compared to the simple saccharides and it is recommended as healthier food component, including for people suffering by diabetes **(Mohanraj and Sivasankar, 2014)**.

The flesh of sweet potato tubers can be white, beige, yellow, orange and purple **(UPOV, 2010)**. **Allen et al. (2012)**, sweet potato cultivars with orange flesh colour contain are rich sources of carotenoids, known as provitamins A. The dominant carotenoid substance in sweet potatoes is β-carotene **(USDA, 2019)**. **Kammona et al. (2015)** found that β-carotene ratio from total carotenoid content in sweet potatoes was varied from 79.0 (white flesh) to 97.9% (purple flesh). The biochemical change of β-carotene in human body is formed vitamin A; however, it is not possible to state that β-carotene should have the same importance as vitamin A **(Hegedűsová et al., 2016)**. The β-carotene is very effective scavenger of free oxygen radicals which could be responsible for skin damage, eye retina degeneration, cataract formation or various types of cancer. From this reason, β-carotene is ranged to the group of important antioxidant substances **(Pisoschi and Pop, 2015)**.

The vitamin C (syn. ascorbic acid) belongs to the most important vitamins and it is characterized by significant antioxidant properties. The most of plants and animals synthesize vitamin C from glucose; however, the human organism is not able to form vitamin C and is dependent on its intake from food **(Schlueter and Johnston, 2011)**. The vitamin C is the less stable and most sensible vitamin and it is used as the indicator of change level in relation to the plant product processing **(Giannakourou and Taoukis, 2003)**. **Schlueter and Johnston (2011)** state that vitamin C protects human body against infection of respiratory system and reduces the risk formation of cardiovascular diseases and several cancer types. **Mei and Tu (2018)** indicate that intake of sufficient amount of vitamin C acts against *Helicobacter pylori* which is marked as an important risk factor for stomach cancer formation. According to the study of **Harrison (2012)**, vitamin C plays important protective role against Alzheimer's disease, characterized by decrease of cognitive abilities. The vitamin C is also important for sperm protection against oxidative damage and higher sperm quality of smokers **(Colagar and Marzony, 2009)**.

Scientific hypothesis

The sweet potato is relatively known but a few grown vegetable species in the Middle European region. There is expected a variable content of tested qualitative parameters among sweet potato cultivars with different-coloured flesh tuber.

MATERIAL AND METHODOLOGY

The field experiments with sweet potato were realized on the land of the Slovak University of Agriculture in Nitra in 2016 and 2017. The climate of experimental area is characterized by warm and dry summer and slightly warm, dry or very dry winter. According to the climatic normal 1951 – 2000 for Nitra, annual mean temperature is 9.9 °C and mean rainfall total is 548 mm **(Šlosár et al, 2016)**. Within vegetation period (May – September), the average air temperature was 18.7 °C in 2016 and 19.3 °C in 2017. The rainfall total, during vegetation period, was 312 (2016) and 216 mm (2017).

Plant material

Sweet potato seedlings were purchased from Croatian producer. In Europe, situation with cultivar assortment of sweet potato is often unclear and confusing. A lot of seedlings are produced according to the mother's tuber availability on the market. Thus, the origin of sweet potato seedlings on market is often un-known. Within this study, four cultivars with different tuber flesh colour were tested (Figure 1). The sweet potato cultivar 'Beauregard' was only one certified cultivar and it is very known cultivar with orange flesh colour. Other three cultivars were marked according to the market place from which tubers for seedling production was purchased and used. These cultivars were named as 'Dubaian' (orange cultivar from United Arab Emirates), 'Višnjica white' and 'Višnjica purple' (white and purple cultivar from Croatia). The basic characteristics of all cultivars, evaluated according to the descriptor **UPOV (2010)**, is described in the Table 1.

Experiment organization

The sweet potato is warm-requiring crop which needs warm season lasting at least four months with an average temperature more than 20 °C and without freeze **(Antonio et al., 2011)**. From this reason, out planting of sweet potato seedlings was realised on the 25th May 2016 and 1st June 2017 when the risk of later spring freeze is significantly reduced.

Within soil preparation for sweet potato growing, nitrogen was only applied on the soil supply level of 60 $kg.ha^{-1}$ according to results of agrochemical soil analyses (Table 2). Sweet potato plants were grown by hillock system, similar to the carrot growing (height of 0.30 m). The distance between hillock rows was 1.20 m. In each row, 18 sweet potato seedlings were planted in distance of 0.30 m. Rows for all tested cultivars were divided to three replications with 6 sweet potato plants. The black non-woven textile was used for soil mulching before planting of sweet potato seedlings because of better microclimate around plants.

The harvest of sweet potato tubers was realised on the 6th October 2016 and 13rd September 2017. Harvested tubers of sweet potato were classified according to average weight of tubers in two size classes: >150 g – marketable yield of tubers and <150 g – non-marketable yield of tubers. Qualitative parameters of sweet potatoes were evaluated in marketable tubers. The average sample of each sweet potato cultivar for analyses was prepared from 6 tubers. All tubers were quartered, and opposite quarters were used for qualitative analyses.

Determination of qualitative parameters

Total carotenoid content estimation

The estimation of total carotenoid content was realised in the laboratory of Department of Vegetable Production, Slovak University of Agriculture in Nitra. The total carotenoid content was estimated by spectrophotometric measurement of substances absorbance in petroleum ether extract on spectrophotometer PHARO 200 at 445 nm wavelengths. As an extraction reagent, acetone was used acetone **(Hegedüsová et al., 2018)**.

Vitamin C content estimation

The estimation of vitamin C content was realised in the laboratory of Department of Chemistry, Janos Selye University in Komárno. HPLC method of vitamin C content estimation **(Hegedüsová et al., 2018)** was used by the help of liquid chromatograph with UV detector, for separation was used RP C18 column, mobile phase was methanol:water (5:95, v/v), UV detection was adjusted to 258 nm (HPLC Waters 2489 UV/VIS Detector).

Total soluble solids estimation

The juice from the homogenized sample of sweet potatoes was squeezed on the dry block of the digital hand-held refractometer (Kern ORD 45BM, Balingen, Germany). The value of soluble solids was directly read. Measurement was performed at room temperature according to **Hegedűsová et al. (2018)**.

Statistic analysis

The statistical analysis of obtained results was performed by using of the Statgraphic Centurion XVII (StatPoint, USA). Results were evaluated by analysis of variance (ANOVA) and average values were tested by LSD test performed at the significance level of 95% (p <0.05).

Table 1 Evaluated morphological characteristics of sweet potato tubers.

Parameter	Beauregard	Dubaian	Višnjica white	Višnjica purple
Shape	ovate	ovate	ovate	ovate/irregular/oblong
Main skin color	light-purple	red-purple	beige	red-purple
Secondary skin color	orange	-	pink	-
Main flesh color	orange	orange	white	purple
Secondary flesh color	beige	-	-	beige

Table 2 Agrochemical soil characteristics before trial experiments in 2016 and 2017.

Year	pH_{KCl}	Humus (%)	Nutrient content ($mg.kg^{-1}$ of soil)					
			$N_{min.}$	P	K	Ca	Mg	S
2016	7.14 N	4.17 H	13.0 M	198.8 VH	487.5 VH	6100 H	816 VH	26.3 M
2017	7.18 N	3.75 G	10.1 M	147.5 H	477.5 VH	5850 H	762.6 VH	91.3 H

Note: N_{min} – N mineral (N inorganic); N – neutral; G – good; M – medium; H – high; VH – very high.

Table 3 Average content of total carotenoids, vitamin C and total soluble solids in sweet potatoes.

Cultivar	Total carotenoids ($mg.kg^{-1}$ ±SD)	Vitamin C ($mg.kg^{-1}$ ±SD)	Total soluble solids (°BRIX ±SD)
Beauregard	78.47 ±7.74^{c}	246.31 ±86.36^{b}	8.52 ±1.61^{b}
Dubaian	122.89 ±9.57^{d}	325.99 ±127.12^{c}	9.72 ±1.63^{c}
Višnjica white	10.71 ±1.51^{b}	179.66 ±41.52^{a}	5.57 ±0.90^{a}
Višnjica purple	4.22 ±0.81^{a}	187.75 ±71.76^{a}	10.13 ±1.63^{d}

Note: SD – standard deviation.

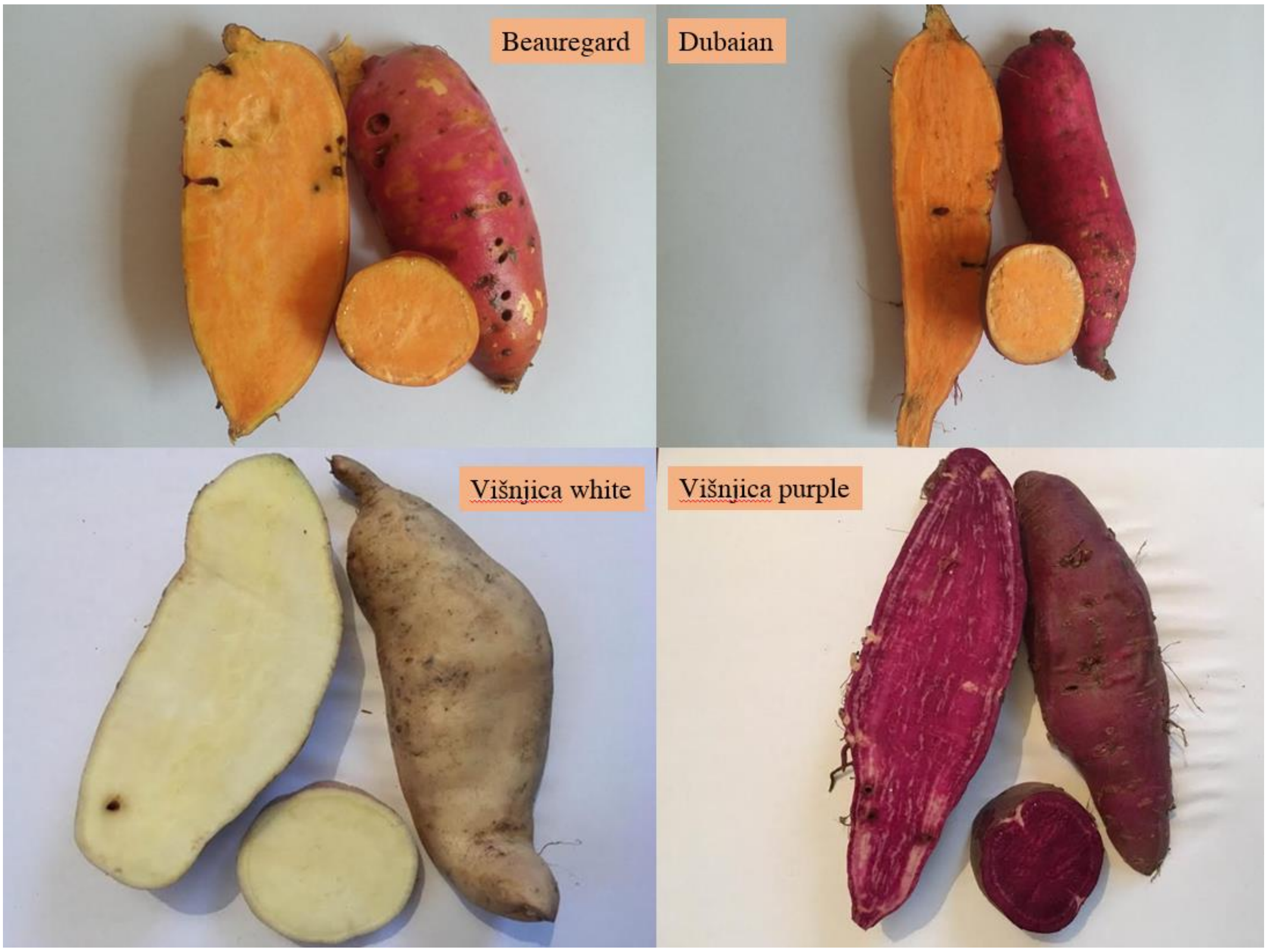

Figure 1 Tested sweet potato cultivars.

Total carotenoid content (TCC)

The statistical analysis of obtained results showed statistically significant (p <0.05) differences of TCC among tested sweet potato cultivars (Table 3). The average values of TCC were ranged from 4.22 ('Višnjica purple') to 122.89 mg.kg^{-1} fresh weight ('Dubaian'). Significant differences of TCC were found among orange and purple/white cultivars; it confirmed similar findings presented by **Allen et al. (2012)** or **Sebuliba, Nsubuga and Muyonga (2001)**. In mentioned studies, authors stated that important source of carotenoids are mainly orange sweet potato cultivars. **Alam, Rana and Islam (2016)** found the variability of TCC in nine orange cultivars of sweet potatoes from 3.8 to 72.4 mg.kg^{-1} f. w. Results found by **Tomlins et al. (2012)** also confirmed that orange cultivars (8.5 – 72.5 mg.kg^{-1} f. w.) are significantly richer sources of carotenoid in comparison with white cultivars of sweet potatoes (0.4 – 1.3 mg.kg^{-1} f. w.). Values of TCC, presented in both studies, were lower than results found in our experiments. The expressive variability of TCC in orange sweet potato cultivars was presented in study of **Ndah and Ojimelukwe (2018)** in which values of TCC was ranged from 18.01 to 180.98 mg.kg^{-1} f. w. Values of TCC in most of cultivars are comparable to orange cultivars tested in our study. **Tang, Cai and Xu (2015)** tested the effect of cultivars with different flesh colour on the TCC in sweet potatoes. The highest TCC was found in orange cultivars (157.9 mg.kg^{-1} f. w.), followed by yellowish-creamy (75.4 mg.kg^{-1}), light-purple (5.19 mg.kg^{-1}), white (4.46 mg.kg^{-1}) and dark-purple cultivars (2.85 mg.kg^{-1}) of sweet potatoes. In comparison to results of our study, TCC was higher in orange cultivars, comparable in purple cultivars and lower in white cultivars of sweet potatoes. **Grace et al. (2014)** found the significantly higher TCC in orange (95.00 mg.kg^{-1} f. w.) sweet potato cultivars compared to the cultivars with yellow (3.40 – 5.16 mg.kg^{-1}) and white (0.55 mg.kg^{-1}) flesh colour. Expressive differences of TCC among sweet potato cultivars, dependent on the colour of tuber flesh, were also found in the study of **Kammona et al. (2015)**. Values of TCC was ranged in following order of tuber flesh colour: orange (389.22 mg.kg^{-1} dry weight) > yellow (138.96 mg.kg^{-1}) > purple (116.28 mg.kg^{-1}) > white (115.18 mg.kg^{-1}). The strong interaction between flesh colour and TCC in sweet potatoes was also presented in studies of **Ellong et al. (2014)**, **Hussein, Billard and Adenet (2014)** and **Leighton. Schönfeldt and Kruger (2010)**.

The most important and dominant carotenoid substance in sweet potatoes is β-carotene **(USDA, 2019)**. According to **Kammona et al. (2015)**, β-carotene ratio from TCC, dependent on the sweet potato flesh colour, was following: purple flesh (97.9%) > orange flesh (93.8%) > yellow flesh (84.1%) > white flesh (79.0%). **Yildirim, Tokuşoğlu and Öztürk (2011)** tested the variability of β-carotene content in ten sweet potato cultivars and it was ranged from 50.1 (yellow) to 70.3 (orange) mg.kg^{-1} f. w. Compared to previous studies, **Suparno, Prabawardani and Pattikawa (2016)** found minimal variability of β-carotene content (62.98 – 64.69 mg.kg^{-1} f. w.) in sweet potatoes. **Wu et al. (2008)** found significantly higher content of β-carotene in orange sweet potato cultivars (55.9 – 231.1 mg.kg^{-1} f. w.) compared to the cultivars with white (23.0 mg.kg^{-1}), yellow (5.2 mg.kg^{-1}) and purple (0.60 mg.kg^{-1}) cultivars. The significant effect of cultivar on the content of β-carotene in sweet potatoes was found in the study of **Vimala et al. (2011)**. Authors tested 42 orange sweet potato cultivars and values of β-carotene was ranged from 10.4 to 143.7 mg.kg^{-1} f. w. Compared to the previous study, **Ukom, Ojimelukwe and Okpara (2009)** found lower β-carotene in orange and white sweet potatoes which was ranged from 5.23 to 11.77 mg.kg^{-1} f. w., dependent on the cultivar. Results presented by **Aywa, Nawiri and Nyambaka (2013)** confirm findings of previous studies. Authors found that sweet potato cultivars are significantly richer source of β-carotene (46.19 – 48.89 mg.kg^{-1} f. w.) compared to cultivars with different flesh colour (20.17 – 26.28 mg.kg^{-1} f. w.).

Vitamin C

The variance analysis of obtained results showed statistically significant (p <0.05) differences of vitamin C content among tested cultivars, except of relation between cultivars 'Višnjica white' and 'Višnjica purple' (Table 3). The average content of vitamin C was increasing in following cultivar order: 'Višnjica white' (179.66 mg.kg^{-1} fresh weight) < 'Višnjica purple' (187.75 mg.kg^{-1}) < 'Beauregard' (246.31 mg.kg^{-1}) < 'Dubaian' (325.99 mg.kg^{-1}).

Rautenbach et al. (2010) tested impact of cultivar on the vitamin C content in sweet potatoes and its values were ranged from 155 to 322 mg.kg^{-1} f. w. These values are comparable to our results. The significant differences of vitamin C content in sweet potatoes (8 different-coloured cultivars) were found in the study of **Ellong et al. (2014)**. The highest vitamin C content was found in yellow cultivars (178 – 291 mg.kg^{-1} f. w.), followed by cultivars with beige (143 mg.kg^{-1}), white (41 – 128 mg.kg^{-1}) and purple (54 mg.kg^{-1}) flesh colour. Compared to our study, vitamin C content was lower in white and purple sweet potato cultivars. The expressive effect of cultivar on the vitamin C content in sweet potatoes was presented by **Yildirim, Tokuşoğlu and Öztürk (2011)** who found its lower values in orange cultivars (252 – 386 mg.kg^{-1} f. w.) in comparison with creamy (252 – 386 mg.kg^{-1}) and yellow (237 – 381 mg.kg^{-1}) flesh colour. In orange cultivars, values of vitamin C content was comparable to our tested cultivars 'Beauregard' and 'Dubaian'. **Aywa, Nawiri and Nyambaka (2013)** found significantly lower values of vitamin C content in comparison with our study. Similarly, authors found higher vitamin C content in orange cultivars compared to white and purple cultivars of sweet potato. The higher content of vitamin C in orange-coloured sweet potatoes in comparison with purple cultivars was also stated by **Grace et al. (2014)**. Compared to our experiment, **Croitoru et al. (2017)** found lower vitamin C content (66 – 117 mg.kg^{-1} f. w.) in tubers of sweet potatoes. The lower values of vitamin C content (129 – 142 mg.kg^{-1} f. w.) was also presented by **Maria and Rodica (2015)**. **Krochmal-Marczak et al. (2013)** determined the vitamin C content in dependency on the flesh colour of sweet potatoes (white, orange, purple). The vitamin C content in orange sweet potato cultivar (242 mg.kg^{-1} f. w.) was lower compared to our tested orange cultivars. On the contrary, authors found higher vitamin C content in white (242 mg.kg^{-1}) and purple (203 mg.kg^{-1}) cultivars of sweet potatoes in comparison with results of our study. The significantly higher vitamin C content in purple (727 mg.kg^{-1} f. w.) and white (672 mg.kg^{-1}) sweet potatoes was found in the study of **Suparno, Prabawardani and Pattikawa (2016)**.

Within study of **Barrera and Picha (2014)**, the average vitamin C content in cultivar 'Beauregard' (214 mg.kg^{-1} f. w.) was lower than in our experiment. **Mitra (2012)** determined the vitamin C content in 15 orange cultivars of sweet potato. Its values were ranged from 129 to 268 mg.kg^{-1} f. w.; only one of tested sweet potato cultivar was higher compared to orange cultivars in our experiment. **Gichuhi et al. (2014)** found nearly 4-fold lower vitamin C content in cultivar 'Beauregard' (64 mg.kg^{-1} f. w.) compared to this cultivar tested in our experiment.

Total soluble solids

According to **Cejpek (2012)**, the method for estimation of total soluble solids (TSS) are used for testing of sugar content in syrup, fruit and vegetable juices or dairy products and total concentration of monosaccharides and disaccharides in any solutions. **Hegedűsová et al. (2018)** define TSS as additive quantity which expresses the content of dissolved substances, mainly sugars, in vegetable extracts. As the unit of TSS, Brix degrees (°BRIX) are used.

The statistical analysis of gained results revealed statistically significant (p <0.05) differences of TSS content among all tested cultivars of sweet potato (Table 3). The highest average content of TSS was found in purple cultivar 'Višnjica purple' (10.13 °BRIX), followed by orange cultivars 'Dubaian' (9.72 °BRIX) and 'Beauregard' (8.52 °BRIX) and white cultivar 'Višnjica white' (5.57 °BRIX). **Nair et al. (2015)** found values of TSS content in sweet potatoes in the range from 7.9 to 8.8 °BRIX. In cultivar 'Beauregard', authors found lower TSS content (7.9 °BRIX) compared to value found in the same cultivar in our experiment.

The significant differences of sugar content in sweet potatoes were presented in several studies. **Krochmal-Marczak et al. (2013)** found significantly higher content of total sugars in white sweet potato cultivar (3.85 g.100g^{-1} f. w.) compared to cultivars with orange (2.90 g.100g^{-1}) and purple (2.16 g.100g^{-1}) flesh colour. In comparison to our study with TSS, it means opposite order of different coloured flesh of sweet potatoes. On the contrary to previous mentioned study, **Sanoussi et al. (2016)** determined the significantly higher sugar content in orange cultivars (22.45 g.100g^{-1} f. w.) compared to white (17.95 g.100g^{-1}) cultivars of sweet potatoes. **Ellong, Billard and Adenet (2014)** found higher sugar content in purple sweet potato cultivar (33.62 g.100g^{-1} f. w.) in comparison with white cultivars (26.79 – 33.12 g.100g^{-1}). The significant impact of cultivar on the sugar content in sweet potatoes was also found by **Yildirim, Tokuşoğlu and Öztürk (2011)**, **Mitra (2012)** and **Alam, Rana and Islam (2016)**. Compared to previous studies, **Salawu et al. (2015)** found minimal differences of sugar content between sweet potato cultivars with purple (65.17 g.100 g^{-1} f. w.) and white (65.10 g.100 g^{-1}) flesh colour.

CONCLUSION

The sweet potato (*Ipomoea batatas* L.) is relatively known vegetable species, but it is grown only on small area in the Middle European region. It belongs among very important and often used vegetable species in the world, mainly in Asia and Africa. The sweet potato cultivars are characterized by different colour of tuber flesh which can be white, beige, yellow, orange and purple. The most used and typical for sweet potatoes are orange cultivars. The aim of this study was to determine and compare selected qualitative parameters of tubers among orange, white and purple sweet potato cultivars. The highest total carotenoid content was found in orange (78.47 – 122.89 mg.kg^{-1} fresh weight) sweet potato cultivars and its values were multiple-fold higher in comparison with purple (4.22 mg.kg^{-1} f. w.) and white (10.71 mg.kg^{-1} f. w.) cultivars. The vitamin C content in orange cultivars (246.31 – 325.99 mg.kg^{-1} f. w.) was also significantly (p <0.05) higher compared to white (179.66 mg.kg^{-1} f. w.) and purple (187.75 mg.kg^{-1} f. w.) cultivars of sweet potatoes. The total soluble solids, expressing mainly sugar content, was higher in purple (10.13 °BRIX) cultivars of sweet potatoes, followed by cultivars with orange (8.52 – 9.72 °BRIX) and white (5.57 °BRIX) tuber flesh. Obtained results indicate that cultivar of sweet potato, characterized by tuber flesh colour, is very important factor from aspect of its composition, taste and contribution for human health.

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