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EVALUATION OF QUANTITATIVE AND QUALITATIVE CHARACTERISTICS OF SELECTED CELERY (*APIUM GRAVEOLENS* VAR. *DULCE*) VARIETIES IN THE CONTEXT OF JUICES PRODUCTION

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ABSTRACT

Celery, *Apium graveolens* var. *Dulce* (Mill.) is a biennial plant, lesser used in Slovakia in comparison with celeriac, but with increasing popularity because of its very health beneficial properties. The aim of the study was to evaluate quantitative (yields) and qualitative (chlorophyll *a* and *b*, soluble solids) parameters in selected patioles of celery in the context of raw juice production in a small-plot field experiment. Six varieties of celery (var. *Dulce*) were planted - ´Helios´, ´Red Soup´, ´Malachit´, ´Verde Pascal´, ´Golden Self- Blanching´ and ´Celebrity´. The harvest was carried out twice a season in terms of August and September. The chlorophyll *a* and chlorophyll *b* were determined spectrophotometrically, Total soluble solids were estimated by the help of refractometer. The lowest values in yields reached ´Malachit´variety, the highest ´Red Soup´ variety. In the evaluation of both harvests the ´Celebrity´ and ´Golden S.´ varieties showed the lowest chlorophyll content. The total soluble solid content reached values ranging from 5.00 to 8.77 °BRIX, in the following order: ´Celebrity´ <´Helios´ <´Golden S.´ < ´Red Soup´ <´Verde Pascal´. The term of harvest had significant influence on chlorophyll *a* and *b*. The effect wasn´t confirmed on yields and soluble solids according to used statistical analyse. There were mainly other kind of characteristics followed in previous scientific studies about celery (var. *Dulce*), such a flavonoids, vitamins, minerals, fibre, the essential oils and phenolic acids, etc. Processing to juices or smoothies allow consuming of other antioxidant – chlorophyll.

Keywords: celery; yields; chlorophyll; total soluble solids

INTRODUCTION

Celery, originating from the Mediterranean area of southern Europe and from the swamps of Egypt and Sweden **Helaly et al. (2013)** is comprised of three cultivated forms: a) celeriac, *Apium graveolens* var. *rapaceum* (Mill.) Gaud. Beaup., which is widespread mainly in Central Europe; b) celery, *Apium graveolens* var. *Dulce* (Mill.) DC., grown primarily in Western Europe and the USA; and the least known c) leaf celery, *Apium graveolens* L. var. *secalinum* Alef., which is mainly used as a spice plant **Rožek (2013)**. *Apium graveolens* L. is particularly popular in Western Europe, Japan and in the USA, where no celeriac is ever grown. It is a biennial plant and it belongs to lesser known vegetables in Slovakia. In the first year, a rosette of upright leaves and long, sharpened stems is created, coloured to white, yellow or green **Uher et al. (2009)**. These long, three to seven centimetres wide, strong flashy and juicy leaf stems (petioles) are utility part of the plant **Pekárková (2004)**. Celery petioles are an excellent part of healthy nutrition. Celery is rich in a variety of nutrients like vitamins, minerals and proteins and it has many pharmacological efficacies, which make it an increasing popular vegetable to consumers **Fu et al. (2013)**. Compared to other types of vegetable, it has low calorie content. It contains substances that act anti-inflammatory. It is suitable for rheumatism and arthritis **Mandžuková (2014)**. Herb contains aromatic essential oil, which together with asparagine activates diuretic effects **Vániková (2006)**. Celery contains vitamins, minerals and aromatics and is considered to be healthy and energy-rich vegetables. 100 g of celery provides about 20 kcal, but 32 mg of vitamin C and 0.2 mg of vitamin A (**Rizzo and Muratore, 2009**). It contains many aromatic compounds, and some flavone glycosides and volatile oils that provide a typical flavour of celery. In the celery there are strong antioxidants, vitamins A, C and E, in high representation also flavones **Hostetler et al. (2012)**. The content of flavonoids and other secondary metabolites is high. Studies have shown that celery has a high content of flavonols (glycosides), especially apigenin-7-O-apiosylglucoside (apiin) **Lin et al. (2007)** and malonylapiin, which can be transformed into apiine **Hostelter et al. (2012)**. **Mandžuková (2014)** states that celery is a good source of calcium, it contains vitamin C, certain vitamins from B group, beta-carotene (provitamin A), calcium, iron, magnesium, phosphorus. According to

Vaughan et al. (2009) celery contains 95 percent of water, therefore there are few proteins, fat and sugar, but many of minerals, some carotenes, vitamin E, and vitamin B complex, the vitamin C content is low 8 mg.100 g^{-1}. Celery is considered to be beneficial for the digestive tract and the cardiovascular system. It has the ability to reduce the level of bad LDL cholesterol in the body due to substances called phthalides. Phthalides trigger the production of bile acids that lower the level of LDL cholesterol in the blood **Rizzo and Muratore (2009)**. In addition, flavonoid luteolin prevents the growth of tumours due to its anti-inflammatory and diuretic effects **Hostelter et al. (2012)**. Freshly pressed fruit and vegetable juices are an excellent source of minerals and vitamins that catalyse chemical reactions that occur in the body. These enzymes also produce energy for the digestion, absorption and conversion of food into the body tissues. An increased intake of fruit and vegetable juices ensures that the human body will absorb more minerals and vitamins. Another useful benefit of fruit and vegetable juices is their ability to promote detoxification of the human body **(Gbasouzor and Okonkwo 2014)**. Juices supplies antimicrobials, antioxidants, diuretics, chlorophyll. Celery juice is strongly alkaline and helps to prevent acidosis, high blood pressure, headaches, heartburn, constipation and flatulency; it has also strong anti-inflammatory properties **(Hostetler, 2012)**. It has also been reported celery juices are reducing systolic and diastolic blood pressure **(Tabassum, 2011, Liu, 2016)**. The aim of the study was to evaluate quantitative (yields) and qualitative (chlorophyll *a* and *b*, soluble solids) parameters in selected patioles of celery in the context of raw juice production.

MATERIAL AND METHODOLOGY

Location and description of the experiment

Small plot field experiment with celery was conducted in areal of the Department of Vegetable production, SUA Nitra, in 2016. The total area of the field trials was 32.5 m^2. Sowing and growing of seedlings were carried out in greenhouses of Botanical Garden of Slovak University of Agriculture, in Nitra.

Climate conditions

The city of Nitra belongs to mild climate area with varying weather characteristics. The meteorological data from the site of trial were provided by the Department of Biometeorology and Hydrology, HLEF, SUA, in Nitra are presented in Table 1.

Characteristics of selected celery varieties

Helios - It is a medium-sized variety of celery (*Apium graveolens* var. *Dulce*). It produces strong, long, meat stems. It is suitable for salads, soups, sauces and meat.

Red Soup - It is an attractive red type of celery (*Apium graveolens* var. *Dulce*) that, as the name suggests, adds a delicious flavor. It is also excellent with shoots or with leaf roots.

Malachit – It is a semi-high non-hybrid variety with dark green leaves. The stems are strong, meaty, long and upright, weak to medium green without anthocyanins. Vegetation time is 80 to 90 days from planting. The recommended growing spacing is 40 x 35 cm or 40 x 40 cm.

´Verde Pascal´ - It is a world-wide grown variety. It produces coarse, long, medium-green coloured petioles with dark leaves. It grows to a height of 60 cm. It requires sandy – aluminous to aluminous soils, lighter to moderate with high humus content and a good supply of calcium. Vegetation time is 80 – 85 days.

´Golden Self- Blanching´ - This is a dwarf variety with tasty, golden-yellow heads and one requiring no earthing-up.

´Celebrity´ - A self-blanching type with short stalks. Quick to mature for the earliest outdoor crops, it has consistently high yields of superb quality stalks with a lovely flavour. Has very little stringiness.

Planting

Healthy, well developed celery seedlings were planted on pre-prepared soil on 16th of May, 2016 into a cultivation spacing 0.50 x 0.60 m. Six rows were planted (one row of each variety), with 12 plants planted in one row.

Treatment of the crop

During vegetation a manual trapping was carried out against weeds and for removal of the soil crust. There was regular irrigation in the morning. During the vegetation, no herbicide was applied; on 24th of July, 2016 fungicide (Kuprikol 40g / 5 l water) against septoriosis was done.

Table 1 Monthly assessments based on climatic normal temperatures and long-term precipitation averages (1961-1990), Nitra, 2016.

Month	t [ºC]	characteristic	Z [mm]	characteristic
V.	15.0	normal	91	very wet
VI.	20.3	very hot	14	extra wet
VII.	21.4	hot	135	extra wet
VIII.	19.5	normal	35	dry
IX.	17.5	hot	37	normal

Table 2 Agrochemical characteristics of the soil before the experiment establishment in mg.kg^{-1}, Nitra, trial place, 2016.

pH	Nan	Nutrient content in mg.kg^{-1} (Mehl.III)				%
	mg.kg^{-1}	P	K	Ca	Mg	of humus
7.17 N	13.0 S	142.5 V	565 VV	14750 VV	740.9 VV	4.14 V
7.14 N	13.0 S	198.8 VV	487.5 VV	14900 VV	767.5 VV	4.17 V

Note: pH: N – neutral, nutrients: VN – very low content, N – low content, S – medium content, D – good content, V – high content, VV – very high content.

Fertilization of the crop

On the basis of agrochemical analysis of the soil the nitrogen was added (Table 2). It was applied in the form of a fertilizer DASA 26/13 in dosage 1.4 kg/ 32.5m² before the planting, after the planting and after the first harvest, it was applied in the form of ammonium (LAD 27) in dosages 0.45 kg/32.5m².

Harvesting and post-harvest treatment

The harvest of the celery was carried out twice a season (en block). The first harvest took place on 4th of August, 2016 and the second one on 6th of September, 2016. The harvest was carried out mechanically (by knife); the whole plants were cut just above the surface of the soil. After harvest each variety was prepared for analysis according to the chosen methodology **Hegedűsová et al. (2015)**.

Determination of quantitative and qualitative parameters

Determination of yields

After harvest the petioles were weighed in the handling room of the Department of Vegetable Production. The weighed samples were recalculated to the yields in $t.ha^{-1}$.

Estimation of chlorophyll a and chlorophyll b content

The chlorophyll *a* and chlorophyll *b* were determined spectrophotometrically (Spektralquant PHARO 200) laterally in the acetone extract on the wavelengths 649 nm and 665 nm in homogenisated fresh plant (150 – 200 g) **Hegedűsová et al. (2015)**. Number of analysed samples for average content of chlorophyll *a* and *b* was 10 in case of each variety.

Total soluble solids estimation

The juice from the homogenized sample 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. (2015)**. Ten samples were analysed for average content soluble solids in case of each variety.

Statistical analysis

A statistical analysis was performed by using of the Statgraphic Centurion XVII (StatPoint Inc. USA). Obtained results were evaluated by analysis of variance (ANOVA) and average values were tested by LSD test performed at the significance level of 95%.

RESULTS

Values of the celery yields ranged from 27.99 $t.ha^{-1}$ (´Malachit´) to 47.33 $t.ha^{-1}$ (´Golden S.´) in first harvest and from 21.01 $t.ha^{-1}$ (´Malachit´) to 51.03 $t.ha^{-1}$ (´Red Soup´) in second harvest as it is figured in Table 3. When comparing data from both harvests in average there was noticed statistically significant difference (p <0.05) between tested varieties. The lowest values in yields reached ´Malachit´ variety (24.50 $t.ha^{-1}$), the highest ´Red Soup´ variety (47.01 $t.ha^{-1}$). Based on the crop yields there was found that for the earlier term of harvest (in August) were more suitable varieties ´Malachit´ and ´Golden Self-Blanching´, as they had a higher yields - ´Malachit´ about 24.93% and the ´Golden S.´ variety about 11.22% compared to the their second harvest. In later harvest term (in September) ´Helios´, ´Red Soup´, ´Verde Pascal´ and ´Celebrity´ reached higher yields than from the first harvest about 6.91%, 18.70%, 5.20% band 9.17% in the following order. By the statistical analysis of all the data, differences between the first and the second harvest weren´t evaluated as significant (Table 3).

The chlorophyll content ranged from 7.21 to 76.55 $mg.kg^{-1}$ (Table 4) in the first harvest, where the lowest content reached the ´Celebrity´ variety and the highest ´Helios´ variety. In the second harvest, the lowest values of chlorophyll *a* were again in the case of the ´Celebrity´ variety (9.52 $mg.100g^{-1}$). The changes in the chlorophyll content were in case of Malachite variety, where it reached the highest value 97.70 $mg.100g^{-1}$. In the evaluation of both harvests, the ´Celebrity´ and ´Golden S.´ varieties showed the lowest chlorophyll values. The differences in the chorophyll content of these varieties were significantly lower compared to the other estimated varieties according to the statistical analysis. In terms of chlorophyll *a* values, there were significant differences between the observed two harvests. For all tested varieties (except of the ´Helios´) the chlorophyll *a* content was increased in the second harvest, the most visibly in case of Malachit variety (increase about 152.13% in the second harvest).

According to Table 4, the content of chlorophyll *b* in observed varieties of celery ranged from 3.46 $mg.100\ g^{-1}$ (´Celebrity´) to 50.06 $mg.100\ g^{-1}$ (´Helios´) in the first harvest and from 3.38 mg.100 $mg.100\ g^{-1}$ (´Celebrity´) to 51.04 $mg.100\ g^{-1}$ (´Malachite´) in the second harvest. The white petioles of the celery are usually grown to obtain the smallest amount of chlorophyll because of delicious taste. From this point of view, based on our results, the ´Celebrity´ and ´Golden S.´ varieties were the most suitable in case of both harvests, as well as in case of both observed pigments (chlo *a* and chlo *b*). Due to the different purpose of the study - aimed to increasing of the chlorophyll content as an antioxidant with using in processing to juices or smoothies, the ´Helios´ variety should be harvested in August, because there was significant reduction (p <0.05) of chlorophyll *b* (about 42.47%) in the second harvest (in September), as well as in case of chlorophyll *a* (decrease about 41.39 %). On the contrary, ´Red Soup´, ´Malachite´ and ´Verde Pascal´ varieties are more interesting during the second harvest, because there was a significantly increase of chlorophyll *b* content during the second harvest about 19.17%, 82.35% and 38.74% respectively at tested p value <0.05. The similar increase was found also in case of chlorophyll *a*.

The total soluble solid content according the Table 5 reached values ranging from 5.00 to 8.77 °BRIX, the average values counted from both harvests moved in the following order: ´Celebrity´ (5.30 °BRIX) <´Helios´ (6.83 °BRIX) <´Golden S.´ (7.18 °BRIX) <´Malachite´ (7.58 °BRIX) <´Red Soup´ (7.82 °BRIX) <´Verde Pascal´ (8.47 °BRIX). The harvest term did not affect the soluble solids content since the differences between the first and the second harvest were not statistically significant (p <0.05) according to the chosen methodology.

Table 3 Influence of variety and term of harvest on the the crop yields of tested celery varieties (t.ha^{-1}).

Variety	1th harvest^{A}	2nd harvest ^{A}	Average
´Helios´	35.00 ±2.59^{b}	37.42 ±1.41^{bc}	36.21 ±2.62^{bc}
´Red Soup´	42.99 ±2.66^{c}	51.03 ±0.93^{d}	47.01 ±1.72^{d}
´Malachit´	27.99 ±0.88^{a}	21.01 ±2.68^{a}	24.50 ±1.42^{a}
´Verde Pascal´	32.33 ±1.42^{ab}	34.01 ±3.10^{b}	33.17 ±0.83^{b}
´ Golden S.´	47.33 ±4.23^{c}	42.02 ±1.08^{c}	44.68 ±3.43^{d}
´Celebrity´	36.66 ±1.50^{b}	40.02 ±2.22^{c}	38.34 ±1.73^{c}

Note: a, b, A, B – Different letters in the upper index represent a statistically proven difference (p <0.05, LSD test, ANOVA), Statgraphic XVII.

Table 4 Average content of chlorophyll a (mg.kg^{-1}) in selected varieties of tested celery varieties.

Variant	1th harvest ^{A}	2nd harvest ^{B}	Average
´Helios´	76.55 ±3.73^{d}	54.14 ±3.57^{b}	67.59 ±12.68^{c}
´Red Soup´	39.39 ±3.66^{c}	67.25 ±6.64^{b}	50.54 ±15.83^{bc}
´Malachit´	38.75 ±3.62^{c}	97.70 ±16.08^{c}	62.33 ±33.37^{bc}
´Verde Pascal´	35.92 ±0.75^{c}	59.00 ±0.65^{b}	45.15 ±12.66^{b}
´ Golden S.´	13.50 ±1.90^{b}	16.01 ±1.47^{a}	14.50 ±2.06^{a}
´Celebrity´	7.21 ±0.99^{a}	9.52 ±0.73^{a}	8.14 ±1.49^{a}

Note: a, b, A, B – Different letters in the upper index represent a statistically proven difference (p <0.05, LSD test, ANOVA), Statgraphic XVII
n = average content = 10 measurements.

Table 5 Average content of chlorophyll b (mg.kg^{-1}) in selected varieties of tested celery varieties.

Variant	1th harvest ^{A}	2nd harvest ^{B}	Average
´Helios´	50.06 ±2.20^{b}	28.80 ±3.05^{b}	41.56 ±11.84^{d}
´Red Soup´	27.23 ±2.23^{b}	32.45 ±3.10^{b}	29.32 ±3.61b^{c}
´Malachit´	27.99 ±2.43^{c}	51.04 ±7.32^{c}	37.21 ±13.26^{cd}
´Verde Pascal´	22.43 ±0.27^{b}	31.12 ±0.63^{b}	25.90 ±4.78^{b}
´ Golden S.´	7.80 ±0.62^{a}	9.06 ±0.69^{a}	8.31 ±0.89^{a}
´Celebrity´	3.46 ±0.58^{a}	3.38 ±0.34^{a}	3.43 ±0.45^{a}

Note: a, b, A, B – Different letters in the upper index represent a statistically proven difference (p <0.05, LSD test, ANOVA), Statgraphic XVII
n = average content = 10 measurements.

Table 6 Average content of total soluble solids (°BRIX) in selected varieties of tested celery varieties.

Variant	1th harvest ^{A}	2nd harvest ^{A}	Average
´Helios´	6.47 ±0.74^{b}	7.20 ±0.10^{b}	6.83 ±0.62^{b}
´Red Soup´	7.97 ±0.31^{c}	7.67 ±0.06^{bc}	7.82 ±0.26^{d}
´Malachit´	7.07 ±0.25^{b}	8.10 ±0.30^{c}	7.58 ±0.62^{cd}
´Verde Pascal´	8.17 ±0.15^{c}	8.77 ±0.57^{d}	8.47 ±0.50^{e}
´ Golden S.´	7.07 ±0.60^{b}	7.30 ±0.20^{b}	7.18 ±0.42^{bc}
´Celebrity´	5.00 ±0.10^{a}	5.60 ±0.17^{a}	5.30 ±0.35^{a}

Note: a, b, A, B – Different letters in the upper index represent a statistically proven difference (p <0.05, LSD test, ANOVA), Statgraphic XVII
n = average content = 10 measurements.

DISCUSSION

Celery (*Apium graveolens* var. *Dulce*) is harvested as a whole plant followed by the root removing. The petioles are used for consumption. According to **Petříková (2012)** the weight of one plant is 500 - 800 g, yield from 1 ha is 35 – 50 t.ha^{-1}, which corresponds to our results. Differences in yields in the two harvests were not significant (p <0.05), which is in accordance to the research of quantitative characteristics in case of **Guerra et al. (2010)**, where no differences in the morphological characteristics measured (total weight, total length, total leaf number and petiole length) were found between the two maturity stages (HD1 – 93 days after transplantation and HD2 – 124 days after transplantation). Varietal differences in crop yields have been confirmed, it is necessary to monitor also the qualitative characteristics of celery in terms of using for juices and smoothies. There were mainly other kind of characteristics followed in

previous scientific studies about celery (var. *Dulce*), such flavonoids **(Li et al. 2014)**, vitamins **(Valšíková et al. 2016, Mezeyová et al. 2017)**, minerals (**Sheng et al. 2009, Moghadam et al., 2016**), fibre **Abd El-Mageed (2011)**, essential oils and phenolic acids **Helaly et al. (2013)**, etc.

Processing to juices or smoothies allow consuming of other antioxidant – chlorophyll. That is the reason of five lesser known varieties testing. Self-blanching petioles of

Figure 1 Plants in the stage of transplantation, Botanical Garden, Nitra, 2016, photo: Gubovičová.

Figure 2 The arrangement of vegetation, Nitra, 2016, photo: Gubovičová.

celery were not in the attention of scientists in the frame of chlorophyll monitoring, the data are not available. The content of chlorophyll was on the other hand tested in leafy celery (var. *Secalinum*). In research of **Helaly et al. (2015)** they tested 3 leaf celeries. Their values moved from 1.20 to 2.15 $mg.g^{-1}$ FW in the first harvest year and from 1.24 to 2.20 $mg.g^{-1}$ FW in the second harvest year. In comparison with our results their values are higher, but in juices the petioles are occurred in higher amount than in case of the herb using for cooking. Variability influence plays the role in increasing of the celery (var. *Dulce*) quality, but importatnt is also using of suitable processing ways (storage, cutting, squeezing conditions, etc.) to conserve the chlorophyll as well as other antioxidants and nutritionally valuable compounds. Such as according to **Manzocco et al. (2009)** by the help of light treatment, which has been reported as a novel preservative approach that is cheap, nontoxic, free of residuals and environment-friendly in comparison with traditional methods. In study of **Zhan et al. (2013)** exposing fresh-cut celery to light preserved 47% and 48% more chlorophyll *a* and chlorophyll *b* content than in darkness during storage, respectively, light exposure significantly maintained sugar content of fresh-cut celery during storage. Exposing petioles to light resulted in 17%, 25% and 67% more sucrose, reducing sugar and glucose contents than in darkness at the end of storage. Our values of total soluble solids content were compared with the values of celeriac, as the studies of celery are not very extensive. According to **Kreck et al. (2006)** celery juices were made of different *Apium graveolens* L. cultivars cultivated at different irrigation levels. The soluble solid was highly dependent on the cultivar. In genuine juices from cultivar "Monarch" a lower concentration of soluble solids (7.83 °BRIX) was detectable, whereas in juices from "Bergers weiße Kugel" higher Brix values (10.25 °BRIX) were obtained. This is reflected by the sugar content, i.e. glucose; fructose and saccharose concentrations were dependent on the variety. Variation in soluble sugars (sucrose, glucose, and fructose) was observed in the celery accessions according to **Helaly et al. (2015).** Fructose was the most abundant sugar detected in the accessions during the first harvest and glucose was the most abundant in the second year. In study of **Nadwodnik et al. (2008) c**elery and common plantain were selected because much of what is known about the transport of mannitol and sorbitol has come from studies of these plant species, and more recently, the relevant transporters for sucrose as well as for sugar alcohols were cloned from these species.

CONCLUSION

Celery (*Apium graveolens* var. *Dulce*) is used in salads, smoothies or in juices because of its high content of health positive compounds such vitamins (A, D, E, K, C, group of B vitamins), minerals, mainly calcium, iron, potassium, sodium or phosphorus as well as carbohydrates in small amount. In common the consumer is looking for white kind of celery, because of its mild and pleasant taste, but with more intensive popularity of juices and smoothies, varieties with higher content of chlorophyll started to be also interesting. Varieties ´Helios´, ´Red Soup´, ´Malachit´ and ´Verde Pascal´ can be consumed in combination with other ingredients of fruity – vegetable juices with benefit of higher antioxidant impact of chlorophyll *a* and *b*. The stalks of ´Golden S.´ and ´Celebrity´ varieties with lower chlorophyll content are more suitable for classical raw or lightly cook using.

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