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EVOLUTION OF SOME PHYSICO-CHEMICAL CHARACTERISTICS OF THE EGGPLANT (*Solanum melongena* L.) FRUITS DURING THEIR GROWTH AND RIPENING

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ABSTRACT. *Fruits of the italian cultivar Violetta Lunga were studied during their growth and ripening regarding some physico-chemical characterstics evolution. Several measurements and analyses have been performed: fruits dimensions, weight, volume, the specific weight of the fruit, dry matter, soluble solids, titratable acidity, total phenolic and total flavonoid content, and antioxidant activity. The total flavonoid content increases in the growth stages of the fruit to a maximum recorded four weeks after fruit formation (41.91 mg / 100 g fw). At the beginning of fruit ripening, the content in flavonoids decreased, having the lowest values at the consumption maturity (9.18 mg /100 g fw). The antioxidant activity at growth stages of the fruit (2.55 mm Trolox/100 g fw) and the lowest values at the consumption maturity (1.38 mm Trolox/100 g fw)*

KEY WORDS: *eggplant, flavonoids, total phenols, antioxidant activity.*

INTRODUCTION

Eggplant (*Solanum melongena L.*) is grown for its fruits, which, although having a lower food value than other vegetables, is highly appreciated in the culinary field due to its pleasant taste and the multitude of dishes what can be made from this vegetable. This and the interesting variety of cultivars and crops, make eggplant a species that deserve to be studied for improving the culture systems (Barbuta et al., 2014). The fruits are eaten, prepared in different ways (salads, fried, moussaka, etc.), as well as for preparing different canned assorted vegetables (hotchpotch, pickles), well appreciated by the Romanian consumers. Is considered that eggplant is originally fron India where grew as wild plant and has been cultivated for the first time in China. Eggplant became very popular in Europe during the Middle Ages when it was first brought by the moors from South Africa. Nowday, the largest growers of eggplant are Egypt, Italy, China, Turkey and Japan. The bitter taste of unripe eggplant unjustly brought a negative reputation for this vegetable in the Middle Ages. For hundreds of years people did not eat eggplants because they were convinced they were bringing madness, leprosy and cancer. Due to the high content of alkaloids, substances that may have allergenic potential or even lead to intoxications, eggplant consumption is contraindicated for people suffering from gout, arthritis, osteoporosis and other inflammatory diseases. Cultivars of eggplants are overall consumed in the diets and have been reported to possess antioxidant potentials (Fategbe et al., 2013). Eggplant is among the top ten vegetables for its antioxidant activity due to its phenolic constituents, which have important health benefits (Akanitapichat et al., 2010). Nasunin, from the skin of purple eggplant fruit, is one phenolic compound implicated in superoxide scavenging activity (Kaneyuki et al., 1999; Noda et al., 2000). Eggplants are highly inflammatory, worsening the symptoms of arthritis, rheumatism and other inflammatory diseases, due to the presence of solanine. The aim of this study was to analyze the evolution of the main physico-chemical characteristics of eggplants fruits during their growth and ripening.

MATERIALS AND METHODS

Plant material

Fruits of the italian cultivar *Violetta Lunga* were studied during their growth and ripening. The fruits were grown in a private farm from the comune of Stoina, Gorj County, Romania. Stoina commune is located in the southeastern part of Gorj County, at 70 km from the city Târgu Jiu. The natural conditions of the climate and the soil allowed the development of varied vegetation in this area with some valuable plant species. The climate is temperate continental with Mediterranean influnces. Gorj County covers the terrain with altitudes between 90 and 2519 m, with an average multiannual temperature of + 10.8 ° C. Regarding the pluviometric regime, the average multiannual rainfall ranges from 585 mm and 750 mm and in the depression areas the winds from the south and southwest prevail. Eggplants have been grown in the field, in organic crop. The planting was carried out in erodated stagnosol, with the experiment being set up as randomized block design in 3 replicates with 30 plants. 10 fruits in 3 replicates were collected in order to perform chemical analysis. Fruit sampling began from fruit formation (30.07) and continued every 7 days until consumption maturity.

Analytical methods

Several measurements and analyses have been performed: fruits dimensions (length, width, thickness), weight, volume, the specific weight of the fruit, dry matter, soluble solids, titratable acidity, total phenolic and total flavonoid content, and antioxidant activity. Were also calculated the size index and the shape index. Fruit linear dimensions (length, L; width, W; thickness, T) were determined with a Luthier digital caliper manufactured by StewartMacDonald (USA) and the results were expressed as mm. Average fruit weight (g) was determined by individual weighing on an analytical scale model ABT-320-4M manufactured by Kern (Balingen, Germany). The fruit volume was determined using a volume cylinder on the principle of Archimedes, the results being expressed in cm^3. Size index was calculated using the formula: (L+T+W)/3 and shape index using the formula (L/W). The specific weight of the fruit was calculated using the formula (SW= w/V) and the results were expressed as g/cm^3. The total dry matter was determined by removing water from the sample in an oven at 105°C and expressed in percent. Soluble solids content of fruit juice was measured with a digital refractometer (Hanna Instruments, Woonsocket, USA). The titratable acidity was determined by titration of a known amount of water extract of fruits with 0.1N NaOH using phenolphthalein as indicator and is expressed as g malic acid /100 g fresh matter. Total phenol content was assessed by using the Folin-Ciocalteu phenol reagent method (Singleton and Rossi, 1965). Folin-Ciocalteu reagent (2N, Merck), Gallic acid (99% purity, Sigma), anhydrous sodium carbonate (99% purity, Sigma) were used. Eggplant homogenate (2g) was extracted with 5 mL methanol in an ultrasonic bath for 45 min at ambient temperature. After extraction, the samples were centrifuged for 5 min at 4200 rpm. Supernatants were filtered through polyamide membranes with pore diameter of 0.45 μm and stored at a temperature of -20°C. 100 μL of each eggplant methanolic extract were mixed with 5 mL of distilled water and 500 μL of Folin-Ciocalteau reagent. After 30 sec to 8 min, 1.5 mL of sodium carbonate (20% w/v) was added. The reaction mixture was diluted with distilled water to a final volume of 10 mL. The preparation of the standard solution of gallic acid followed the same procedure. The absorbance at 765 nm of each mixture was measured on a Varian Cary 50 UV spectrophotometer (Varian Co., USA) after incubation for 30 min at 40°C. The readings are expressed as mg of gallic acid equivalents (GAE) kg-1fw. The total flavonoid content was assessed by using the colorimetric method (Zhishen, Mengcheng, and Jianming, 1999). An aliquot of 1 ml standard catechin (99% purity, Sigma) solution at different concentrations (0-100 mg / l, external calibration with n = 6 concentrations) or sample (methanolic extracts of eggplants obtained according to the same protocol as described for total phenolic content) was placed in 10 ml tubes containing 4 ml distilled water. 0.3 ml of 5% $NaNO_2$ was added and after 5 minutes, 0.3 ml of 10% $AlCl_3$ was added. At 6 minutes 2 ml of 1 M NaOH was added. The reaction mixture was immediately diluted with distilled water to a final volume of 10 mL and stirred vigorously. Absorbance was measured at 510 nm on Varian Cary 50 UV-Vis spectrophotometer. The readings are expressed as mg/100 g fw. Antioxidant activity was measured in methanol eggplant extracts using the DPPH (2,2-diphenyl-1-picrylhydrazyl) assay. Methanol (Merck, Germany), 2,2-diphenyl-1-picrylhydrazyl (DPPH) (Sigma-Aldrich, Germany), and 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox) (Merck, Germany) were employed. The extraction of samples was made according to the same protocol as described for total phenolic content. The free radical scavenging ability of the extracts against DPPH free radical was evaluated as described by Oliveira et al. (2008), with some modifications. Each methanol eggplant extract (50µL) was mixed with 3 mL of a 0.004% (v/v) DPPH methanolic solution. The mixture was incubated for 30 min at room temperature in the dark and the absorbance was measured at 517 nm on Varian Cary 50 UV-Vis spectrophotometer. The DPPH free radical scavenging ability was subsequently calculated with respect to the Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), which was used as a standard reference to convert the inhibition capability of each extract solution to the mmol Trolox equivalent antioxidant activity L^{-1}. The radical was freshly prepared and protected from the light. A blank control of methanol/water mixture was used in each assay. All assays were conducted in triplicate. The data is expressed in mmol Trolox kg^{-1} fw.

RESULTS AND DISCUSSIONS

The results regarding the variation of the physical properties of the eggplants during their growth and ripening are shown in Table 1. The data obtained reveals that the eggplant's dimensions increase during the growth and ripening, the highest growth rate being recorded in the week III-IV after the fruit formation. After this period increases in terms of size have a lower rate. The decrease of the growth rate of the dimensions in the second part of the period of growth and development is correlated with the increase of the individual weight of the fruits. This indicates that the ripening process has begun, which is manifested by the synthesis and accumulation of high molecular weight chemicals. Regarding the shape of the fruits (the shape

Table 1. Variation of some physical properties of the eggplants during their growth and ripening *Violetta Lunga* cultivar.

Sampling	Width (W) mm	Thickness (T) mm	Length (L) mm	Weight (w) g	Volume (V) cm^3	Size index W+T+L/3	Shape index L/W	Specific weight g/cm^3
30.07	13.16÷1.84	12.93÷0.41	37.56÷6.00	4.2÷0.63	4.33÷0.64	21.21÷2.65	2.85÷0.35	0.96÷0.11
06.08	18.66÷2.79	18.03÷2.16	67.23÷11.42	11.9÷2.03	13.66÷1.80	34.64÷5.95	3.60÷0.52	0.87÷0.10
13.08	26.13÷4.79	25.63÷3.84	105.73÷20.08	23.63÷3.30	36.66÷6.59	52.49÷9.61	4.04÷0.61	0.64÷0.12
20.08	27.1÷4.60	26.66÷3.46	127÷19.32	42.96÷7.30	42.00÷6.72	60.23÷11.44	4.68÷0.63	1.02÷0.17
26.08	28.56÷3.64	27.96÷3.07	211.83÷36.01	73.60÷13.24	99.00÷17.52	87.39÷15.98	5.41÷0.81	0.74÷0.11
31.08	36.70÷4.77	35.23÷5.98	189.09÷24.58	113.13÷20.49	153.00÷23.48	89.45÷16.97	5.05÷0.74	0.71÷0.09
07.09	37.4÷5.23	35.7÷4.99	204.50÷22.54	115.03÷19.55	158.33÷28.81	92.14÷15.47	5.57÷0.76	0.75÷0.09

Table 2. Evolution of dry matter, soluble solids content and titratable acidity during grwth and ripening of the eggplant.

Sampling	Water content %	Dry matter %	Soluble solids %	Titratable acidity G malic acid/100 g fw
30.07	91.47÷10.06	8.53÷1.66	6.05÷1.08	0.134÷0.02
06.08	91.43 ÷ 9.89	8.57÷1.50	7.61÷1.34	0.167÷0.03
13.08	91.12 ÷ 9.11	8.88÷1.31	7.92÷1.23	0.134÷0.01
20.08	90.58÷ 8.82	9.42÷1.32	6.30÷1.11	0.134÷0.02
26.08	90.00÷ 10.80	10.00÷12.67	9.01÷1.58	0.100÷0.01
31.08	88.46÷10.61	11.54÷1.85	8.61÷1.56	0.067÷0.01
07.09	87.27÷11.34	12.73÷2.02	8.72÷1.61	0.067÷0.01

Table 3. Evolution of the total polyphenols, total flavonoids content and antioxidant activity of the eggplant during their growth and ripening.

Sampling	Total phenol content mg/100 g fw	Total flavonoid content mg/100 g fw	Antioxidant activity mm Trolox/100 g fw
30.07	34.06÷5.38	15.92÷2.61	2.55÷0.43
06.08	46.59÷7.96	31.25÷4.96	2.03÷0.34
13.08	62.93÷10.38	32.34÷5.59	2.21÷0.35
20.08	86.15÷15.59	41.91÷6.99	1.13÷0.18
26.08	212.81÷40.85	19.66÷3.12	1.05÷0.14
31.08	241.81÷41.83	20.95÷3.31	0.85÷0.13
07.09	305.62÷58.67	9.18÷1.24	1.38÷0.22

index), from the data presented, it is observed that the fruits have the characteristic shape of the cultivar since their formation but the ratio between the length and the thickness of the fruit is lower compared to the maturated fruit. At this stage the eggplants have a double shape index compared to the beginning of growth. The final shape of the fruits was finalized at the beginning of the ripening process, respectively the end of the fruit growing process. At the same time, it is found that the dimensions of the fruits as well as their individual weight at maturity of consumption fall under the characteristic values of the cultivar, due to the culture mode (organic crop) in which no chemical fertilization and diseases and pests control were applied. Also these values may be due to different climatic conditions compared to the center of origin of the *Violetta Lunga* cultivar (Italy). The results regarding the evolution of the total dry matter, soluble solids content and titratable acidity of the fruits during their growth and ripening are shown in Table 2. It is observed that during the growth and ripening of the fruits there was a continuous accumulation of chemical components in them, even though eggplant recorded lower content of dry matter than other species. The eggplants belonging to the cultivar *Violetta Lunga* grown in organic crop showed a higher dry matter content (12.73%) compared to the data presented by María D. Raigón et al. (2008) who reported dry matter content wich rangeds between 4.69 and 7.29%. Similar data were reported by Srikanth Sabolu et al. (2014) with a dry matter content of 11.6%. Regarding the soluble solids content of the eggplant, the obtained data showed an upward trend during growth of fruits followed by a relative stagnation of it during the ripening (8.72%). The obtained data are higher than those shown by Jaime Prohens et al. (2007) which presented a content of soluble solids of 6.49%. The titratable acidity showed the highest values (1.67 g malic acid / 100 g fw) at the beginning of fruits growing, decreasing continuously up to the consumption maturity, the data being related with those obtained by N. Katsoulas et al. (2009). The data regarding the evolution of eggplant content in total phenols and total flavonoids as well as their antioxidant activity are presented in Table 3. The data shows that in the first stages of growth and ripening of the eggplant fruits the total phenols content has small values compared to those obtained at the maturity of consumption. The phenols accumulation has a low rate during the fruit growth which increases suddenly during their ripening, at the consumption maturity the content being about 10 times greater than at the beginning of fruit growth. However, at consumption maturity, the obtained data regarding the total phenol content of eggplant were lower than those obtained by Hanson et al. (2006) (1.33 ÷ 0.75 g / 100 g fw) but according with those obtained by K.M. Somawathi et al. (2014) și Kaur et al. (2014). Flavonoids are phenolic compounds known for their antioxidant properties. The total flavonoid content increases in the growth stages of the fruit to a maximum recorded four weeks after fruit formation (41.91 mg / 100 g fw). At the beginning of fruit ripening, the content in flavonoids decreased, having the lowest values at the consumption maturity (9.18 mg /100 g fw). The obtained data at the consumption maturity are according to those obtained by Kaur et al. (2014) (8.65 mg / 100 g fw). The antioxidant activity of eggplant is influenced by its content of flavonoids and phenols. The data showed that the eggplant had the highest antioxidant activity at growth stages of the fruit (2.55 mm Trolox/100 g fw) and the lowest values at the consumption maturity (1.38 mm Trolox/100 g fw) wich are according to those obtained by Kaur et al. (2014) (1.25 mm Trolox / 100 g fw) and Somawathi et al. (2014).

CONCLUSIONS

The eggplant contains important phytonutrients such as phenolic compounds that have high antioxidant capabilities. However the eggplant has a relatively low content in chemical compounds compared to other species. The evolution of physical and chemical characteristics of the Eggplant (Solanum melongena L.) fruits showed different evolution trends during their growth and ripening. The accumulation of important chemical compounds such as flavonoids had a maximum at four weeks after fruit formation while others showed the maximum accumulation at the consumption maturity of the fruits.

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