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Quality of Eggplant Fruits in Relation to Growing Medium Used in Greenhouse Cultivation and to a Cultivar

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Abstract

The objective of this study was to examine sensory quality and physical traits of eggplant (*Solanum melongena* L.) fruits in relation to growing medium used in greenhouse cultivation. Eggplants were grown in a greenhouse with controlled climate and drip fertilizing system, in the three different mediums: coconut fiber, wood fiber (environment friendly mediums) and rockwool (standard horticultural medium). Cultivars used in the experiment were: 'Scorpio', 'Oscar', 'Tango' and DRA 2086. Fruits were harvested in June, at optimal maturity. Sensory quality of roasted fruits was analyzed in the panel of 12 experts using the quantitative descriptive analysis (QDA). The set of 19 descriptors of quality plus overall quality were evaluated. Fruit colour was measured with HunterLab colorimeter, using CIE L*a*b* system. Fruit firmness was measured with HPE II durometer, and puncture load with a penetrometer. Results showed that growing mediums influenced some sensory traits, but genotype showed stronger influence on the quality of fruits. Physical traits of fruits were low related to growing mediums, but more to genotype. All the three growing mediums showed their suitability for eggplant cultivation in respect of quality of the fruits.

Keywords: aubergine, cultivars, sensory quality, growing mediums, greenhouse cultivation

Introduction

Eggplant (aubergine) is a tender vegeTab. crop, and in temperate climate conditions, like those in Mid-Eastern Europe region, it can be grown successfully only under protection (i.e. in greenhouses or PE foil-made tunnels). Sensory quality is of primary importance in marketing of vegetables, since sensory traits are usually the main factor determining consumer's satisfaction (Abbott, 1999). The quantitative descriptive analysis (QDA) is usually applied for detailed description of sensory characteristics of food. In the method an assumption is done that sensory quality is a complex of many descriptors (attributes), which can be individually estimated by a consumer (Meilgaard *et al.*, 1999; Shewfelt, 1999; Murray *et al.*, 2001). An alternative statistical method is multivariate data analysis in which all attributes are analyzed simultaneously providing a holistic interpretation of correlation and redundancy between the attributes (Chabanet, 2000). Internationally approved standards for methods of sensory evaluation are applied (Anonymous, 1996, 1998, 1999). There are reports considering that pre-harvest factors can seriously influence sensory quality of vegeTab. crops (Mattheis and Fellman, 1999). There are few reports concerning sensory characteristics of eggplant fruits. Gajewski and Arasimowicz (2004) found that eggplant cultivars grown in a PE foil tunnel differed in some sensory traits when they were evaluated immediately after harvest and maturity stage of fruits also affected their quality. Fruits obtained from plants grown in a greenhouse with controlled climate differed in sensory traits from fruits of plants grown in a foil tunnel (Gajewski *et al.*, 2007, 2009). Also postharvest storage can influence sensory characteristics of eggplant fruits, as it was reported by Gajewski *et al.* (2006). Overall sensory quality of the fruits was found being significantly lower after 3-week storage than that of freshly harvested ones.

Soilless plant cultures were popular in vegeTab. crops production during the last decades because of their important advantages (Jensen, 1999). Up to now, in greenhouse cultivation of vegetables rockwool slabs are the most commonly used growing medium. This medium shows inert characteristics, which are valuable traits in plant cultivation. Troubles with rockwool utilization after completing the growing cycle stimulate researches to introduce other, more environment friendly mediums to horticultural practice. Since peat use in horticulture is negatively rated for ecological reasons, other natural organic materials are investigated to introduce into practice. Plant fiber is a material with good physical and chemical characteristics in relation with the growing possibilities. From plant fibers, wood fiber and coconut fiber are especially used as horticultural mediums (Gruda and Schnitzler, 2004). Coconut fiber has a larger oxygen capacity than rockwool, it has good water holding ability, which makes it particularly suiTab. for hydroponic systems with intermittent watering cycles.

The aim of this work was to compare quality characteristics of eggplant fruits of four cultivars, in relation to growing medium used in greenhouse cultivation. Two ecological mediums – coconut fiber and wood fiber were used, in comparison to standard rockwool medium. We were also looking for a regression model for a relationship between overall sensory quality and the set of sensory attributes.

Materials and methods

Material

The experiment was carried out at Warsaw University of Life Sciences in 2008. Eggplant cultivars chosen for the experiment were: 'Scorpio', 'Oscar', 'Tango' and DRA 2086. These cultivars are in offer of Dutch seed suppliers (De Ruiter Seeds). Fruits of 'Scorpio', 'Oscar' and DRA 2086 are typical for violet-black skin fruit type, and fruits of 'Tango' are of plain creamy-white skin. Three different growing mediums were applied: horticultural slabs made of coconut fiber (Ceres Intern.), slabs made of wood fiber (Steico S.A.) and slabs made of rockwool (Grodan BV). Slabs dimensions were 100x15x7.5 cm (length x width x height). The experiment was established in random design, in three replicates, with 8 plants in each. Eggplants were planted to the growing mediums in the middle of April. Modern greenhouse with controlled climate and drip irrigation system for watering and fertilizing ('fertigation') was used in the experiment. Plants were fertilized during vegetation period with similar rates of macro- and micro-nutrients. Nutrients concentration in the solution, EC (electro-conductivity) and pH were continuously controlled and kept at uniform levels for all objects. The concentration of nutrients in water (in mg dm–3) was as follows: N-NO3 – 140, P – 70, K – 360, Mg – 60, Ca – 200, Fe – 2, Mn – 0.6, B – 0.3, Cu – 0.15, Zn – 0.3, Mo – 0.05. During fruits development (from the beginning of June) the temperature in the greenhouse ranged from 20-25°C during the day to about 18-20°C during the night. The plants were trained, with two stems left, and tied to vertical strings. Fruits for quality evaluation were harvested in June, at maturity stage optimal for consumption. The maturity of fruits was determined on the basis of fruits dimensions and their skin colour, which should be typical for the cultivar.

Sensory evaluation

Sensory evaluation of the fruits was performed in the panel consisting of 12 experts, previously selected and trained, according to an ISO standard (Anonymous 1996). The assessment was carried out in a laboratory, equipped according to the ISO standard (Anonymous 1998). For the fruits evaluation the quantitative descriptive analysis (QDA) was used. At the first part of QDA procedure 'brainstorming' sessions were run to select attributes for the fruits. Panelists received samples of fruits varying in sensory properties and individually generated a set of 19 descriptors for odour, colour, texture and flavour. Also an overall sensory fruit quality, which is a complex rating of all sensory traits, was evaluated (vvvvv 1). Every assessor was given a random fruit samples. The analysis was performed in separate booths, equipped with computers for data acquisition. For the assessments whole fruits were roasted in foil bags for 60 minutes at the temperature of 180oC, and then cooled down to ambient temperature. Samples of the fruits (slices, with 1 cm thickness) were put to coded plastic boxes, covered with lids, and served to the assessors. The assessments were marked on non-structural lines, which showed also anchoring points for each descriptor (low intensity – high intensity of impression). Results were converted to numerical values (from 0 to 10 units). The analysis was performed during two independent sessions, in two replications.

Instrumental analysis

Physical traits related to the fruits texture were determined with instrumental methods.

Fruit flesh firmness was measured with Fruit Firmness Tester HPE II (Bareiss, Germany), equipped with a 5 mm diameter, round-ended probe, according to the method used by Huyskens-Keil *et al*. (2006). Firmness was measured in the range of 0–100, where the value 100 was the measured data from a standardized metal disc. The measurement for each fruit was carried out on four equidistant records. The average value was computed on 10 fruits per combination and was expressed in HPE values.

The force needed to puncture the fruit flesh without skin ('puncture load') was determined by hand penetrometer (David Bishop Instruments), using a 10 mm diameter probe. The measurement for each fruit was carried out on four equidistant points. The average force value was computed on 4 fruits per combination and expressed in newtons (N).

Skin colour of the fruits was measured with HunterLab XE colorimeter, and the parameters were expressed in CIE L*a*b* system, where L* is lightness (ranged from 0 to 100 units), a* is light intensity in red (+) or green (–) spectrum, b* is intensity in yellow (+) or blue (–) spectrum.

Data elaboration

For coding samples in sensory evaluation and for sensory data's initial processing, 'Analsens' software was used. For the variance analysis 'Statgraphics Plus 4.1' software was applied, and Tukey's HSD test was used to show which values differ significantly at P = 0.05. Principal component analysis (PCA) and regression analysis were also applied.

Results and discussion

Genetic variation and environmental conditions, including nutrients availability in the soil are usually the main factors influencing the quality of vegeTab. crops (Shewfeld, 1999, Maniutiu *et al*., 2008). There are evidences that environmental conditions do influence sensory quality of eggplant fruits (Gajewski *et al*., 2009). Taken into account the environmental conditions, soil (or growing medium, in the case of soilless methods) is one of the most important factors in vegeTab. production. In soilless greenhouse cultivation of vegetables there is a need to find more environment-friendly growing mediums for plant production. In this research we tried to determine how the two ecological growing mediums, manufactured of coconut fiber or wood fiber, influence product quality traits. Since quality of vegetables is largely related to sensory traits of the product, we focused on traits related to sensory characteristics of the fruits. There is shortage of information in literature on the influence of growing mediums on quality traits of eggplant fruits, so discussion of the results is restricted. Sensory quality of eggplant fruits was determined after cooking (roasting), since the eggplant fruits are usually consumed in that form. Results obtained pointed out that eggplant fruits showed quite a big differentiation in most sensory quality attributes, and these differences were mostly related to the cultivar. Influence of growing medium type on sensory characteristics of the fruits was not so obvious, and was mostly differentiated between cultivars. Sensory characteristics of eggplant fruits in relation to growing mediums is presented here separately for the four cultivars in the graphical form of sensory profiles (*Fig.*s 1-4).

This method of sensory data presentation is commonly used in literature (Chabanet, 2000; Jacobsson *et al*., 2004). It can be seen on the profiles that fruits of 'Scorpio' showed very little reaction on growing mediums in respect of attributes of odour and flavour (Fig. 1). The same can be said in the case of 'Oscar' (Fig. 2) and DRW 2086 fruits (Fig. 4). Odour attributes of the fruits, as well as flavour attributes, were mostly insignificantly related to growing mediums applied. Generally, all eggplant cultivars showed more evident reaction on different growing mediums in respect of texture attributes of fruits, than in respect of odour or flavour attributes. Fruits obtained from the plants grown in rockwool showed the highest flesh firmness. This tendency was especially evident in the case of DRW 2086 cv. fruits. The fruits obtained from plants grown in the coconut fiber were usually least fibrous (except 'Scorpio'). Differences between fruits in respect of overall sensory quality showed no clear influence of growing mediums, but differences between cultivars were evident (Fig. 5). Fruits of 'Scorpio' and 'Oscar' were rated as the best and those of 'Tango' as the worst ones. Differentiation among cultivars in respect of overall quality of fruits was related to rates given by experts for individual sensory attributes. For example, fruits of 'Tango' cv. showed the highest level of odour intensity, the highest flesh firmness and fibrousness, as well as the lowest level of skin hardness. Visual impression of flesh colour differed very much among the cultivars. The darkest (dark brown) flesh was typical for DRA 2086 cv. fruits. The least firm flesh had the fruits of 'Tango'. This cultivar had also most fibrous fruits. Skin hardness is an important quality trait when the fruit is eaten as a whole, with the skin. Relatively very hard skin had the fruits of 'Tango', es-

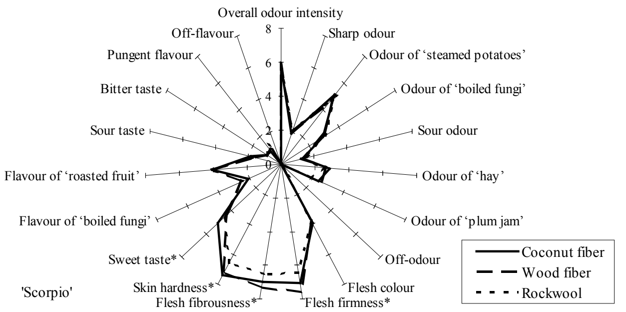

Fig. 1. Sensory quality profile for 'Scorpio' . Note to Fig 1-4: differences significant at P=0.05 are marked with asterisk.

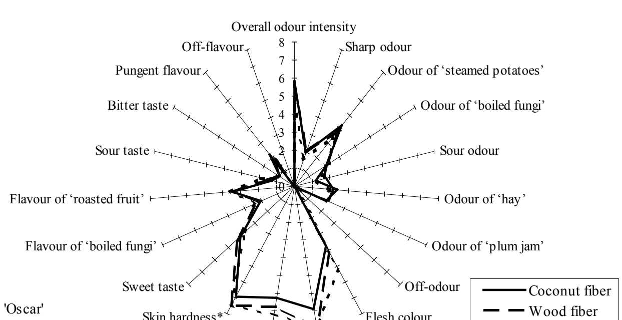

Fig. 2. Sensory quality profile for 'Oscar'

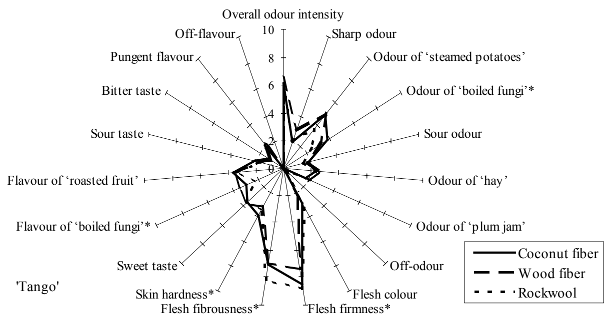

Fig. 3. Sensory quality profile for 'Tango'

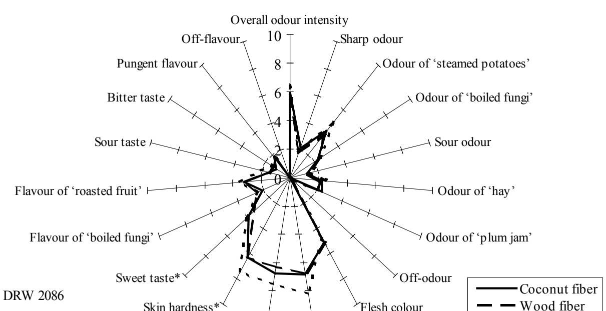

Fig.. 4. Sensory quality profile for DRW 2086 cv.

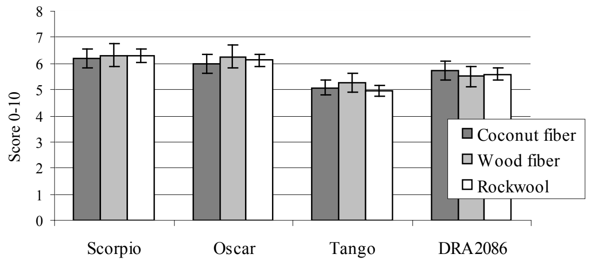

Fig. 5. The overall sensory quality of eggplant cultivars fruits in relation to growing mediums, with standard errors (±)

pecially when the plants were grown in wood fiber. Generally, sweet taste of a fruit is an effect of sugars presence in the flesh. Significant changes of sugars content were observed during eggplant fruit development (Esteban *et al*., 1992). Also during storage of eggplant fruits sugars content can change, which results in changes of sweet taste intensity, what was observed in our previous work (Gajewski, 2002b). The most intensive sweet taste was found for fruits of 'Scorpio' and 'Oscar'. Fruits of 'Scorpio' showed also the highest flavour intensity of 'roasted fruit'. This flavour is a specific flavour, found by experts in roasted eggplant fruits, but in the case of evaluated cultivars the intensity of it was rated on rather low level, with small differences among cultivars. However, the highest level of this flavour was found for 'Scorpio'. Humans are born with an innate dislike for bitter taste and preference for sweet one. Bitter taste, which is characteristic for eggplant fruits, but not desirable in a higher amount, was rated on a low level in all fruits, and was the most intensive for DRA 2086 fruits. Bitter taste of eggplant fruit may result from polyphenolic acids and alkaloids presence in the fruits, which was reported in the other work (Gajewski and Arasimowicz, 2006). Small differences between eggplant cultivars were noticeable in respect of bitter taste intensity. The least intensive sharp, pungent flavour was found in fruits of 'Scorpio'. Regardless of a cultivar and growing medium, none of the fruits showed any noticeable amount of off-flavour, which is generally thought as an undesirable trait.

In order to find the influence of quality attributes on quality characteristics of eggplant fruits, a principal component analysis (PCA) was performed. The PCA was done on mean values over assessors and sensory replicates for the genotypes, growing mediums and the 20 attributes. The PCA bi-plot is visualized in Fig. 6. The first two principal components explain together 59% of the variation between samples. The first principal component alone accounts for 33% of the variation and the second one for 26%. The relationship between sensory attributes and fruit samples can be determined by their location on the projection. Points A1, B1 and C1 are situated close to each other and close to the vector of overall quality, which indicates similar sensory characteristics of adequate fruit samples – fruits of 'Scorpio', grown on the three mediums, and their good sensory quality. Other fruit samples

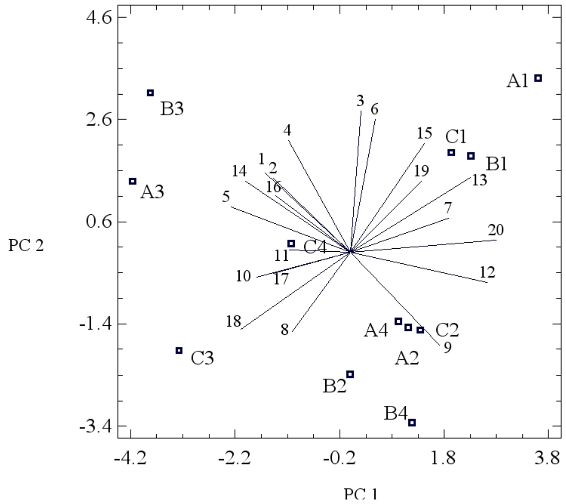

Fig. 6. PCA projection for sensory attributes of eggplant fruits.
PC1 (principal component 1) – 33%, PC2 (principal component 2) – 26%. Attributes: 1 – overall odour intensity, 2 – sharp odour, 3 – odour of 'steamed potatoes', 4 – odour of 'boiled fungi', 5 – sour odour, 6 – odour of 'hay', 7 – odour of 'plum jam', 8 – off-odour, 9 – flesh colour, 10 – flesh firmness, 11 – flesh fibrousness, 12 - skin hardness, 13 – sweet taste, 14 – flavour of 'boiled fungi', 15 – flavour of 'roasted fruit', 16 – sour taste, 17 - bitter taste, 18 - pungent flavour, 19 - off-flavour, 20 – overall quality.
Samples (mediums/cultivars): A1 – coconut/Scorpio; A2 – coconut/Oscar; A3 - coconut/Tango; A4 – coconut/DRA2086; B1 – wood/Scorpio; B2 – wood/Oscar; B3 - wood/DRA2086; B4 - wood/Scorpio; C1 – rockwool/Scorpio; C2 - rockwool/Oscar; C3 - rockwool/Tango; C4 - rockwool/DRA2086.

show different localization on the graph, which is related to different sensory quality of the fruits, in relation to the genotype and growing mediums. Points A3, B3 and C3 are situated on opposite direction of overall quality vector, which indicates the lowest overall quality of these fruit samples. The vector of overall quality has opposite direction to the vectors of sour odour, flesh firmness and flesh fibrousness, so the overall quality is inversely correlated to these attributes, and positively correlated to sweet taste intensity and skin firmness (the lower, the better). A high correlation was found for the 'negatively' perceived attributes, and flesh firmness.

To describe a relationship between overall sensory quality scores and the set of 19 sensory attributes of eggplant fruits, the linear multiple regression model was calculated. In the literature some approaches to find a relationship between results of sensory and instrumental evaluation of vegetables quality were reported (Fillion and Kilcast, 2002; Gajewski and Arasimowicz, 2004; Gajewski *et al*., 2008). Here, to describe the relationship between scores for overall sensory quality and for sensory attributes, a linear multiple regression model was applied, with the assumption that the relationship is of a linear character. It is a simplification, since it is known that relationship between the intensity of most sensory attributes and overall sensory quality is usually of a nonlinear character (Meilgaard *et al*., 1999). The R2 statistics indicates that the model explains 61.2% of the variability of overall sensory quality (the relationship is significant at P = 0.001), which

Tab. 1. Definitions of sensory attributes used in the quantitative descriptive analysis

No.	Attribute	Definition	Anchoring points
1	Overall odour intensity	General impression of odour intensity	UndetecTab. – very intensive
2	Sharp odour	Pungent, spicy odour	UndetecTab. – very intensive
3	Odour of 'steamed potatoes'	Characteristic odour of steamed potatoes	UndetecTab. – very intensive
4	Odour of 'boiled fungi'	Characteristic odour for boiled fresh fungi	UndetecTab. – very intensive
5	Sour odour	Odour of sour character	UndetecTab. – very intensive
6	Odour of 'hay'	Odour characteristic to long stored hay	UndetecTab. – very intensive
7	Odour of 'plum jam'	Sweety odour, characteristic to plum jam	UndetecTab. – very intensive
8	Off-odour	Unusual odour for eggplant fruit	UndetecTab. – very intensive
9	Flesh colour	Visual evaluation of flesh colour	Light – dark brown
10	Flesh firmness	Degree of force needed to chew the flesh	Firm - soft
11	Flesh fibrousness	Mouthfeel of flesh homogenousness	Smooth – very fibrous
12	Skin hardness	Degree of force needed to bite the skin	Hard – soft
13	Sweet taste	Basic taste	UndetecTab. – very intensive
14	Flavour of 'boiled fungi'	Characteristic flavour of boiled fresh fungi	UndetecTab. – very intensive
15	Flavour of 'roasted fruit'	Characteristic flavour of roasted apples	UndetecTab. – very intensive
16	Sour taste	Basic taste	UndetecTab. – very intensive
17	Bitter taste	Basic taste	UndetecTab. – very intensive
18	Pungent flavour	Impression of burning on tongue	UndetecTab. – very intensive
19	Off-flavour	Unusual flavour for eggplant fruit	UndetecTab. – very intensive
20	Overall quality	Score for general sensory impression	Low – high quality

is a quite high value. The equation of the fitted model is as follows:

$$Yo = 5.346 - 0.012\,x1 - 0.106\,x2 - 0.037\,x3 - 0.056\,x4 - 0.125\,x5 + 0.020\,x6 + 0.159\,x7 - 0.267\,x8 - 0.106\,x9 - 0.083\,x10 + 0.139\,x11 + 0.160\,x12 + 0.275\,x13 + 0.139\,x14 - 0.076\,x15 - 0.431\,x16 - 0.220\,x17 - 0.156\,x18 + 0.002\,x19$$

In the equation: Yo – value expected for overall quality rating of eggplant fruit; x1 – x19 - values obtained for sensory descriptors rating of eggplant fruit, numbered according to Tab. 1. Overall quality and all descriptors are expressed in numerical values from 0 to 10 units.

The importance of each attribute in overall impression of sensory quality can be evaluated from this model. It can be seen that the highest numerical values were typical for the following quality attributes: odour of 'plum jam', off-odour, skin hardness, sweet taste, sour taste, bitter taste and pungent taste. Therefore, it can be concluded that the importance of these attributes in sensory quality evaluation was the highest.

Flesh firmness and fibrousness are the attributes related to physical characteristics of fruit flesh and can influence sensory quality, therefore consumer acceptance too (Jha and Matsuoka, 1999; Fillion and Kilcast, 2002). Flesh firmness of the fruits, measured instrumentally, varied among cultivars and ranged from about 40 to 46 HPE units (Tab. 1). The influence of growing medium on flesh firmness was insignificant, but the influence of genotype was significant. The most firm flesh had the fruits of DRA 2086, and the less firm fruits of 'Tango'. Puncture load, is the force required for pushing a cylindrical probe into a plant tissue to a depth that causes irreversible crushing of flesh. Puncture load ranged from 6.6 to 8.5 N, and was the highest for fruits obtained from plants grown on rockwool medium. Differences between cultivars in that respect were also noticeable, and DRA 2086 fruits needed the highest force for flesh puncture. Puncture load values found in this work are close to those obtained in other work with different eggplant cultivars (Gajewski 2002a).

To compare fruits' appearance, skin colour was instrumentally measured with the colorimeter. Skin colour parameters of the fruits are shown in Tab. 1. Fruits from different mediums did not significantly differ in skin lightness (L^* value), redness (a^* value) and in yellowness or blueness (b^* value). Differences in colour parameters between the cultivars were obvious, since there were chosen cultivars of different fruit colour. As the colour of eggplant fruits is related to maturity stage, the data presented confirm that the fruits were harvested at a similar maturity and there was no influence of growing medium on that quality parameter.

Conclusions

Results of the experiment showed that kind of growing medium used in greenhouse cultivation of vegetables influences some of sensory quality attributes of eggplant fruits, concerning texture. However, all the three growing mediums applied - coconut fiber, wood fiber and rockwool - showed their suitability for eggplant greenhouse cultivation, in respect of keeping the fruits quality. Therefore, it can be concluded that both environment friendly mediums, i.e. coconut fiber and wood fiber, could be used as the replacement of rockwool medium in horticultural practice. Investigated eggplant cultivars differed in sensory characteristics of their fruits and in overall sensory quality, irrespective of growing mediums applied for their cultivation. The lowest overall sensory quality was found for the fruits of 'Tango'. As the additional conclusion it can be added that overall sensory quality of the fruits of eggplant cultivars may be predicted based on scores for individual sensory attributes, using the model of linear multiple regression calculated.

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