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Original paper

Evaluation of strawberry fruit quality for new selections and cultivars

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Abstract

The fruit characteristics of new strawberry genotypes reflect their value for the present and future breeding programs. Beyond the agronomic characteristics, the evaluation of biometric, colorimetric and biochemical characteristics of fresh fruits complete the description of strawberry genotypes. Starting from these ideas, the aim of present study was to evaluate the biometric, colorimetric and biochemical characteristics of seven strawberry cultivars and selections. In this respect, a study was carried out in the experimental field of the Small Fruit and Strawberry Department belongings to Research Institute for Fruit Growing Pitesti, Romania, during years 2016 and 2017. The analysed quality characteristics of the strawberry fruits were the following: biometric characteristics (plant yield, weight, diameter, length and firmness of the fruits), colorimetric characteristics (lightness, hue angle, Chroma index, chromaticity) and biochemical characteristics (pH, total soluble solids, total acidity, soluble solids/total acidity ratio, total sugars, vitamin C, total polyphenols). The evaluation of the quality characteristics of the seven studied strawberry genotypes highlighted the differences among them. The results of this study highlights that selection 08-10-5 has the potential to become a new and valuable variety considering some of the most important fruit quality characteristics (colour parameters analysed, pH, total soluble solids, soluble solids/total acidity ratio and also by the content of vitamin C and total polyphenols).

Keywords Fragaria×ananassa, biometric, colorimetric and biochemical characteristics.

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Introduction

The fruits of cultivated strawberry (*Fragaria x ananassa* Duch.) are among of the most popular soft fruits in the world. Grace of the most recent breeding programs, the global customer is 'rewarded' with strawberry fruits from new cultivars and selections (KRUGER & al [13]). The term customer includes here on the one hand farmers and on the other hand consumers. The hedonistic preference of consumers is covered by some bio components of strawberries fruit: appearance, size, firmness, taste, flavour and colour, which are also quality attributes (DRĂGHICI & al [6]). Despite their fragility, the strawberry fruits are known for their taste, aroma balance and nutritional value given by influence of vitamin C in TAC and the high content of polyphenols and ellagic acid, the latter being known as anticancer agent (GIAMPIERI & al [9]). As resources of biocomponents with antioxidant proprieties and beyond the hedonistic preference, the fresh soft fruits like strawberries and other berries are included in daily alimentary diets (AFRIN & al [2]; POPA & al [20]).

The priorities of breeding programmes are linked to the farmers' interest concerning the new strawberry varieties traits, such as are the yielding capacity, yield quality, resistance to stress factors, fruit shelf-life. The most recent research priority is strong oriented to the sensorial and nutritional fruits characteristics (CAPOCASA & al [4]). The creation of new genotypes with higher nutritional value is recommended to be linked with the acceptance of the specific market determined by specific criteria. The sensorial traits as well as nutritional traits of strawberry fruits are directing correlated with genotypes, growing conditions and crop technologies (MEZZETTI [16]).

The Romanian strawberry production is provided by small farms from multiannual field crops. The earlier production is provided in late May by the Romanian Premial variety and the latest by the Magic Romanian variety, till the end of June, both of them being June-bearing varieties. The main production is provided by the Northwestern region of Romania.

The purpose of the strawberry breeding program is to develop new competitive strawberry genotypes better adapted to specific growing conditions through evaluation of the germplasm collection. The evaluation of genotypes in terms of fruit quality is an important component completing their description; quality is an important feature both for fresh and processed fruits (POIANA & al [19]). Fruit quality is determined by a complex of physical and biochemical properties (SCHWIETERMAN & al [22]).

The aim of the present study was to evaluate the biometric, colorimetric and biochemical characteristics of seven strawberry cultivars and selections. In this respect, there were considered the plant yield as agronomic characteristic, the weight, size, firmness, colour, soluble solids content (SS), ascorbic acid (AA), total sugars (TS), and total acidity (TA) as fruits quality characteristics, and total antioxidant capacity (TAC) and total polyphenols (TPH) as nutritional parameters (BARRETT & al [3]). The importance of such a study is given by the fact that the evaluation of fruit quality traits and their temporal trends should help inform future strategies for genetic improvement (WHITAKER & al [28]).

Materials and Methods

The design of the experiment

The study was carried out in the experimental field of the Small Berry and Strawberry Department, belongings to Research Institute for Fruit Growing Pitesti, Romania, during two years, respectively 2016 and 2017. The area of experimental plots is placed in a meadow terrace of the Argeş River and is climatically characterised as being moderately hot and humid. The climatic parameters registered during years 2016 and 2017 for the area of study had the following average values: 11.1°C the annual average air temperature; -20.4°C the absolute minimum daily temperature; 37.1°C the absolute maximum daily temperature; 12.4°C the daily average thermal amplitude; 2,373.2 hours of sunshine; 71.4% the average relative air humidity; 704.1 mm the average annual rainfall; 726.6 mm the evapotranspiration (ETo Penman-Monteith); 22.5 mm the rainfall deficit (ETo Penman-Monteith).

The experimental field is located on a soil that is part of the protisol type, wet aluviosoil type, formed on fluvial deposits with a clayey and sandy granulometric composition.

The soil from the experimental plots was analysed before planting. Thus, the level of pH (5.8) provides acidic reaction. The total nitrogen content was very low (0.09%) which shows a poor supply with this element, and the content of accessible phosphorus (P_2O_5-17.5 ppm) is specific for acidic soils. The humus content was also poor (1.8%).

The fertilization with chemical fertilizers was based on agrochemical parameters analysed. Due to phosphorus and nitrogen deficiencies, NPK complex fertilizer was applied. Appropriate fertility for strawberry field crop is ensured by a humus content of 2-3% and an acidic reaction with a pH value between 5.6 and 7.0 (HOPPULA & KARHU [11]; PRITTS & LUBY [21]).

In the two experimental years seven genotypes of strawberry have been evaluated. Three cultivars of national and international commercial interest (Argentera and Garda – two new Italian varieties; Magic – one of the most cultivated Romanian variety) and four advanced selections (09-21-4; 08-15-5; 08-10-5; 08-14-2) were analysed for the evaluation of strawberry fruits quality (Figure 1).

The experimental plot was organized in open field, as monofactorial experience, having in evaluation a single factor – the genotype, being organized according to the parcel subdivision method in 3 repetitions per genotype. The planting distance was 90 x 30 cm. The genotypes fruits quality was evaluated according to the International Union for the Protection of New Varieties of Plants TG/22/10 list of descriptors.

The fruit samples were collected at full maturity stage and were analyzed immediately after harvest. The evaluation of the fruit quality of the studied genotypes was made by determinations on the biometric, colorimetric and biochemical characteristics of strawberry fresh fruits.

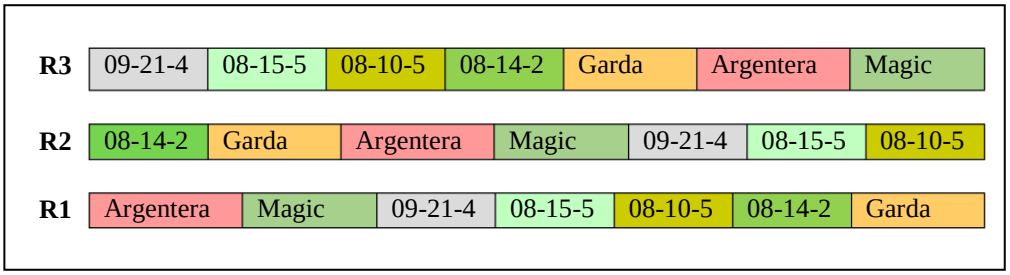

Figure 1. Plant genetic material and open field experience scheme.

Biometric characteristics of the fresh fruits

The total fruit weight per plant (plant yield), as agronomic characteristic of genotypes, was determined by weighing ripened fruits at each harvest and then summing all harvests. The average fruit weight was determined by weighing a sample of 20 fruits for each repetition at each harvest. The same fruit samples were used for measuring the average fruit length and diameter, by using a calliper. The firmness of the pulp was determined on a sample of 20 fruits for each repetition and harvest, using the handheld penetrometer HFE II Fff Qualitest with a measuring device of 0.50 cm^2 in diameter and with results expressed in N.

Colorimetric characteristics of the fresh fruits

In order to measure the fruit skin colour, the determinations were made on two diametrically opposed points on each fruit from the sample of 20 fruits per repetition and harvest, using the Konica Minolta colour detector [red (a*), yellow (b*) and brightness (L*)].

Using CIE $L^*a^*b^*$as uniform colour scale for fruits colour determination, the differences between the graphically points, in the colour space, are connected to the visual differences between the graphically represented colours (STURZEANU & al [23]). In the cube form of the CIE $L^*a^*b^*$colour space, the L^* axis represents the brightness, where the maximum value 100 express the white colour and the minimum value 0 the black colour. Axes a^* and b^* do not have specific numerical limits. Positive values of a^* axis show the red colour and negative values show the green colour. Concerning b^* axis, the positive values show the yellow colour and the negative values show the blue colour. Low values of colour indicators L^*, a^*, b^*, h^o, C^* indicate the dark colour of the fruit (ZORRILLA-FONTANESI & al [29]). The Chroma index (C^*) was calculated by the formula: $(a^{*2} + b^{*2})^{1/2}$ (ZORRILLA-FONTANESI & al [29]). The angle of colour (h^o) was calculated by the formula: $h^o = (b^*/a^*)$, where 0^o = red-violet, 90^o = yellow, 180^o = blue - green, and 270^o = blue (MCGUIRE [15]).

Biochemical characteristics of the fresh fruits

The biochemical characteristics of the fruits were determined in a sample of approximately 200 g per repetition. The pH of the fruits was determined with the IQ Scientific digital pH meter on average samples for each harvest. Total soluble solids content of fruits, expressed in % Brix, was determined by refracto-metric method using ABBE digital refractometer (PR Series). The content of organic acids, expressed as g/L total acidity, was analysed by the titrimetric method using 0.1 N sodium hydroxide. The total sugars content (%) was determined using the Fehling-Soxlet method (1964). The Vitamin C content expressed in mg/100 g of fresh fruit was determined by the titrimetric method after the extraction with 2% hydrochloric acid. The total polyphenols content expressed as milligrams of gallic acid/kg of fresh fruit, was determined by using spectrophotometrically method with Carl Zeiss Jena Spectrophotometer, and the extraction of the polyphenols was made using, as solvent, methanolin water, ratio methanol:water of 80:1.

The results were calculated, analyzed and interpreted using Duncan's Multiple Range Test to determine the significance of the differences between variants.

Results and Discussion

Biometric characteristics of the fresh fruits

For one harvest season, total fruit weight per plant (plant yield), weight, diameter, height, size index, shape index and firmness of strawberry fresh fruits were significantly different among genotypes (Table 1).

The highest average plant yields were recorded at genotypes 08-14-2 (347.47 g/plant) and Garda (330.16 g/plant). The plant yields registered on 08-14-2 and Garda cv. are significantly higher than those registered to the other studied genotypes. The lowest plant yield was noted on 08-10-5 selection (97.67 g).

The average fruit weight is a trait which expresses the size of the fruit, being a commercially important characteristic, especially when the fruits are intended for fresh consumption. The average weight of investigated strawberry fruits ranged from 26.67 g (08-15-5 selection) and 16.33 g (08-10-5 selection), the differences between those being significant.

By measuring the height and the diameter of the fruits, the size and shape index can be calculated to identify the differences between genotypes without error, higher diameter and length of fruits being associated with a higher size of fruits. The measurement of fruit diameter and

length have shown, both, higher average value on 08-15-5 selection (42.11 mm, respectively 49.68 mm) and lower value on Magic cv. (34.60 mm, respectively 34.85 mm). The longest fruits were recorded at 2 selections: 08-14-2 (50.48 mm), respectively 08-15-5 (49.68 mm). Based on the recorded data and considering that a higher size of strawberry fruits is associated with a better acceptance of consumers, the 08-15-5 selection has shown a superiority of fruit size and weight. Despite its fruits weight, diameter and length, Garda cv. have registered one of the highest fruit yields per plant (330.16 g), as well as selection 08-14-2 (347.47 g).

The strawberry fruit firmness is associated with resistance to transportation and storage. The analysis of fruit firmness has showed that genotypes: 09-21-4, Garda and Argentera registered the highest values of fruit firmness (51.43 N, 49.41 N and 47.6 N), while the lowest value was recorded for Magic cv. (15.2 N).

Table 1. Average values of biometric characteristics of the strawberry fruits

EXPERIMENTAL FACTOR		Biometric characteristics of the fresh fruits				
		Plant yield (g)	Fruit weight (g)	Diameter (mm)	Length (mm)	Firmness (N)
Genotypes	09-21-4	148.96bc	22.67b	36.51abc	45.02ab	51.43a
	08-15-5	185.50b	26.67a	42.11a	49.68a	29.61b
	08-10-5	97.67c	16.33d	41.43ab	45.22ab	28.32b
	08-14-2	347.47a	22.00bc	37.3abc	50.48a	29.66b
	Argentera	199.69b	21.67bc	36.94 abc	40.23bc	47.6a
	Garda	330.16a	19.33c	32.73c	45.94ab	49.41a
	Magic	190.44b	19.00cd	34.60bc	34.85c	15.2c

*values that do not have common letters differ significantly for a statistical assurance level of 5% (P≤0.05)

Colorimetric characteristics of the fresh fruits

The strawberry fruit colour represents one of the most important characteristics influencing the choice of fruits by consumers, the bright red fruits being preferred (TIWARI & al [25]).

Concerning fruit colour, the CIE L* a* b* colour range recorded positive values for all genotypes. The results of the colour parameters revealed statistically significant differences between the genotypes, except for the colour angle where no significant differences were found. L* (brightness) is the absolute attribute for colour perception and refers to how an area appears to be bright; the mean values of this attribute were grouped into three homogeneous classes of statistical significance and varied between 25.76 (09-21-4 selection) and 36.39 (08-10-5 selection). Genotypes 08-14-2 and Argentera had intermediate values between two homogeneous groups.

Analyzing the average values of the fruit colour hue index (h°) they oscillated between 16.66 units at Magic cv. and 26.34 units at 08-14-2 selection, the differences between the genotypes being insignificant. The average values of the fruit colour index (C*) were also classified in four homogeneous statistically classes, 08-10-5 selection recording significantly higher values (38.14) than the other genotypes.

Table 2. Average values of colorimetric characteristics of the strawberry fruits

EXPERIMENTAL FACTOR		Colorimetric characteristics of the fresh fruits				
		Brightness (L*)	Hue angle (h°)	Chroma Index (C*)	Chromaticity a*- axis (red-green)	Chromaticity b*- axis (yellow-blue)
Genotypes	09-21-4	25.76c	23.87a	25.31c	23.09b	10.32bc
	08-15-5	27.58c	22.38a	26.17c	24.20b	9.94bc
	08-10-5	36.39a	25.83a	38.14a	34.28a	16.60a
	08-14-2	28.88bc	26.34a	27.58c	24.69b	12.25b
	Argentera	27.77bc	24.97a	24.11c	21.82b	10.21bc
	Garda	27.05c	24.91a	19.61d	17.78c	8.24c
	Magic	32.01b	16.66a	32.49b	31.13a	9.32bc

*values that do not have common letters differ significantly for a statistical assurance level of 5% (P≤0.05)

Biochemical characteristics of the fresh fruits

The pH of strawberry fruits affects sensorial quality being predictor of flavour intensity, sweet and sour taste (GUNNESS & al [10]). The colour stability and quality are strong correlated with the pH level (WAHYUNINGSIH & al [27]). More than that, the low value of acidity and high pH value affects the fruit colour. Low values of pH influence the degradation of some biochemical components, like sugars (PATTEE [17]). Fruit pH has registered a significant variation on strawberry genotypes. The highest level of pH was noted for 08-10-5 selection (4.0) and the lowest (3.2) for 09-21-4 selection.

According to some studies (VOĆA & al [26]), total soluble solids content falls within the range 5.2 to 10.4%, up to 11.6% depending on the cultivar. Analyzing total soluble solids content of the fruits, there were significant differences between the studied genotypes. Thus, 08-10-5 selection recorded the highest value of the total soluble solids content (13.2% Brix), while Garda and Magic cv. had the lowest values of total solids content (6.3% Brix and respectively 7.76% Brix). Some authors reported that strawberry fruits obtained in field crops located in cooler and wet areas registered higher values for total acidity (GHERGHI & al [8]). For strawberry fresh fruits an optimal flavour is generated by high content of sugar and low content of acid. The better taste is generated by a higher sugar/acid ratio (KIM & al [12]). Concerning the total acidity content, a maximum value was noted for Argentera cv. (10.4 g/L), while the minimum value was noted for Garda cv. (5.7 g/L) (Table 3).

The ratio between total soluble solids and total acidity, as balance between sugars and acids, still remains one of the main parameter for fruits quality evaluation. More than that, some cultivars are appreciated by their "harmonious" total soluble solids/total acidity ratio (VOĆA & al [26]). In our study (Table 3), the higher ratio between total soluble solids and total acidity was noted on 08-10-5 selection (1.78) given by the highest content in total solids, and in opposite, the lower value was noted at Argentera cv. (0.91) due to the highest value of total acidity.

Strawberry sweetness is one of the important sensorial parameters witch influence the consumers' behaviour. Sugars alongside acids were accomplishing the taste of strawberry fruits. The total sugars falls within the normal range of species and the average limits for strawberry fruits are 3.45-8.90% (GHERGHI & al [8]). Significant differences were noted among genotypes. Thus, the levels of total sugars content varied between 3.07% (08-15-5 selection) and 8.62 % (09-21-4 selection).

Vitamin C content in strawberry fresh fruit is influenced by genotype, among other important factors like climatic conditions from pre-crop to post-harvest operations (LEE & KADER [14]). Strawberries are appreciated as an important resource of vitamin C, with an average content of 60 mg/100 g (CORDENUNSI & al [5]). Table 3 shows that the average values of the vitamin C content of the strawberry genotypes analysed falls within the normal range of variation (25-120 mg/100 g fresh fruit). The richest genotype in vitamin C is Garda cv. (96.8 mg/100) and the lowest content was highlighted at Magic cv. (39.26 mg/100). The advanced selections with content of vitamin C over 60 mg/100 g were 08-15-5 and 08-10-5 selections (61.6 mg/100).

According to the recent research results, strawberry fruits are an important resource of polyphenols (SUN & al [24]; AABY & al [1]), through anthocyanin pigments being possible the expression of their unique red color. Several authors reported that the total polyphenol content range from 2,350 mg/kg (PÉREZ-JIMÉNEZ & al [18]) to 8,000 mg total polyphenols/kg fresh fruit (FREDES & al [7]). Values of the content in total polyphenols of the seven studied strawberry genotypes in fresh fruit noted in Table 3 are higher than the limits above mentioned. The results of the studied genotypes shown a very high levels of total polyphenols ranging between 8,062 mg/kg fresh fruit (Garda cv.) and 10,600 mg/kg fresh fruit (08-15-5 selection).

Table 3. Average values of biochemical characteristics of the strawberry fruits

EXPERIMENTAL FACTORS		Biochemical characteristics of the fresh fruits						
		pH	Total soluble solids (% Brix)	Total acidity (g/L)	Total soluble solids/ Total acidity	Total sugars (%)	Vitamin C (mg/100g)	Total poliphenols (mg/kg)
Genotypes	09-21-4	3.20 c	8.80 c	9.30 b	0.95 d	8.62 a	52.80 d	10,500.00 b
	08-15-5	3.40bc	8.40 d	8.90 c	0.94 d	3.07 f	61.60 c	10,600.00 a
	08-10-5	4.00 a	13.20 a	7.40 d	1.78 a	5.02 c	61.60 c	9,540.60 d
	08-14-2	3.40bc	9.50 b	9.30 b	1.02 c	5.31 b	66.00 b	10,500.00 b
	Argentera	3.40bc	9.50 b	10.40 a	0.91 d	5.31 b	52.80 d	9,441.37 e
	Garda	3.40bc	6.30 f	5.70 f	1.10 b	4.67 d	96.80 a	8,062.0 f
	Magic	3.60 b	7.80 e	7.00 e	1.11 b	4.18 e	39.26 e	9,780.50 c

Conclusion

The evaluation of biometric, colorimetric and biochemical characteristics of the seven studied strawberry cultivars and selections highlighted the differences among genotypes.

The new selection 08-10-5 have shown higher values of all the colour parameters analysed, pH, total soluble solids, soluble solids/total acidity ratio.

Genotype 08-14-2 has shown the highest fruit yield per plant, while genotype 09-21-4 was characterised by the firmer fruit. The genotype 08-15-5 has expressed the highest values of fruits weight, diameter and length.

The results of this study highlights that selection 08-10-5 has the potential to become a new and valuable variety considering some of the most important fruit quality characteristics (colour parameters analysed, pH, total soluble solids, total soluble solids/total acidity ratio and also by the content of vitamin C and total polyphenols).

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