ISSN 0100-2945 DOI: http://dx.doi.org /10.1590/0100-29452018821

Revista Brasileira de Fruticultura

Post-harvest characterization of strawberry hybrids obtained from the crossing between commercial cultivars

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Abstract - The lack of programs to improve the strawberry crop in Brazil has led to a growing increase in the use of seedlings imported from Chile, which leads to a certain dependence of imported material on the part of the producers and increases the production even more, since the producers have. This proves even more the need for the development of cultivars adapted to the local conditions of cultivation. In this sense, the aim was to evaluate the post-harvest of fruits of 15 hybrids of strawberry obtained from the cross between commercial cultivars, in order to select the materials with chemical quality superior to the cultivars most planted in Brazil. The contents of soluble solids, titratable acidity, ratio, vitamin C, anthocyanins and phenol were evaluated. The characterization of strawberry hybrids indicated that the RVFS 13-07, RVFS 13-24, RVCS 13-07, RVCS 13-10 and RVCA 13-08 materials stood out in post-harvest evaluations, with higher levels of functional compounds (vitamin C, anthocyanins and phenolics) and higher values of quality parameters (soluble solids, titratable acidity and ratio), important characteristics for the in natura consumption or for use by the industry. These hybrids were shown to be promising to continue the crop breeding program by demonstrating that they carried characteristics of interest for intraspecific crosses. The values obtained for the analyzed characteristics were higher than the values found in the literature for the cultivars most planted and consumed in Brazil and in the World, which demonstrates the efficiency in the selection process.

Index terms: *Fragaria ananassa,* quality; breeding program, functional compounds.

Caracterização pós-colheita de híbridos de morangueiro obtidos do cruzamento entre cultivares comerciais

Resumo - A falta de programas de melhoramento da cultura do morangueiro no Brasil levou a crescente aumento da utilização de mudas importadas do Chile, gerando certa dependência do material importado por parte dos produtores e onerando ainda mais a produção, pois os produtores têm de pagar às empresas que detêm os royalties de algumas variedades. O que comprova ainda mais a necessidade de desenvolvimento de cultivares adaptados às condições locais de cultivo. Nesse sentido, buscou-se avaliar a pós-colheita de frutos de 15 híbridos de morangueiro obtidos do cruzamento entre cultivares comerciais, a fim de selecionar os materiais com qualidade química superior às cultivares mais plantadas no Brasil. Foram avaliados os teores de sólidos solúveis, acidez titulável, ratio, vitamina C, antocianinas e fenólicos. A caracterização dos híbridos de morangueiro indicou que os materiais RVFS 13-07, RVFS 13-24, RVCS 13-07, RVCS 13-10 e RVCA 13-08 se destacaram nas avaliações pós-colheita, com maiores teores de compostos funcionais (vitamina C, antocianinas e fenólicos) e maiores valores dos parâmetros de qualidade (sólidos solúveis, acidez titulável e *ratio*), características importantes, seja para o consumo *in natura,* seja para utilização pela indústria. Esses híbridos mostraram-se promissores para continuar no programa de melhoramento genético da cultura ao demonstrarem que levaram características de interesse dos cruzamentos intraespecíficos. Os valores obtidos para as características analisadas foram superiores aos valores encontrados na literatura para as cultivares mais plantadas e consumidas no Brasil e no Mundo, o que demonstra a eficiência no processo de seleção.

Termos para indexação: *Fragaria ananassa*, qualidade, melhoramento genético, compostos funcionais.

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Received: August 14, 2017.
Accepted : February 01, 2018.

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Introduction

In the world context, it is estimated that strawberry production has doubled in the last decade and in 2014 reached more than 8 million tons (FAOSTAT, 2014). Among the Brazilian states, the largest comprises Minas Gerais (40,245 t), Rio Grande do Sul (9,819 t), Paraná (6,265 t) and São Paulo (5,030 t) (GUIMARÃES et al., 2015). The strawberry crop in the State of Paraná produced in the harvest of 2015 around 22.64 thousand tons, with gross value of the production - GVP of R$ 164.15 million.

The strawberry genetic improvement in Brazil began in 1941 at the Agronomic Institute of Campinas-SP and in 1950 at the Experimental Station of Pelotas-RS, now Embrapa Clima Temperado. Several of the materials used by these programs were obtained from the importation of seedlings and achenes from genetic improvement programs in the United States. However, from the 1990s, genetically improved cultivars from international programs were introduced with great success in the Brazilian producing regions, making Brazilian cultivars obsolete (GALVÃO et al., 2017).

Brazil, increasingly, has imported seedlings from Argentina and Chile, raising its dependence on external sources, generating an increase in production costs and delays in planting, which can start only at the end of April, being late for some regions that start their crops in March (ANTUNES; PERES, 2013). Moreover, the entry of these plants in Brazil in large-scale endangers the production by the possibility of introduction of pathogens and pests. The main alternative to reducing dependence on imported cultivars and reducing plant health risks comes from the progress of the Brazilian genetic improvement programs, which are currently stagnant or in slow development.

Genetic improvement has similar characteristics of interest for all breeding programs, but their relative importance is different for breeders as it depends on each region (HANCOCK et al., 2010).

In order to select promising materials, agronomic evaluations of cultivars performance are not enough. In the improvement, the characteristics that are linked to the quality of the fruits are flavor, shape, color, firmness, brightness and more recently the contents of bioactive compounds (vitamins, phenolic compounds, etc.), which is due to the increasing demands of consumers for products that promote health, since scientific studies demonstrate the beneficial effects of its compounds as antioxidant, anti-inflammatory and anticancer power (PINELI et al., 2011).

Strawberry is a fruit that has great nutritional appeal, because it has functional properties, such as antioxidant action, ability to reduce susceptibility to infections, diuretic effect and anti-inflammatory activity. It is rich in vitamin C and has phenolic compounds. These groups are rarely found in free form, and may be linked to proteins, lipids, terpenoids, hydroxycinnamic acid, carbohydrates and can form ester with organic acids (ROCHA et al., 2008). Phenolic compounds also act as natural antioxidants, have anticarcinogenic activity and lower incidence of cardiovascular diseases (PINELI et al., 2015).

The objective of the study was to perform a post-harvest characterization of strawberry hybrids obtained from the commercial cultivars, in order to select materials with superior characteristics to the cultivars planted in Brazil.

Material and methods

The experiment was developed at the State University of the Center-West, UNICENTRO in Guarapuava, PR, (24°14'52" S latitude, 51° 41'06" W longitude and 1,120 m altitude).

The experimental design was a randomized complete block (DBC) with three replicates. The plot consisted of 15 plants of each hybrid (1.5 m) and three replicates.

The soil was prepared and the base fertilization was carried out three days in advance according to the soil chemical analysis (Ca/Mg: 2.8/1 cmol dm^{-3}, O.M.: 41.99 g dm^{-3}, pH: 6.41, P: 7.92 mg dm^{-3}, K: 0.98 cmol dm^{-3}, Ca: 4.20 cmol dm^{-3}). It was applied 1650 kg ha^{-1} of single superphosphate, 250 kg ha^{-1} of potassium chloride and 295 kg ha^{-1} of urea.

The spacing used was 0.30 m x 0.40 m forming two lines. The irrigation system adopted was with dripping tubes, spacing 0.30 m between drips.

The plots were covered with black polyethylene film (*mulching*) with a thickness of 30 uM. Throughout the cycle, the fertilization was performed every 30 days, consisting of 60 kg ha^{-1} of ammonium sulfate, 11.5 kg ha^{-1} of potassium sulfate and 14.5 kg ha^{-1} of potassium chloride. At the beginning of flowering, the plants were sprayed with boric acid and zinc sulfate at the concentration of 1% and 2%, respectively, and in the stage of fruit production with calcium chloride at 0.4% every 15 days. Fertilizations were carried out based on soil chemical analysis and according to the recommendations for the crop. No phytosanitary control was carried out.

Fifteen hybrids were obtained from the commercial cultivar, known as RVCA 13-06; RVCA 13-08; RVCS 13-02; RVCS 13-07; RVCS 13-10; RVDA 13-01; RVDA 13-11; RVFA 13-14; RVFS 13-07; RVFS 13-24; RVOT 13-11; RVOT 13-22; RVSA 13-08; RVTA 13-16 and RVTS 13-06 (Table 1).

Table 1. Strawberry hybrids resulting of crossing among commercial cultivars.

Hybrids (code)	Crossing
RVCA 13-06	Camarosa x Aromas
RVCA 13-08	Camarosa x Aromas
RVCS 13-02	Camarosa x Sweet Charlie
RVCS 13-07	Camarosa x Sweet Charlie
RVCS 13-10	Camarosa x Sweet Charlie
RVDA 13-01	Dover x Aromas
RVDA 13-11	Dover x Aromas
RVFA 13-14	Festival x Aromas
RVFS 13-07	Festival x Sweet Charlie
RVFS 13-24	Festival x Sweet Charlie
RVOT 13-11	Oso Grande x Tudla
RVOT 13-22	Oso Grande x Tudla
RVSA 13-08	Sweet Charlie x Aromas
RVTA 13-16	Tudla x Aromas
RVTS 13-06	Tudla x Sweet Charlie

The fruits were harvested during the fruiting period and from each commercial harvest, five fruits with a homogeneous maturation pattern were frozen to compose the sample that was evaluated at the end of the experiment. Fruits with more than 80% of the surface with red-intense coloring were adopted as the harvesting standard. At the time of the laboratory analysis, the strawberries were thawed, crushed and homogenized.

The post-harvest characterization of the strawberry fruits involved the following laboratory analyzes, performed in triplicate: determination of soluble solids content (SS), performed in digital refractometer and expressed in ºBrix; determination of the titratable acidity (TA), performed by the titration method of Aldofo Lutz Institute (1985) and expressed as a percentage of citric acid; determination of the ratio, relationship between soluble solids contents and titratable acidity (SS / TA); determination of the levels of vitamin C, performed by the standard titration method of Benassi and Antunes (1988) and expressed as mg of ascorbic acid/100g sample; determination of total phenolic contents by the spectrophotometric method of Woisky and Salatino (1998) and expressed in mg of Gallic acid/100 g sample and determination of anthocyanin contents, performed by the spectrophotometric method of the pH difference of Giusti and Wrolstad (2001) and expressed in mg cyanidin-3-glycoside/100 g sample.

Data were submitted to the normality of the residual variances by the Shapiro-Wilk test, followed by analysis of variance and later the means were grouped by the Scott-Knott test at the 5% level of significance with the aid of the statistical program SISVAR version 5.6.

Results and discussion

The analysis of variance indicated that there was a difference ($p < 0.05$) among the strawberry hybrids for all post-harvest characteristics evaluated.

For the soluble solids (SS) (Table 2), the hybrids presented values ranging from 6.3 to 9.7 ° Brix. Hybrids RVFS 13-24 and RVCS 13-07 were the ones that stood out the most for the characteristic, with a very expressive value (both with 9.7ºBrix), differing from other materials. Comparatively, Camargo et al. (2009) found in the same cultivation region values of 8.1°Brix for Camarosa and 9.3°Brix for Sweet Charlie cultivated in the conventional system, these same cultivars were used at the crossing that originated the hybrids evaluated in the present study, which may indicate the probability of related genes inheritance. Antunes et al. (2010) evaluated six commercial strawberry cultivars in the southern region of Brazil and obtained values of 6.8 to 8.7ºBrix, with an average of 7.90ºBrix, which corroborates the average obtained for the evaluated hybrids.

Regarding the titratable acidity content, the highest value was determined in the RVFS 13-07 hybrid (1.11% citric acid), differing from other materials. The acid values obtained with most hybrids approximate to those found by Camargo et al. (2009) in strawberry fruits grown by the conventional method, 0.90% for Camarosa and 0.91% for Sweet Charlie, which proves that in genetic improvement programs the characteristics of interest can be passed on at crossings. The organic acids present in the fruits influence taste, odor, color, stability and quality maintenance. Antunes et al. (2010) determined an average of 0.72% of acidity in fruits of six strawberry cultivars in RS, a value slightly higher than that determined by the authors.

Table 2. Average of soluble solids (SS), titratable acidity (TA), ratio (SS/TA), vitamin C, anthocyanins and phenolics of fruits of 15 strawberry hybrids obtained by crossing of commercial cultivars.

Hybrids	SS (ºBrix)	TA (%citric acid)	SS/TA	Vitamin C (mg ascorbic acid / 100g sample)	Anthocyanin (mg cyanidin-3-glycoside /100g sample)	Phenolic (mg Gallic acid /100g sample)
RVCA 13-06	7.9d	0.95b	8.3c	166.6a	47.8e	191.6b
RVCA 13-08	8.3c	0.99b	8.4c	166.3a	59.0d	197.6a
RVCS 13-02	6.3f	0.74d	8.5c	159.0a	65.7c	191.2b
RVCS 13-07	9.7a	0.86c	11.3a	126.0b	68.2c	192.5b
RVCS 13-10	8.1c	0.87c	9.3c	149.2a	67.1c	197.1a
RVDA 13-01	6.6f	0.69d	9.6c	142.4b	60.7d	197.0a
RVDA 13-11	7.1e	0.85c	8.4c	163.6a	59.7d	195.8a
RVFA 13-14	7.1e	0.81c	8.8c	154.9a	66.0c	195.2a
RVFS 13-07	8.6b	1.11a	7.8c	182.0a	81.0a	193.4b
RVFS 13-24	9.7a	0.82c	11.9a	120.2b	60.2d	191.5b
RVOT 13-11	7.4e	0.72d	10.3b	133.0b	71.8b	180.3c
RVOT 13-22	7.7d	0.71d	10.8b	127.8b	72.4b	175.9d
RVSA 13-08	8.1c	0.80c	10.2b	136.8b	74.3b	193.6b
RVTA 13-16	7.3e	0.82c	8.9c	152.9a	66.5c	195.3a
RVTS 13-06	8.8b	0.85c	10.3b	135.8b	62.1d	195.5a
Means	7.9	0.66	9.52	147.8	65.5	192.2

* Means followed by the same letter in the column did not differ by the Scott-Knott test ($p < 0.05$).

Considering the SS/TA ratio, which is a determinant of commercial fruit quality, two hybrids stood out, RVFS 13-24 (11.9) and RVCS 13-07 (11.3), both of which differed from the other evaluated hybrids. These values are considered to be very satisfactory because, according to Kader (2002), it is highly recommended to have a minimum of 7% soluble solids, and/or a maximum of 0.80% titratable acidity, i.e. this ratio must be higher than 8.75. The RVFS 13-24 and RVCS 13-07 hybrid ratio values were higher than those found by Camargo et al. (2009) for Sweet Charlie (10.30) and Camarosa (8.96) in the same growing region.

The vitamin C contents of the hybrids were divided into two groups. The first group had fruits ranging from 149.2 (RVCS 13-10) to 182.0 (RVFS 13-07) mg of ascorbic acid $100g^{-1}$ and the second group, from 142.4 (RVDA 13-01) to 120.2 (RVFS 13-24) mg of ascorbic acid $100g^{-1}$. According to Lee and Kader (2000), the vitamin C content of strawberry fruits may vary depending on the variety, cropping system, fruit maturation, pre-harvest climatic conditions and post-harvest management. Olsson (2004) still reiterates that between cultivars there may be variation in ascorbic acid concentration of two to three times, which can be evidenced by the results obtained in the present study.

For the anthocyanins characteristic, the highest pigment content was determined in the RVFS 13-07 hybrid (81.0 mg of cyanidin-3-glycoside $100g^{-1}$ sample), which differed from the other evaluated materials. The anthocyanin content may present as a criterion for choosing cultivars because of the health benefits. Musa (2016), in RS, found close values when comparing anthocyanin levels of cultivar Festival and San Andreas. In the conventional system, cv. Festival averaged 46.91 mg $100g^{-1}$ and San Andreas 41.18mg $100g^{-1}$. Already, Calvete et al. (2008) and Antunes et al (2010), also in RS, obtained anthocyanin values ranging from 21 to 56 mg $100g^{-1}$ for eight cultivars and 22.44 to 38.01 mg $100mL^{-1}$ for six cultivars, respectively. Comparatively, anthocyanins values determined in this study were higher than that found by other authors, as reported above, this may have been influenced by weather factors such as temperature and lighting (TEIXEIRA et al., 2008) or by genetic factors influencing the content of secondary compounds in fruits, in the case of strawberry, the differences among the various cultivars that are produced around the world have been extensively reported (VIZZOTTO, 2012).

The phenolic content of the hybrids fruits evaluated in the present study ranged from 175.9 (RVOT 13-22) to 197.6 (RVCA 13-08) mg of gallic acid $100g^{-1}$. Rocha et al. (2008) determined the phenolic content in three strawberry cultivars (Aroma, Toyorrinho and Oso Grande) in the region of Lavras/MG and found, respectively, values of 202.87; 217.14 and 222.85 mg of tannic acid 100 g^{-1} of pulp, higher than those found with hybrids in the Guarapuava region. There are many factors that can influence the phytochemical content in fruits and one of them is the stage of development, the total phenolic compounds content has a decrease from 80 to 90% from the stage where the fruit is green to when it is white and then, maintains this constant value until the end of fruit development. When assessing the effect of different levels of fertilization, using as basis the recommendation of the Chemical and Soil Fertility Commission (SBCS, 2004), the content of phenolic compounds in strawberries has been observed that when the recommended fertilizer level is used or this one plus 50%, the levels of phenolic compounds and antioxidant activity were higher than the other treatments in the Camarosa cultivar, which was not observed in the Festival cultivar, showing that the cultivar factor is very important for the decision of the technologies that will be used, aiming at fruit quality (VIZZOTTO, 2012).

Conclusion

The results obtained here demonstrate that the use of the parents can result in good progenies, however these results are dependent on the combination, since in some crossing, in which these cultivars participated as one of the parents, the results were not so promising.

The characterization of strawberry hybrids in the Guarapuava/PR region indicated that RVFS 13-07, RVFS 13-24, RVCS 13-07, RVCS 13-10 and RVCA 13-08 materials stood out in the post-harvest evaluation, with higher levels of functional compounds (vitamin C, anthocyanins and phenolics) and higher values of quality parameters (soluble solids, titratable acidity and ratio), important characteristics either for the in natura consumption or for by the industry use. These hybrids proved promising to continue the crop genetic improvement program by demonstrating that they carried characteristics of interest at the crossing.

The values obtained for the analyzed characteristics were higher than the values found in the literature for the most planted and consumed cultivars in Brazil and in the world, which demonstrates the efficiency in the selection process.

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