

Postharvest quality of strawberry produced during two consecutive seasons

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ABSTRACT

Maintaining plants in the field for two consecutive crop cycles is one of the latest techniques used by strawberry growers to reduce production costs. The goal of this research was to evaluate the postharvest fruit quality of six strawberry cultivars produced for two consecutive seasons with the same plants. They were planted from May to July 2010 under low-tunnel and fruits were evaluated in two growing seasons (season 1= January, February, and March 2011 and season 2= August, September, and October 2011), totaling three harvests of each cultivar in each year season. Fruits were picked up randomly among 500 plants of each cultivar, organized into five replications of five fruits and kept for three days before analysis under refrigeration (average temperature of 4°C). Variables analyzed were: soluble solids content, titratable acidity, soluble solids content/titratable acidity, flesh firmness, C vitamin content, sensory characteristics (sweetness, flavor, acidity, aroma, shape and flesh firmness), and mineral composition (Ca, Fe, K, Mg, Mn, Cu and Zn). 'Albion', 'Monterey' and 'San Andreas' showed good physical, chemical and sensory characteristics in both seasons. In general, fruits produced during the season 1 showed better physical, chemical and sensory characteristics than fruits produced in season 2. 'Palomar' and 'Portola' were better than the other cultivars concerning C vitamin content in both seasons. 'Palomar' showed higher potassium, calcium, magnesium, manganese and zinc levels, and 'Portola' showed higher calcium and iron levels.

Keywords: *Fragaria x ananassa*, sensorial analysis, antioxidant, minerals, functional food, C vitamin.

RESUMO

Qualidade pós-colheita de morango produzido durante dois ciclos consecutivos

Uma das tecnologias recentes utilizadas pelos produtores de morango visando reduzir os custos de produção é a manutenção das plantas a campo por dois ciclos consecutivos, propiciando duas safras com a mesma muda. O objetivo desta pesquisa foi avaliar a qualidade pós-colheita dos frutos de seis cultivares de morango durante dois ciclos consecutivos com a mesma muda. As mudas foram plantadas de maio a julho de 2010 sob túnel baixo e os frutos foram avaliados em duas épocas (época 1= janeiro, fevereiro e março de 2011; época 2= agosto, setembro e outubro de 2011), totalizando três colheitas de cada cultivar em cada época do ano. Os frutos foram colhidos de forma aleatória dentre 500 plantas de cada cultivar, organizados em cinco repetições de cinco frutos e mantidos por três dias sob refrigeração (temperatura média de 4°C). As variáveis analisadas foram teor de sólidos solúveis, acidez titulável, relação teor de sólidos solúveis/acidez titulável, firmeza de polpa, teor de vitamina C, características sensoriais (doçura, sabor, acidez, aroma, formato e firmeza de polpa) e composição mineral (Ca, Fe, K, Mg, Mn, Cu e Zn). As cultivares Albion, Monterey e San Andreas destacaram-se quanto às suas características físicas, químicas e sensoriais nas duas épocas de cultivo. De maneira geral, os frutos produzidos na época 1 apresentaram melhores características físicas, químicas e sensoriais que os frutos produzidos na época 2. As cultivares Palomar e Portola destacaram-se das demais quanto ao teor de vitamina C nas duas épocas de cultivo. Palomar destacou-se quanto aos teores de potássio, cálcio, magnésio, manganês e zinco e a cultivar Portola quanto aos teores de cálcio e ferro.

Palavras-chave: *Fragaria x ananassa*, análise sensorial, antioxidante, minerais, alimento funcional, vitamina C.

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Strawberry harvest begins at approximately 60/80 days after transplanting plantlets to the field (Cantillano, 2005). One of the recent techniques used by strawberry growers is the biennial crop replanting, in which plants are maintained in the field for two consecutive cycles, allowing two crops with the same plants at Season 1 (January, February and March) and Season 2 (August, September and October), which reduces cost, because plantlets are one of the main costs of strawberry production (Oliveira &

Scivittaro, 2009).

One of the obstacles for the strawberry production is the low number of cultivars available (Oliveira *et al.*, 2008). 'Camino Real' (short-day cultivar) and 'Albion' (day-neutral cultivar), from the University of California Breeding Program, are important cultivars in Southern Brazil. However, other cultivars from the same origin are also occasionally planted, but with very little information about their field performance (Oliveira *et al.*, 2006; Antunes *et al.*, 2010), what is even more

relevant when considering the biennial crop replanting.

Attributes such as fruit size, texture, presence of functional compounds and C-vitamin content depend on genetic and environmental factors and should be considered in the selection of new cultivars (Camargo *et al.*, 2011; Silva *et al.*, 2013; Basu *et al.*, 2014). The food composition has been a frequent focus of researches seeking to identify nutritional differences among cultivars (Tulipani *et al.*, 2008; Cantillano *et al.*, 2012), and also among cultivation techniques

(Darolt, 2003; Cantillano *et al.*, 2012).

Also, strawberry fruits must present good acceptance by the consumer market, because choosing, at the purchase act, is generally based on fruit appearance, but the decision towards buying the same product again depends mainly on the flavor (Kader, 1999). Sensory analysis appears to be an important tool in evaluating the quality of food products (Ferreira *et al.*, 2000). Simple instrumental measurements are not able to predict the sensory characteristics of strawberry cultivars (Vicente *et al.*, 2014). However, few scientific articles studying fruit quality have included sensory evaluations, due to difficulties concerning the judges selection and training, as well as the ethical issues related to researches involving human beings.

Among the sensory analysis methods available to measure the preference of consumers, the Quantitative Descriptive Analysis (QDA) is probably the most widely used method due to the reliability and validity of its results, in addition to its simplicity of execution. The result of evaluating QDA is converted into numerical scores, which are statistically analyzed to determine the preference for a specific sample from the evaluated set (Dutcoski, 2007).

The goal of this research was to evaluate the postharvest fruit quality of six strawberry cultivars (Albion, Camino Real, Palomar, Portola, Monterrey and San Andreas) produced for two consecutive seasons with the same runners.

MATERIAL AND METHODS

This study was carried out in a commercial strawberry farm operating in an Integrated Production Management, under low tunnel structure, in 2010/11, located in São José dos Pinhais, Metropolitan Region of Curitiba (CMR), Paraná state, Brazil (25°36'48"S, 49°04'55"W, 932 m altitude).

Strawberry seedlings of 'Camino Real' and 'Palomar' (short-day cultivars) were transplanted in May 2010 and 'Albion', 'Portola', 'Monterrey' and 'San Andreas' (day-neutral cultivars)

were transplanted in July 2010. These seedlings were transplanted to 33 beds measuring 6 m long, 1 m wide and 0.5 m high, and they were set out 0.3 m apart. Twenty days before transplanting, soil was fertilized with 60 g m² of NPK formula 4-12-8. After that, fertilization was applied weekly, beginning 15 days after transplanting, by fertigation with 12 kg ha⁻¹ of NPK 15-30-15.

Physico-chemical, C vitamin content, and sensory analyses were carried out with fruits harvested in 2011 during two growing seasons (season 1= in January, February and March and season 2= in August, September and October), in a total of three samples of each cultivar from each season. Fruits were harvest at 75% of the external surface with red color. The harvest was carried out from 8 to 10 AM; fruits were picked randomly among 500 plants of each cultivar. The physico-chemical analyses were made with 25 fruits of each cultivar. Fruits were organized into five replications of five fruits and kept for three days before analysis under refrigeration (average temperature of 4°C).

Physico-chemical characteristics evaluated were titratable acidity (TA), soluble solids (SS), both according to the methodology described by Horwitz & Latimer (2005). These analyses provided the values for calculating the SS/TA ratio. Fruit firmness was measured using Brookfield CT3 Texture Analyzer with a probe of 2 mm of diameter, 5 mm of penetration at speed of 5 mm s⁻¹.

C vitamin content was evaluated as recommend by Horwitz & Latimer (2005). Twenty fruit samples of each cultivar were randomly taken from the studied area on January, February and March and on August, September and October. Fifty grams of 2% oxalic acid was added to 25 g of each sample. After that, 20 grams of this solution were taken out and transferred to a 50 mL volumetric flask and filled with oxalic acid. The titration was done with DCFI (2,6, dichlorophenol-indophenol) and with the solution described above, which was filtered in paper, an aliquot of 10 mL being withdrawn for analyzes. Results were expressed in milligrams of

ascorbic acid per 100 g of sample.

Sensory analysis was undertaken with 55 people, who were strawberry consumers and interested in participating on a regular basis of this strawberry sensory analysis. The project aim was explained to the participants when they were first contacted, as well as the importance of their participation, the meanings of sensory analysis terminology, and how the evaluations would be made by QDA methodology, as recommended by Dutcoski (2007).

QDA form containing an unstructured scale of 10 cm for each of the attributes to be evaluated: sweetness, flavor, acidity, aroma, shape, and flesh firmness was presented to each participant. They were trained to register their strawberry opinions on the QDA form from bad to good. These fruits were previously cleaned under running tap water. After training, 22 judges were selected, those that had a higher sensibility and perception for judging each attribute, as recommended by Dutcoski (2007).

During sensory analysis each strawberry cultivar was analyzed three times in each year season. Judges received three samples of five fruits of each cultivar, which were identified by code. Scores given on the QDA scale were converted into numerical scores and analyzed statistically to determine the samples preferences (Dutcoski, 2007). This research in accordance to the ethical research on human beings was approved by the Ethics Committee of the Federal University of Paraná under the number 0950.075.10.06.

For mineral analysis, twenty fruits of each cultivar were randomly harvested in August 2011 and submitted to the analysis of calcium, potassium, manganese, magnesium, iron, copper and zinc, according to Martins & Reissman (2007). For these analyses, fruits were dehydrated in oven at 60°C during approximately five days and grounded in coffee grinder MDR301-Cadence, then a sub-sample of 1 g was extracted for calcination at 550°C and solubilization in 3 M HCl. Elements were determined with conventional atomic absorption spectrophotometer with air/acetylene flame.

Results were submitted to variance

analysis and cultivars were compared to each other and within each season by Tukey 1%.

RESULTS AND DISCUSSION

All cultivars produced fruits during season 1 with higher soluble solids contents than those produced during season 2 (Table 1). This may be explained because plants kept in the field during more than 12 months (season 2) are less vigorous than those harvested sooner (Oliveira *et al.*, 2006). During season 1 'Albion' fruits showed the highest soluble solids content, followed by 'Monterrey'. During season 2 'Palomar' fruits kept this feature, followed by 'Albion' fruits (Table 1).

All strawberry cultivars, in both seasons, showed lower soluble solids

content (Table 1) than those levels observed in other strawberry cultivars (Conti *et al.*, 2002; Resende *et al.*, 2008), and also none of them showed at least 7% soluble solids content, the minimum amount recommended for strawberry flavor acceptance (Kader, 1999).

All cultivars acidity, in both seasons, was higher than 0.8%, the maximum recommended for strawberry flavor acceptance (Kader, 1999). The high fruit acidity in season 1 can be attributed to the high summer temperatures and to the long days, condition under which plants emit stolon that, every two nodes (in general), emits new leaves and roots (Filgueira, 2008). The high acidity in season 2 can also be related to decreasing plant vigor (Oliveira *et al.*, 2006). 'Camino Real' and 'Palomar' showed during the season 1 the lowest

levels of titratable acidity, and during the season 2 it was observed for 'Palomar' and 'Portola' fruits.

Due to the low sugar level and to the high acidity, no cultivar in any season (Table 1) reached the SS/AT of at least 8.75, value recommended for strawberry flavor acceptance (Kader, 1999). The high fruit acidity was probably the main factor compromising SS/AT, mainly in season 2 (Table 1), although the soluble solids content was also lower than recommended. Nevertheless, scientific studies show that 'Camino Real' and 'Albion' fruits can reach higher SS/AT [8.47 in 'Camino Real' (Camargo *et al.*, 2011); 9.13 in 'Camino Real' (Silva, 2011) and 16.26 in 'Albion' (Silva, 2011)]. So, it is possible to assume that it is not recommended to keep strawberry plants in the field for more than 12 months, a usual technology

Table 1. Means of soluble solid content, titratable acidity, soluble solid content/titratable acidity, flesh firmness, and C vitamin content (mg ascorbic acid 100 g⁻¹ fruit) of six strawberry cultivars on growing season 1 (January, February and March) and on growing season 2 (August, September and October) [médias dos teores de sólidos solúveis, acidez titulável, relação do teor de sólidos solúveis pela acidez titulável, firmeza de polpa e teores médios de vitamina C (mg de ácido ascórbico 100 g⁻¹ de fruto) de frutos de seis cultivares de morangueiro produzidas na época 1 (janeiro, fevereiro e março) e na época 2 (agosto, setembro e outubro)]. Curitiba, UFPR, 2011.

Cultivars	Soluble solid content (%)		Titratable acidity (citric acid, %)		SS\TA ratio	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Camino Real	6.23 e A	5.89 b B	0.92 c B	1.51 a A	7.41 a A	3.95 ab B
Palomar	6.43 d A	6.02 a B	0.94 c B	1.17 d A	7.59 a A	5.15 a B
Albion	6.95 a A	5.89 b B	0.99 b B	1.34 a B	7.29 a A	4.41 ab B
Monterrey	6.64 b A	5.11 d B	1.06 a B	1.32 b A	6.52 a A	4.07 ab B
Portola	6.07 f A	4.65 e B	0.98 b B	1.22 c A	6.74 a A	3.83 b B
San Andreas	6.57 c A	5.26 c B	1.04 a B	1.51 a A	6.53 a A	3.53 b B
F	9.60		1.69		0.86	
CV (%)	7.71		168.00		6.68	
	Flesh firmness (N)		C vitamin content (mg ascorbic acid/100 g)			
	Season 1	Season 2	Season 1		Season 2	
Camino Real	69.44 ab B	145.20 a A	69.44 ab B		145.15 a A	
Palomar	77.23 a A	86.14 c A	77.23 a A		86.14 c A	
Albion	49.76 b B	113.10 ab A	49.76 b B		113.12 ab A	
Monterrey	70.39 a B	99.23 bc A	70.39 a B		99.23 bc A	
Portola	72.16 a B	120.50 ab A	72.16 a B		120.53 ab A	
San Andreas	74.74 a B	97.84 bc A	74.74 a B		97.84 bc A	
F	6.25		9.72			
CV (%)	4.85		2.79			

Mean values followed by same lowercase letters in the columns and uppercase in rows do not differ by Tukey test, $p \leq 0.01$ [médias seguidas de mesma letra minúscula na coluna e maiúscula na linha não diferem estatisticamente entre si pelo teste de Tukey ($p \leq 0.01$)].

Table 2. Means for fruit acidity, aroma, shape, and flesh firmness of six strawberry cultivars on growing season 1 (January, February and March) and on growing season 2 (August, September and October) evaluated by Quantitative Descriptive Analysis [médias das notas atribuídas para acidez, aroma, formato e firmeza de polpa de frutos de seis cultivares de morangueiro produzidas na época 1 (janeiro, fevereiro e março) e na época 2 (agosto, setembro e outubro) e avaliadas por Análise Descritiva Quantitativa]. Curitiba, UFPR, 2011.

Cultivars	Aroma		Shape		Acidity		Flesh firmness	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Camino Real	6.72 abA	5.28 b B	7.95 a A	6.59 b B	7.26 a A	7.11 a A	7.55 a A	7.20 ab A
Palomar	6.11 abA	6.39 a A	7.44 a A	7.27 abA	6.71 ab A	6.32 a A	7.36 a A	6.99 b A
Albion	7.49 a A	6.76 a B	7.59 a A	7.35 abA	6.77 ab A	7.01 a A	7.82 a A	7.24 ab B
Monterey	6.74 abA	6.05 abB	7.55 a A	7.76 a A	7.18 ab A	7.08 a A	7.50 a A	7.36 ab A
Portola	6.23 b A	6.08 abA	7.74 a A	7.54 a A	6.37 b A	6.78 a A	7.43 a A	7.70 a A
San Andreas	6.86 abA	6.56 a A	7.90 a A	7.45 a A	7.07 ab A	7.22 a A	7.69 a A	7.56 ab A
F	33.52		4.49		0.85		1.57	
CV (%)	27.30		29.58		31.25		27.83	

Mean values followed by same lowercase letters in the columns and uppercase in rows do not differ by Tukey test, $p \leq 0.01$ [médias seguidas de mesma letra minúscula na coluna e maiúscula na linha não diferem estatisticamente entre si pelo teste de Tukey ($p \leq 0.01$)].

applied in CMR. This statement is in agreement with the annual replanting recommendations, although this represents 24% of the production costs (Oliveira & Scivittaro, 2006). The annual replanting recommendation prevents the accumulation of pests and diseases from one year to another (Oliveira *et al.*, 2006), and also certainly maintains plants vigorous. However, even with the low ratio (SS/AT), the local consumers buy these products routinely, clearly demonstrating the need for implementation of more sensory analysis to improve fruit quality.

Strawberry fruits with flesh firmness lower than 83.55 N are considered too soft, and when it is higher than 135.16 N are considered too firm (Conti *et al.*, 2002). In this way, at season 1 all cultivars produced fruits considered too soft (Table 1). This parameter is very important because it affects the post-harvest shelf life and transport damage occurrence (Bieniasz *et al.*, 2012). These results may be due to high temperatures and high relative humidity in summer time (data not presented), which give fruits a less firm texture (Filgueira, 2008). Among all fruits harvested during season 1 'Albion' was that with softest firmness, and should be chosen with a lot of care, mainly when the product final destination is to distant markets.

All fruits showed lower C vitamin content during season 1 than during

the season 2 (Table 1). This result can be explained because C vitamin is heat-labile, and easily oxidized if exposed to high temperature (Calegario *et al.*, 2002). Higher C vitamin content during the coldest season was also found in strawberry fruits by Pineli *et al.* (2012). 'Palomar' and 'Portola' fruits showed higher C vitamin content in both growing seasons (Table 1). This suggests that these cultivars can be promising when the cultivation purpose is focused on fruits antioxidant potential, such as verified in strawberry juices (Wan & Lin, 2003). C vitamin content was similar to the content found by Malgarim *et al.* (2006), and below to the values found by Rocha *et al.* (2008).

The physiological behavior of short-day strawberry cultivars is correlated with temperature and photoperiod, and as the photoperiod decreases, flowering and fruiting are stimulated (Filgueira, 2008). However, 'Camino Real' and 'Palomar' (both short-day cultivars) were not better than the day-neutral cultivars, grown during the season 2. This demonstrates the high day-neutral cultivars adaptation. Day-neutral cultivars grown during season 1 were expected to be better than short-day cultivars, but this did not occur (Table 1). Different cultivars performances within the same planting season can be explained by the genotypic components and its environment interaction. Local

weather conditions, such as rain, light intensity, and temperature, probably affected the strawberry cultivar performance, as well as found by Pineli *et al.* (2012).

Sweetness sensory scores were smaller than those assigned in other sensory attributes analyzed, and they were similar during the two growing seasons, from 5.50 to 6.48 (Table 2). Similar behavior was observed on fruit flavor, with scores ranging from 5.87 to 6.72. These results for sweetness and taste reflect the low soluble solids content (Table 1). It agrees with Resende *et al.* (2008) who evaluated strawberry cultivars ratios (SS/TA) and fruits consumer's acceptability. They observed that higher ratios (SS/TA) were associated with better fruit flavor perception.

Sensory analysis did not verify acidity differences between the two growing seasons (Table 2), such as was verified by chemical analysis (Table 1). As could be expected, scores assigned for this parameter (Table 2) were almost as low as those assigned to sweetness and flavor. This demonstrates that even though the local market consumes the product, it does not present a good acceptability.

Minimum differences were verified on the fruits aroma in both seasons (Table 2), but apparently there was a trend showing that this parameter was

Table 3. Means for K, Ca, Mg, Fe, Mn and Zn content on six strawberry cultivars [teores médios de K, Ca, Mg, Fe, Mn e Zn presentes em seis cultivares de morangueiro]. Curitiba, UFPT, 2011.

Cultivars	K (g/kg)	Ca (g/kg)	Mg (g/kg)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
Camino Real	16.99b	0.33bc	1.08b	21.76c	14.91d	5.88b
Palomar	20.59a	0.39a	1.33a	23.35c	20.31a	6.79a
Albion	18.18b	0.29cd	1.01b	26.21b	19.82a	5.88b
Monterey	16.50b	0.36ab	1.00b	16.29d	17.70b	5.85b
Portola	16.08b	0.37a	1.10b	36.80a	16.17c	5.86b
San Andreas	18.34ab	0.25d	1.02b	15.64d	13.00e	6.92a
F	10.05	27.36	11.85	281.90	148.60	33.54
CV (%)	5.84	6.09	6.69	3.96	2.75	2.85

Mean values followed by same lowercase letter in the columns and uppercase in rows do not differ by Tukey test, $p \leq 0.01$ [médias seguidas da mesma letra na coluna não diferem estatisticamente entre si pelo teste de Tukey ($p \leq 0.01$)].

not so good evaluated in season 1 as it was in season 2. This may have occurred because fruit aroma comes from volatile compounds, which do not manifest themselves under low temperatures with such intensity, due to the lower plants metabolic activity during the cold season. This agrees with observations of Jouquand *et al.* (2008) that one of the factors affecting strawberry fruits aroma is the harvest season.

Cultivars showed similar fruit shape during the two growing seasons, except for 'Camino Real', harvested during season 2, which corresponds to the winter period (Table 2). Strawberry fruits shape depends on ovules fertilization, and their distribution around the receptacle. In order to obtain fruits without deformations, a uniform pollen distribution on stigmas is needed (Malagodi-Braga, 2002). This distribution can be made by pollinators. Insects absence during flowering period, associated with insufficient pollen amount, can result in fruit deformation (Chang *et al.*, 2001). Presumably the short amount of pollinator insects occurring during the winter season, combined with morphological 'Camino Real' features decreased the flower fertilization, causing fruits malformation and the worst sensory analysis.

Fruits produced during season 1 showed similar flesh firmness (Table 2). However, during season 2 'Palomar' fruits were worse than the others (Table 2). By comparing the analysis, carried out

with the texture analyzer (Table 1) and the sensory analysis, a greater accuracy of the mechanical method comparing with sensory ability was identified. These results clearly demonstrate the importance of implementation of the sensory analysis along with the physico-chemical analysis, which in this situation did not reflect the consumer preference.

Mineral composition depends on the evaluated cultivar (Table 3), such as was observed by Tulipani *et al.* (2008) and Pineli *et al.* (2012). Under these conditions most nutrients were higher on 'Palomar' fruits except for iron (Fe) level, whose superiority was of 'Portola' fruits. Copper (Cu) was the only mineral that did not present significant differences among cultivars (Table 3). This information is very important when the purpose of strawberry production is its nutritional property (Rocha *et al.*, 2008).

Potassium (K), calcium (Ca), iron (Fe), and manganese (Mn) levels (Table 3) were similar to those found in strawberry fruits by Wang & Lin (2003), and smaller than the values found in strawberry fruits by Rocha *et al.* (2008). Zinc (Zn) level (Table 3) was lower than that found in strawberry fruits by Wang & Lin (2003) and Rocha *et al.* (2008). This can be explained because the nutritional composition is multifactorial, i.e., it is affected by soil, weather, and/or genetic composition (Darolt, 2003).

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