



PRODUCTION, CHEMICAL COMPONENTS, AND CONTENT OF BIOACTIVE COMPOUNDS OF STRAWBERRY CULTIVARS

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ABSTRACT

There are only a few strawberry cultivars available in Brazil and all are imported from North America and Europe. Thus, the introduction of new materials and their evaluation under Brazilian environmental conditions is imperative. The objective of this study was to evaluate the production, chemical components, and concentration of bioactive compounds in strawberry cultivars under edaphoclimatic conditions in the municipality of Pelotas-RS. The experiment was conducted in the field with low tunnels in 2011 and 2012. The experiment in the field was arranged in a completely randomized design, with eight treatments (cultivars), four replications. Each plot consisted of nine plants. The experiment in laboratory was arranged in a completely randomized 8x3 factorial design (8 cultivars and 3 months of harvest) and 4 replications. The variables analyzed were fruit number and fruit mass per plant, production, yield, soluble solid content, titratable acidity, ascorbic acid, anthocyanins, phenolic compounds, and antioxidant activity. Cultivar and harvest month influenced acidity, and the contents of soluble solids, ascorbic acid, and bioactive compounds. Cultivar Camarosa showed higher production, and higher contents of anthocyanin, phenolic compounds, and soluble solids. Cultivars 'Palomar and 'Aromas' stand out for the content of ascorbic acid.

Palavras-chave:

Adaptação
Antocianinas
Compostos fenólicos
Fragaria x ananassa Duch
Genótipo
Sólidos solúveis

PRODUÇÃO, COMPONENTES QUÍMICOS E CONTEÚDO DE COMPOSTOS BIOATIVOS DE CULTIVARES DE MORANGUEIRO

RESUMO

O número de cultivares de morangueiro disponíveis no Brasil é pequeno, sendo sua totalidade importada da América do Norte e da Europa. Desta forma, é de suma importância a introdução de novos materiais e avaliação desses em condições ambientais brasileiras. O objetivo deste trabalho foi avaliar a produção, os componentes químicos e a concentração de compostos bioativos de cultivares de morangos produzidos nas condições edafoclimáticas de Pelotas-RS. O experimento foi conduzido em solo, com túnel baixo em 2011 e 2012. O delineamento adotado para o experimento a campo foi o inteiramente casualizado, com oito tratamentos (cultivares) e quatro repetições, onde cada unidade experimental foi composta por nove plantas. Para as avaliações de laboratório, inteiramente casualizado, em esquema fatorial 8x3 (oito cultivares e três meses de colheita) e quatro repetições. Avaliou-se número e massa de frutas planta⁻¹, produção, produtividade, conteúdo de sólidos solúveis, acidez titulável, ácido ascórbico, antocianinas, compostos fenólicos e atividade antioxidante. A cultivar e o mês de colheita influenciaram no teor de sólidos solúveis, acidez, teor de ácido ascórbico e conteúdo de compostos bioativos. Observou-se maior produção, teor de antocianinas, compostos fenólicos e sólidos solúveis para a cultivar Camarosa. 'Palomar e 'Aromas' destacam-se quanto ao conteúdo de ácido ascórbico.

INTRODUCTION

According to estimates made by FAO, Brazil is not among the world's leading strawberry producers: an area of only 400 hectares is reported and annual production of 3,390 tons (FAOSTAT 2019).

The domestic strawberry production is almost all directed to the fresh fruit market (98%) (ANTUNES; PERES, 2013); however, it is still insufficient to supply the internal market due to the growing annual consumption. Furthermore, the strawberry cultivation is an activity of considerable economic importance because of its high profitability per area.

The choice of cultivars is one of the factors that largely determine the success of strawberry cultivation. Cultivars must be adapted to the edaphoclimatic characteristics of each region, especially temperature and photoperiod (DUARTE FILHO *et al.*, 2007). Flowering and fruit setting of strawberry are decisively influenced by climatic conditions, cultural practices, and genetic characteristics of the cultivars. Thus, a high-yielding cultivar in a certain region may not adapt to another environment and not result in high yields (PEREIRA *et al.*, 2013).

Flowering, fruiting, and consequently the production of strawberries, as well as the sugar and acid content of the fruits are influenced by the cultivar, among other factors (CRESPO *et al.*, 2010; PEREIRA *et al.*, 2013; GUNDUZ; OZDEMIR, 2014). Possibly, genetics is also linked to other fruit quality characteristics and attributes related to healthiness, which are valued by the increasingly demanding consumer market.

In this sense, identifying cultivars that adapt to the growing conditions in the region of Pelotas-RS and produce consumer-appealing fruits is a challenge to be met. In this sense, this study aimed to evaluate production, physicochemical quality, and content of bioactive compounds in strawberry cultivars produced under the edaphoclimatic conditions in Pelotas-RS.

MATERIAL AND METHODS

The experiment was conducted in the field for

two consecutive years, 2011 and 2012, in an area belonging to Embrapa Temperate Climate, Pelotas-RS, 31°40'S, 52°26'W; 60m. The climate of the region is subtropical mesothermal-humid (Cfb), with no dry season and mild winters (KÖPPEN, 1931). In 2011, rainfall ranged from 96.4 to 78.7 mm from July to October. In 2012, in the same months, the rainfall ranged from 106.9 to 162.8 mm (EMBRAPA 2014). The soil in the experimental area is classified as typic eutrophic Red Argisol (EMBRAPA, 2006).

The field experiment was arranged in a completely randomized design, with eight treatments (cultivars) and four replications. Each plot consisted of nine plants. The experiment in laboratory was arranged in a completely randomized 8x3 factorial design (8 cultivars: Festival, Camarosa, Camino Real, Aromas, Portola, Albion, San Andreas, Monterey, and Palomar, and 3 months of harvest: August, September, and November), and four repetitions. A sampling was conducted by collecting 1 kg of fruit for each sample, of which four replications were used for the phytochemical analyses and three replications for the physicochemical analyses.

Analysis of Variance (ANOVA) and the F test ($P \leq 0.05$) were conducted with the data, and if significant, they were compared by the Tukey or Scott Knott test at 5% significance.

Plug strawberry transplants were purchased from the Patagonia region. Planting in 2011 included three short-day cultivars: Festival (University of Florida), Camarosa, and Camino Real (University of California); and five neutral-day cultivars: Aromas, Portola, Albion, San Andreas and Monterey (University of California). In 2012, the same cultivars were evaluated, except that 'Festival' was replaced by 'Palomar'.

At the time of transplanting, in both years, the roots were pruned as described by Cocco *et al.* (2012). Transplanting was carried out as soon as cultivars were available, at different planting dates and, consequently, harvest dates also varied (Table 1).

Planting was done in the conventional system: in 20 m long, 1.1 m wide, and 0.2 m high raised beds, mulched by 40- μ m-thick black polyethylene, for three rows of plants spaced 0.3 x 0.3 m, in a

population of 62500 plants per hectare, covered by low tunnels of 100µm thick transparent low-density polyethylene held by polyvinyl chloride (PVC) hoops of 0.8 m maximum height.

The sides of the low tunnel were opened according to weather conditions. On sunny days, they were opened early in the morning (8:00 am) and in the late afternoon (5:00 pm) they were closed. On rainy days, the tunnels were kept closed.

A drip irrigation system consisting of two drip lines was used to water the plants in the bed twice a week. Chemical fertilization was carried out according to the recommendations for the crop (SANTOS; MEDEIROS, 2003). The plants were fertigated twice a week with 50g of 18-18-18 KristalonTM. During the crop cycle, dry leaves, stolons, and fruits with disease symptoms were removed from the plants.

Phytosanitary control was carried out by monitoring plants (curative) using fungicides, insecticides, and acaricides recommended for the crop and registered with the Ministry of Agriculture and Livestock (MAPA), as symptoms appeared, throughout the crop cycle.

The harvest began in the first half of August in the 2011 crop and at the end of July in 2012 and lasted until the second half of January 2012 in the 2011 crop and until the last day of November in the 2012 crop. It was done twice per week. Strawberries were picked fully ripe, with 100% red color, weighed on a digital scale, and counted.

Production was obtained by weighing the total mass of the harvested strawberries. The mass obtained by summing all harvests during the experiment was divided by the number of plants in the experimental plot, consisting of nine plants, and the ratio between them represented the average

production per plant. The results were expressed as fruit fresh mass per plant (g plant⁻¹). Yield was estimated as t ha⁻¹ and calculated as the number of plants per unit area, considering a population of 62500 plants ha⁻¹. The mean fruit mass (g) was calculated by dividing the total fruit mass plant⁻¹ by the number of fruit plant⁻¹. The mean number of fruit was obtained by counting the strawberries and dividing by the number of plants in the plot.

The chemical evaluations, contents of ascorbic acid, phenolic compounds, anthocyanins, and the antioxidant activity were determined for strawberries produced only in 2012, in September, October, and November, with a 30-day interval between evaluations.

All analyses were performed at the Food Center of Embrapa Temperate Climate, Pelotas, RS.

Fruit were handpicked at random in the first hour of the morning. First, they were placed on a tray, then into plastic bags labeled with the cultivar name, stored in a Styrofoam box, and transported to the laboratory.

In the laboratory, initially, fruits were selected by discarding the rotten ones, and the leaves were removed. Afterwards, two samples were separated: one for the physicochemical analysis and the other for the analysis of bioactive compounds. The sample for the analysis of bioactive compounds was frozen at -18 °C for the further analyses of anthocyanins, phenolic compounds, and determination of the antioxidant activity. Soluble solids (SS), titratable acidity (TA), and ascorbic acid content were evaluated using fresh fruit.

Soluble solids, titratable acidity, and ascorbic acid content were determined using the juice centrifuged from 100g of fresh sample, with three replications. The soluble solids content

Table 1. Planting and harvest dates in the two years (2011-2012) of evaluation of strawberry cultivars

Cultivar	Year 2011		Year 2012	
	Planting date	Harvest data	Planting date	Harvest data
Festival	05/18	08/01	-	-
*Palomar	-	-	05/30	07/31
Camarosa	05/18	08/16	04/23	07/31
Camino Real	05/18	08/30	07/04	08/13
Aromas	06/29	09/13	07/04	09/10
Portola	06/29	09/06	07/04	09/10
Albion	06/29	09/06	04/23	07/24
San Andreas	06/29	09/06	04/23	07/24
Monterey	06/29	08/30	07/04	09/10

*'Palomar' short day cultivar replaced the non-available cultivar Festival in 2012

was determined in a digital refractometer, with temperature corrected to 20°C. A drop of pure juice was read and the result was expressed as ° Brix. Titratable acidity was determined by the potentiometric method, with a 0.1 N NaOH solution until reaching pH 8.1 and was expressed as the percentage of citric acid (%). All determinations followed the methods described in AOAC (2000). The SS/TA ratio was calculated (soluble solids content divided by the titratable acidity) for the different cultivars (BRACKMANN *et al.*, 2011).

The ascorbic acid content was quantified by titration of L-ascorbic acid with a 2,6-dichloroindophenol solution, according to the methodology of AOAC (2000).

To quantify the bioactive compounds and determine the antioxidant activity, the step of total extraction of the compounds (anthocyanins and phenolic compounds) was carried out first, with four replications.

In the extraction, a solution of 95% methanol acidified with a 1.5 M HCL was used in the proportion of 85:15.

To obtain the extract, the samples were centrifuged at - 4 °C until total separation of the supernatant. Then, the content of anthocyanins, phenolic compounds and antioxidant activity were quantified using the extract.

The quantification of total anthocyanins was performed using the methodology adapted from Fuleki and Francis (1968). Samples were read at 535nm in a spectrophotometer (Thermo Spectronic, Genesys 10uv). The results were calculated using a standard curve of cyanidin-3-glycoside and expressed as mg cyanidin-3-glycoside.100 g⁻¹ sample (FULEKI; FRANCIS, 1968).

The total phenolic compounds were determined by the method described by Swain and Hillis, 1959. The phenolic compounds were quantified by means of a colorimetric reaction using the Folin-Ciocalteu reagent. Sample readings were taken in a spectrophotometer at 765nm, after 2 hours of reaction. The results were expressed as mg chlorogenic acid.100g⁻¹ fresh fruit, which were obtained from a standard curve (SWAIN; HILLIS, 1959)

The total antioxidant capacity was measured against the stable radical DPPH (2,2-diphenyl-1-picrylhydrazyl), according to the method described by Brand-Williams *et al.* (1995). The reaction was carried out with a DPPH solution (0.044 g L⁻¹) and the absorbance was measured at 515nm after

24h of reaction in a place protected from light, at room temperature (below 25°C). The antioxidant activity was determined with a standard trolox curve and expressed as mg trolox eq .100g⁻¹ fresh fruit (BRAND –WILLIAMS *et al.*, 1995).

RESULTS AND DISCUSSION

In the 2011 harvest, the strawberry cultivars Festival, Camarosa, Aromas, and Monterey were the most productive (Table 2), with average production ranging from 741.89 to 876.12 g.plant⁻¹. They were followed by the cvs. Portola, Camino Real, and San Andreas (561.61 to 594.00 g.plant⁻¹), which were also not statistically different. The least productive cultivar was Albion (420.58 g.plant⁻¹).

Results of this study obtained in 2011 are similar to the reports of Vignolo *et al.* (2011) for cvs. Camarosa (813.2 g.plant⁻¹) and Camino Real (540.4 g.plant⁻¹) from a research carried out in Pelotas-RS. However, Pereira *et al.* (2013), in a study conducted in the south of Minas Gerais (22°28'16"S, 46°08'42"W, 1,375 m altitude), found lower production during the productive stage. The authors reported the values of 322.30 g.plant⁻¹ for cv. Festival, 372.06 g.plant⁻¹ for cv. Aromas, and 358.06 g.plant⁻¹ for cv. Camarosa, which is probably due to edaphoclimatic differences. Ruan *et al.* (2013) evaluateated neutral day cultivars and obtained 294.8 g.plant⁻¹ for Albion, 333.6 g.plant⁻¹ for Monterey, 309.1 g.plant⁻¹ for San Andreas and 524.4 g.plant⁻¹ for Portola, which, except for the similar results of Portola, the other cvs showed productions lower than those of this work.

In 2012, the production of strawberries was much lower than in 2011, with values among cultivars ranging from 137.97 to 381.5 g.plant⁻¹ as well as the cvs showing different behaviors (Table 2). Cultivar Camarosa was the most productive (381.5 g.plant⁻¹), followed by cv. Albion (263.86 g.plant⁻¹), then Portola, Aromas, Palomar, San Andreas, which were not significantly different, varying from 137.97 to 207.19 g.plant⁻¹. The cvs. Monterey and Camino Real were the least productive in 2012, with production ranging from 60.11 to 73.55 g.plant⁻¹. The year 2012 was atypical for strawberry production in the region of Pelotas, with high rainfall, from 106.9 to 162.8 mm, from July to October, while rainfall in 2011 varied from 96.4 to 78 .7 mm (Table 3). It may also have been influenced by the winds that reached 75.6 km h⁻¹ in September 2012 (EMBRAPA, 2014).

Table 2. Number of fruit plant⁻¹, production, yield, and mean fruit mass of strawberry cultivars (*Fragaria x ananassa* Duch.) in the 2011 and 2012 harvests. Pelotas-RS, Embrapa Temperate Climate, 2021

Cultivar	Mean number (fruit.plant ⁻¹)	Production (g.plant ⁻¹)	Yield (t.ha ⁻¹)	Mean fruit mass (g.frut ⁻¹)
2011				
Camarosa	53.71 b	788.06 a	49.25 a	14.69 b
Aromas	48.86 b	741.89 a	46.37 a	15.16 b
Monterey	48.84 b	808.86 a	50.55 a	16.57 a
Portola	35.70 c	578.4 b	36.15 b	16.26 a
Festival	67.83 a	876.12 a	54.75 a	12.92 c
Camino Real	33.97 c	594.00 b	37.12 b	17.51 a
San Andreas	31.42 c	561.61 b	35.10 b	17.88 a
Albion	24.73 d	420.58 c	26.29 c	17.06 a
CV (%)	9.5	10.17	10.17	5.72
Mean	43.13	671.19	41.95	16.00
2012				
Camarosa	27.92 a	381.5 a	17.15 a	13.6 b
Aromas	15.61 b	197.45 c	8.87 c	12.58 b
Monterey	5.83 d	73.55 d	3.31 d	12.54 b
Portola	16.22 b	207.19 c	9.31 c	12.78 b
Palomar	14.77 b	165.83 c	7.45 c	11.17 b
Camino Real	5.93 d	60.11 d	2.70 d	11.90 b
San Andreas	11.03 c	137.97 c	6.2 c	12.47 b
Albion	15.84 b	263.86 b	11.86 b	16.67 a
CV (%)	17.65	21.34	24.38	7.81
Mean	14.03	185.93	8.36	12.96

Means followed by different letters in the column are significantly different by the Scott-Knott test at 5% probability

Table 3. Averages of temperature and total precipitation for the harvests 2011/2012 and 2012/2013 in Pelotas, RS. Embrapa Temperate Climate, Pelotas, RS, 2021

Month	Average temperature (°C)		Total rainfall (mm)	
	2011	2012	2011	2012
April	-	18.5	-	47.2
May	16.0	18.1	100.2	14.1
June	13.4	13.9	101.5	56.5
July	12.2	11.6	96.4	162.8
August	13.1	17.4	110.9	108.1
September	15.0	16.7	104.8	146.8
October	13.3	19.6	78.7	106.9
November	20.6	22.1	70.9	40.6
December	21.1	-	66.5	-
January	23.1	-	80.2	-

Source: Agrometeorology Laboratory of Embrapa Temperate Climate

Ballington *et al.* (2008) evaluated the production of neutral-day strawberry cultivars in 2002, 2003, and 2004. Similarly, the authors found variation between cultivars and between years. They found

productions for cvs Everest and Seascope of 430 g.plant⁻¹ in 2002, while in 2004, values ranged from 710 to 968 g.plant⁻¹.

The largest number of fruit.plant⁻¹ (Table 2) in

2011 was recorded for cv. Festival (67.83 fruit.plant⁻¹), followed by cvs. Camarosa, Aromas, and Monterey, which ranged from 48.84 to 53.71 fruit.plant⁻¹. In 2012, cv. Camarosa (27.92 fruit.plant⁻¹) stood out and was followed by cvs. Palomar, Aromas, Portola, and Albion with means varying from 14.77 to 16.22 fruit.plant⁻¹, which were not statistically different. For the same cultivars, Vignolo *et al.* (2011), reported means from 26.5 to 43.6 fruit.plant⁻¹ and Ruan, Lee, and Young (2013) from 36.9 to 42.7 fruit.plant⁻¹. However, Pereira *et al.* (2013) obtained lower means, ranging from 17.84 to 21.81 fruit.plant⁻¹.

The cultivars that stood out for mean fruit mass in 2011 were Monterey, Portola, Camino Real, San Andreas, and Albion, varying from 16.26 to 17.88 g. Cultivar Festival produced a larger number of fruits and had a greater production, however, the fruits presented less mass, around 12.92g. Genetic characteristics and the management determine fruit size; it also depends on the fruit load, but there is not always a direct relationship between increased productivity and decreased fruit size and vice versa

In 2012, cv. Albion had the highest fruit mass, with 16.67 g per fruit, but the others showed masses from 11.17 to 13.6 g, which were not statistically different. These masses are in agreement with the results of Resende *et al.* (2010) who reported means from 8.45 to 16.09 g per fruit for the cultivars Dover, Sweet Charlie, Camarosa, and Oso Grande. These results also corroborate Vignolo *et al.* (2011), who found 18.5 g for cv. Camarosa and 20.2g for cv. Camino Real. This demonstrates the influence of the genotype on the productive behavior of cultivars, in addition, the productive response is affected by climatic factors such as rainfall. In addition, the year 2012 was atypical for fruit production in the region of Pelotas, not only due to rainfall that was higher from July to October (Table 3) – months of higher production – but also due to the incoming winds, which achieved 75.6 km/h in September 2012 and harmed inflorescences, bee activity, and, consequently, pollination.

The evaluation of the quality of the fruits in terms of soluble solids content, acidity, and the balance between sweetness and acidity (SST/ATT) showed an interaction ($p \leq 0.05$) between cultivar and harvest month (Table 4). Jouquand *et al.* (2008)

also observed variation in the content of chemical components of strawberry between harvest months, showing that climatic factors may influence the production of these compounds. However, Crespo *et al.* (2010) and Gunduz and Ozdemir (2014) found a greater influence of the genetic factor on the production of these compounds compared to factors such as the production system and cultivation site.

The content of soluble solids (SS) and titratable acidity (TA) in strawberries were higher in November (°Brix from 7.8 to 9.95 and acidity from 0.70 to 0.93) than in September (°Brix from 7.2 to 8.7 and acidity from 0.69 to 0.80) and October (°Brix from 5.6 to 7.4 and acidity from 0.68 to 0.94) for the cultivars evaluated (Table 4). Except for the cultivar Albion (Soluble Solids and Acidity) and Portola (Acidity). This behavior can be explained by the progressive increase in light intensity and temperature from August to December in Rio Grande do Sul. Periods of greater light intensity and higher temperatures favor the metabolism of plants, inducing accumulation of sugars. This variable may also be related to the degradation of starch into glucose at the end of ripening, favored by environmental conditions, since temperature is an effective enzyme activator (reaction catalyst). Nevertheless, it was not possible to evaluate the chemical components in the cultivars Monterey, Camino Real, San Andreas, and Camarosa because the amount of fruit produced during the 2012 productive stage was not enough for the analyses, leading the authors to ponder what could have caused this reduction?

The balance between sweetness and acidity in the strawberry decisively influences fruit acceptance and can be examined by the ratio between the content of soluble solids and titratable acidity (SST/ATT). Among the cultivars, Palomar had the highest means for this variable in September (11.69) and October (10.42). In November, when light increases and, consequently, photosynthesis is favored, SST/ATT become higher and closer among cultivars (10.77 to 11.88), except for cv. Albion (9.71), but cv. 'Aromas' stood out.

The soluble solid content and the titratable acidity found in the literature for strawberries varies according to the cultivar, cultivation

Table 4. Physicochemical characteristics of strawberry cultivars harvested in September, October, and November 2012. Pelotas-RS, Embrapa Temperate Climate, 2012. Pelotas-RS, Embrapa Temperate Climate, 2021

		Soluble solids (°Brix)		
Cultivar	September	October	November	
Camarosa	8.7aB	7.4aC	9.95aA	
Aromas	7.2eB	5.6cC	9.15bA	
Albion	8.2bcA	7.3aB	8.35cC	
Palomar	8.4bA	7.4aB	8.3cA	
Portola	7.5dB	5.9bC	7.8dA	
CV (%)		1.14		
		Acidity (% Citri acid)		
Cultivar	September	October	November	
Cultivar	Setembro	Outubro	Novembro	
Camarosa	0.79aB	0.76bC	0.93aA	
Aromas	0.69dC	0.75bB	0.77cA	
Albion	0.75bC	0.94aA	0.86bB	
Palomar	0.72cB	0.71cB	0.74cA	
Portola	0.80aA	0.68dC	0.70dB	
CV (%)		3.03		
		SS/AT ratio		
Cultivar	September	October	November	
Camarosa	11.01bA	9.65bB	10.77bA	
Aromas	10.44cdB	7.47dC	11.88aA	
Albion	10.92bcA	7.74dC	9.71cB	
Palomar	11.69aA	10.42aC	11.16bB	
Portola	9.37eB	8.63cC	11.04bA	
CV (%)		1.72		
Cultivar		p≤0.05		
Month		p≤0.05		
Cultivar x month		p≤0.05		

Means followed by different small letters in the columns and different capital letters in the rows are significantly different by the Tukey test at 5%. ns= non significant

system, and climatic conditions prevailing in the production year. The means obtained in this work are consistent with the literature, with soluble solids content ranging from 5.8 to 10° Brix (ANTUNES *et al.*, 2010; MASNÝ; ZURAWICZ, 2010) and titratable acidity from 0.40 to 0.98% (ANTUNES *et al.*, 2010; PORTELA *et al.*, 2012).

Recent studies have shown that bioactive compounds such as anthocyanins and phenolic compounds have therapeutic properties and high antioxidant potential (ALVAREZ-SUAREZ *et al.*, 2014; KRUGER *et al.*, 2014). Our results presented in Tables 5 and 6 show the influence of the cultivar factor on the content of ascorbic acid, anthocyanins,

phenolic compounds, and antioxidant activity, as well as on the content of soluble solids and organic acids.

Ascorbic acid is a water-soluble compound, has antioxidant activity and plays an important role in the human immune system. Table 5 shows the values for this compound ranging from (42.33 to 81.08 mg.100mL⁻¹ for strawberry cultivars evaluated during the 2012 production cycle. In the same manner, Singh *et al.* (2011) and Crespo *et al.* (2010) quantified the ascorbic acid content of strawberry cultivars and found a wide range between them. Crespo *et al.* (2010) reported ascorbic acid from 20 to 70 mg.100g⁻¹

for strawberries grown in different regions while Singh *et al.* (2011) compared cultivars and found a range from 68.32 to 95.17 mg.100g⁻¹, except for the cv. Ofra, which differed from the others with 107.50 mg.100g⁻¹.

In this study, cv. Palomar had the highest ascorbic acid content, ranging from 65.08 to 81.08 mg.100mL⁻¹ in September and October, but in November, cv. Aromas showed the highest content (78.3 mg.100mL⁻¹). At harvest, the fruits picked in October had the highest ascorbic acid content, followed by berries harvested in November and then in September. In the same way as the chemical components, quantification of ascorbic acid content in the cultivars Monterey, Camino Real, and San Andreas was not possible due to lack of production in 2012, which was caused by plant depletion.

The content of anthocyanins ranged from 40.81 mg.100g⁻¹ for cv. Aromas in October to 92.18 mg.100g⁻¹ for cv. Camarosa in September (Table 6). Camarosa produced the greatest amount of compounds throughout the production cycle. Singh *et al.* (2011) also found variation in the content of anthocyanins among strawberry cultivars and reported values from 40.53 to 125.41 mg.100g⁻¹. Josuttis *et al.* (2012) recorded contents ranging from 24 to 88.1 mg.100g⁻¹ for strawberries produced in different regions, agreeing with the findings of this study. Among the months of harvest, the highest content of this compound was found in November for most cultivars.

From September to November in southern Rio Grande do Sul there is increased sunlight incidence and plants synthesize anthocyanins to protect them from solar radiation, therefore, the increase in anthocyanin concentration. Cultivar Camarosa presented the same anthocyanin content throughout the production cycle.

The results for content of phenolic compounds and antioxidant activity are shown in Table 6. The contents of phenolic compounds ranged from 235.83 mg.100g⁻¹ for Albion in October to 490.97 mg.100g⁻¹ for Camarosa in September. In September and October, cv. Camarosa produced the highest concentrations of phenolic compounds, however, in November, it had the lowest concentration compared with the other cultivars. Josuttis *et al.* (2012) also found a wide range (152.6 to 320.95 mg.100g⁻¹) for the content of phenolic compounds in strawberry cultivars produced in four regions. The antioxidant activity ranged from 842.97 mg .100g⁻¹ for Aromas in October to 3752.62 for Albion in September.

In September, during the harvest, the content of phenolic compounds in strawberries was 20% to 40% higher than the contents measured in October and November. The antioxidant activity measured in September was 3 to 4 times higher than in October and November. However, Oliveira *et al.* (2009) observed different behavior for strawberries of cultivars Camarosa and Festival during the productive stage, from October to December. They found an increase from 20% to 30% in the content of phenolic compounds over the harvest period.

Table 5. Ascorbic acid content of strawberry cultivars harvested in September, October, and November 2012. Pelotas-RS, Embrapa Temperate Climate, 2021

Cultivar	Ascorbic acid (mg ascorbic acid.100mL ⁻¹)		
	September	October	November
Camarosa	48.94cC	63.85dB	66.66cA
Aromas	50.26cC	67.59cB	78.31aA
Albion	42.33dC	70.61bA	65.37cB
Portola	53.44bB	63.85dA	51.78dB
Palomar	65.08aC	81.08aA	74.11bB
CV (%)		1.78	
Cultivar		p≤0.05	
Month		p≤0.05	
Cultivar x month		p≤0.05	

Means followed by different small letters in the columns and different capital letters in the rows are significantly different by the Tukey test at 5%. ns= non significant

Table 6. Content of anthocyanins, phenolic compounds, and antioxidant activity of strawberry cultivars harvested in September, October, and November 2012 Pelotas-RS, Embrapa Temperate Climate, 2021

Anthocyanins (mg.100g ⁻¹)			
Cultivar	September	October	November
Camarosa	92.18aA	90.46aA	87.07aA
Aromas	62.61bB	40.81cC	80.84aA
Albion	52.17 bB	57.12bB	77.03aA
CV (%)		9.19	
Phenolic compounds (mg.100g ⁻¹)			
Cultivar	September	October	November
Camarosa	490.97aA	280.67aB	276.91bB
Aromas	395.21bA	239.17bC	307.71abB
Albion	331.35cA	235.83bB	321.60aA
CV (%)		7.12	
Antioxidant activity (mg.100g ⁻¹)			
Cultivar	September	October	November
Camarosa	3627.11bA	882.06aC	1149.90aB
Aromas	3602.71bA	842.97aC	1070.08aB
Albion	3752.62aA	844.20aC	1139.78aB
CV (%)		2.98	
Cultivar		p≤0.05	
Month		p≤0.05	
Cultivar x month		p≤0.05	

Means followed by different small letters in the columns and different capital letters in the rows are significantly different by the Tukey test at 5%. ns= non significant

CONCLUSIONS

- Cultivar and harvest month influence fruit quality in terms of soluble solids, acidity, ascorbic acid content, and bioactive compounds content.
- The cultivars Palomar and Aromas stand out with respect to ascorbic acid content.
- In the edaphoclimatic conditions of the region of Pelotas, cultivar Camarosa stands out for the production of strawberries and the contents of anthocyanins, phenolic compounds, and soluble solids.
- The contents of ascorbic acid, phenolic compounds, and anthocyanins may vary during the strawberry production cycle depending on the climatic conditions and respond differently to environmental factors, since the highest production of phenolic compounds was found

in September, of ascorbic acid in October, and anthocyanins in November.

AUTHORSHIP CONTRIBUTION STATEMENT

CARVALHO, S.F.: Data curation, investigation, Methodology, Writing – original draft, Writing – review & editing; **CORRÊA, A.P.A.:** Data curation, Formal Analysis, Investigation, Writing – original draft; **FERREIRA, L.V.:** Conceptualization, Formal Analysis, Investigation, Methodology, Writing – review & editing; **VIZZOTO, M.:** Methodology, Supervision, Validation, Writing – review & editing; **ANTUNES, L.E.C.:** Methodology, Resources, Supervision, Validation, Writing – review & editing.

DECLARATION OF INTERESTS

The authors declare that they have no known

competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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REFERENCES

ALVAREZ-SUAREZ, J. M; GIAMPIERI, F.; TULIPANI, S.; DISTEFANO, T. C. G.; GONZALES-PARAMAS, A. M.; SANTOS-BUEGA, C.; BUSCO, F.; QUILES, J. L.; CORDERO, M. C.; BOMPADRE, S.; MEZZETTI, B.; BATTINO, M. One-month strawberry-rich anthocyanin supplementation ameliorates cardiovascular risk, oxidative stress markers and platelet activation in humans. **Journal of Nutritional Biochemistry**, v. 25, p. 289-294, 2014.

ANTUNES, L. E. C; CALVETE, E. O; ROCHA, H. C; NIENOW, A. A; CECCHETTI, D; RIVA, E; MARAN, R. Produção de cultivares de morangueiro polinizadas pela abelha jataí em ambiente protegido. **Horticultura Brasileira**. Brasília. v.28, n.2, p. 222-226, 2010.

ANTUNES, L. E. C; PERES, N. A. Strawberry Production in Brazil and South America. **International Journal of Fruit Science**. v. 13, p. 156-161, 2013.

AOAC. Association of Official Analytical Chemists. Official Methods of Analysis International. 17th ed. Arlington: D. Feistane, 2000.

BALLINGTON, J. R; POLING, B; OLIVE, K. Day-neutral Strawberry Production for Season Extension in the Midsouth. **Hortscienc**, v. 43, n.7, p.1982–1986, 2008.

BRACKMANN, A.; PAVANELLO, E. P.; BOTH, V.; JANISCH, D. I.; SCHMITT, O. J.; GIMÉNEZ, G. Avaliação de genótipos de morangueiro quanto à qualidade e potencial de armazenamento. **Revista Ceres**, v. 58, n.5, p. 542-547, 2011.

BRAND-WILLIAMS, W; CUVELIER, M. E; BERSET, C. Use of a free radical method to evaluate antioxidant activity. **Lebensmittel-Wissenschaft und Technologie** v.28, p.25-30, 1995.

COCCO, C.; FERREIRA, L. V; GONÇALVES, M. A; PICOLOTTO, L; ANTUNES, L.E.C. Strawberry yield submitted to different root pruning intensities of transplants. **Revista Brasileira de Fruticultura**, v. 34, n. 4, p.1284-1288, 2012.

CRESPO, P; BORDONABA, J.G; TERRY, L.A; CARLEN, C. Characterisation of major taste and health-related compounds of four strawberry genotypes grow at different Swiss production sites. **Food Chemistry**, v. 122, p.16-24, 2010.

Embrapa. Empresa Brasileira de Pesquisa Agropecuária (CNPQ). Sistema brasileiro de classificação de solos. CNPQ: Rio de Janeiro, 2006.

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. 2014. Laboratório de agrometeorologia. Available in <http://www.cpact.embrapa.br/agromet/>. Accessed: March 19, 2020.

FAO. FAOSTAT: production: crops. 2019. Available in: <http://www.fao.org/faostat/en/#data/QC>. Accessed: November 16, 2020.

FULEKI, T; FRANCIS, F.J. Quantitative methods for anthocyanins 1. Extraction and determination of total anthocyanin in cranberries. **Journal of Food Science**, v. 33, p.72-77, 1968.

GUNDUZ, K; OZDEMIR, E. The effects of genotype and growing conditions on antioxidant capacity, phenolic compounds, organic acid and individual sugars strawberry. **Food Chemistry**, v. 155, p. 298-303, 2014.

JOSUTTIS, M; CARLEN, C; CRESPO, P; NESTBY, R; TOLDAN-ANDERSEN, T. B; DIETRICH, H; KRUGER, E. A comparison of bioactive compounds of strawberry fruit from Europe affected by genotype and latitude. **Journal of Berry Research**, v. 2, p. 73-95, 2012.

JOUQUAND, J; CHANDLER, C; PLOTTO, A; GOODNER, K. A. A sensory and chemical analysis of fresh strawberries over harvest dates and seasons reveals factors that affect eating quality. **Journal of the American Society for Horticultural Science**, v.133, p.859-867, 2008.

KÖPPEN, W. Climatologia. México: Fundo de Cultura Econômica, 1931.

KRUGER, M. J; DAVIES, N; MYBURGH, K. H; LECOUR, S. Proanthocyanidins, anthocyanins and cardiovascular diseases. **Food Research International** v. 59, p. 41- 52, 2014.

MASNY, A; ZURAWICZ, E. Productive value of new foreign strawberry cultivars evaluated in 2007-2010. **Journal of Fruit and Ornamental Plant Research** v.18, p.273-282, 2010.

OLIVEIRA, R. P; SCIVITTARO, W. B; da ROCHA, P. S. G; SEVERO, J; SILVA, J. A. S; GULARTE, V.F. Strawberry Festival: nova cultivar de morangueiro recomendada para o Rio Grande do Sul. **Boletim de pesquisa e desenvolvimento** 96, Embrapa Clima Temperado. Pelotas-RS. 22 p, 2009.

PEREIRA, W. R; SOUZA, R. J; YURI, J. E; FERREIRA, S. Produtividade de cultivares de morangueiro, submetidas a diferentes épocas de plantio. **Horticultura Brasileira** v.31, n.3, p.500-503, 2013.

PORTELA, I. P; PEIL, R. M. N; RODRIGUES, S; CARINI, F. Densidade de plantio, crescimento, produtividade e qualidade das frutas de morangueiro 'Camino Real' em hidroponia. **Revista Brasileira de Fruticultura**, v.34, n, 3, p.792-798, 2012.

RESENDE, J. T. V; MORALES, R. G. F; FARIA, M. V; RISSINI, A. L. L; CAMARGO, L. K. P; CAMARGO, C. K. Produtividade e teor de sólidos solúveis de frutos de cultivares de morangueiro em ambiente protegido. **Horticultura Brasileira**, v. 28, p. 185-189, 2010.

SANTOS, A. M; MEDEIROS, A. R. M. Morango: Produção frutas do Brasil, 40 ed. Pelotas: EMBRAPA Clima Temperado, 2003.

SINGH, A. B. K; SINGH, B. C; DEKA, S. K; SANWL R. K; PATEL, M. R. V. The genetic variability, inheritance and inter relationships of ascorbic acid, β -carotene, phenol and anthocyanin content in strawberry. **Scientia Horticulturae**, v.129, p.86-90, 2011.

SWAIN, T; HILLIS, W. E. The phenolic constituents of *Prunus domestica* L. The quantitative analysis of phenolic constituents. **Journal of Science and Food Agriculture**, v.10, p.63-68, 1959.

VIGNOLO, G. K; ARAÚJO, V. F; KUNDE, R. J; SILVEIRA, C. A. P; ANTUNES, L. E. C. Produção de morangos a partir de fertilizantes alternativos em pré-plantio. **Ciência Rural**, v.41, n.10, p.1755-1761, 2011.