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Physical and quality fruit parameters of new strawberry genotypes

Abstract – The objective of this work was to evaluate physical and chemical fruit parameters of new strawberry genotypes under field conditions. The study was carried out during the 2018 and 2019 seasons. Twelve genotypes from the breeding program of Embrapa and two commercial cultivars (Camino Real and Merced) were evaluated. The assessed parameters were: average fruit number, average fruit weight, soluble solids, titrable acidity, and the soluble solids/titrable acidity ratio. Among the studied strawberry genotypes, the 8-1, 35-22 ('BRS DC22'), 31-13, 7-5, and 32-2 selections produce more fruits per plant. Among the new genotypes, 'BRS DC25' (Fênix) and 31-13 present the best average fruit weight in both evaluated seasons. The highest sugar content is observed in genotypes 35-22 ('BRS DC22') and 65-2, whereas 8-1 and 'BRS DC25' (Fênix) show the highest acidity. The 7-5, 35-22 ('BRS DC22'), 34-2, and 35-6 genotypes present the best soluble solid/acidity ratio.

Index terms: *Fragaria x ananassa*, berry, cultivar, performance, seasonality.

Parâmetros físicos e de qualidade de frutos de novos genótipos de morangueiro

Resumo – O objetivo deste trabalho foi avaliar parâmetros físicos e químicos de frutos de novos genótipos de morangueiro em condições de campo. O estudo foi realizado durante as safras de 2018 e 2019. Foram avaliados 12 genótipos do programa de melhoramento genético da Embrapa e duas cultivares comerciais (Camino Real e Merced). Os parâmetros avaliados foram: número médio de frutos, massa média de frutos, sólidos solúveis, acidez titulável e relação sólidos solúveis/acidez titulável. Entre os genótipos de morango estudados, as seleções 8-1, 35-22 ('BRS DC22'), 31-13, 7-5 e 32-2 produzem mais frutos por planta. Entre os novos genótipos, 'BRS DC25' (Fênix) e 31-13 apresentam a melhor massa média de frutos nos dois períodos avaliados. O maior teor de açúcar é observado nos genótipos 35-22 ('BRS DC22') e 65-2, enquanto 8-1 e 'BRS DC25' (Fênix) apresentam a maior acidez titulável. Os genótipos 7-5, 35-22 ('BRS DC22'), 34-2 e 35-6 apresentaram a melhor relação sólidos solúveis/acidez.

Termos para indexação: *Fragaria x ananassa*, frutas vermelhas, cultivar, rendimento, sazonalidade.

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Introduction

Since the 20th century, strawberry (*Fragaria x ananassa*) cultivation has gained economic importance in Brazil, especially in the states of Minas Gerais, São Paulo, and Rio Grande do Sul. The first Brazilian cultivars, developed in the 1960s by Embrapa Clima Temperado and

Instituto Agronômico de Campinas (IAC), adapted to the soil and climate conditions of the Southern and Southeastern Brazilian regions, resulted in high fruit yield and quality, which established a profitable production chain in the regions, making the strawberry an economically significant crop in the regions (Bonow & Antunes, 2023). However, the breeding programs were interrupted, and those cultivars became obsolete.

Brazil is among the seven largest strawberry producers in the world, the largest in South America, with approximately 5,200 hectares, of which Minas Gerais state leads with almost 50% of the cultivated area (Bonow & Antunes, 2023).

Variations in climate conditions, altitude, health and soil fertility, production system adopted (Velasco-López et al., 2020), cultivar choice (Nascimento et al., 2023; Silva et al., 2023), type and origin of nursery plants influence production results and, consequently, affect the business profitability.

Currently, the varietal profile is dominated by North American cultivars, especially those developed by University of California. However, to choose the correct cultivars to be used, local adaptability studies should be considered (Passos et al., 2015; Silva et al., 2023) to allow identifying which cultivars are best adapted to edaphoclimatic conditions, plant management (Fagundes et al., 2024), and production systems.

Although Camarosa had been a standard cultivar for many years (Hernández-Martínez et al., 2023), there are many others available to Brazilian growers, such as 'Camino Real', 'Ventana', 'Aromas', 'Diamante', 'Florida Festival', 'Campinas', 'Earlibrite', 'Galexia', 'Candonga', 'Plarionfre', 'Aleluia', 'Toyonoka', 'Oso Grande', 'Albion', 'Monterey', 'San Andreas', 'Palomar', 'Portola', 'Dover', and 'Sweet Charlie' (Zeist & Resende, 2019), of which some do not have a relevant position in the Brazilian market yet because of their lack of desirable characteristics, whereas some do, such as 'Camino Real', 'San Andreas', and 'Albion'.

Over the past 100 years, the main breeding programs worldwide have focused on adaption, plant resistance, quality parameters, and fruit size as important traits to select new cultivars (Menzel, 2023). In Brazil, breeding programs have reported that new strawberry genotypes have great potential (Zeist & Resende, 2019; Pieri et al., 2023; Nascimento et al., 2023; Silva et al., 2023) for cultivation in tropical regions (Moreira et al., 2022), in subtropical climates (Souza et al., 2021; Brandt et al., 2022; Pereira et al., 2022), and in high altitude areas (Zanin et al., 2019, 2020). The programs seek to identify quality genotypes (Nunes et al., 2022) adapted to the multiple production systems, both soil (Moritz et al., 2021) and soilless cultivations.

In Brazil and worldwide (Brym et al., 2022), to determine the quality of a cultivar, strawberry breeding programs evaluate both quality parameters, such as production indices per plant and per area, and sensory parameters, like weight, mass, flavor, and texture (Zanin et al., 2019, 2020; Cervantes et al., 2020; Fagherazzi et al., 2021; Brandt et al., 2022; Moreira et al., 2022; Nunes et al., 2022; Hernández-Martínez et al., 2023; Pereira et al., 2023). Therefore, Embrapa breeding program aims to identify genotypes that meet the demands of growers, nurserymen, and consumers.

In 2009, Embrapa resumed the strawberry breeding program, aiming to generate strawberry cultivars with better adaptation to Brazilian growing conditions, with satisfactory flavor and texture, resilient to biotic (Fagundes et al., 2024) and abiotic stressors, and potential for local nurseries (Antunes et al., 2023).

The objective of this work was to evaluate physical and chemical parameters of new strawberry genotypes under field conditions.

Materials and Methods

The study was carried out in the municipality of Pelotas, Rio Grande do Sul state, Brazil (31°39'39.9"S, 52°25'50.4"W, at 66 m of altitude), during the 2018 and 2019 crop seasons. According to the Köppen-Geiger's classification, the climate in the region is Cfa type, that is, humid temperate with hot summers, air temperature and average annual rainfall are 19.3°C and 1,728 mm, respectively (Table 1).

Advanced strawberry selections from Strawberry Genetic Breeding Program of Embrapa, namely as 7-5, 8-1, 8-2, 32-2, 31-9, 31-13, 32-5, 34-2, 35-6, 35-22 (registered as 'BRS DC22'), 35-25 [released as 'BRS DC25' (Fênix)], and 65-2, as well as the commercial cultivars Camino Real and Merced were evaluated.

The plants were cultivated in an annual hill system, with no fumigation in the soil and beds covered with a 50 μm black polyethylene film (mulching) and with a 150 μm thick transparent polyethylene low tunnel. Soil pH correction and pre-planting fertilization were performed based on a soil chemical analysis. Drip tapes were used for fertirrigation, with a spacing of 0.2 m between drippers, whenever necessary. Applications of agricultural defensives were done according to necessity (Bello Filho et al., 2024).

The experimental design was in randomized blocks, with ten treatments during 2018 season, planted on May 18th, and eight treatments during the 2019 season, planted on May 23th, both with four replicates. Each plot consisted of six plants, with 240 plants in 2018 and 192 plants in 2019 in total. The plant spacing was 0.3 m between rows and 0.3 m between plantlets. Embrapa strawberry plantlets were produced according to the methodology described by Durner et al. (2002) and Antunes et al. (2023), that is, by rooting the tips taken from the stolons of the plants, kept off the ground, which were rooted and potted in trays of expanded polystyrene of 72 cells, with a capacity of 113 mL of substrate (Carolina Soil do Brasil, Santa Cruz do Sul, RS, Brazil). Plantlets of commercial strawberry cultivars were purchased from Argentina by local importers (Bioagro, Araucária, PR, Brazil).

The strawberries considered ripe, that is, the ones that had, at least, 75% of red epidermis, were harvested twice a week. Harvesting began in August and ended in December, in both seasons. Average fruit number (AFN) and average fruit weight (AFW) per plant were recorded on a digital scale. The fruit number and weight per plant were obtained through the sum of all harvested fruits in each season and divided by the number of alive plants in the experimental unit monthly. Fruit weight average was calculated by the ratio between those two variables. At the end of the study, all monthly averages were added to calculate fruit number per plant (AFN) and average fruit weight (AFW). Only marketable fruits were considered, discarding those with serious defects and with a mass below 10 g.

The samples were homogenized and crushed to determine the soluble solids (SS) content of the pure juice, and, to express the results in ºBrix, a PAL-1 digital refractometer (Atago, Ribeirão Preto, SP, Brazil) was used. The experimental unit was a sample of five fruits from each genotype with three replicates. The titratable acidity (TA) was evaluated by titration, using 2 mL of juice diluted in 90 mL of distilled water, whose dilution was titrated with 0.1 N sodium hydroxide solution to pH 8.1 and the results were expressed in percentage of citric acid (AOAC, 1995). The SS/TA ratio was calculated through the ratio between the SS content and the TA. The data were analyzed (ANOVA) and the means compared by Scott Knott's test at 5% error probability, with the aid of the statistical program SISVAR 5.6 version (Ferreira, 2014).

Table 1. Annual averages of climatic variables recorded by Agrometeorology Laboratory (Agromet) of Embrapa Temperate Agriculture.

Month	T_{mean} (°C)[1]		T_{max} (°C)		T_{min} (°C)		P_{mm}		HCH	CH	
	2018	2019	2018	2019	2018	2019	2018	2019		2018	2019
January	23.9	24.5	29.3	29.3	19.3	20.7	182.0	304.0	-	-	-
February	22.6	23.2	28.8	28.5	17.8	18.9	59.8	150.2	-	-	-
March	21.2	21.5	27.4	27.0	16.4	17.2	136.8	54.0	-	-	-
April	22.4	20.1	27.9	25.0	18.6	16.4	136.2	168.2	-	-	-
May	17.4	17.6	21.8	21.8	13.9	14.2	42.6	138.8	28	3	0
June	12.1	17.1	16.9	22.4	8.1	12.8	42.6	35.4	80	80	21
July	12.9	12.2	16.8	17.2	9.4	7.9	225.2	179.2	119	32	128
August	12.7	14.6	17.5	20.9	8.9	9.7	203.2	78.2	64	28	94
September	17.5	14.7	21.7	20.1	14.4	10.1	324.0	207.6	31	0	47
October	17.0	18.6	22.5	23.2	13.4	14.8	133.0	376.0	-	-	-
November	21.3	21.0	26.8	25.9	16.5	16.7	53.2	72.0	-	-	-
December	22.2	22.9	28.2	29.6	17.6	17.1	100.2	53.6	-	-	-
Average	19.3	19.3	24.6	24.1	15.4	15.6					
SPCHA[2]							1,638.0	1,817.0	322	143	290

[1]T_{mean}, mean average air temperature; T_{max}, mean maximum air temperature; T_{min}, mean minimum air temperature; P_{mm}, mean precipitation; HCH, mean historical chilling hours accumulation (<7.2°C) during the period of 1984–2017; CH, mean chilling hours (<7.2°C) in the weather stations of Embrapa Temperate Agriculture. [2]Sum precipitation and chilling hours accumulated.

Results and Discussion

Under the adopted trial conditions in 2018 and 2019 seasons (Table 1), it was observed that there were different responses among the genotypes evaluated. Regarding the AFN, it was observed that 'Camino Real' highlighted for both seasons, followed by 8-1 selection (2018 season) and 'Merced' (2019 season). The results of the second group showed that 35-22, 31-13, 7-5, 32-2 selections, and 'Merced' did not differ in 2018 season, whereas 35-22 and 'BRS DC25' (Fênix) did not differ in 2019 season. It can be attributed to the origin of the plantlets of foreigner cultivars compared with the original plants used in this study (Antunes et al., 2023), since, according to Cocco et al. (2016), these cultivars present higher reserve content and, consequently, have greater production potential.

Regarding AFW, although 'Merced' and 'BRS DC25' (Fênix) are noteworthy for both seasons, they did not differ from 'Camino Real' and 31-13 selection in 2018 season (Table 2), which indicates that the genotypes developed by Embrapa breeding program have competitive potential. The results found for number and fruit average weight per plant of the foreigner cultivars evaluated also indicate that Embrapa culltivars have pontential as competitive new ones (Nascimento et al., 2023; Silva et al., 2023), as observed in other studies (Zanin et al., 2019; Brandt et al., 2022).

The satisfactory performance of Embrapa selections and cultivars may have happened because they do not require cold weather to be produced. Tray plants were produced during the summer with no effect of the cold on the accumulation of carbohydrates at plantlet formation stage. However, after being transferred to the field, the accumulated cold observed from June onwards (Table 1), associated with the photoperiod reduction, may have physiologically stimulated the plants to produce flowers and fruits of adequate weight (Table 2). Even below the historical average, production parameters in both harvests were consistent, including the year with the lowest cold accumulation (Table 1).

The results obtained for fruit weight and number are superior to those observed by Pereira et al. (2022), Brandt et al. (2022), but similar to those reported by Zanin et al. (2019). All authors attributed the good performance of the studied genotypes to the climate and soil conditions used for cultivation, whereas they related low productivity to non-adaptation of some genotypes to the study site (Zanin et al., 2019). In addition, climate variations during the harvest, such as temperature (Menzel, 2023), relative humidity, precipitation (Table 1), and possible incidences of pests and diseases influence negatively the production parameters, such as fruit number and weight.

Strawberry is produced especially in the Southern and Southeastern Brazilian regions, both in low and

Table 2. Average fruit number per plant (AFN) and average fruit weight (AFW) of strawberry (*Fragaria x ananassa*) genotypes in the 2018 and 2019 crop seasons(1).

Strawberry genotype	AFN		AFW (g per fruit)	
	2018	2019	2018	2019
Merced	33.7b	49.2a	19.7a	21.6a
Camino Real	45.8a	50.3a	18.3a	18.4b
7-5	30.8b	-	15.7b	-
8-1	40.3a	-	11.9c	-
8-2	25.4c	-	16.8b	-
32-2	28.5b	-	17.0b	-
31-9	-	31.1c		17.6c
31-13	32.1b	-	19.1a	-
32-5	-	25.4c		15.8d
34-2	-	32.8c		15.7d
35-6	-	42.5b		15.4d
35-22 ('BRS DC22')	32.3b	43.6b	15.8b	16.2d
35-25 ['BRS DC25' (Fênix)]	23.0c	31.7c	20.8a	20.4a
65-2	22.0c		16.4b	
CV (%)	17.9	12.5	7.5	6.4

(1)Means followed by the same letter at the same column do not differ by Scott-Knott’s test, at 5% probability. CV, coefficient of variation.

high altitude, with specific microclimates conditions (Silva et al., 2023). Considering the recorded historical chilling hour accumulation data (Table 1), it was observed that plantlets produced without sufficient chilling hours accumulation at nursery still delivered good level of fruit mass and weight (Table 2), which showed that the genotypes were more adapted to this specific condition.

Regarding flavor in the 2018 season, the best obtained results for soluble solid content were 7-5, followed by 35-22, and 65-2 selections (Table 3). These results are superior to those presented by Pinheiro et al. (2023), who evaluated six strawberry genotypes: 'Sweet Charlie', 'Camarosa', 'Camino Real', 'Monterey', 'Albion', and 'Aromas', in the same cultivation system used in this research; however, the authors obtained less than 9.7 °Brix of soluble solid content. The variations found are common in strawberries during harvest season due to climate conditions, such as cloudy weather and non-prolonged sun exposure, which reduce sugar accumulation. Additionally, both low and high temperatures reflect in the SS/TA ratio (Simkova et al., 2023).

Zanin et al. (2019) found that Italian genotypes presented similar performance to those obtained in this study for SS, but with lower acidity, resulting in higher ratio levels. Simkova et al. (2023) found that some conditions, as high altitude and mean temperature, result in lower acidity, whereas pre-harvest weather can also affect fruit quality at the time of data collection (Brym et al., 2022).

New genotypes obtained a maximum value of 7.4 °Brix of SS, as 'FRF PA3' in high altitude, lower than those obtained in this study, which evidences the influence of the environment in this type of experiment, since the municipalities of Pelotas and Vacaria, in the state of Rio Grande do Sul, are located above sea level: 86 m and 870 m, respectively (Santos et al., 2021), as well as the municipality of Lages (884 m), in the state of Santa Catarina (Zanin et al., 2020), that is also located in high altitude, but with different climate conditions. The 8-1 selection had the total acidity being compared with 'Camino Real' and 'BRS DC25' (Fênix) in the same group (Table 3). 'Merced' presented the major acidity, corroborating with Pinheiro et al. (2023) data, consisting of high acidity in commercial cultivars.

For SS/TA ratio, the advanced selections differed within the genotypes, being 35-22 and 7-5 selections the highest, whereas 'Merced' and 'Camino Real' were the lowest. Passos et al. (2015) evaluated seven genotypes, of which 'Aleluia' and 'Festival' reached the best ratios, and 'Tudla' the worst one (7.23), less than the results presented in this study. The authors

Table 3. Soluble solid content (SS), titratable acidity content (TA), and soluble solid/titratable acidity ratio (SS/TA) of strawberry (*Fragaria x ananassa*) genotypes in the 2018 and 2019 crop seasons[(1)].

Strawberry genotype	Soluble solid (ºBrix)		Titratable acidity		SS/TA	
	2018	2019	2018	2019	2018	2019
Merced	9.1d	6.10[ns(2)]	1.0a	0.70[ns]	9.0d	9.2b
Camino Real	7.9e	6.40	0.9b	0.60	8.3d	10.3a
7-5	12.6a	-	0.7d	-	17.6a	-
8-1	10.1c	-	0.9b	-	10.9c	-
8-2	8.7d	-	0.7d	-	11.5c	-
32-2	10.1c	-	0.8c	-	12.1c	-
31-9	-	6.00	-	0.70	-	9.1b
31-13	9.7c	-	0.9c	-	11.0c	-
32-5	-	6.50	-	0.70	-	9.3b
34-2	-	6.50	-	0.60	-	10.1a
35-6	-	6.00	-	0.60	-	10.0a
35-22 ('BRS DC22')	11.4b	6.30	0.6e	0.60	19.0a	10.6a
35-25 ['BRS DC25' (Fênix)]	10.3c	6.13	0.9b	0.70	11.1c	9.0b
65-2	11.2b	-	0.7d	-	15.4b	-
CV[(3)] (%)	6.5	9.40	4.4	9.39	8.9	4.9

[(1)]Means followed by the same letter at the same column do not differ by the Scott-Knott's test at a 5% probability. [(2)]ns, no significant at the same column. [(3)]CV, coefficient of variation.

attributed the low performance of 'Camino Real' to its greater cold requirement, since the tray plants were produced during the summer at a local nursery in São Paulo state without accumulating cold during their fist stages.

Regarding fruit quality, a variable that influences the sensorial perception among consumers, there were no significant differences between strawberry cultivars and selections for soluble solid contents and flesh acidity in 2019 season, probably influenced by the rainy season (Table 1), which was higher than 500 mm between September and October 2019, which affected the quality indices.

Although the discussed parameters are influenced by environment conditions, it was observed that strawberry selections were, in general, similar to the commercial cultivars in terms of soluble solid contents and flesh acidity during the crop season. Therefore, taking the cultivars Merced and Camino Real as references, since they have a commercial position in Brazil, it is possible to conclude that the strawberry genotypes studied have conditions to compete in the Brazilian market.

Conclusions

1. Among the strawberry (*Fragaria x ananassa*) genotypes studied, the 8-1, 35-22 ('BRS DC22'), 31-13, 7-5, and 32-2 selections produce more fruits per plant.
2. 'BRS DC25' (Fênix) and 31-13 present the best average fruit weight in both evaluated seasons among genotypes studied.
3. The major sugar content is observed in 35-22 ('BRS DC22') and 65-2 genotypes, while 8-1 and 'BRS DC25' (Fênix) showed the highest acidity.
4. The 7-5, 35-22 ('BRS DC22'), 34-2, and 35-6 genotypes present the best soluble solid/acidity ratio.

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