https://doi.org/10.18406/2316-1817v17nunico20251955 e-ISSN 2316-1817

Physicochemical characterization of fruits from experimental strawberry clones

Marcos Rian dos Santos[1], Ronivaldo Crispim da Veiga Junior[2], Lívia Maria Silva Adami[3], Ana Flávia Della Testa[4], Marcelo Henrique Avelar Mendes[5], Luciane Vilela Resende[6], Mariana Borges de Lima Dutra[7], Sindynara Ferreira[8]

[1] Federal Institute of Education, Science, and Technology of Southern Minas Gerais (IFSULDEMINAS), Inconfidentes Campus. Undergraduate student in Agricultural Engineering. E-mail: marcos.rian@alunos.ifsuldeminas.edu.br

[2] Federal Institute of Education, Science, and Technology of Southern Minas Gerais (IFSULDEMINAS), Inconfidentes Campus. Undergraduate student in Agricultural Engineering. E-mail: ronivaldo.crispim@alunos.ifsuldeminas.edu.br

[3] Federal Institute of Education, Science, and Technology of Southern Minas Gerais (IFSULDEMINAS), Inconfidentes Campus. Undergraduate student in Food Engineering. E-mail: livia.adami@alunos.ifsuldeminas.edu.br

[4] Federal Institute of Education, Science, and Technology of Southern Minas Gerais (IFSULDEMINAS), Inconfidentes Campus. Undergraduate student in FoodEngineering. E-mail: ana.testa@alunos.ifsuldeminas.edu.br

[5] Federal University of Lavras. PhD student in Plant Science. E-mail: marcelo.mendes3@estudante.ufla.br

[6] Federal University of Lavras. Teacher and researcher. E-mail: luciane.vilela@dag.ufla.br

[7] Federal Institute of Education, Science, and Technology of Southern Minas Gerais (IFSULDEMINAS), Inconfidentes Campus. Teacher and researcher. Email: mariana.dutra@ifsuldeminas.edu.br

[8] Federal Institute of Education, Science, and Technology of Southern Minas Gerais (IFSULDEMINAS), Inconfidentes Campus. Teacher and researcher. E-mail:sindynara.ferreira@ifsuldeminas.edu.br

Received in: 14/09/2024
Accepted in: 13/03/2025

Abstract

Strawberry production has been increasingly growing worldwide, as the fruit is extremely popular due to its color, aroma, flavor and high nutritional value. To increase its productivity and quality new genetic materials are being developed and tested. Strawberry genetic improvement programs have sought to increasingly improve the fruit's physical, chemical and sensory characteristics, as the market becomes more demanding. In this regard, developing knowledge about the chemical properties of strawberry resulting from genetic crossings is fundamental. As such, this work was developed in order to present the physicochemical characterization of strawberry cultivars and experimental clones cultivated in southern Minas Gerais. Hybrids MDA23, MDA01 and MCA94 and commercial cultivars Pircinque and Albion were analyzed in triplicate. Variables evaluated included pH, titratable acidity, soluble solids content, ratio, colorimetry, ash and fruit moisture. The genotypes Pircinque, MCA94 and MDA01 achieved the highest values for soluble solids and pH. Regarding moisture, MDA23 showed higher content compared with the others. As for ash, MDA01 had the lowest value when compared with the other genotypes. The Pircinque cultivar exhibited the highest titratable acidity content, as well as for some colorimetric parameters. All experimental clones proved promising to be cultivated in southern Minas Gerais considering the analyzed parameters.

Keywords: *Fragaria* x *ananassa* Duch. Genetic improvement. After harvest.

Introduction

Strawberry (*Fragaria x ananassa* Duch.) is appreciated by consumers due to its sensory characteristics (taste, aroma and texture), in addition to having a favorable nutritional content, high economic return and being a functional food (PAPAROZZI *et al.*, 2018). Most of the produced fruit (about 70 %) is sold fresh and the rest goes to industrial processing (FARNEZI *et al.*, 2020).

Several global and national social, economic and climatic changes have driven the revision of old paradigms on human food, now fixed on quality and functionality in association with environmental protection (ANTUNES, REISSER JUNIOR, SCHWENGBER, 2016).

Consumers of fresh strawberry are increasingly looking for quality fruits without defects and having intense red color, adequate size and characteristic flavor and freshness (TURQUETT *et al.*, 2021). Taste is mainly determined by soluble solids content, and color by the accumulation of phenolic compounds and anthocyanins (HOSSAIN *et al.*, 2016). Among the demands of the fruit consumer market, strawberry stands out for its versatility in cooking, sensory characteristics, and chemical and nutritional composition (BOONYAKIAT *et al.*, 2016).

World strawberry production has been growing significantly in recent years, with China being the largest producer with 4.209 million tons, followed by the USA with 1.250 million tons and Egypt 731,000 tons. In Brazil, production has been increasing every year. In 2023, estimates point to 187,795 tons produced in an area of approximately 4,836 hectares, with a yield of 38.83 t ha^{-1}, becoming the ninth largest producer in the world (FAO, 2023). Produced mainly in the states of Minas Gerais, Paraná, Rio Grande do Sul, and São Paulo, strawberry average productivity in Brazil totals 39 tons per hectare (ANTUNES, BONOW, 2021).

Despite the increasing productivity, the small number of cultivars adapted to the climatic conditions of the main producing regions has become a limiting factor for optimized crop development. Currently, the main cultivars used by Brazilian producers are imported from Spain, Chile and the United States, raising the cost of production due to royalties payment for using the technology (GIL-ARIZA *et al.*, 2009; ZEIST, RESENDE, 2019). This underscores the need to establish genetic improvement programs for strawberry in Brazil to find materials with greater performance in edaphoclimatic conditions that can increase productivity and generate consumer market acceptance.

Genetic improvement for strawberry in Brazil is being developed by research for modernizing production systems, with strategies for different segments of the production chain, to find new varieties that have characteristics such as productivity, development against pests and diseases, fruit quality and post-harvest, seeking to meet the demands of farmers, nursery workers and national consumers (ANTUNES, BONOW, 2021).

Evaluating parameters regarding the nutritional quality of strawberry is key to better identify and explore the main factors that determine its biochemical potential. Flavor is related to several characteristics such as the balance of sugars and acids, color, and ascorbic acid content (SANTOS, 1999; OLIVEIRA, BONOW, 2012). Soluble solids content has been used as an indicator of quality, both for consumption and for industrial processing, as the consumer market prefers sweeter fruits (CONTI, MINAMI, TAVARES, 2002; SOUZA *et al.*, 2017). Titratable acidity is widely used to indicate acidic or sour taste, whereas pH is the most viable method to determine the quality of processed products (SOUZA *et al.*, 2017).

While southern Minas Gerais features among the most important regions for strawberry cultivation, studies analyzing the physicochemical composition of the different genetic materials that are being developed and planted in the region are scarce. As a way to evaluate some of these genotypes, this study was developed in order to present the physicochemical characterization of strawberry cultivars and experimental clones cultivated in southern Minas Gerais.

Material and methods

The experiment was implemented at the Federal Institute of Education, Science and Technology of the South of Minas Gerais (IFSULDEMINAS), Inconfidentes campus, at the School Farm, located in the municipality of Inconfidentes, southern Minas Gerais, with latitude 22° 18’ S, longitude 46° 20’ Ø, altitude 869 meters. According to Köppen’s classification, the climate is considered humid subtropical, with dry winter and mild summer. Average annual rainfall in the municipality is around 1724.2 mm, the average annual temperature is 18 °C, with average maximum of 26.4 °C and average minimum of 14.3 °C (PREFEITURA MUNICIPAL DE INCONFIDENTES, 2024).

Harvest was performed between the months of October and December 2023. The experimental design adopted was randomized blocks with five treatments and four replications, totaling 20 experimental plots in which five plants per genotype were placed. In total, 100 seedlings were used with a spacing of 0.15 m between plants and 0.30 m between blocks. Five strawberry genetic materials were evaluated: three experimental hybrids from the genetic improvement program at the Federal University of Lavras (UFLA) - MCA94, MDA01 and MDA23; and two commercial cultivars - Albion and Pircinque.

Seedlings were produced in a greenhouse from stolons emitted by the matrices of each genetic material. After sprouting, the seedling were transplanted to hydroponic suspended semi-seeded benches for strawberry cultivation measuring 0.20 m deep, 0.20 m wide and 18 m long, divided into two benches of 9 meters each, one next to the other. The gutters were filled with Biomix® commercial substrate composed of pine/eucalyptus bark and coconut fiber, with 45 % moisture and pH of 6.8.

Irrigation was carried out using drip tapes, always keeping the substrate at field capacity. Irrigations occurred three times a day, at 9 am, 12 pm, and 4 pm, for a period of two minutes per irrigation.

Maintenance fertilizations were performed by fertigation using potassium nitrate, calcium nitrate, magnesium sulfate (57 g each), 27.5 g of MAP, 4.5 g of Brexil®, and 6.5 g of Ferrilene® dissolved in 500 liters of water. In the seedling growth phase, from June to July 2023, the electrical conductivity (EC) used was 0.5 Siemens per meter (S/m); when production started, the EC changed to 0.8 S/m.

The fruits of each genotype were harvested separately and immediately frozen in plastic jars at -18 ºC for latter triplicate analysis. They remained frozen until enough material was accumulated for the evaluations. About 30 to 50 grams of fruit pulp were sampled, which were crushed and homogenized for analyzing hydrogen potential (pH), soluble solids content (SS), titratable acidity (TA), colorimetry, moisture (M) and ash (A). Physicochemical analyses were performed in the Soil and Bromatology Laboratories of IFSULDEMINAS – Inconfidentes Campus.

pH was measured using a weight gauge Tec-3MP (Tecnal), according to the methodology provided by the Association of Official Analytical Chemists (AOAC, 2012). Titratable acidity (TA) was determined by titration with NaOH solution (0.1 N) using phenolphthalein as indicator, according to the AOAC method (2012). Data were expressed in percentage of citric acid per 100 g of pulp.

Soluble solids (SS) content was determined by direct reading using a Reichert AR benchtop digital refractometer - 200 (room temperature), according to the AOAC (2012), and the results were expressed as percentage of soluble solids. Ratio (SS/TA) was obtained by dividing the readings of soluble solids (SS) by the contents in percentage of titratable acidity (TA). The ratio was calculated because it is an indicator of fruit taste, especially when consumed fresh (MANICA et al., 1998).

Colorimetric parameters were analyzed using a Konica Minolta colorimeter (Model CM-2300). For this, three measurements were taken from the pulp for each treatment. The internationally recommended color specification system, defined by the Commission Internationale de l'Éclairage (CIE), uses the CIE L scale*, a*, b*, commonly referred to as CIELAB system. L* value represents the variations from black (L = 0) to white (L = 100), indicating the degree of brightness. The chromaticity value a* represents the variations from green (negative values) to red (positive values). The chromaticity value b* represents the variations from blue (negative values) to yellow (positive values) (MARTÍNEZ, VICARIO, HEREDIA, 2007).

Moisture content (M) of the crushed fruits was determined gravimetrically by drying at 105 °C until constant mass. Results were expressed in grams (AOAC, 2012). Ash (A) was analyzed by heating the sample to temperatures close to 550-570 °C, following the method of the Adolfo Lutz Institute (IAL, 2008).

Means were compared using the Scott and Knott (1974) test at 5 % probability. Statistical analysis was performed using the Sisvar software® (FERREIRA, 2011). A Kohonen's self-organizing map wad generated to classify samples into clusters according to the similarity of their properties. SOM Toolbox 2.1 package (VATANEN *et al.*, 2015) was used in the Matlab R2015a program, along with the necessary modifications, to improve the obtaining and validation of the clusters employing the Davies-Bouldin and Silhouette indexes.

Results and discussion

The analyzed genotypes had high potential regarding sensory quality observed through soluble solids content, titratable acidity, ratio between soluble solids and titratable acidity, pH, moisture, ash and colorimetry (Table 1). Significant differences occurred between the genetic materials used, with differences between the clones which are promising for the genetic improvement program.

For the SS parameter, Pircinque, MCA94 and MDA01 do not differ statistically, presenting values higher than MDA23 and Albion (Table 1). Schaidhauer (2021) found higher SS values, with the Albion cultivar reaching mean levels of 7.77 %. For the Pircinque cultivar, Schneider (2022) found SS levels between 6.48 and 9.96 %, results similar to those obtained in the present research. According to Conti, Minami, and Tavares (2002) and Souza *et al.* (2017), SS content is an important indicator of quality for commercializing fresh fruits. SS levels in strawberries are influenced by the environmental conditions in which the fruits were produced, the stage of maturation at harvest and vary according to the genetic characteristics of each cultivar (RAHMAN *et al.*, 2016).

The highest TA levels occurred for the Pircinque cultivar, differing statistically from the remaining genetic materials analyzed with 1.36 % TA content, higher than the values obtained by Schneider (2022), who found levels of 0.60 %. Experimental clone MCA94 obtained higher TA

Table 1. Mean values of soluble solids (SS), titratable acidity (TA), ratio between soluble solids and titratable acidity (Ratio), hydrogen potential (pH), moisture (M), ash (A), L* (white to black coloration), a* (green to red coloration) and b* (blue to yellow coloration) parameters. IFSULDEMINAS – Inconfidentes Campus. Inconfidentes - MG, 2024

MATERIAL[1]	**SS**	**TA**	**Ratio**	**pH**	**M**	**A**	**L***	**a***	**b***
	%	**%**			**%**	**%**			
PIRCINQUE	8.20 a	1.36 a	6.04 a	3.85 a	92.81 d	0.40 a	36.40 a	25.76 a	12.25 a
MCA94	7.33 a	1.21 b	6.08 a	3.92 a	93.77 c	0.43 a	15.85 c	18.99 b	10.22 a
MDA01	7.37 a	1.14 d	6.48 a	4.00 a	94.45 b	0.19 b	14.52 c	16.91 b	8.54 a
MDA23	6.57 b	1.10 d	5.98 a	3.61 c	94.75 a	0.36 a	9.90 d	15.94 b	6.95 a
ALBION	5.60 b	1.16 c	4.82 a	3.72 b	94.44 b	0.41 a	28.31 b	19.41 b	9.56 a
CV%[2]	9.59	1.69	10.99	1.41	0.16	18.51	13.51	11.34	18.14

[1] Means followed by the same letters in the column do not differ statistically at 5 % probability by Scott and Knott (1974) test.

[2] CV%: coefficient of variation in percentage.

Source: authors (2024).

values than Albion. Schaidhauer (2021) found similar results for TA, with values between 0.99 and 1.34 % for the Albion cultivar. Experimental clones MDA01 and MDA23 came closer to the recommended levels in relation to all other genetic materials analyzed (Table 1). According to Belitz, Grosch and Shieberle (2009), the ideal average composition of TA is around 1.10 %, being valuable data for assessing the processing and conservation status, indicating acidic or sour flavor.

SS/TA ratio had no statistical difference between the genetic materials, ranging from 4.82 to 6.48 (Table 1). Usually, fruits with higher SS/TA values have a mild flavor and better sensory acceptance, and are preferred by consumers (BARANKEVICZ *et al.*, 2015). In this regard, this relation acts a quality index for rating the sweetness of the fruit. According to Kader (2002), to obtain an acceptable flavor in strawberries, this SS/TA ratio must be higher than 8.75. Thus, fruits with a higher SS/TA ratio have more pronounced sweetness (KINGS *et al.*, 2015).

Regarding pH, MDA01, MCA94 and Pircinque did not differ from each other (Table 1), reaching the highest values. MDA23 was the more acidic clone compared with all the other genetic materials analyzed. The fresh strawberry consumption market prefers less acidic fruits with a pH above 3.5, whereas strawberries with a pH below 3.5 are appropriate for industrial use (RODAS *et al.*, 2013).

As for moisture (M), the lowest content (92.81 %) was found for the Pircinque cultivar differing from the other genotypes. Hybrid MDA23 achieved the highest moisture content (94.75 %), also differing statistically from the other materials evaluated. MDA01 and Albion did not differ from each other regarding moisture.

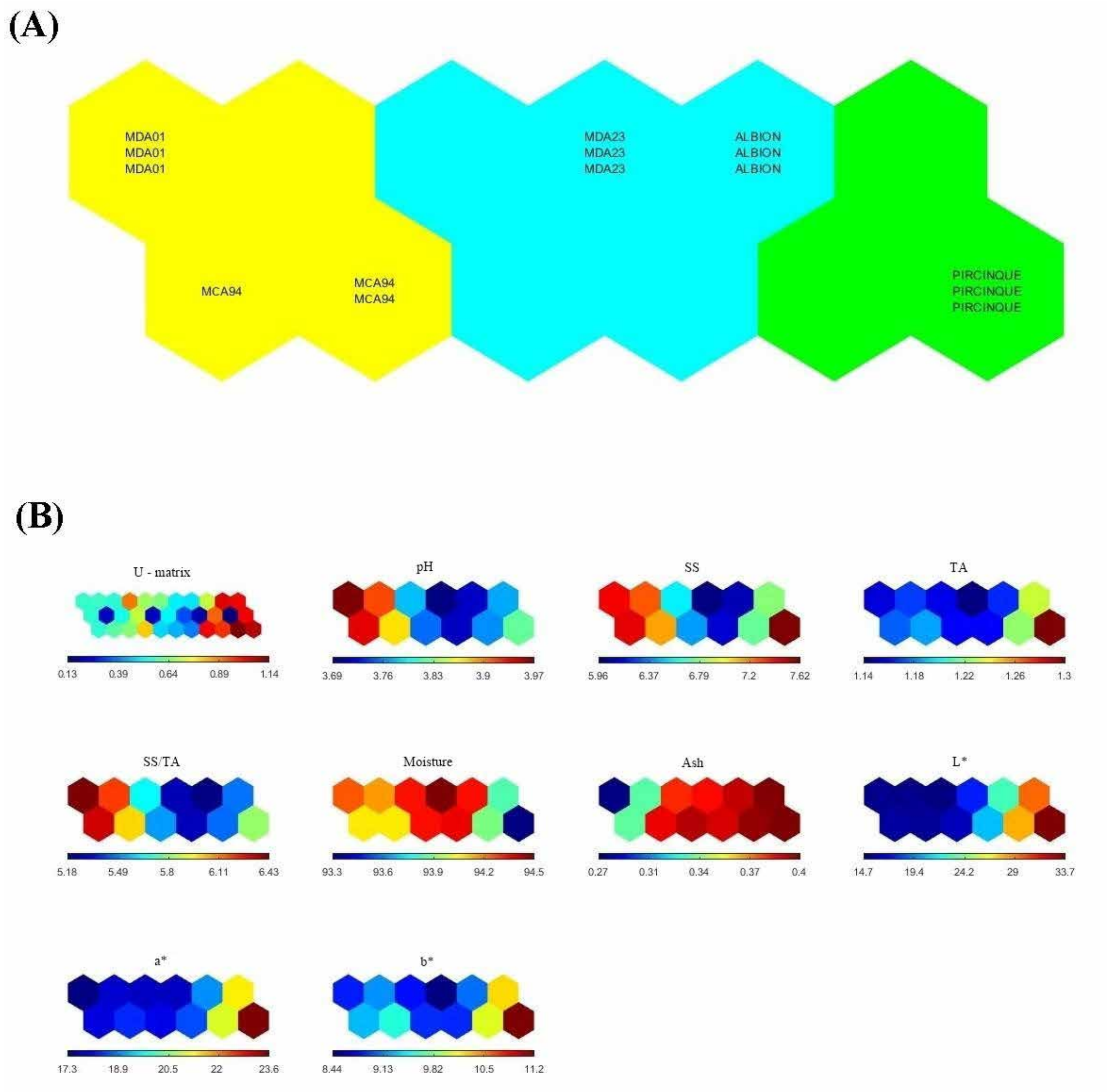
As for ash (A), experimental clone MDA01 (0.19 %) had the lowest content among the materials analyzed. The other genotypes did not differ statistically (Table 1). Ash of a food sample is the inorganic residue that remains after burning of the organic matter (MOLON, 2013). Ash content may be considered as a general quality measure in food, since higher ash contents also indicate higher levels of calcium, magnesium, iron, phosphorus, sodium and other mineral components in the fruits (ZHENG, WANG, 2003). The ash obtained does not necessarily have the same composition as the mineral matter present in the food, as there may be loss due to volatilization or some interaction in the sample's constituents (PARK, 2006).

Regarding the colorimetry parameter L* (luminosity), which represents variations from black (L=0) to white (L=100), the Pircinque cultivar achieved the highest values (36.40), differing statistically from the others, followed by Albion (28.31), also different from the other materials. Experimental clones MCA94 and MDA01 did not differ statistically, with values lower than the commercial cultivars Albion and Pircinque. MDA23 obtained the lowest value for L*, with 9.90. For variable a*, which represents the variations from green (negative values) to red (positive values), the Pircinque cultivar reached 25.76, differing from the other genotypes. MCA94 (18.99), MDA01 (16.91), MDA23 (15.94) and Albion (19.41) did not differ from each other for this characteristic. As for b*, which represents the variations from blue (negative values) to yellow (positive values), positive values occurred with more yellowish color for all genetic materials, not differing from each other. These colorimetry parameters are important because fruits with a more stable and attractive color tend to be associated with better quality and often determine the product's final value

Data from the experimental analyses underwent artificial neural network analysis using a competitive algorithm—Kohonen self-organized map (ANN/KSOM). Maps with different dimensions were generated to obtain the best data-representing arrangement according to the best validation indexes of clusters – Davies-Bouldin and Silhouette – along with smaller measurement errors (quantification, topographic and combined). The two-dimensional neural cluster map, the component maps of each analysis, and the U matrix are presented in Figure 1. The color scale indicates the distance between adjacent neurons. Variations in the results obtained are indicated by the color gradient of the bars located at the bottom of each map, excepting the U matrix.

The Davies-Bouldin index represents the degree of similarity between clusters, regardless of the partitioning method used and the number of clusters. The lower its value, the better will be the clusters. Silhouette index refers to the quality of the grouping based on the proximity

Figure 1. Two-dimensional cluster neural network showing the formation of three groups with their respective treatments (A), component maps and distance matrix (Matrix U) for pH, soluble solids (SS), titratable acidity (TA), ratio (SS/TA), moisture (M), ash (A), L*, a* and b* (B). IFSULDEMINAS – Inconfidentes Campus. Inconfidentes - MG, 2024



Source: authors (2024).

between objects in a group and the proximity of those objects to the nearest group. It can vary from 1 to -1 and the higher the value, the better (REZENDE, MARCACINI, MOURA, 2011; CHIP *et al.*, 2020).

This research was developed using a hexagonal network (2 x 6) with a Davies-Bouldin index of 0.446 and a Silhouette index of 0.760, which allows visualizing the correlations between the input parameters coded by value scores, relating the colors to the values of each variable of the weight vector in Figure 1.

Error values were also considered to determine the size of the neural map and assess network accuracy. Quantization error was 0.289, the topographic error was 0, and the combined error was 0.424. Low error values are important because they indicate that the best neuron is closer to the input vectors, which increases network generalizability. Quantization error is the Euclidean distance of the difference between all input vectors with respect to the vector of the winning neuron averaging all interactions. The topographic error is calculated by verifying which is the best and second best tuning neuron at all inputs. The values found show an adequate topology of the input data (ARCOVERDE *et al.*, 2011; NOVAES *et al.*, 2017). Interpreting the results involves analyzing the component plans.

Each hexagon present in the ANN/KSOM two-dimensional neural map represents a neuron in which the treatments studied are grouped according to their similarities. Based on this assumption, the samples appear divided into three clusters (Figure 1A).

The cluster located at the center of the map, in bluer, concerns the Albion and MDA23 samples. The cluster on the left, colored yellow, refers to the MDA01 and MCA94 samples. Highlighted in green, on the right, are the clusters for the Pircinque samples. From it one can infer that the U matrix (Figure 1B) corroborates the formation of three clusters, considering that the dark red highlights the great distance between neurons and consequently between different treatments.

Considering that the position occupied by a sample in the neural map (Figure 1A) corresponds to its same position in the component map (Figure 1B), one can identify the main variables responsible for the grouping and separation of samples. The central cluster was highly influenced by the lower values of soluble solids and pH, and by the high moisture content. The left cluster (yellow) has high pH and ratio (SS/AT) values, intermediate values for soluble solids and low values for the colorimetric parameters a* and b*. The right cluster was more influenced mainly by the high SS, TA, L*, a* and b* values, and the low humidity content. These observations corroborate Table 1, but the parameters of ratio (SS/TA) and b*, despite lacking statistical differences between the genotypes (Table 1), influence cluster formation.

Comparing Figures 1A and 1B may indicate the action of genetic factors and how they respond differently when under the same cultivation environment. Applying Kohonen's self-organizing map allowed to explore more efficiently the tendency of genotypes to cluster in relation to physicochemical analyses.

Conclusions

Pircinque, MCA94 and MDA01 genotypes achieved the highest values for soluble solids and pH. Regarding moisture, MDA23 had higher content compared with the others. As for ash, MDA01 had the lowest value when compared with the other genotypes. The Pircinque cultivar exhibited the highest titratable acidity, L* and a* content.

All experimental clones proved promising to be cultivated in southern Minas Gerais considering the analyzed parameters.

Acknowledgments

We thank IFSULDEMINAS – *Campus* Inconfidentes, Federal University of Lavras (UFLA) and the team that assisted us during the work.

References

ANTUNES, L. E. C.; BONOW, S. Morango: produção crescente. Embrapa Clima Temperado. **Cultivar HF**, Ano XIX, nº 128, p. 23-27, 2021. Disponível em: https://www.alice.cnptia.embrapa.br/alice/bitstream/doc/1133270/1/Producao-crescente.pdf. Acesso em: 22 jul. 2024.

ANTUNES, L. E. C.; REISSER JUNIOR, C.; SCHWENGBER, J. E. **Morangueiro**. Brasília, DF: Embrapa, 2016. Disponível em: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/179724/1/Luis-Eduardo-MORANGUEIRO-miolo.pdf. Acesso em: 22 jul. 2024.

AOAC - **Official Methods of Analysis of AOAC international.** 19th edition. AOAC 54 International, Gaithersburg, Maryland, USA, 2012.

ARCOVERDE, G. F. B.; ALMEIDA, C. M. de; XIMENES, A. de C.; MAEDA, E. E.; ARAÚJO, L. S. de. Identificação de áreas prioritárias para recuperação florestal com o uso de rede neural de mapas auto-organizáveis. **Boletim de Ciências Geodésicas**, v. 17, n. 3, p. 379–400, 2011. DOI: 10.1590/S1982-21702011000300004.

BARANKEVICZ, G. B.; NOVELLO, D.; RESENDE, J. T. V.; SCHWARZ, K.; SANTOS, E.F. Características físicas e químicas da polpa de híbridos de tomateiro, durante o armazenamento congelado. **Horticultura Brasileira**, v. 33, n. 1, p. 7–11, 2015. DOI: 10.1590/S0102-0536 20150000100002.

BELITZ, H.; GROSCH, W.; SCHIEBERLE, P. **Food chemistry:** revised and extended edition. 4.ed. Heidelberg, Germany: Springer, 2009. 1070 p. DOI: https://doi.org/10.1007/978-3-540-69934-7

BOONYAKIAT, D.; CHUAMUANGPHAN, C.; MANIWARA, P.; SEEHANAM, P. Comparison of physic-chemical quality of different strawberry cultivars at three maturity stages. **International Food Research Journal**, v. 23, n. 6, p. 2405–2412, 2016.

CONTI, J. H.; MINAMI, K.; TAVARES, F. C. A. Produção e qualidade de frutos de diferentes cultivares de morangueiro em ensaios conduzidos em Atibaia e Piracicaba. **Horticultura Brasileira**, v. 20, n. 1, p. 10-17, 2002. DOI: 10.1590/S0102-05362002000100002.

CRISPIM, D. L.; FERNANDES, L. L.; FERREIRA FILHO, D. F.; LIRA, B. R. P. Comparison of cluster methods agglomerative hierarchical in sustainability indicators in municipalities of Pará state. **Research, Society and Development**, v. 9, n. 2, e60922067, 2020. DOI: 10.33448/rsd-v9i2.2067.

FAO - Food and Agriculture Organization of the United Nations. 2023 [viewed 13 March 2025]. **Countries by commodity** [online]. Rome: FAO, 2023. Disponível em: https://www.fao.org/faostat/en/#rankings/countries_by_commodity. Acesso em: 22 jul. 2024.

FARNEZI, P. K. B.; OLIVEIRA, L. L. de; SARDINHA, L. T.; FRANÇA, A. C.; MACHADO, C. M. M.; MACEDO, L. A. Production and physical and chemical characterization of strawberry (*Fragaria x Ananassa* Duch) under different sources of phosphate fertilization. **Brazilian Journal of Development**, v. 6, n. 9, p. 65051-65066, 2020. DOI:10.34117/bjdv6n9-077.

FERREIRA, D. F. Sisvar: a computer statistical analysis system. **Ciência e Agrotecnologia**, v. 35, n. 6, p. 1039-1042, 2011.

GIL-ARIZA, D. J.; AMAYA, I.; LÓPEZ-ARANDA, J. M.; SÁNCHEZ-SEVILLA, J. F.; BOTELLA, M. Á.; VALPUESTA, V. Impact of plant breeding on the genetic diversity of cultivated strawberry as revealed by expressed sequence tag-derived simple sequence repeat markers. **Journal of the American Society for Horticultural Science**, v. 134, n. 3, p. 337-347, 2009. DOI: 10.21273/JASHS.134.3.337.

HOSSAIN, A.; BEGUM, P.; ZANNAT, M. S; RAHMAN, M. H.; AHSAN, M.; ISLAM, S. N. Nutrient composition of strawberry genotypes cultivated in a horticulture farm. **Food Chemistry**, v. 199, n. 1, p. 648–652, 2016. DOI: 10.1016/j.foodchem.2015.12.056.

IAL - INSTITUTO ADOLFO LUTZ. Procedimentos e determinações gerais. In: **Métodos físico-químicos para análise de alimentos**. 4. ed. São Paulo: Instituto Adolfo Lutz, 2008, p. 83-158. Disponível em: http://www.ial.sp.gov.br/resources/editorinplace/ial/2016_3_19/analisedealimentosial_2008.pdf. Acesso em: 22 jul. 2024.

KADER, A. A. Standardization and inspection of fresh fruits and vegetables. In: KADER, A. (Ed.). **Postharvest technology of horticultural crops**. 3.ed. University of California, Division of Agriculture and Natural Resources, Oakland, CA, USA, 2002. p. 287-360.

MANICA, I.; KIST, H.; MICHELETTO, E. L.; KRAUSE, C. A. Competição entre quatro cultivares e duas seleções de goiabeira. **Pesquisa Agropecuária Brasileira**, v. 33, n. 8, p. 1305-1313, 1998. Disponível em: https://seer.sct.embrapa.br/index.php/pab/article/view/4964/7104. Acesso em: 22 jul. 2024.

MARTÍNEZ, A. J. M.; VICARIO, I. M.; HEREDIA, F. J. Rapid assessment of vitamin A activity through objective color measurements for the quality control of orange juices with diverse carotenoid profiles. **Journal of Agricultural and Food Chemistry**, v. 55, n. 8, p. 2808-2815, 2007.

MOLON, R. **Qualidade e composição físico-química de frutas de morangueiro**. 2013. 35 f. Trabalho de Conclusão de Curso (Graduação) – Universidade Tecnológica Federal do Paraná, Medianeira, 2013. Disponível em: https://repositorio.utfpr.edu.br/jspui/handle/1/13339. Acesso em: 22 jul. 2024.

NOVAES, C. G.; ROMÃO, I. L. da S.; SANTOS, B. G.; RIBEIRO, J. P.; BEZERRA, M. A.; SILVA, E. G. P. da. Screening of *Passiflora* L. mineral content using principal component analysis and Kohonen self-organizing maps. **Food Chemisty**, v. 233, p. 507-513, 2017. DOI: 10.1016/j.foodchem.2017.04.111

OLIVEIRA, A. C. B. de; BONOW, S. Novos desafios para o melhoramento genético da cultura do morangueiro no Brasil. **Informe Agropecuário**, v. 33, n. 268, p. 21-26, 2012. Disponível em: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/69365/1/Ana-Claudia-p.-21-26.pdf. Acesso em: 22 jul. 2024.

PAPAROZZI, E. T.; MEYER, G. E.; SCHLEGEL, V.; BLANKENSHIP, E. E.; ADAMS, S. A.; CONLEY, M. E.; LOSEKE, B.; READ, P. E. Strawberry cultivars vary in productivity, sugars and phytonutrient content when grown in a greenhouse during the winter. **Scientia Horticulturae**, v. 227, n. 1, p. 1–9, 2018. DOI: 10.1016/j.scienta.2017.07.048.

PARK, K. J. **Análises de materiais biológicos**. Universidade Estadual de Campinas, Faculdade de Engenharia Agrícola, 2006. Disponível em:

https://scholar.google.com.br/citations?view_op=view_citation&hl=pt-BR&user=WSy7xpwAAAAJ&citation_for_view=WSy7xpwAAAAJ:2osOgNQ5qMEC. Acesso em: 22 jul. 2024.

PREFEITURA MUNICIPAL DE INCONFIDENTES. **Sobre o município**. Disponível em: https://inconfidentes.mg.gov.br/o-municipio/sobre-o-municipio/. Acesso em: 22 jul. 2024.

RAHMAN, M. M.; MONIRUZZAMAN, M.; AHMAD, M. R.; SARKER, B. C.; ALAM, M. K. Maturity stages affect the postharvest quality and shelf - life of fruits of strawberry genotypes growing in subtropical regions. **Journal of the Saudi Society of Agricultural Sciences**, v. 15, n. 1, p. 28-37, 2016. DOI: 10.1016/j.jssas.2014.05.002.

REIS, R. C.; VIANA, E. de S.; JESUS, J. L. de; DANTAS, J. L. L.; LUCENA, R. S. Caracterização físico-química de frutos de novos híbridos e linhagens de mamoeiro. **Pesquisa Agropecuária Brasileira**, v. 50, n. 3, p. 210-217, 2015. DOI: 10.1590/S0100-204X2015000300004.

REZENDE, S. O.; MARCACINI, R. M.; MOURA, M. F. O uso da mineração de textos para extração e organização não supervisionada de conhecimento. **Revista de Sistemas de Informação da FSMA**, v. 1, n. 7, p. 7-21, 2011. Disponível em: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/37233/1/FSMA.pdf. Acesso em: 22 jul. 2024.

RODAS, C. L.; SILVA, I. P. da; COELHO, V. A. T.; FERREIRA, D. M. G.; SOUZA, R. J. de; CARVALHO, J. G. de. Chemical properties and rates of external color of strawberry fruits grown using nitrogen and potassium fertigation. **Idesia**, v. 31, n. 1, p. 53-58, 2013. Disponível em: https://www.scielo.cl/pdf/idesia/v31n1/art07.pdf. Acesso em: 22 jul. 2024.

SANTOS, A. M. dos. Melhoramento genético do morangueiro. **Informe Agropecuário**, v. 20, n. 198, p. 24-29, 1999.

SCHAIDHAUER, K. G. **Caracterização físico-química e potencial antioxidante de cultivares de morangueiro em dois estágios de maturação**. 2022. 36 f. Trabalho de Conclusão de Curso (Bacharelado em Agronomia) - Universidade Federal do Pampa, Itaqui, 2021. Disponível em: https://dspace.unipampa.edu.br/bitstream/riu/7243/1/Karin%20Gibinski%20Schaidhauer%20-%202021.pdf. Acesso em: 22 jul. 2024.

SCHNEIDER, A. R. **Adaptabilidade de novas seleções de morangueiro desenvolvidas pela Embrapa, em cultivo protegido e fora de solo no município de Cerro Largo-RS**. 55f. il: 2022. Trabalho de Conclusão de Curso (Graduação) - Universidade Federal da Fronteira Sul, Curso de Bacharelado em Agronomia, Cerro Largo/RS, 2022. Disponível em: https://rd.uffs.edu.br/bitstream/prefix/5598/1/SCHNEIDER.pdf. Acesso em: 22 jul. 2024.

SCOTT, A.; KNOTT, M. A cluster analysis method for grouping means in the analysis of variance. **Biometrics**, p. 507-512, 1974.

SOUZA, D. C. de; VIEIRA, S. D.; RESENDE, L. V.; GALVAO, A. G.; FERRAZ, A. K. L.; RESENDE, J. T. V.; ELIAS, H. H. S. Propriedades físico-químicas em frutos de híbridos experimentais de morangueiro. **Agrotrópica**, v. 29, n. 1, p. 85-96, 2017. DOI: 10.21757/0103-3816.2017v29n1p85-96

TURQUETT, L. C. das. G. B.; BASTOS, R. A.; LIMA, J. P. de; VALENTE, G. de F. S. Evaluation of edible cover made from chitosan, rice bran and cassava starch in postharvest conservation of strawberries. **Brazilian Journal of Development**, v. 7, n. 3, p. 33153-33171, 2021. DOI: 10.34117/bjdv7n3-845

VATANEN, T.; OSMALA, M.; RAIKO, T.; LAGUS, K.; SYSI-AHO, M.; OREŠIČ, M.; HONKELA, T.; LÄHDESMÄKI, H. Self-organization and missing values in SOM and GTM. **Neurocomputing**, v. 147, p. 60-70, 2015. DOI: 10.1016/j.neucom.2014.02.061.

ZEIST, A. R.; RESENDE, J. T. V. de. Strawberry breeding in Brazil: current momentum and perspectives. **Horticultura Brasileira**, v. 37, n. 1, p. 7–16, 2019.

ZHENG, W.; WANG, S. Y. Oxygen radical absorbing capacity of phenolics in blueberries, cranberries, chokeberries, and lingonberries. **Jounal of Agricultural and Food Chemistry**, v. 51, n. 2, p. 502-509, 2003. DOI: 0.1021/jf020728u.