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Biometric and physicochemical characterization of *Capsicum chinense* commercialized in the interior of Goiás, Brazil

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Abstract
Pepper reflects the ethnic diversity and richness of Brazil's food traditions. The *Capsicum chinense* species, cultivated by small producers, generates jobs and contributes to the economy of family farmers. In this context, this study aimed to perform the biometric and physicochemical characterization of *Capsicum chinense* commercialized in the interior of Goiás, Brazil. Fifty intact and ripe fruits were collected in São Luís de Montes Belos, Goiás, in October and November 2023, sanitized, and sent for analysis of weight and diameters, as well as moisture, ash, lipids, soluble solids, total sugars, and titratable acidity. Significant variations (p<0.05) in length, diameter, and weight were found, with fruit length showing the greatest variability. Nevertheless, diameters were more consistent, indicating a degree of uniformity that may influence market appeal. The fruits exhibited low total titratable acidity and moderate soluble solids content, resulting in a balanced flavor profile. Total sugars and ash content were also relatively consistent, while the high moisture and low lipid content reflected the fruits' fresh and low-fat nature. Overall, the findings align with previous studies, highlighting the stability in the nutritional and physical properties of *Capsicum chinense* commercialized in the interior of Goiás, which could enhance their commercial and culinary potential.

Keywords: Characterization, *Capsicum chinense*, Goiás, Brazil

Introduction
In addition to being widely used as a condiment, pepper carries intrinsic cultural values, reflecting the ethnic diversity and richness of Brazil's food traditions. In the economic context, the production and export of peppers, such as varieties of the *Capsicum* genus, gained relevance from the 20th century onwards, driven by the growing demand in both domestic and international markets [1]. Pepper is also valued for its functional and medicinal properties, which has attracted investments in research and the development of new products, strengthening its production chain [2]. Recent studies demonstrate the potential of Brazilian peppers, especially *Capsicum chinense*, for the functional food market, as well as their importance in generating jobs and contributing to the economy of small family farmers [3].
The cultivation of *Capsicum chinense* by small producers in the interior of Brazil has stood out as a viable alternative for income generation and the promotion of food security. The pepper, especially the variety known as “pimenta de cheiro” or malagueta, is a crop that adapts well to Brazilian climatic conditions, allowing small farmers to explore its production within family farming systems [4]. The cultivation of *Capsicum chinense* not only provides a significant increase in family income but also contributes to the preservation of traditional knowledge and sustainable agricultural practices [5]. The diversity of cultivated varieties, combined with the growing market interest in organic and local products, has driven demand and enhanced the value of artisanal production. Furthermore, the inclusion of these small producers in direct marketing networks has strengthened their productive capabilities and promoted regional economic development [6].

Quality control is a fundamental aspect of producing *Capsicum chinense* fruits, as it ensures the standardization and safety of the final product, meeting the requirements of both domestic and international markets. To ensure this quality, the use of physical-chemical and biometric analyses is essential [7]. Physical-chemical analyses, such as the determination of titratable acidity, soluble solids content, and moisture, allow for the evaluation of the nutritional and sensory composition of the fruits, aspects that directly affect their commercial acceptance and utilization in food industries. Additionally, these analyses provide crucial information about the quality of the fruits, influencing their preservation and market potential [8].

In relation to this, biometric analyses, which include measuring parameters such as length, diameter, and weight of the fruits, are effective tools for detecting genetic variability within *Capsicum chinense* populations. These morphological characteristics are frequently used as indicators of genetic diversity, which can be explored for the genetic improvement of the species [9]. Genetic variability within the same population of *Capsicum chinense* can indicate potential for selecting cultivars better adapted to specific cultivation conditions as well as for resistance to pests and diseases [10]. Therefore, integrating quality control data, physical-chemical analyses, and biometric analyses becomes a powerful strategy for detecting genetic variation and improving the agricultural production of peppers, allowing farmers and industries to obtain high-quality products with differentiated characteristics. In this context, this study aimed to carry out the biometric and physicochemical characterization of *Capsicum chinense* commercialized in the interior of Goiás, Brazil.

Methodology

Capsicum chinense fruits were acquired in October and November 2023 in the city of São Luís de Montes Belos, Goiás, Brazil, which has a hot tropical and subhumid climate. Peppers were produced on small rural properties that use soil fertilization with cattle manure, commercial fertilizer, and drip irrigation.

Next, 50 samples were selected based on their physical integrity and optimal ripeness. Immediately after, they were sanitized and sent to the Food Technology Laboratory and the Physicochemical Laboratory at the Centro Universitário Brasília de Goiás (UNIBRASILIA) for analysis.

At the Food Technology Laboratory, samples were weighed on a digital scale (precision 0.001g) and measured for length (longitudinal diameter) and width (transversal diameter) or the average diameter derived from three diameters measured at different points using a digital caliper (precision 0.01 mm), considering or not the tip, which is a characteristic element of the pepper. The length was measured from the basal to the apical portion of the fruit. The width was measured in the central part of the fruit, in the same location where the diameter measurement was taken. Finally, the shape of each pepper was characterized by the longitudinal diameter/transversal diameter (LD/TD) ratio [11].

At the Physicochemical Laboratory, tests for moisture, ash, lipids, total soluble solids, total sugars, and total titratable acidity were performed following the methodology of the Instituto Adolfo Lutz (2008) [12].

For data analysis, the Windows edition of GraphPad Prism 5.01 software was employed, and the outcomes were presented as absolute values and/or mean±standard deviation (SD). For the statistical evaluation, one-way or two-way ANOVA was performed, followed by Bonferroni correction for multiple comparisons, with significance determined at P values <0.05.

Results and Discussion

The physical parameters of *Capsicum chinense* fruits (Table 1) reveal significant differences in terms of variation and consistency across the evaluated measures, as indicated by the one-way ANOVA statistical analysis with a significance level of $p<0.05$ and Bonferroni post-hoc tests. The total fruit length had a mean of 27.418±2.807 mm, with a variation of 12.2%, suggesting a relative homogeneity in the fruit dimensions. The 95% confidence interval for this variable (26.363-28.112 mm) reinforces the precision of the mean estimate, indicating that most fruits follow this distribution.

Table 1: Physical parameters of *Capsicum chinense* fruits. *$p<0.05$. One-way ANOVA and Bonferroni post-hoc tests.

Parameters *	mean±SD	Coefficient of variation (CV%)	Confidence Index (95%)
Total length (mm)	27.418±2.807	12.2	26.363-28.112
Longitudinal diameter (mm)	17.221±1.399	9.1	16.906-17.784
Cross-sectional diameter (mm)	16.782±1.404	9	16.214-17.014
Width (mm)	15.771±1.412	9.1	15.466-16.390
Tip (mm)	12.894±2.637	18.5	12.405-13.981
Weight (g)	1.602±0.234	15.8	1.572-1.642

Comparing the longitudinal and cross-sectional diameters, the fruits presented close means, with a longitudinal diameter of 17.221±1.399 mm and a cross-sectional diameter of 16.782±1.404 mm. Both had lower coefficients of variation than the total length (9.1% and 9%, respectively), indicating less variability in these dimensions. These results suggest that although the total length varies more, the diameters are more uniform, which could have implications for the overall appearance of the fruits and their commercial acceptance. Furthermore, the confidence intervals for these measurements are quite narrow, demonstrating consistency among the samples.

Another parameter evaluated was the fruit width, which had a mean of 15.771±1.412 mm, with a variation of 9.1%, similar to the diameters, indicating that the transverse dimensions of the fruits tend to be more stable. The tip of the fruits, however, showed greater variability, with a coefficient of variation of 18.5%, reflecting a higher heterogeneity in this characteristic, with a mean of 12.894±2.637 mm. The confidence interval (12.405-13.981 mm) shows a wide variation, possibly influenced by genetic or environmental factors.

Finally, fruits weight had a mean of 1.602±0.234 g, with a coefficient of variation of 15.8%, showing significant variation among peppers. This difference in weight may be related to fruit dimensions, particularly in terms of the variability observed in length and tip. The confidence interval for weight (1.572-1.642 g) confirms that although

there is variation, most fruits remain within a narrow range, which is important from a standardization perspective for consumption and marketability.

Results obtained here are comparable to those of Faria (2009) [13], who, while investigating the genetic variability of peppers, found values of 27.442 mm for length, 17.891 mm for width, and 3.015 g for weight in samples of *Capsicum* peppers. Alvares (2011) [14], in studying the genetic variability of *Capsicum chinense* Jacq., reported average values of 23.84 mm for length, 13.87 mm for width, and 1.51 g for weight, with CV of 19.8%, 15.2%, and 41.1%, respectively. Meanwhile, Reis *et al.* (2015) [11], in conducting a biometric and physicochemical characterization of *Capsicum chinense* sold in the city of Barra do Bugres, Mato Grosso, observed a length of 25.001 mm, width of 15.063 mm, and an average weight of 1.530 g.

The physicochemical parameters of *Capsicum chinense* fruits (Table 2) provide a comprehensive view of the chemical composition and nutritional content of the species. The total titratable acidity (TTA) showed a mean of 0.31±0.001, demonstrating low variation, indicating that the acidity in the fruits is relatively consistent. The reduced standard deviation suggests that, in most of the fruits analyzed, acidity levels were homogeneous, likely having little influence on the final taste. It is well established that lower acidity leads to better preservation of the product. Reis *et al.* (2015) [11] found a mean TTA of 0.27%, similar to the values reported in this study. On the other hand, Crisóstomo *et al.* (2008) [15] observed average levels of 0.48%, significantly higher than those in this study ($p<0.05$).

Table 2: Physicochemical characteristics of *Capsicum chinense* fruits. *$p<0.05$. One-way ANOVA and Bonferroni post-hoc tests.

Characteristics *	Mean±SD
Total titratable acidity (TTA) (%)	0.31±0.001
Total soluble solids (°Brix)	7.1±0.22
Total sugars (mg mL^{-1})	0.2±0.005
Ash (%)	1.22±0.06
Humidity (%)	90.48±0.71
Lipids (%)	0.18±0.008

Total soluble solids (°Brix) reached a mean of 7.1±0.22, with small variation, indicating a considerable concentration of sugars and other soluble compounds in the pulp. This value is important for determining the fruit's potential in culinary applications, as it is directly related to the perception of sweetness. Compared to acidity, the ratio between soluble solids and acidity defines the flavor balance, suggesting that *Capsicum chinense* fruits have a milder flavor profile. Kluge *et al.* (2002) [16] explain that the correlation between total soluble solids content and titratable acidity is linked to the balance between sugars and acids in fruits, directly affecting their taste. Regarding this relationship, caution is necessary, as some fruits with low levels of acids and soluble solids may exhibit high titratable acidity/total soluble solids ratios, which can lead to incorrect interpretations of the product's sensory quality. Studies on peppers of the *Capsicum chinense* species conducted by Lannes *et al.* (2007) [3] found soluble solids content ranging from 6 to 10°Brix. Segatto (2007) [17] reported a soluble solids content of 10.38°Brix in pepper fruits from the state of Minas Gerais.

Total sugars had a mean of 0.2±0.005 mg mL^{-1}, with minimal variation among the fruits. This low standard deviation reinforces the uniformity of sugar content across the analyzed samples, which is relevant for fruit consistency in terms of taste. The low levels of sugar observed contrast with the soluble solids, suggesting that other compounds, besides sugars, contribute to the °Brix value, such as organic acids and minerals.

The ash percentage, indicating the mineral content in the fruits, had a mean value of 1.22±0.06%, like that reported in studies by Reis *et al.* (2015) [11] and Oliveira (2011) [18]. This parameter is significant in demonstrating the nutritional value of the fruits, as it reflects the number of mineral components after the sample's combustion. The moderate standard deviation indicates that, although there is some variation in mineral concentration among the fruits, most have a relatively consistent mineral composition. In addition to ash, certain salts can be detected, which do not significantly affect the result of the analysis.

Moisture, which reached 90.48±0.71%, reflects the high-water content in *Capsicum chinense* fruits, which is characteristic of fresh fruits. The low variation in this parameter suggests that the analyzed fruits maintained similar hydration levels, which can directly influence texture and perishability. High moisture is also related to the low lipid content, which was 0.18±0.008%, demonstrating that the fruits are low in fats, a common trait in peppers and other vegetable fruits.

Conclusion

The study of the physical and physicochemical parameters of *Capsicum chinense* fruits revealed significant variations in length, diameter, and weight, with fruit length showing the highest variability. Notwithstanding, diameters were more consistent, indicating a degree of uniformity that may influence market appeal. The fruits exhibited low TTA and moderate soluble solids content, resulting in a balanced flavor profile. Total sugars and ash content were also relatively consistent, while the high moisture and low lipid content reflected the fruits' fresh and low-fat nature. Overall, findings align with previous studies, emphasizing the stability in the nutritional and physical properties of *Capsicum chinense* commercialized in the interior of Goiás, which could enhance their commercial and culinary potential.

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Declaration of interest statement

Authors declare no conflicts of interest.

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