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Biometric analysis of Palmer mangoes

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Abstract

Mango, a climacteric fruit, faces significant losses in the supply chain due to damages, resulting in a substantial waste of approximately 30% of the production. Among widely marketed varieties, the 'Palmer' cultivar stands out due to its flavor and coloration. The efficiency in the transportation and storage of these fruits is intricately linked to various attributes, especially their physical characteristics. In this context, the present study conducted a biometric evaluation of 145 'Palmer' mangoes harvested in Coxim, Mato Grosso do Sul. Parameters such as weight, length, width, and thickness of the fruits were analyzed using a semi-analytical balance and caliper. The results revealed that the mangoes produced in Coxim weigh around 396 g, with a length of 13 cm, width of 8 cm, and thickness of 7.5 cm. These measurements are smaller than the commercially marketed fruits of the same variety but larger than those of the Espada, Rosa, and Van Dyke varieties. Additionally, all analyzed variables showed a positive correlation, indicating that as one variable increases, the others also increase. This underscores the importance of special care in handling fruits throughout the supply chain, given their density of 0.534 g/cm³ and extensive contact area. These findings emphasize the pressing need for improvements in packaging, transportation, and storage processes to reduce losses and waste, thereby contributing to a more efficient and sustainable management in the mango supply chain.

Keywords: height, *Mangifera indica.*, thickness, weight, width

Introduction

Mangifera indica L. belongs to the Anacardiaceae family in the Sapindaceae order and reaches a height of 30 m. The tree is native to India but is now cultivated in many tropical and subtropical regions. Climatic conditions have a significant impact on mango flowering time. In the tropics, flowering begins at the height of the dry season, just in time for the rainy season, which favors fruit (mango) development. Mangoes provide energy, dietary fiber, carbohydrates, proteins, fats, vitamins, and various phytochemicals. Some of the main bioactive compounds identified in mangoes include phenolic acids, polyphenols, carotenoids, and vitamins, mainly ascorbic acid, thiamine, riboflavin, and niacin. Nutrient composition can vary according to fruit variety; there are over 1,000 mango varieties worldwide. Among the existing varieties, only a few are grown and marketed on a commercial scale, such as the Palmer mango cultivar (Jahurul et al., 2015; Adeonipekun et al., 2023; Yahia et al., 2023).

The marketing of fresh produce faces a lot of uncertainty due to dealing with perishable goods. Climatic conditions can affect production as well as final customer demand. Product deterioration and damage caused by pests also impact the supply chain. Among the factors influencing fruit wastage is the size and shape of the product, where larger fruits are often more susceptible to damage during handling and transportation (Arivazhagan et al., 2016; Meyer et al., 2017). The inability to quickly bring ripe mangoes to the market results in fruit wastage. Currently, about 30% of mangoes are damaged due to lengthy supply chain processes, poor storage conditions, and damage during transportation and fruit handling (Laguerre et al., 2023; Vu et al., 2023).

In this manner, the biometrics of mangoes will

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be evaluated with the aim of characterizing the fruits produced in Coxim, considering mass, length, width, and thickness, since these attributes can influence the efficiency of fruit transportation and storage, affecting the supply chain's ability to meet market demand and are significant for commercial valuation.

Material and methods

Mangoes cv. Palmer

The mangoes cv. Palmer were manually harvested at São Pedro Farm, located in the municipality of Coxim, Mato Grosso do Sul (18°27'11.8"S and 54°35'08.3"W). In this study 145 mangoes were harvested, prioritizing the 6:00 AM timeframe to take advantage of favorable conditions and minimize fruit transpiration. Fruit coloration was assessed, and fruits at stages 2, 3, or 4 were selected (Embrapa, 2008). The fruits were transported to the Federal Institute of Mato Grosso do Sul - Campus Coxim (IFMS - Campus Coxim) in produce boxes. The fruits underwent a sanitation process, including washing with ultrapure water and immersion in a 200 ppm sodium hypochlorite solution (Sodium hypochlorite, Anhembi Industries, Brazil) for 15 minutes, followed by rinsing with ultrapure water and draining at room temperature for 15 minutes.

Mass Determination

The fruits were weighed on a semi-analytical balance (BL3200H, Shimadzu Corporation, Japan), and the mass was recorded in grams (g).

Length Measurement

The assessment of length was carried out by measuring the distance between the basal and apical portions of the fruit using a universal digital caliper (Digital Electronic Caliper 150 mm, Caliper, China).

Width Measurement

The fruits were placed on a flat surface, and the width was measured at the midpoint of the fruits using a universal digital caliper (Digital Electronic Caliper 150 mm, Caliper, China).

Thickness Measurement

Using a universal digital caliper (Digital Electronic Caliper 150 mm, Caliper, China), the thickness was measured at the central point of the fruits.

Statistical Analysis

The results of the evaluations underwent descriptive statistical analysis (mean, median, minimum value, maximum value, standard deviation, and coefficient of variation) and correlation analysis. These assessments were conducted using the open-source software R, version 4.3.0.

Results and Discussion

The mangoes of the cv. Palmer variety that were examined displayed an oblong shape with a greenish-purple coloration. These mangoes have a length that is 39.21% greater than their width, and the thickness is less than the width, as demonstrated in (**Table 1**).

Among the attributes examined, the results related to thickness demonstrated the least dispersion, suggesting that this characteristic is the most homogeneous. In contrast, the variability in weight values stood out more prominently. Consequently, weight may be more appropriately represented by the median, while mean values may be more suitable for describing length, width, and thickness. Ceagesp (2022) established classification criteria for Palmer mangoes in the wholesale market, dividing them into four categories (A, B, C, and D) based on weight. Category A encompasses mangoes weighing from 501 to 650g, commanding a higher price due to their larger size. Category B includes mangoes over 650g, competitive in price due to their greater size. Category C covers mangoes ranging from 400 to 500g, striking a balance between size and intermediate pricing. Category D consists of mangoes weighing less than 400g, offering more affordability due to their smaller size. This categorization streamlines the pricing and efficient commercialization of Palmer mangoes (**Figure 1**).

As previously observed (Figure 1), 52.08% of the assessed fruits have a weight below 400g, 32.64% weigh between 400 and 500g, and 15.28% of the fruits weigh between 501 and 650g. The lack of uniformity in production can negatively impact consumer purchasing perception (Musacchi & Serra, 2018).

Table 1. Statistical variables of the four biometric characteristics.

Variable	Weight (g)	Length (cm)	Width (cm)	Thickness (cm)
Mean	416.36	13.11	7.97	7.49
Median	395.9	13.08	7.91	7.44
Minimum value	235.98	11.02	6.43	6.41
Maximum value	623.95	15.42	9.42	8.57
Standard deviation	78.75	0.98	0.59	0.47
Coefficient of variation	18.91	7.45	7.43	6.35

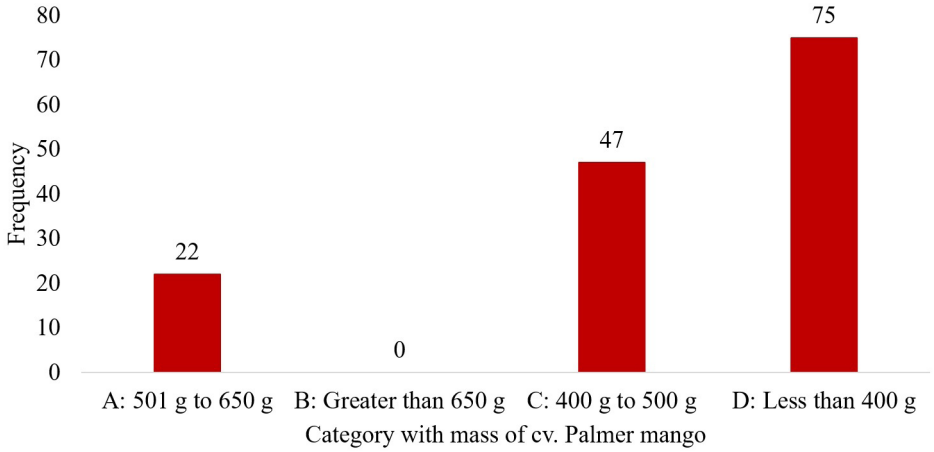

Figure 1. Frequency distribution of the weight of cv. Palmer mangoes collected according to Ceagesp (2022) valuation categories.

Compared to other commercially available mango varieties, mango cv. Palmer studied had an average weight lower than that of Tommy Atkins (460g), Haden (515g), Palmer category A (515g), Keitt (610g) and Kent (775g) and higher than that of Espada (300g), Rosa (350g) and Van Dyke (350g) (Costa & Santos, 2023).

In the context of Pearson correlation statistical analysis, a significant positive relationship was observed among all the variables under investigation. This result indicates that as one of the variables increases, the others tend to grow simultaneously, suggesting a positive linear association between these variables. This implies that changes in one variable are generally associated with corresponding changes in the others (**Figure 2**).

It was observed that the mass of cv. Palmer mangoes shows a moderately strong positive correlation with the other variables (Figure 2; **Table 2**). According to Schober et al. (2020), a correlation less than 0.40 is considered weak, from 0.40 to 0.69 is moderate, and 0.70 or higher is strong.

In this manner, the parameter of length exhibits a moderate correlation (with r values between 0.3 and 0.5) with both the width and thickness of the mangoes. The relationship between width and length is also characterized by moderate correlation. Furthermore, the correlation between the width and thickness of the mangoes is similar, indicating a moderate association between these variables. On the other hand, it is

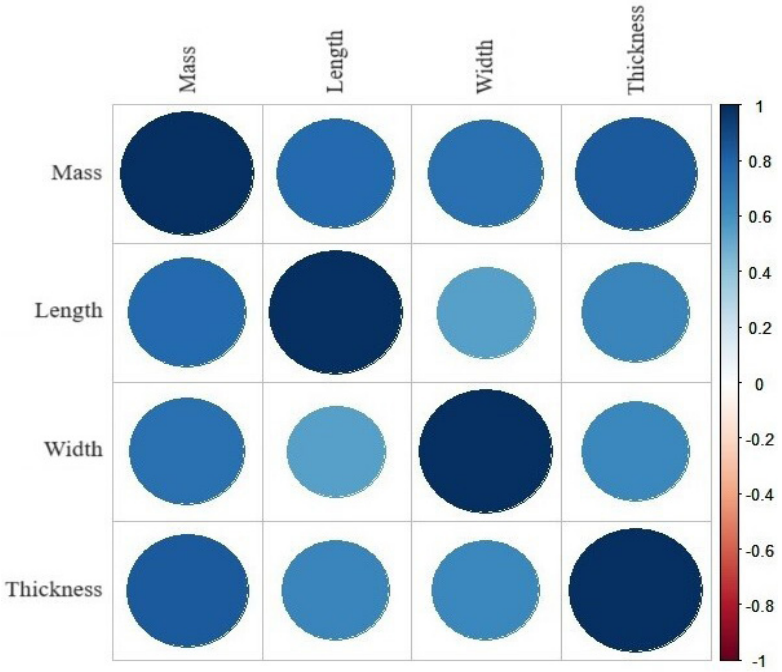

Figure 2. Pearson correlation graph of the physical parameters of the fruits.

Table 2. Pearson correlation strength of the physical parameters of the fruits.

Parameter	Mass	Length	Width	Thickness
Mass	1.00	0.77	0.74	0.83
Length	0.77	1.00	0.54	0.65
Width	0.74	0.54	1.00	0.65
Thickness	0.83	0.65	0.65	1.00

noteworthy that the relationship between the mass of mangoes and their length is strong (with r values between 0.7 and 1.00), indicating a significant and positive linear association between these two variables. This suggests that an increase in the mass of mangoes is strongly related to their length.

There are also viable alternatives for assessing biometric characteristics of fruits, such as the application of monochromatic computer vision techniques, the use of equations to estimate mass from length and width measurements, capturing images with RGB-D cameras for estimation, and the use of dedicated smartphone apps for such estimates (Wang et al., 2017; Wang et al., 2018; Patel et al., 2021; Amaral & Walsh, 2023).

The physical characterization of fruits from small-scale producers plays a significant role for several reasons. Firstly, this process provides valuable insights into the intrinsic quality of the fruits and their potential uses (Batista et al., 2015). Secondly, physical characterization contributes to the development of efficient and economically viable classification systems (Joshi & Awate, 2016). Lastly, but not least, this approach simplifies the comparison of quality characteristics among different fruits (Kafkas, 2021). These points underscore the importance of physical characterization in optimizing the production of small-scale producers, fostering improvements in quality and competitiveness in the market.

Conclusion

Palmer variety mangoes produced in Coxim that have been evaluated meet commercial standards; however, they are commercially undervalued. It is cruciar to conduct a sensory analysis of smaller fruits and introduce them to the Market, as larger fruits tend to have a higher incidence of physical damage, as their contact area is greater during handling and transportation. This necessitates more care and attention in the production chain, along with the adoption of new technologies for fruit preservation.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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