Correlations between physical and chemical characteristics of Cortibel guava (*Psidium guajava* L.) fruits grown in the Brazilian Cerrado

Correlaciones entre las características físicas y químicas de los frutos de guayaba (*Psidium guajava* L.) Cortibel cultivados en el Cerrado brasileño

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Abstract

The correlation between physical and chemical attributes of fruits can serve as indicators for the ideal harvest time and function as selection criteria to enhance the management and productivity of crops. This study aimed to investigate the correlations among physical and chemical properties of Cortibel guava fruits grown in the Brazilian Cerrado. Parameters assessed included skin and pulp color, weight, diameter, length, total soluble solids, titratable acidity, and the ratio of these characteristics. Data were analyzed using Pearson's linear correlation with a significance level of $P < 0.05$. Several physical and chemical properties of the fruits exhibited significant correlations. The highest correlation coefficients were observed between weight and fruit diameter, as well as between hue angle of the skin and skin lightness. The properties of Cortibel guava fruits cultivated in the Brazilian Cerrado exhibit significant correlations. These findings enable the utilization of straightforward parameters in the selection processes of Cortibel guava for breeding objectives.

Keywords
Psidium guajava (L.) • fruit quality • indirect selection • physicochemical properties

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Resumen

La correlación entre los atributos físicos y químicos de las frutas puede servir como indicador del momento ideal de cosecha y funcionar como criterio de selección para mejorar el manejo y la productividad de los cultivos. Este estudio tuvo como objetivo investigar las correlaciones entre las propiedades físicas y químicas de los frutos de guayaba Cortibel cultivados en el Cerrado brasileño. Los parámetros evaluados incluyeron color de cáscara y pulpa, peso, diámetro, longitud, sólidos solubles totales, acidez titulable y la relación de estas características. Los datos se analizaron mediante la correlación lineal de Pearson con un nivel de significancia de P <0,05. Varias propiedades físicas y químicas de los frutos exhibieron correlaciones significativas. Los mayores coeficientes de correlación se observaron entre el peso y el diámetro del fruto, así como entre el ángulo de tonalidad de la cáscara y su luminosidad. Las propiedades de los frutos de guayaba Cortibel cultivados en el Cerrado brasileño exhiben correlaciones significativas. Estos hallazgos permiten la utilización de parámetros sencillos en los procesos de selección de guayaba Cortibel para objetivos de mejoramiento.

Palabras clave

Psidium guajava (L.) • calidad de la fruta • selección indirecta • propiedades fisicoquímicas

Introduction

Native to South America, the guava tree (*Psidium guajava* L.) has adapted to tropical and subtropical regions and is widely cultivated in these areas (28). The fruits hold high economic value due to their quality, favorable consumer acceptance, and rapid revenue, thereby enhancing their productive potential (3, 28). Guava is a significant crop in numerous countries, with fruits rich in minerals, flavonoid compounds, antioxidants, and vitamins, particularly vitamin C, which can be up to four times higher than in oranges (10, 26).

First bred in Santa Teresa - ES, Brazil, Cortibel guava production has since increased in the Brazilian Southwest because of its fungal resistance. This variety yields firm, fleshy fruits with an appealing exterior, high productivity, and extended shelf life, making them suitable for export. The fruits exhibit a wrinkled appearance with red pulp and are well-received in the fresh fruit market (1, 27).

Fruit characterization and the correlation between their attributes enable the study of genetic diversity among accessions or populations and the identification of potential parents or even genotypes with superior qualities (24). The discovery of high-quality materials in vegetatively propagated fruit species, such as the guava tree, facilitates the replication of superior quality fruits (26).

Characterization based on the physical and chemical properties of cultivars determines the intended market segment for the fruits, whether for processing or fresh fruit consumption. Fruits intended for processing must have high titratable acidity and soluble solid content in the pulp, while those for fresh consumption require low acidity and high soluble solids. Assessing the characterization and correlations of these attributes enables the production of high-potential fruits for both segments (5, 28).

Variables such as weight, length, and equatorial diameter are important attributes in breeding programs. These factors assist in selecting genotypes with desirable commercial properties for the fresh fruit market (8). Understanding physical and chemical attributes enables maintaining fruit quality and developing new products (15), as well as offering cost-effective methods for selecting species with high potential for use in breeding programs (16). Studying the correlations between these attributes is promising, as it helps determine the harvest point, functions as a selection criterion, and provides techniques to enhance crop management and productivity (2, 19).

Numerous authors have evaluated the correlations between physical and chemical attributes of guava fruits in different regions, including characteristics of four guava varieties in Colombia (22), fruits from 122 accessions across Pakistan (17), fruits of 22 genotypes in

New Delhi, India (23), fruits from nine genotypes in Punjab, India (13), fruits of six localities in the Sumapaz province of Colombia (6), fruits of 128 accessions in four different regions of Kenya (4), and fruits from eight indigenous guava cultivars in Pakistan (28).

Agronomic evaluations suggest that the Southwest region of Goiás, Brazil, holds promising potential for fruit tree cultivation. The region's climatic conditions and high-quality soil are conducive to the establishment of various crops, particularly those suited to tropical climates. However, research on the correlations between physical and chemical attributes of Cortibel guava fruits in this Brazilian state remains limited. Understanding these correlations and how an increase in one attribute can influence others is crucial, as it can aid breeding program managers in making more efficient decisions during selection to achieve desired outcomes.

Considering the above, the hypothesis is that Cortibel guava fruits produced in the Brazilian Cerrado exhibit significant correlations between their attributes, allowing for selection in future crosses. Consequently, this study aimed to evaluate the correlations between the physical and chemical properties of Cortibel guava grown in the Brazilian Cerrado.

Material and methods

The experiment was conducted in an experimental orchard in Jataí, Goiás, Brazil, situated at 17°53'08'' S and 51°40'12'' W, at an altitude of 696 m, from October to January. During this period, the relative humidity ranged from 64% to 80%. The region's climate is of the tropical savannah type (Aw), with a rainy season from October to April and a dry season from May to September. The average annual rainfall and temperature are 1,541 mm and 23.3°C, respectively (18).

The study sample consisted of 120 fruits with red pulp and smooth skin, collected from the middle third of 10 four-year-old plants. Fully ripe fruits were hand-harvested using visual evaluation to determine the ideal harvest point. All fruits with yellow skin were considered mature. After harvesting, the fruits were washed, air-dried, and weighed in the laboratory. A completely randomized experimental design was employed, with ten plants and 12 replications (fruits) per plant. The fruits were assessed for length, diameter, weight, skin and pulp color as determined by the CIELAB color space, total soluble solids (TSS), titratable acidity (TA), and the ratio between total soluble solids and titratable acidity (TSS/TA).

The length and diameter of the fruits (mm) were measured using a digital caliper (Mitutoyo®, Japan). The weight (g) was determined by individually weighing the fruits on a digital scale with a precision of 0.01 g (Marte Científica®, Brazil). Skin and pulp color were evaluated using the coordinates L* (degree of lightness), a* (red), b* (yellow), C* (Chroma), and h° (hue angle [arctan b*/a*]), measured by a digital colorimeter at two spots (Konica Minolta® CR-10, Japan). The L* value represents the brightness of the sample, ranging from 0 (least luminous) to 100 (most luminous); a* represents green (from 0 to -60) and red (from 0 to +60) colors; b* represents the yellow color (from 0 to +60); C* represents color saturation; and h° is the hue angle (from 0 to 360°), indicating the quadrant in which the sample color is located (11).

The pulp was processed in an electric blender without adding water and filtered through a nylon sieve. The total soluble solids content (°Brix) was measured by placing two drops of pulp onto a digital refractometer (Atago® model Palette PR-101, Japan). Titratable acidity (%) was obtained by titration using an NaOH solution and 1% phenolphthalein as an indicator (14). The ratio was calculated as the quotient of total soluble solids to titratable acidity. Data were analyzed for Pearson's linear correlation ($P < 0.05$) between the physical and chemical characteristics of the fruits using SAS software.

Results and discussion

Most of the evaluated characteristics exhibited a positive and significant correlation. A positive correlation was observed between fruit weight and diameter (r = 0.890) and between length and diameter (r = 0.560), indicating that these variables increase at the same rate (table 1).

Table 1. Pearson's correlation coefficients for the weight (g), diameter and length (mm), L*, a*, b*, C* and hue angle of the skin and pulp, total soluble solids (°Brix), titratable acidity (%), and the ratio of Cortibel guava (*Psidium guajava*) grown in the Brazilian Cerrado.

Tabla 1. Coeficientes de correlación de Pearson para el peso (g), diámetro y longitud (mm), L*, a*, b*, C* y tonalidad de la cáscara y pulpa, sólidos solubles totales (°Brix), acidez titulable (%), y proporción de guayaba Cortibel (*Psidium guajava*) cultivadas en el Cerrado brasileño.

	W	D	L	L*S	a*S	b*S	C*S	h°S
W	1.00							
D	0.890**	1.00						
L	0.747**	0.560**	1.00					
L*S	0.098^{ns}	0.132^{ns}	0.018^{ns}	1.00				
a*S	0.180**	0.195**	0.042^{ns}	0.359**	1.00			
b*S	-0.009^{ns}	0.017^{ns}	-0.019^{ns}	0.233**	0.163^{ns}	1.00		
C*S	0.048^{ns}	0.064^{ns}	0.016^{ns}	0.491**	0.298**	0.489**	1.00	
h°S	-0.084^{ns}	-0.108^{ns}	-0.022^{ns}	-0.349**	-0.867**	-0.192**	-0.349**	1.00
L*P	0.190**	0.157^{ns}	0.202**	0.085^{ns}	-0.306**	-0.070^{ns}	-0.128^{ns}	0.267**
a*P	-0.022^{ns}	-0.008^{ns}	-0.143^{ns}	-0.073^{ns}	0.235**	0.005^{ns}	0.119^{ns}	-0.207**
b*P	0.098^{ns}	0.070^{ns}	0.031^{ns}	0.023^{ns}	-0.249**	-0.093^{ns}	-0.126^{ns}	0.202**
C*P	0.118^{ns}	0.085^{ns}	-0.044^{ns}	-0.109^{ns}	-0.015^{ns}	-0.072^{ns}	-0.014^{ns}	-0.009^{ns}
h°P	0.063^{ns}	0.024^{ns}	0.171^{ns}	0.053^{ns}	-0.274**	-0.032^{ns}	-0.152^{ns}	0.233**
TSS	0.037^{ns}	0.040^{ns}	-0.009^{ns}	0.096^{ns}	-0.089^{ns}	0.028^{ns}	0.024^{ns}	0.113^{ns}
TA	-0.181**	-0.145^{ns}	-0.181**	0.101^{ns}	-0.159^{ns}	0.021^{ns}	0.146^{ns}	0.104^{ns}
TSS/TA	0.033^{ns}	-0.003^{ns}	0.008^{ns}	-0.013^{ns}	0.175^{ns}	0.033^{ns}	-0.115^{ns}	-0.091^{ns}

	L*P	a*P	b*P	C*P	h°P	TSS	TA	TSS/TA
W								
D								
L								
L*S								
a*S								
b*S								
C*S								
h°S								
L*P	1.00							
a*P	-0.591**	1.00						
b*P	0.644**	-0.248**	1.00					
C*P	0.060^{ns}	0.615**	0.555**	1.00				
h°P	0.723**	-0.948**	0.473**	-0.401**	1.00			
TSS	0.175^{ns}	0.014^{ns}	0.109^{ns}	0.089^{ns}	0.003^{ns}	1.00		
TA	-0.047^{ns}	0.096^{ns}	-0.002^{ns}	0.029^{ns}	-0.093^{ns}	0.106^{ns}	1.00	
TSS/TA	-0.023^{ns}	-0.029^{ns}	-0.010^{ns}	-0.033^{ns}	-0.008^{ns}	0.359**	-0.734**	1.00

** $P < 0.05$, ns = not significant. W: weight; D: diameter; L: length; L*S: lightness of the skin; a*S: red of the skin; b*S: yellow of the skin; C*S: chromaticity of the skin; h°S: hue angle of the skin; L*P: lightness of the pulp; a*P: red of the pulp; b*P: yellow of the pulp; C*P: chromaticity of the pulp; h°P: hue angle of the pulp; TSS: total soluble solids; TA: titratable acidity; TSS/TA: total soluble solids content and titratable acidity ratio.

** $P < 0,05$, ns = no significativo. W: peso; D: diámetro; L: longitud; L*S: luminosidad de la cáscara; a*S: enrojecimiento de la cáscara; b*S: color amarillo de la cáscara; C*S: cromaticidad de la cáscara; h°S: tonalidad de la cáscara; L*P: luminosidad de la pulpa; a*P: enrojecimiento de la pulpa; b*P: color amarillo de la pulpa; C*P: cromaticidad de la pulpa; h°P: tonalidad de la pulpa; TSS: sólidos solubles totales; TA: acidez titulable; TSS/TA: relación de contenido de sólidos solubles totales y de acidez titulable.

Positive correlations are common among such characteristics in fruit species because larger fruits typically have a greater weight and amount of pulp, making them more appealing to consumers (9). Fruit species, such as passion fruit grown in Viçosa, Minas Gerais, Brazil (21), and guava cultivated in Colombia (6), India (13), and Pakistan (17), yielded similar results.

Correlation coefficients can be classified as very strong when R-values range from ± 0.91 to ± 1.00, strong for values ranging from ± 0.71 to ± 0.90, average when they range from ± 0.51 to ±0.70, and weak when R-values range from ± 0.31 to ± 0.50 (12). In the present study, there is a very strong correlation between fruit weight and diameter and a strong correlation between fruit length and diameter. The positive association between weight, length, and diameter underscores the importance of these characteristics in the selection of fruits for breeding purposes (13).

The correlations between h° and L* of the pulp (r = 0.723), C* and a* of the skin (r = 0.489), C* and a* of the pulp (r = 0.615), L* and b* of the pulp (r = 0.64), and between h° and a* of the pulp (r = 0.473) were positive and significant (table 1, page 13).

The positive and significant correlation between h° and L* of the pulp in the present study indicates that these fruits have the potential to exhibit brighter red pulp. There was also a positive correlation for C* with b* of the skin and for C* with a* of the pulp, indicating that these fruits display skin of a more pronounced yellow color and pulp of an intense red color. The external appearance of fruits, including color, is the first quality parameter that consumers evaluate when selecting fruits (9).

Negative correlations were observed between the h° of the skin and a* of the pulp (r = -0.207), L* and a* of the pulp (r = -0.591), h° and a* of the pulp (r = -0.948), and between C* and h° of the pulp (r = -0.401), indicating that lightness and hue angle fluctuate during fruit ripening. This occurs due to increased pigment concentrations and oxidative reactions during ripening, which results in a change in dark colors and elevated luminosity values (20).

Negative correlations were found for titratable acidity with weight (r = -0.181) and length (r = -0.181) (table 1, page 13), suggesting that acidity content decreases as fruit size increases. Acidity content in fruits diminishes with their maturation and development (25). The negative correlations obtained in the present study support this information, indicating that fully ripe and developed fruits exhibit lower titratable acidity.

The ratio exhibited a positive correlation with total soluble solids (r = 0.359) (table 1, page 13), signifying that an increase in soluble solid content in the pulp enhances this characteristic. The ratio serves as a maturity indicator, playing a crucial role in fruits for both fresh consumption and processing industries. It also indicates flavor, as fully ripe fruits with higher ratio values have a balance between soluble solid content and titratable acidity. As observed in the present study, the ratio may also indicate physiological maturity for many other fruit species (25).

No significant correlation was found between total soluble solid content and titratable acidity (r = 0.106) (table 1, page 13), which suggests that these two characteristics do not depend on each other. Selection criteria for breeding purposes stipulate that fruits must have high levels of acidity and soluble solids to meet the requirements of processing industries (7). Given that processing industries require fruits with higher titratable acidity and soluble solid content (28), the Cortibel guava fruits produced in the present study can satisfy the demand of this segment.

Conclusion

Some physical and chemical characteristics of the Cortibel guava fruits grown in the Brazilian Cerrado show significant correlations. These results allow using simple evaluations, such as fruit size or skin and pulp color, to estimate productive parameters during the selection of Cortibel guava and to detect materials of interest. The correlation of these characteristics directs the appropriate commercial use of the fruits.

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