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Colorimetric variation and correlation of biometric parameters between umbu matrices

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Abstract – The umbu tree is an endemic species and is found in the Brazilian semi-arid. Umbu is highly appreciated for its socioeconomic importance and significant diversity of quality attributes. This study aims to explore the color-related variations between umbu matrices, and to evaluate the correlation between the main biometric attributes of quality. With this, 14 matrices were explored at the commercial ripening stage and submitted to colorimetric analysis (a*, b*, C* and L*) and determination of biometric parameters (fruit mass, length, width, shape, firmness, percentages of peel, seed, pulp, and yield). The colorimetric parameters were evaluated by the Scott-Knott mean test and dendrogram, and biometrics were submitted to linear correlation analysis. It was observed that in the peel green predominates, compared to the pulp, and the lowest luminosity indexes (L*) consist of the fruits with hairy peel. The saturation (C*) has a direct relationship with parameter b*; in addition, the dendrogram indicates the formation of four groups between the matrices. The correlation analysis of biometric parameters showed significant tendencies. Therefore, the results reinforce that the parameters evaluated can provide an important tool in selecting and quality control these fruits, since the required characteristics change according to their commercial purpose.

Index Terms: Fruit quality, *Spondias tuberosa*, umbuzeiro, caatinga.

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Variação colorimétrica e correlação de parâmetros biométricos entre matrizes de umbu

Resumo – O umbuzeiro (*Spondias tuberosa* arr. Câmara) é uma espécie endêmica do semiárido brasileiro. O umbu é muito apreciado, com importância socioeconômica e significativa diversidade de atributos de qualidade. O objetivo deste estudo foi explorar as variações colorimétricas entre matrizes de umbu e avaliar a correlação entre os principais atributos biométricos de qualidade. Com isso, foram explorados frutos de 14 matrizes no estádio de maturação comercial, submetidos à análise colorimétrica (a*, b*, C* e L*) e determinação de parâmetros biométricos (massa do fruto, comprimento, largura, forma, firmeza, percentuais de casca, semente, polpa e rendimento). Os parâmetros colorimétricos foram avaliados pelo teste de média Scott-Knott e pela obtenção de dendrograma; e os biométricos, submetidos à análise de correlação linear. Observou-se que na casca predomina o verde, em comparação à polpa, e os menores índices de luminosidade (L*) consistiram nos frutos com casca pilosa, e a saturação (C*) apresentou relação direta com o parâmetro b*; além disso, o dendrograma indicou a formação de quatro grupos entre as matrizes. A análise de correlação dos parâmetros biométricos apresentou tendências significativas importantes. Os resultados reforçaram que os parâmetros avaliados podem conferir uma importante ferramenta na seleção e no controle de qualidade, pois as características exigidas mudam conforme a finalidade comercial.

Termos para indexação: Qualidade de frutos, *Spondias tuberosa*, umbuzeiro, caatinga.

The umbu tree (*Spondias tuberosa*) belongs to the family Anacardiaceae, is distributed throughout the Brazilian semi-arid region, and has not been reported to occur anywhere else in the world, making it endemic (MARQUES; FREITAS, 2020). The umbu is a fruit classified as a drupe with an average diameter of 2 – 4 cm and mass of 10 – 20 g; however, as it is an allogamous species widely distributed, clear variations in appearance and chemical composition, among other important characteristics, are reported along the center of origin (LIMA et al. 2018).

The umbu is highly appreciated for its succulence and sweet-sour taste, consumed mainly fresh through juice, sweets, a dairy drink called “umbuzada”, etc. (NASCIMENTO et al. 2013, PAODJUENAS et al. 2019). Its production is restricted to the rainy season, making it a source of income for the local population (BATISTA et al. 2015).

Despite its great socioeconomic importance, acceptability, and high tendency to commercial expansion, there is no commercial cultivation of umbu, in which the obtainment of the fruits occurs in an extractive way (MERTENS et al. 2017; LIMA et al. 2018), although the variability of individuals within and between regions indicates an incipient process of domestication of this species (LINS NETO et al. 2012).

In terms of fruit diversity and their various attributes, it is of great importance to explore them, considering that throughout the production chain it is necessary to understand some behaviors and tendencies to obtain possible tools that assist in an efficient management that involves everything from the selection of individuals to quality control, according to possible market demands.

Among the attributes, coloration is a very important parameter for umbu because it is considered a visual tool that indicates its quality, especially in relation to the ripening stage. Furthermore, other apparent characteristics are often considered during the quality control process, such as size, firmness, and shape, which are often associated with each other. Therefore, to precisely understand these relations and non-conventional fruit variations, such as umbu, it is necessary to optimize the management itself and encompass the exploration possibilities.

In this regard, this study aimed to explore the possible variations related to color among different umbu matrices and to evaluate the correlation between the main biometric quality attributes.

In this study, fruits from 14 different umbu matrices from the Paraiban Cariri region in the city of Serra Branca (07º29'00" S, 36º39'54" W, altitude - 493 m) were exploited. About 160 hectares were covered, and the matrices were selected in the field based on apparent characteristics such as size, shape, and hairiness (Figure 1). Among them, the furthest matrices from each other were 3 and 4, with a distance of 3.6 km between them, and the nearest were 12 and 13, with a distance of 35 m between them (Figure 2).

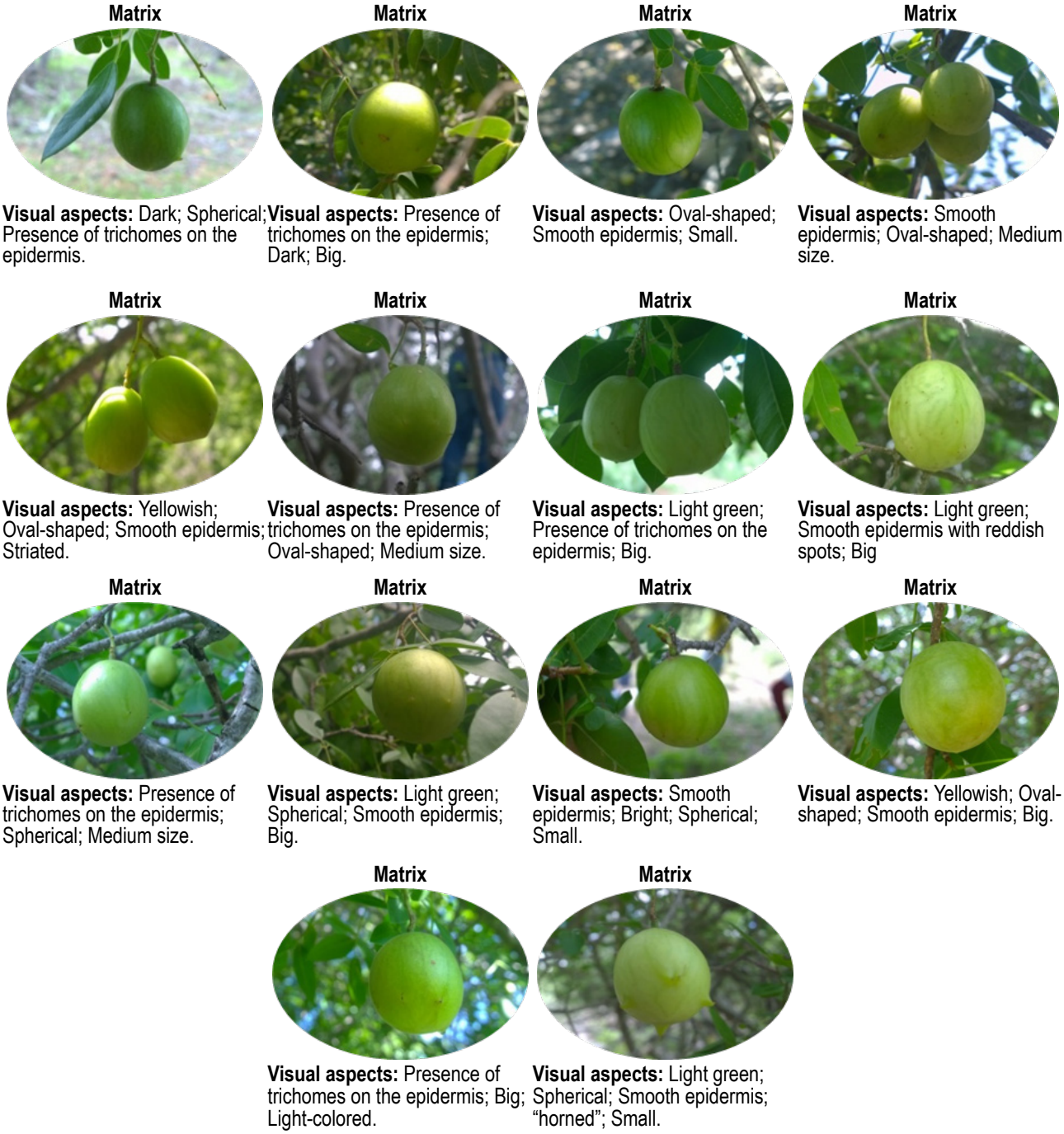

Figure 1. Fruits from selected matrices and their visual aspects observed in the field. Crop 2019 (Serra Branca-PB).

Source: Of its own autorship, 2019.

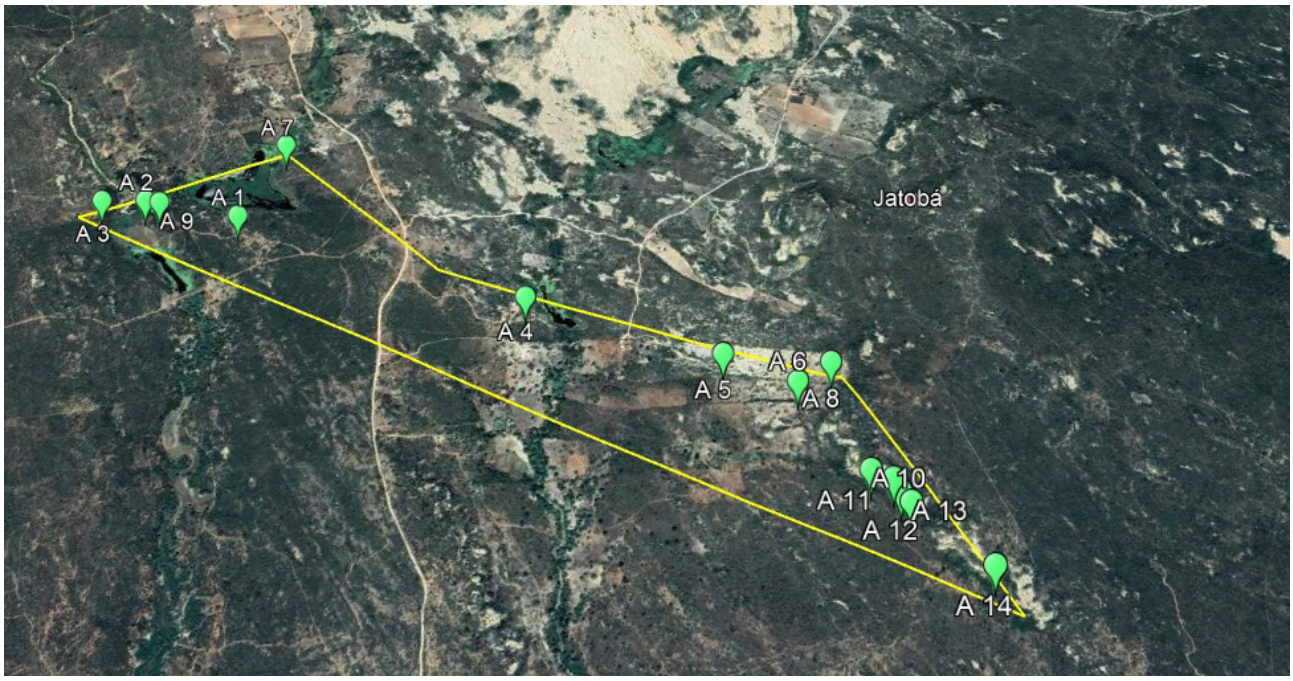

Figure 2. Geographical distribution of the 14 umbu tree matrices in the 160-hectare study area. Serra Branca/PB (Fonte: Google Earth).

For each matrix, 100 fruits were harvested between 6 and 10 in the morning, along the entire length of the crowns, and selected visually based on commercial maturity, called by Campos (2007) as almost ripe fruit, based on the peel coloration and apparent firmness. After collection, the fruits were packed in plastic bags, identified, and later transported in styrofoam boxes with ice to the Post-Harvest Physiology Laboratory of the Center for Human, Social, and Agrarian Sciences (CCHSA), Federal University of Paraíba (UFPB). In the laboratory, a selection was made among the fruits according to the absence of mechanical damage and diseases. For the analyses, three repetitions of 25 fruits were separated per experimental unit.

Color analysis of the fruit peel and pulp was performed according to the CIELab (Commission Internationale de L'eclairage) system, using a Delta Color portable digital colorimeter, measuring the parameters of luminosity (L*), saturation (C*), green/red (a*) and yellow/blue (b*) coordinates. Each reading was repeated in three distinct spots per fruit.

Furthermore, the fruit masses were obtained on an analytical scale, and then the longitudinal (length) and transverse (width) diameters (cm) were measured with the help of a caliper, and from their relationship, the shape of the fruits was determined. The closer the longitudinal/transverse diameter is to 1, the more the fruit tends to be spherical, and as this value increases the fruit is more oval-shaped (Chitarra e Chitarra, 2005).

The firmness was analyzed using a Instrutherm digital penetrometer, model PTR-300, with a 3 mm tip (5–200 N ± 1 N) inserted on the equatorial region of the fruits, with the results expressed in Newtons.

At the end, the fruits were peeled manually with the help of a stainless steel knife to obtain the mass of the shell, seed, and pulp, which were expressed as a percentage in relation to the whole fruit. Next, the yield was determined from the sum of the percentages of peel and pulp.

The results were subjected to the preliminary Shapiro-Wilk test for normality, and then the colorimetric parameters were evaluated using the Scott-Knott mean test at 1% probability and grouping to obtain a dendogram. The biometric parameters were subjected to linear correlation analysis. The software used to conduct the analysis was the Rstudio version 3 (2009-2019 RStudio, Inc.).

The umbu peel color is one of the main visual attractions, mainly because it is an indication of quality when it comes to the ripening stage and is characterized by its yellowish green hue.

For the peel, the a* coordinate varied between -8,97 (matrix 2) and -5,55 (matrix 12), with an average of -7,24 (Tabela 1). In this parameter, the lower the value, the higher the green hue; thus, the matrices 2, 3, 4, 5, 6, 7, 8, and 9 were those that had a greater predominance of green. However, it was observed that for the matrices 3, 6, 8, and 9, the values for b* were higher, indicating a more yellowish tone in the coloration. The fruits from the matrix 11 presented one of the highest values for a*, which occurred because they presented reddish spots on the peel. Moreover, in general, the matrices that are more similar to each other in relation to the coloration of the peel were 3,6 and 8; as well as matrices 4, 5 and 7.

Table 1. Colorimetric variation (a* - red/green and b* - yellow/blue) of the peel and pulp of umbu tree (*Spondias tuberosa*) fruits from 14 matrices located in Serra Branca-PB.

MATRIX	PEEL		PULP	
	a*	b*	a*	b*
1	-6.99 c	30.10 b	-6.81 b	32.73 a
2	-8.97 e	29.01 c	-8.32 c	33.27 a
3	-7.71 d	33.33 a	-7.13 b	30.64 b
4	-8.06 d	30.80 b	-5.89 a	27.54 c
5	-7.75 d	30.94 b	-6.60 b	31.85 a
6	-7.48 d	32.23 a	-7.10 b	29.17 c
7	-7.48 d	30.47 b	-5.47 a	29.87 b
8	-8.18 d	32.69 a	-5.63 a	28.72 c
9	-8.53 e	33.25 a	-6.67 b	30.71 b
10	-6.57 b	30.30 b	-6.99 b	33.17 a
11	-5.60 a	24.12 e	-5.71 a	26.41 d
12	-5.55 a	25.67 d	-5.64 a	25.53 d
13	-6.31 b	26.92 d	-5.72 a	26.61 d
14	-6.25 b	28.89 c	-6.21 a	30.82 b
Mean	-7.24	29.91	-6.42	29.79
CV (%)	-4.62	2.70	-5.16	3.38
P-value	<.0001	<.0001	<.0001	<.0001

a*: green/red coordinate. b*: yellow/blue coordinate. CV (%): coefficient of variation.

Means in the same column with capital letters differ from each other by the Scott-Knott test with p<0.001.

Regarding the pulp. a lower predominance of green was observed. which may be directly related to the lower chlorophyll content in this part of the fruit (RIBEIRO et al. 2019). The fruits from matrix 2 stood out for having the highest hue of green for both pulp and peel. However. matrices 11. 12. and 13 showed similarity in hue. as did matrices 7 and 14.

In terms of luminosity (L*). the fruits with brighter peels corresponded to the matrices 5. 6. 11. 12. 13. and 14. which during the field analysis were considered smooth fruits. except for the fruits from matrix 5 (Table 2).

Table 2. Colorimetric variation (L* - Luminosity and C* - Saturation) of the peel and pulp of umbu tree (Spondias tuberosa) fruits from 14 matrices located in Serra Branca-PB.

MATRIX	PEEL		PULP	
	L*	C*	L*	C*
1	52.30 c	30.80 b	57.95 b	33.44 a
2	51.96 c	29.32 c	53.92 d	34.30 a
3	56.83 b	34.21 a	62.14 a	31.47 b
4	57.39 b	31.84 b	61.08 a	28.16 c
5	59.82 a	31.90 b	59.63 b	32.53 a
6	60.89 a	33.09 a	56.20 c	30.03 b
7	56.07 b	31.31 b	60.81 a	30.37 b
8	53.49 c	33.70 a	56.25 c	29.28 c
9	56.01 b	34.34 a	54.73 d	31.47 b
10	53.87 c	31.01 b	54.48 d	33.85 a
11	61.18 a	25.03 d	52.87 e	27.03 c
12	59.87 a	26.28 d	51.29 e	24.74 d
13	59.92 a	26.41 d	52.68 e	27.71 c
14	62.32 a	29.51 c	59.01 b	31.44 b
Mean	57.28	30.63	56.64	30.42
CV (%)	1.90	3.61	2.02	3.57
P-value	<.0001	<.0001	<.0001	<.0001

L*: Luminosity. C*: saturation. CV (%): coefficient of variation.

Means in the same column with capital letters differ from each other by the Scott-Knott test with p<0.001.

Therefore. this higher reflectance may be associated with the absence of trichomes. referring to the group of specialized cells of the epidermis that resemble hairs (SIMPLÍCIO et al. 2022). which makes the fruits more opaque. Therefore. the majority of the matrices that had the lowest luminosity indexes consisted of fruits with hairy peel. except

for matrices 2 and 9. As for saturation (C*). the matrices 3. 6. 8. and 9 composed the fruits with the highest color intensity. and the matrices 11. 12. and 13 composed the fruits with the lowest color intensity; however. it was possible to observe an inverse relationship with the a* parameter. in which the fruits considered lighter in color in fact presented less predominance of green and were proportional to the b* parameter. in which more intense fruits were the most yellowish in color.

For the pulp. brightness varied more than saturation. in which matrices 3. 4. and 7 showed higher L* and matrices 11. 12. and 13 the lowest value. Overall. this characteristic was superior to what was reported by Teodosio et al. 2021. which obtained the highest opacity in the umbu pulp at the same ripening stage with an average value of 52. For the saturation (C*). it was verified that there was a similarity of distribution with the b* parameter. which indicates that the yellowish fruits tend to present a more accentuated color. and the matrices that presented pulp with more intense color were 1. 2. 5. and 10.

Taking into account all the colorimetric parameters analyzed for peel and pulp. the dendrogram (Figure 3) indicates the formation of four groups. in which the matrices 13. 12. and 11 present the greatest distinction from the others. followed by matrix 2 with the least direct connection to the others. Moreover. the third group formed consisted of the largest number of matrices (7. 4. 9. 8. 14. 6. 5 and 3). followed by the high similarity between 10 and 1. These results reinforce that the colorimetric variation among the umbu matrices is indeed considerable and that these parameters can provide an important tool in the selection and quality control of these fruits.

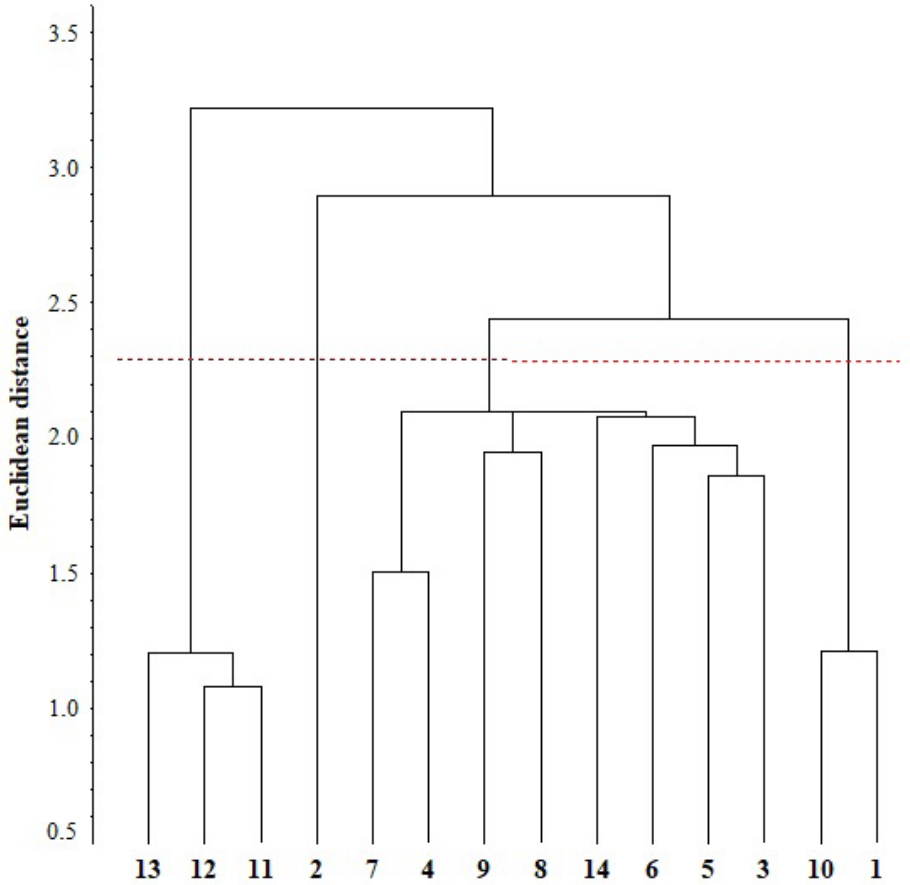

Figure 3. Grouping dendrograms of fruits corresponding to 14 matrices of umbu (*Spondias tuberosa*) located in Serra Branca – PB. according to the colorimetric parameters of the peel and pulp.

From the linear correlation analysis between the biometric parameters evaluated (Table 3). it was possible to verify different significant tendencies. which should also be considered an important tool in the selection and quality control of these fruits. Yield and mass tended to be greater in fruits with lower peel and seed content and higher percentages of pulp. In addition. width and length are intrinsically correlated and increase in parallel with fruit mass.

Although it is expected that there is a direct positive correlation between mass and yield. some fruits may have more prominent seeds that directly influence the increase in fruit mass. culminating in a decrease in yield (peel + pulp); this can be observed from the high negative correlation between seed contend and yield.

The percentages of peel and seed are inversely proportional to that of pulp; this justifies the relationship between these parameters and yield. A negative correlation was also observed between width and mass with peel content. indicating that as the fruit grows. this proportion decreases. In addition. it was verified that wider fruits tended to have a higher percentage of pulp.

In summary. the study reinforces that the colorimetric variation explored is considerable and can be an important tool in the quality management and exploitation of these fruits. as well as the correlations observed since the characteristics demanded change according to the commercial purpose.

Table 3. Linear correlation analysis between different biometric parameters of umbu tree (Spondias tuberosa) fruits from 14 matrices located in Serra Branca-PB.

	Yield	Mass	%peel	%seed	%pulp	Firm.	Len.	Wid.
Yield	1.00							
Mass	0.27	1.00						
% peel	-0.48*	-0.57**	1.00					
% seed.	-0.95**	-0.33	0.61**	1.00				
% pulp	0.82**	0.50*	-0.88**	-0.88**	1.00			
Firm.	-0.08	0.32	-0.01	0.09	-0.03	1.00		
Len.	0.13	0.87**	-0.35	-0.14	0.30	0.28	1.00	
Wid.	0.25	0.96**	-0.52*	-0.31	0.46*	0.37	0.80**	1.00

Firm: Firmness (N). Len: length (cm). Wid: width (cm). * and **: Significance level at 5 and 1% probability level by the t-test.

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