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Can chemical attributes replace sensory evaluation in consumer preference for papaya fruits?

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Abstract: The expansion of the papaya crop depends on cultivars with superior characteristics and human acceptance of the product. Thus, the objective was to study the sensory aspect and the main chemical characteristics of the fruit in 23 papaya genotypes cultivated in the north of the state of Espírito Santo and to evaluate if any chemical characteristic can be used to replace the evaluation by the hedonic scale. At 12 months after planting, fruit samples were evaluated for soluble solids content, titratable acidity, SS/TA ratio and a nine-point structured hedonic scale. The samples submitted to the hedonic scale were represented in codes and evaluated according to the experimental design in randomized blocks, totaling 12 treatments with 15 replications in the first experiment and 11 treatments and 21 replications in the second experiment. The data obtained were submitted to analysis of variance and Tukey's test at 5% probability. The means of the four characteristics, in the two experiments, were submitted to Pearson's linear correlation analysis. There was marked variability between the genotypes by the hedonic scale in the two experiments, highlighting the hybrids CR1 x São Mateus and JS12 x SSAM as the most accepted by the consumer.

Keywords: *Carica papaya* L. Heterosis. Plant breeding. Genetic variability. Statistica analysis.

Adherence to the scope of BJEDIS: The work uses the parametric statistic Pearson's linear correlation coefficient as a resource for making and deciding on the replacement of hedonic scale measurements for a characteristic that is easier to obtain in fruits and papaya.

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1. INTRODUCTION

The papaya crop (*Carica papaya* L.) has been highlighted as one of the most cultivated and consumed fruit trees in the tropical and subtropical regions of the world, being an important source of income and jobs. Brazil produced 8.9% of all world production in 2020 (1), and in that same year, the main producing states were Espírito Santo, Bahia, Ceará, and Rio Grande do Norte, respectively, accounting together for 85.3% of national production (2).

Among the problems that affect papaya cultivation is the low number of commercially cultivated varieties and hybrids (3), which meet the requirements of domestic and foreign markets. An alternative and viable solution to these problems is the expansion of the genetic base of papaya, exploring the genetic variability available in germplasm banks (4, 5, 6, 7) and through breeding programs through the development and evaluation of new hybrids that will meet the requirements of producers and consumers (8, 9, 10).

Papaya is part of a balanced diet for most humans, where in 100 g of pulp from the cultivar Formosa, an average of 45 kcal is available; 11.06% carbohydrate; 25 mg calcium; 17 mg of magnesium; 222 mg of potassium, and 78.5 mg of vitamin C (11). However, its chemical composition may vary according to the cultivar, climatic conditions, soil fertility, time of year, development stage, maturation, fruit portion, and others (12).

Due to the importance of the papaya crop in Brazil, much remains to be explored in terms of obtaining new varieties and hybrids with characteristics that meet the needs of producers and consumers. In Espírito Santo, a partnership between public and private institutions has developed and evaluated hybrids to obtain cultivars with promising agronomic and commercial characteristics (10, 13, 7). The new cultivars must meet both promising market characteristics and consumer acceptance (14).

Sensory methods are applied to measure reactions produced by people when ingesting certain foods and are considered “the study of the human response to a product to answer fundamental questions for the development, maintenance and placing of a product on the market” (15, 16). However, despite the importance of sensory evaluations, these are performed less frequently than other evaluations that characterize the chemical and physical properties of the fruits.

The objective of this work was to study, through correlations, the relationship between the sensory aspect and the main chemical characteristics of 23 papaya genotypes, and to verify the possibility of making the selection of the best hybrids, through chemical characteristics.

2. MATERIALS AND METHOD

The study was carried out at Fazenda Santa Teresinha, belonging to the company Caliman Agrícola SA, located between parallels 19° 11' 49” of south latitude and 40° 05' 52” of west longitude and an approximate altitude of 30 meters (17), in Linhares, Espírito Santo, from July 2012 to July 2013. The region's climate is AW (humid tropical), with rain in summer and dry winter.

Fruits of 23 papaya genotypes (*Carica papaya* L.) were evaluated in two experiments, most of them hybrids resulting from crosses between parents belonging to the Germplasm Bank of Caliman Agrícola SA, with description in Table 1.

Table **1**. Description of the 23 papaya (*Carica papaya* L.) genotypes used in Experiments A and B belonging to the Germplasm Bank of Caliman Agrícola S.A.

Evaluated genotype	Heterotic groups	Characterization of the genotype
Experiment A		
THB	"Solo"	Commercial variety
CR1 x São Mateus	“Formosa” x “Solo”	Simple hybrid
CR1 x 72/12	“Formosa” x “Solo”	Simple hybrid
CR2 x São Mateus	“Formosa” x “Solo”	Simple hybrid

CR3 x São Mateus	“Formosa” x “Solo”	Simple hybrid
CR1 x Maradol	“Formosa” x “Formosa”	Simple hybrid
CR2 x Sekati	“Formosa” x “Formosa”	Simple hybrid
CR3 x Maradol	“Formosa” x “Formosa”	Simple hybrid
CR1 x Calimosa	“Formosa” x “Formosa”	Triple hybrid
CR3 x Sekati	“Formosa” x “Formosa”	Simple hybrid
CR1 x SSAM	“Formosa” x “Solo”	Simple hybrid
BSA x Golden Short Petiole	“Solo” x “Solo”	Simple hybrid

Continued Table 1

Evaluated genotype	Heterotic groups	Characterization of the genotype
Experiment B		
CR3 x SSAM	“Formosa” x “Solo”	Simple hybrid
CR3 x Calimosa	“Formosa” x “Formosa”	Triple hybrid
CR3 x JS12	“Formosa” x “Formosa”	Simple hybrid
CR3 x 72/12	“Formosa” x “Solo”	Simple hybrid
CR3 x Progeny Tainung	“Formosa” x “Solo”	Simple hybrid
CR1 x Sekati	“Formosa” x “Formosa”	Simple hybrid
CR1 x Progeny Tainung	“Formosa” x “Solo”	Simple hybrid
CR1 x JS12	“Formosa” x “Formosa”	Single hybrid
CR2 x SS32	“Formosa” x “Solo”	Simple hybrid
JS12 x SSAM	“Formosa” x “Solo”	Simple hybrid
Calimosa	"Formosa"	Commercial single hybrid

The hybrids were obtained from crosses, collecting hermaphrodite flowers in the pre-anthesis phase, containing pollen grains that were transferred to flowers of female plants also in the pre-anthesis phase with hand pollination. The previously marked plants and their flowers were individually protected with waterproof paper bags to avoid contamination with unwanted pollen and the crosses were identified using plastic labels. The fruits were harvested 135 to 150 days after pollination at maturation stage II (1/4 of the mature fruit) and subjected to rest for seven to ten days at room temperature, enough time for the immature seeds to reach the full maximum development of germination and vigor.

Experiments A and B were carried out in a randomized block design, in July 2012, with four replications and 15 plants per plot with a spacing of 3.6 m between rows and 1.5 m between plants, with the cultural treatments carried out following the recommendation of the culture (18).

The fruits used in the evaluation of this experiment were harvested at random, 300 days after transplanting the seedlings. At the time, they had a yellow surface, being submitted to the hedonic scale test and chemical analysis. The hedonic scale tests, for the two experiments, were carried out on different days, being applied to tasters among students and employees of the North University Center of Espírito Santo, chosen at random. A hedonic scale with a nine-point 'general rating' attribute was used, called extremely disliked (1), disliked a lot (2), disliked moderately (3), disliked slightly (4), indifferent (5), liked slightly (6), I liked it moderately (7), I liked it a lot (8) and I liked it extremely (9) (19). For the tasting, samples, taken from the equatorial part of the fruits, which had a size of approximately 2 x 2 cm, were placed in coded plastic dishes (Figure 1). Mineral water was used to remove the flavor between the samples of the different genotypes. The samples were identified with codes according to the experimental design in randomized blocks. Considering each person as a block, according to Santana et al. (14), experiments A and B consisted of 15 and 21 blocks, as 15 and 21 people were evaluated, respectively. Tasting evaluations were performed on May 13 and 15, 2013 for experiments A and B, respectively. mineral water was used. The samples were identified with codes according to the experimental design in randomized blocks. Considering each person as a block, according

to Santana et al. (14), experiments A and B consisted of 15 and 21 blocks, as 15 and 21 people were evaluated, respectively. Tasting evaluations were performed on May 13 and 15, 2013 for experiments A and B, respectively. mineral water was used. The samples were identified with codes according to the experimental design in randomized blocks. Considering each person as a block, according to Santana et al. (14), experiments A and B consisted of 15 and 21 blocks, as 15 and 21 people were evaluated, respectively. Tasting evaluations were performed on May 13 and 15, 2013 for experiments A and B, respectively.

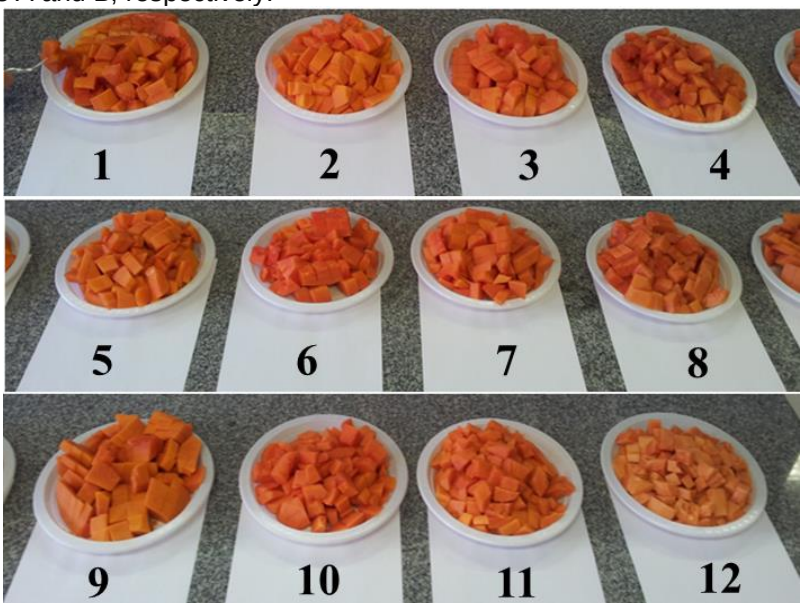

Figure **1**. Representation of papaya fruit samples, obtained in experiment A, submitted to tasting for hedonic scale test.

Aiming to characterize the point of consumption of the fruits supplied in the test, chemical analyzes were carried out to evaluate the content of soluble solids (SS), by direct reading in a benchtop refractometer type ABBE model RTA-100 expressed in ºBrix and the titratable acidity (TA), by reading in the laboratory using titration from a 0.1 M NaOH solution (9) and expressed in g of citric acid per 100 mL^{-1} of pulp; and the ratio between soluble solids and titratable acidity (SS/TA).

The data obtained through the hedonic scale, in both experiments, were submitted for analysis of variance to verify the existence of a statistically significant difference between the genotypes. Then, the means of the hedonic scale were submitted to the Tukey test (21) at a 5% probability. Pearson's correlation was also performed between the results of the averages of the hedonic scale and the evaluated chemical characteristics.

All analyzes were performed using the computational resources of the Genes program (22).

3. RESULTS AND DISCUSSION

In the 'general evaluation' attribute, we tried to gather all the characteristics regarding the acceptance of the fruit pulp by the hedonic scale test applied to tasters, which showed significant differences between the genotypes in experiments A and B, at 1% probability (Table 2). In experiment A, the average values recorded ranged from 3.87 for the CR3 x Sekati hybrid to 7.20 for the CR1 x São Mateus hybrid, this hybrid being statistically superior to the others (Table 3). For experiment B, the values ranged from 4.62 for the hybrid CR3 x JS12 to 7.52 registered for the hybrid JS12 x SSAM, being this hybrid statistically superior to the others (Tables 4). The commercial genotype THB, from experiment A, presented an average of 6.47, and the commercial hybrid Calimosa, from experiment B, presented an average of 6.87. Of the genotypes evaluated in experiment A, only five received scores higher than 6.00 and in

experiment B, nine genotypes were evaluated with scores higher than 6.00, indicating that most of the genotypes in experiment B were appreciated for flavor since the minimum acceptable score of the product by the consumer is 6.0.

According to Soler et al. (23), sensory analysis is performed through the use of human senses: vision, taste, smell, hearing, and skin sensitivity. Sensory analysis tests make it possible to transform subjective data into objective data, in addition to generating valuable information about the quality and acceptability or not of consumers for a particular product.

The hedonic scale is easily understood by consumers and is being used by many companies to obtain valid and reliable results. In it, the consumer expresses his acceptance of the product following a previously established scale that varies gradually, based on the attributes "likes" and "dislikes". Santana et al. (14), working with improved papaya genotypes, observed that the CMF031 genotype, which was more accepted by the panelists, presented a value of 7.04 for the sensory evaluation of fruit for flavor in the year I and 7.00 in the evaluation of year II, also presenting the highest values for the content of soluble solids (ºBrix) and vitamin C.

Table **2**. Summary of the analysis of variance for the evaluation of the hedonic scale of the fruits of the papaya (*Carica papaya* L.) genotypes of the two experiments evaluated with the respective means and coefficient of variation (CV)

Experiment	Medium Square			Average	CV (%)
	Block	Genotypes	Residue		
Hedonic scale - Exp. A[1]	5.59	17.32**	2.27	5.64	26.72
Hedonic scale - Exp. B[2]	7.20	12.97**	1.81	6.40	21.01

Significant at 1% by the F test.
[1]Degree of freedom: Block = 14; Genotypes = 11 and Residue = 154.
[2]Degree of freedom: Block = 20; Genotypes = 10 and Residue = 200.

The SS values ranged from 9.0 to 12.7 and 10.70 to 15.00 ºBrix, respectively for the genotypes of experiments A and B (Tables 3 and 4). Oliveira et al. (3), evaluating 19 accessions from the Active Germplasm Bank, two varieties of the "Solo" group and the hybrid Calimosa, observed SS values between 5.00 and 16.20 ºBrix. Santana et al. (14), studying improved papaya genotypes from the "Solo" and "Formosa" groups, obtained SS values in the range of 12 to 14 ºBrix. Such SS differences may be related to fluctuations in the source-sink relationship, which occur throughout the cycle, affecting the sugar levels in the fruit. The results obtained in this work are consistent with the requirements established by Normative Instruction 04/2010 (24) which establishes that the fruits must have a minimum content of 11.0 ºBrix or even lower value as long as it does not compromise their proposed use.

Table **3**. Means of four fruit characters (at 3/4 of maturation) of "experiment A" evaluated in 12 papaya genotypes (*Carica papaya* L.)

Genotypes	Characters			
	SS[2](ºBrix)	TA[2]	SS/TA	Hedonic Scale[*,1]
CR1 x S. Mateus	12.70	0.15	85.59	7.20 to
CR1 x 72/12	10.25	0.10	105.92	4.73 cd
CR2 x S. Mateus	10.70	0.16	66.34	5.13 bcd
CR3 x S. Mateus	11.30	0.12	92.19	5.60 abcd
CR1 x Maradol	9.50	0.10	98.17	4.33 d

CR2 x Sekati	11.30	0.10	109.48	5.40 abcd
CR3 x Maradol	9.70	0.12	83.53	5.00 bcd
CR1 x Calimosa	11.70	0.10	113.25	6.53 abc
CR3 x Sekati	9.00	0.12	73.43	3.87 d
CR1 x SSAM	12.00	0.12	103.34	6.73 ab
BSA x Golden Short Petiole	12.50	0.11	113.98	6.73 ab
THB	12.30	0.15	82.90	6.47 abc

[1]Means followed by the same letter in the column do not differ from each other by Tukey's test at 5% probability.
[2]SS content ofsoluble solids; TA - Titratable acidity (g of citric acid per 100 mL^{-1} of pulp).
[*]Evaluation criterion used in the acceptance test with hedonic scale where the individual expresses the degree of liking and disliking a certain product: 9 - I liked it extremely; 8 - I liked it a lot; 7 - I liked it moderately; 6 - I liked it slightly; 5 - indifferent; 4 - I disliked it slightly; 3 - moderately disliked; 2 - I disliked it a lot; 1 - I disliked it extremely.

Table **4**. Means of four fruit characters (at 3/4 of maturation) of “experiment B” evaluated in 11 papaya genotypes (*Carica papaya* L.)

Genotypes	Characters			
	SS[2] (ºBrix)	TA[2]	SS/TA	Hedonic Scale*,1
CR3 x SSAM	11.20	0.08	133.55	6.19 abc
CR3 x Calimosa	13.00	0.13	100.76	6.67 abc
CR3 x JS 12	11.20	0.08	133.55	4.62 d
CR3 x 72/12	12.20	0.11	111.24	6.43 abc
CR3 xprogenyTainung	11.40	0.09	126.22	6.76 abc
CR1 x Sekati	10.70	0.12	92.14	5.67 cd
CR1 x Progeny Tainung	12.70	0.06	218.74	7.19 a.m.
CR1 x JS 12	13.00	0.09	143.94	6.43 abc
CR2 x SS32	12.50	0.11	113.98	6.05 abc
JS 12 x SSAM	15.00	0.12	129.17	7.52 to
Calimosa	15.00	0.11	136.77	6.86 abc

[1]Means followed by the same letter in the column do not differ from each other by Tukey's test at 5% probability.
[2]SS content ofsoluble solids; TA - Titratable acidity (g of citric acid per 100 mL^{-1} of pulp).
[*]Evaluation criterion used in the acceptance test with hedonic scale where the individual expresses the degree of liking and disliking a certain product: 9 - I liked it extremely; 8 - I liked it a lot; 7 - I liked it moderately; 6 - I liked it slightly; 5 - indifferent; 4 - I disliked it slightly; 3 - moderately disliked; 2 - I disliked it a lot; 1 - I disliked it extremely.

It is known that organic acids make an important contribution to the quality of fruit flavor, especially regarding the balance between their content and acidity and those of sugars (25). Regarding TA, variation was recorded in the

range of 0.10 to 0.16 g (experiment A, Table 3) and 0.06 to 0.13 g of citric acid per 100 mL^{-1} of pulp (experiment B, Table 4). Similar values are mentioned in the literature, in the evaluation of several improved papaya genotypes, from 0.04 to 0.13 g and from 0.07 to 0.11 g of citric acid 100 g^{-1} of the sample by Santana et al. (14) and Viana et al. (13), respectively.

The values of the SS/TA ratio, between 74.7 and 275.7, are similar to those detected by Fagundes and Yamanishi (26) in the characterization of papaya fruits of the "Solo" group sold in four establishments in Brasília. The SS/TA ratio, known as the maturity index, has been explored by several authors in studies on the papaya crop (14, 28, 21). It represents the balance between sugars and organic acids in the formation of the flavor and aroma of the fruit. Higher SS/TA values indicate a more pronounced sweetness, and the genotypes that present these higher indices are the most preferred by consumers.

The fruits of the genotypes evaluated with the highest means on the hedonic scale also exhibited the highest levels of SS, showing a positive correlation of 0.9636 (Experiment A) and 0.6825 (Experiment B) (Tables 5 and 6). Therefore, the selection of the best genotypes can be carried out based on the quantification of SS, being this method more practical, less costly, and efficient when compared to the hedonic scale.

Table **5**. Correlation between the four fruit characters (at 3/4 of maturation) of "experiment A", in which 12 genotypes, 11 new hybrids and a commercial variety of papaya (*Carica papaya* L.)

Characters	SS[1] (ºBrix)	TA[1]	SS/TA	Hedonic Scale
SS (ºBrix)	1.00	0.2963	0.3513	0.9636**
AT		1.00	-0.7770**	0.2822
SS/AT			1.00	0.3425
Hedonic scale				1.00

[1]SS - content of soluble solids; TA - Titratable acidity (g of citric acid per 100 mL^{-1} of pulp)
** significant at 1% probability level ($p < 0.01$) by Pearson's linear correlation.

Table **6**. Correlation between the four fruit characters (at 3/4 of maturity) in "experiment B", in which 11 genotypes, ten new hybrids and a commercial papaya hybrid (*Carica papaya* L.)

Characters	SS[1] (ºBrix)	TA[1]	SS/AT	Hedonic Scale
SS (ºBrix)[1]	1.00	0.3254	0.19	0.6825**
AT		1.00	-0.8031**	0.1283
SS/AT			1.00	0.3415
Hedonic Scale				1.00

[1]SS - content of soluble solids; TA - Titratable acidity (g of citric acid per 100 mL^{-1} of pulp)
** significant at 1% probability level ($p < 0.01$) by Pearson's linear correlation.

From the results of this study, it can be seen that the evaluation of the soluble solids contente can be used to replace sensory evaluations, providing greater agility, practicality and economy in the evaluation of new papaya genotypes.

CONCLUSION

The acceptance of the best genotypes by the consumer can be performed from the quantification of the soluble solids contents because they present a high positive correlation with the hedonic scale, being a more practical, cheaper, and efficient method.

CONFLICT OF INTEREST

There is no conflict of interest.

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Sample CRediT author statement

Adriel Lima Nascimento: Conceptualization, Bibliographic research, Data analysis, Preparation of the original draft, Editing and Revision. **Omar Schmildt:** Preliminary Studies, Data Analysis, Editing and Review. **Édlen dos Santos Bonelá:** Conceptualization, Editing and Review. **Alan Lima Nascimento**: Conceptualization, Supervision and Review. **Vinicius de Souza Oliveira**: Conceptualization, Supervision and Review. **Renan Garcia Malikouski:** Conceptualization, Supervision and Review. **Edilson Romais Schmildt:** Data analysis, Preparation of the original draft, Editing and Revision.

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