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Postharvest fruit quality of new papaya tree hybrids produced in semiarid region

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This work aimed to evaluate the new postharvest quality of papaya tree hybrids grown in a region of semi-arid climate, aiming to find the most suitable for marketing as new cultivars. It was conducted in a commercial farm in the municipality of Mossoró-RN, an experiment in a randomized block design with 14 treatments (12 hybrids in testing, plus two more cultivars already marketed, Tainung No. 1 and Sunrise Solo), with 4 replications. The fruits were harvested during the second maturation stage (fruit with up to 25% yellow skin) and taken to the Postharvest Laboratory of UFERSA, where they were accommodated at room temperature (22 ± 1°C and 60 ± 5% RH) until they reaches the fifth maturation stage (fully ripe fruit, with 76-100% of yellow skin), and analyzed for their physical, physical-chemical and biochemical traits. There was great variability among hybrids for the evaluated quality characteristics. However, the hybrids showed characteristics such as mass and dimensions of fruits, vitamin C, soluble solids, pulp thickness that fall under the classification for commercialization both in the domestic and international markets, with the exception of the hybrids H36.45, H36.56, and H45.56, which have yellow pulp, which is not favored in the consumer market.

Key words: *Carica papaya* L., vitamin C, soluble solid, firmness of fruit.

INTRODUCTION

The papaya tree *(Carica papaya* L.) is a fruit tree grown in almost all the national territory, with emphasis in the states Bahia with 718.000 tons in 2013, followed by Espírito Santo, Minas Gerais, Ceará and Rio Grande do Norte. Brazil is the second largest producer in the world with a total production of 1.6 million tonnes in a cultivated area of 31.989 ha and with the yield 51.02 t/ha in 2013 (Reetz et al., 2015).

Among the difficulties faced by papaya tree crop, there is the limitation of alternatives, the choice of cultivars and/or commercial hybrids for planting that meet both the requirements of the domestic and international markets. Additionally, there is also the high price of hybrid seeds of papaya tree of the Formosa group, which has led many growers to perform successive plantings with the F2, F3 and F4 generations of hybrids, which causes several

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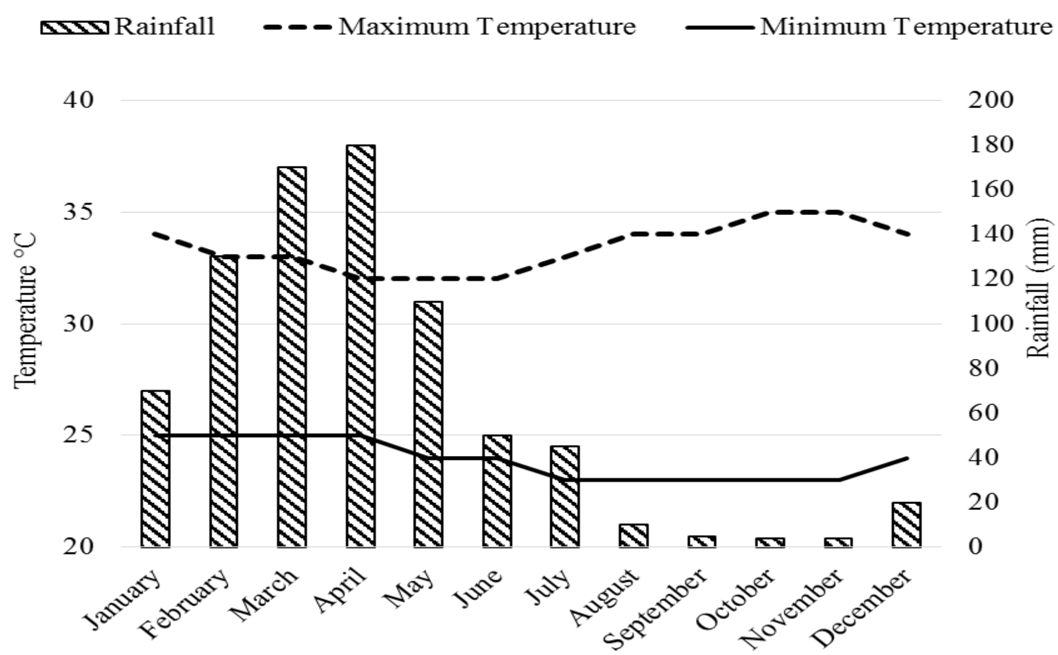

Figure 1. Temperature Analysis, maximum and minimum, and monthly rainfall in the municipality of Mossoro-RN in 2012.

problems, among them the loss of vigor and segregation to fruit shape (Marin et al., 2001; Serrano and Cattaneo, 2010).

Commercially the most cultivated varieties belong to the Solo and Formosa groups. Preferred for producing fruit in the export process, with smaller sizes, varieties of the Solo group are explored in various regions of the world. On the other hand, the fruits of the Formosa group are larger and usually commercial hybrids that are gaining space both in the domestic and foreign markets, where it has been seeing strong growth in sales mainly to Europe, Canada and the United States (Dantas and Oliveira, 2009).

From these two groups, only three cultivars occupy most of the commercial plantations. The most exploited cultivars in Brazil are ‘Sunrise Solo’ and ‘Improved Sunrise Solo cv. 72/12’ belonging to the Solo group, better known as Havaí Papaya or Amazônia and ‘Tainung 01’ and Tainung 02’ of the Formosa group (Embrapa, 2013).

There is a low availability of cultivars for use in papaya crop. This fact makes her more vulnerable to crop diseases, pests and soil and edaphoclimatic variations, which can affect the sustainability of this agribusiness. Thus, the development work with new materials can help to increase the genetic variability of papaya tree crops through the selection of new genotypes showing resistance to major pests and diseases, good productivity and fruit quality that meets consumer demands (Oliveira et al., 2010), as consumers are increasingly demanding about the quality of the fruits that they are consuming, this being a prime factor to overcome competitive markets.

Studies on indicators of irrigated agriculture in different continents has shown great variations to this type of crop, drawing attention to the best investments and risk reduction through the programming of the use of water resources and standardization of suitable crops to the farmer (Valipour, 2015a; Valipour, 2015b). However, the development of new genotypes become extremely important, due obtain new cultivars that are productive, with good quality fruit and that adapt to different regions with low rainfall and limited availability of water for irrigation.

Fruit quality is influenced by edaphoclimatic conditions, variety, plant nutrition, timing and production site (Aular and Natale, 2013). This work aimed to evaluate the postharvest quality of new papaya tree hybrid fruits resulting from research on genetic improvement for this culture, and cultivated in the municipality of Mossoró-RN a semiarid climate region, aiming to find the most useful to marketing as new cultivars.

MATERIALS AND METHODS

The experiment was conducted in a commercial area of the company Agrícola Famosa SA in the rural municipality of Mossoró-RN. According to Köppen climate classification, the climate in the region is the BSwh’ type, that is, hot and dry steppe with rainy season lingering from summer to autumn (Carmo Filho et al., 1987). The annual rainfall is around 450 to 600 mm, with the months from February to May being the wettest four months and from August to November the driest four months (Figure 1), soil type Quartzarenic Neosoil.

The experiment was designed in randomized blocks, with four repetitions, with 14 treatments evaluated, with plots constituted of six plants, spaced 4.0 × 2.0 m. The treatments or genotypes were: two cultivars already commercialized, the Tainung No. 01 and Sunrise, plus twelve more hybrids in testing (H10.26, H10.60, H10.72, H26.60, H26.72, H33.36, H33.45, H33.56, H36.45, H36.56, H45.56, H60.72) provided by Embrapa Mandioca e Fruticultura, Cruz das Almas - BA.

In the months of October to December of 2012 the harvest took place, when fruits were harvested and selected in maturation stage 2 (fruit up to 25% of the surface with yellow skin) and then transported to the postharvest laboratory of the Federal Rural University of the Semi-Arid, where they were accommodated at room temperature (22 ± 1°C and 60 ± 5% RH) until they reached the maturity stage 5 (fully ripe fruit, with 76-100% of yellow skin), when the same were fully mature (Sanches, 2003).

The following characteristics were evaluated: fruit mass, determined by the average value of individual weighting with the results expressed in grams (g); length and diameter with the aid of a caliper rule and results expressed in centimeters (cm), relation length/diameter (fruit shape) obtained by calculating the ratio between the two, and the classification made according to scale adapted from Lopes (1982), in which fruit have compressed (RF <0.9), spherical (RF ≤ 0.9 ≤ 1.1), caplet (1.1 <RF ≤ 1 , 7) and cylindrical (RF> 1.7) format; internal cavity and pulp thickness using a digital caliper in millimeters (mm); pulp coloration using a 1-5 color scale (1 - yellow, 2 - intense yellow, 3 - salmon, 4 - orange, 5 - intense orange); fruit firmness, determined with the fruit pressure tester penetrometer, obtaining readings in lbf, lately converted into (N) vitamin C determined by titration with Tilman solution (DFI - 2,6-dichloro-phenol-indophenol 0.02%) according to the methodology proposed by Strohecker and Henning (1967) and the results expressed in ascorbic acid 100 g^{-1} mg; soluble solids (SS) directly in the homogenized juice of the edible fraction through reading in digital refractometer (PR model -. 100, Palette, Atago Co, LTD, Japan), results expressed in percentage (%) (AOAC, 2005); titratable acidity (TA) according to the method of the Association of Official Analytical Chemistry (2005), the results expressed as citric acid percentage, and the ratio soluble solids/titratable acidity was obtained by the ratio between soluble solids and titratable acidity of the fruit pulp; pH, with the aid of a potentiometer (AOAC, 2005), the soluble sugar by Antrona method according to Yemn and Willis (1954); total and soluble pectin were extracted by the methodology described by McCready and MacComb (1952) and determined according to Blumenkrantz and Asboe-Hansen (1973), the results expressed in mg of galacturonic acid per 100 g fresh pulp mass, using a standard curve for galacturonic acid; pectinmethylesterases enzyme activity (PMEs), determined by the method of Jen and Robinson (1984), result expressed in EU/min/g of tissue; and the activity of the polygalacturonase enzyme (PG), for extracting the enzyme source (Pressey and Avants, 1973), the determination was performed by the DNS method (Miller, 1959) and the results expressed as UAE/g fresh weight.

The results were submitted to analysis of variance and the average of qualitative data compared by the Scott-Knott test at 5% with the aid of the SISVAR (System for Analysis of Variance) statistical software.

RESULTS AND DISCUSSION

The fruits of the hybrids showed average values for mass ranging from 461.1 g (hybrid H10.72) to 946.2 g (hybrid H10.60). These values were lower than those obtained for Tainung No. 1 and higher than those found for the Sunrise Solo, which was statistically similar to the hybrid H10.72 (Table 1). Dias et al. (2011) evaluating the papaya genotypes, revealed a large variation for the fruit mass, with values ranging from 260 to 1890 g. Given the results for this variable, it can be seen that the hybrids have potential for selecting plants for the production of fruits with standards that meet the international market, since it requires mass around 500 g, as well as the domestic market requiring fruit with mass between 800 and 1500 g (Dantas and Lima, 2001; Ocampo et al., 2006; Dias et al., 2011).

The dimensions of the fruit also showed a large variation. For the length of the fruit, the hybrids that got the highest values were H10.60, H26.72, H33.36, H33.45, H33.56, H36.45, H36.56 and H45.56, which are lower than the Tainung no. 1 and higher than the Sunrise Solo, which presented lower undifferentiated length from the hybrid H60.72. As for the diameter of the fruit, the hybrids that had higher values were H10.26, H10.60, H33.45, H33.56, H36.45 and H45.56, not differentiating from the Tainung No. 1, and the other hybrids showed lower values, but higher than the Sunrise Solo who got smaller diameter (Table 1). For these characteristics, in the types of papaya tree of the Solo and Formosa groups, classification is very subjective when it comes to genotypes with high variability in the size and shape of fruit (Dias et al., 2011) as evaluated in this work.

For the relationship between length and diameter of the fruits it can be observed a separation between two groups, one in which the hybrids that resembled Tainung No. 1 of the Formosa group, with values above 2, with fruits having a cylindrical shape, and another group in which the hybrids resembled the Sunrise Soil Soil group, with values around 1.7 featuring an oblong shape fruit (Table 1). However, the present hybrids present format suitable for marketing, since they have shapes similar to those genotypes that are currently available on the market.

Regarding the color of the pulp, most hybrids have orange coloring similar to Tainung No. 1 and Sunrise Solo. With the exception of H10.60 and H26.72 hybrids, which have intense orange pulp color, and hybrids H36.45, H36.56 H45.56 which have yellow color (Table 2), a characteristic that is not the preferred by most consumers due to the habit of consumption of fruits with red pulp and associating this coloration that the fruits are not fully mature.

The thickness of the pulp showed a small variation between the values, with observed formation of two groups, one with the hybrids H10.60, H33.45, H33.56, H36.45 and H45.56, which did not differentiate from the Tainung No. 1, obtaining the highest values, and another group with the hybrids H10.26, H10.72, H26.60, H26.72, H33.36, H36.56 and H60.72 that were similar to Sunrise Solo with lower values (Table 2). All genotypes showed pulp thickness higher than 20 mm, considered ideal for papaya marketing (Martins et al., 2006). This variable is

Table 1. Means of mass (MASS), length (LENG), diameter (DIAM) and length and diameter ratio (COMP/DIAM) of fruits papaya tree hybrids.

Genotypes	MASS(g)	LENG(cm)	DIAM(cm)	LENG/DIAM
Tainungnº1	1337.9[a]	24.7[a]	11.2[a]	2.2[a]
Sunrisesolo	262.2d	11.3[d]	6.5[c]	1.7[b]
H10.26	762.9[b]	16.9[c]	9.7[a]	1.7[b]
H10.60	946.2[b]	19.2[b]	10.6[a]	1.8[b]
H10.72	461.1d	16.3[c]	8.1[b]	2.0[a]
H26.60	576.7[c]	16.5[c]	8.7[b]	1.8[b]
H26.72	711.7[c]	19.5[b]	9.2[b]	2.1[a]
H33.36	629.1[c]	19.1[b]	8.6[b]	2.2[a]
H33.45	886.6[b]	20.5[b]	9.8[a]	2.1[a]
H33.56	936.9[b]	20.5[b]	10.2[a]	2.0[a]
H36.45	853.2[b]	20.7[b]	9.4[a]	2.2[a]
H36.56	717.1[c]	19.9[b]	9.0[b]	2.2[a]
H45.56	812.1[b]	19.9[b]	10.4[a]	1.9[b]
H60.72	531.6[c]	14.2[d]	8.7[b]	1.7[b]
General mean	744.7	18.5	9.3	1.9
CV(%)	25.87	11.93	10.30	10.63

Means followed by the same letter do not differ by the Scott-Knott test at 5% probability.

Table 2. Means of color pulp, pulp thickness (PT), internal cavity (IC) of fruits papaya tree hybrids.

Genotypes	Pulp color	PT (mm)	IC (mm)
Tainung nº1	Orange	28.8[a]	54.2[a]
Sunrise solo	Orange	21.1[b]	22.7[c]
H10.26	Orange	24.5[b]	48.1[a]
H10.60	Intense orange	27.9[a]	49.8[a]
H10.72	Orange	22.8[b]	35.3[b]
H26.60	Orange	23.9[b]	39.4[b]
H26.72	Intense orange	23.9[b]	44.0[b]
H33.36	Orange	22.4[b]	40.7[b]
H33.45	Orange	28.6[a]	40.6[b]
H33.56	Orange	27.7[a]	46.6[a]
H36.45	Yellow	27.0[a]	39.3[b]
H36.56	Yellow	24.3[b]	41.0[b]
H45.56	Yellow	28.3[a]	46.9[a]
H60.72	Orange	22.1[b]	43.2[b]
General mean	-	25.2	42.3
CV (%)	-	12.56	12.49

Means followed by the same letter do not differ by the Scott-Knott test at 5% probability.

closely related to the quality of the fruits, because fruits with thicker pulp tend to have higher firmness (Oliveira et al., 2010), confirming what was also observed in this study.

The values for internal cavity of the fruit ranged from 22.7 to 54.2 mm. With the hybrids H33.56, H10.26, H10.60 and H45.56 presenting larger cavity not differentiating from the Tainung No. 1. The hybrids H10.72, H26.60, H26.72, H33.36, H33.45, H36.45, H36.56 and H60.72 had lower diameter of the inner cavity, but superior to the Sunrise Solo, that presented the smaller values for this variable (Table 2). Fruits with lower internal cavity, greater firmness and thickness pulp, have a higher pulp yield and are more resistant to transport to distant markets (Fioravanço et al., 1992).

The firmness of the fruit is a characteristic of

Table 3. Means of fruit firmness (FIRM), total pectin (TP), soluble pectin (SP) polygalacturonase (PG) and pectinmethylesterase (PME) of fruits papaya tree hybrids.

Genotypes	FIRM (N)	TP[1]	SP[1]	PG[2]	PME[3]
Tainung nº1	23.6[b]	444.9[a]	344.4[b]	239.8[a]	1081.4[d]
Sunrise solo	14.4[d]	462.3[a]	373.7[a]	301.9[a]	4127.3[a]
H10.26	21.2[c]	391.2[b]	356.4[a]	271.7[a]	1471.8d
H10.60	23.2[b]	366.3[b]	366.1[a]	137.9[b]	2672.8[b]
H10.72	15.1[d]	415.2[b]	373.4[a]	243.6[a]	2702.0[b]
H26.60	16.6[d]	466.9[a]	370.2[a]	243.2[a]	2887.6[b]
H26.72	15.2[d]	405.9[b]	370.9[a]	237.7[a]	2690.7[b]
H33.36	12.9[d]	398.0[b]	321.1[b]	269.2[a]	2771.4[b]
H33.45	19.8[c]	447.5[a]	331.5[b]	180.9[b]	2119.1[c]
H33.56	17.2[c]	444.3[a]	396.3[a]	231.1[a]	2292.6[c]
H36.45	19.5[c]	436.8[a]	296.1[b]	140.8[b]	1350.9[d]
H36.56	18.2[c]	480.1[a]	317.2[b]	149.6[b]	2855.6[b]
H45.56	32.6[a]	450.8[a]	343.9[b]	178.8[b]	1751.6[c]
H60.72	17.4[c]	451.4[a]	385.0[a]	307.8[a]	2465.5[b]
General mean	19.1	432.9	355.8	223.8	2374.3
CV (%)	11.69	10.62	5.97	26.44	11.82

Means followed by the same letter do not differ by the Scott-Knott test at 5% probability. [1]mg Á. Gal. 100 g^{-1}; [2]UAE g^{-1} of fresh weight; [3]U.E min^{-1} g^{-1} of tissue.

fundamental importance in the assessment of fruits, both for management and for the acceptance by the consumer market (Cuquel et al., 2012). Directly influencing the strength of the fruit from mechanical shocks during transportation and marketing, providing a longer shelf life. The hybrid H45.56 showed the highest firmness. It can be observed in a cluster with the lowest values for the hybrids H10.72, H26.60, H26.72 and H33.36 (range 12.9 to 15.1 N) that were similar to the Sunrise Solo; this lower firmness is directly related to the high activity of pectinmethylesterase and polygalacturonase, and high content of soluble pectin in these hybrids (Table 3).

For total pectin, hybrids who obtained the highest values were H26.60, H33.45, H33.56, H36.45, H36.56, H45.56 and H60.72 that did not differentiate from the Tainung 1 and Sunrise Solo (Table 3). Higher total pectin rates are important in the postharvest fruit conservation because pectins influence the texture of the fruit, as well as reduce costs in the industrial processing area due to less need for the addition of commercial pectin and reduction of sweet mass manufacturing time (Chitarra and Chitarra, 2005).

As for the soluble pectin the highest values were found for the hybrids H10.26, H10.60, H10.72, H26.60, H26.72, H33.56 and H60.72 that did not differentiate from Sunrise Solo (Table 3) . The high percentage of soluble pectin indicates fruits with less firmness, which makes the fruit more susceptible to mechanical damage, reducing its post-harvest life and renders the transport of fruits to great distances impractical.

Regarding the enzymes that degrade the cell wall, the polygalacturonase showed lower enzymatic activity in the hybrids H10.60, H33.45, H36.45, H36.56 and H45.56, as for pectinmethylesterase the least activity was in the hybrids H10.26 and H36.45 that not differed from Tainung No. 1 (Table 3). These genotypes showed greater fruit firmness, as the lower activity of these enzymes along with other pectinases, the greater the firmness of the fruit. Ethylene production during papaya ripening stage has strong participation in modulating the activity of these enzymes (Krongyut et al., 2011). According to Antunes et al. (2006), the activity of PMEs must precede PG activity, since the former has a demethylating function and prepares the polygalacturonic chain for th PG action, depolymerizing it. After the PG action, undemethylated pectic chains are exposed and may suffer, although to a lesser extent, the action of PMEs.

The fruits presented high levels of vitamin C, which ranged from 96.5 to 122.3 mg/100 g. The hybrids H10.26, H10.72, H26.72, H33.36, H33.56, H36.45 and H36.56 showed vitamin C content higher than the other hybrids and Tainung No. 1 and Sunrise Solo (Table 4). Wide variation in vitamin C values can be found among the fruits of different genotypes, probably due to the effect of weather conditions and soil nutrition, besides the characteristics of the genotype itself.

The titratable acidity showed little variation despite significant differences, with all hybrids presented lower acidity than the Sunrise Solo, and the hybrids H33.36, H33.45, H33.56, H36.45, H45.56 and H60.72, similar acidity to Tainung No. 1 (Table 4). These values were

Table 4. Means of vitamin C (VIT C, mg 100 g^{-1}), titratable acidity (TA) and pH of fruits papaya tree hybrids.

Genotypes	VIT C (mg 100 g^{-1})	TA (% Á. cítrico)	pH
Tainung nº1	97.6^c	0.125^d	4.55^a
Sunrise solo	97.7^c	0.180^a	4.80^a
H10.26	113.2^a	0.166^b	4.78^a
H10.60	105.5^b	0.156^c	4.87^a
H10.72	122.3^a	0.156^c	4.95^a
H26.60	94.8^c	0.147^c	4.75^a
H26.72	114.2^a	0.167^b	4.89^a
H33.36	119.5^a	0.132^d	4.98^a
H33.45	105.6^b	0.126^d	4.98^a
H33.56	117.1^a	0.136^d	4.91^a
H36.45	118.7^a	0.123^d	4.79^a
H36.56	112.5^a	0.109^e	4.92^a
H45.56	105.6^b	0.129^d	4.83^a
H60.72	105.7^b	0.126^d	4.89^a
General mean	109.3	0.141	4.85
CV (%)	4.67	6.45	3.54

Means followed by the same letter do not differ by the Scott-Knott test at 5% probability.

Table 5. Means of soluble solids (SS), relation SS/TA and soluble sugars (SA) of fruits papaya tree hybrids.

Genotypes	SS (%)	SS/TA	SA (%)
Tainung nº1	13.1^b	104.8^b	9.0^c
Sunrise solo	14.3^a	79.4^d	10.3^b
H10.26	15.3^a	92.2^c	11.2^a
H10.60	13.0^b	83.3^d	8.8^c
H10.72	15.7^a	100.6^b	10.9^a
H26.60	13.7^b	93.2^c	9.9^b
H26.72	14.5^a	86.8^c	10.5^b
H33.36	13.9^b	105.3^b	10.8^a
H33.45	13.1^b	104.4^b	10.3^b
H33.56	13.5^b	99.3^b	10.8^a
H36.45	12.6^b	102.4^b	10.1^b
H36.56	13.3^b	122.0^a	10.3^b
H45.56	12.7^b	98.4^b	8.9^c
H60.72	14.8^a	117.5^a	10.9^a
General mean	13.8	97.9	10.2
CV (%)	5.94	6.37	6.03

Means followed by the same letter do not differ by the Scott-Knott test at 5% probability.

superior to the variation found by Alonso et al. (2008) from 0.012 to 0.034% by evaluating the productive behavior of different varieties of papaya tree in an experiment carried out in Cuba. Large variations in papaya in acidity values can occur due to variations of each genetic material in the use of organic acids as respiratory process substrates, the management of fertilizer and spacing, as well as harvest date (Souza et al., 2009; Fontes et al., 2012).

For the pH there was no significant difference between hybrids and cultivars already marketed (Table 4). These values were lower than those found by Dias et al. (2011) that found 5.22 and 5.64 in the evaluation of papaya tree genotypes with use of agronomic descriptors.

Regarding the soluble solids, hybrids H10.26 H10.72 H26.72 H60.72 showed higher values, not differentiating between them and the Sunrise Solo (Table 5). The hybrids evaluated in this work fall within the requirements for marketing based on this variable, both for the domestic market, where the minimum requirement for this feature is 11%, according to rules Instruction No. 4 of January 22, 2010 for papaya; as well as for the foreign market, where the minimum required is 12% (Manica, 1996).

For the SS/TA relation there was a change from 79.4 to 117.5, and the lower values were observed for hybrid H10.60 that didn't differ from Sunrise Solo. The hybrids H36.56 and H60.72 showed higher values than the others (Table 5). The relationship between sugars and organic acids becomes more representative than the isolated measurement of these, providing good perception of the balance between these two, resulting in a pleasant feeling for the consumer's taste (Fernandes et al., 2010).

For the soluble sugars, there was a group with the highest values for the hybrids H60.72, H33.56, H33.36, H10.72 and H10.26; and one with the lowest values for the hybrids H10.60 and H45.56 that did not differ among themselves and from Tainung No. 1 (Table 5). The concentration and content of sugars play a fundamental role in flavor, also being indicators of fruit maturity stage. This composition can vary due to environmental factors, sunlight quality, temperature, maturity stage, among cultivars, planting practices, as well as the type and dosage of fertilizers (Nascimento et al., 2003).

Conclusion

There was great variability among hybrids for the evaluated quality characteristics. However, all studied hybrids have characteristics such as weight, firmness, pulp thickness, vitamin C, soluble solids, titratable acidity and total sugars, within the quality standards for commercialization both in the domestic market and internationally, except for the the H36.45, H36.56, and H45.56 hybrids, that have yellow flesh that does not meet the preference of most of the consumer markets.

Conflict of Interest

The authors have not declared any conflict of interest.

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