Article

Morphological and physicochemical characterization of selected soursop accessions fruits in Nayarit

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Abstract

In Mexico there is a morphological and biochemical variability of soursop germplasm, mainly due to its propagation by seed. The last years were identified in Nayarit accessions (TR, VCA1, VCA4, VCA5 and VCA10) with outstanding characteristics; therefore, in 2017 the morphological and physicochemical characterization of fruits of these accessions was carried out. The morphological characterization was carried out with the descriptors of the guide of tests of distinction, homogeneity and stability of the international union for the protection of plant varieties (UPOV) in annonaceae. The physicochemical parameters were determined by the AOAC methods. Morphological differences were found in size and shape of fruits, size of spines, quantity and size of seeds. In the fruits of TR and VCA4 the largest size predominated and in the VCA5 smaller size. The trapezoidal shape predominated in the TR and the conical in VCA1 and VCA4. The TR and VCA10 fruits had greater bark thickness and smaller spines; while the VCA4 had larger spines. Fruits TR, VCA4 and VCA10 had a higher number of seeds and VCA5 had a lower number; with larger seeds in the TR and less in VCA1 and VCA4. There were no differences in pulp yield (68.7-72.4%), but it was directly proportional to the fruit size (r= 0.532) with $p< 0.001$. In the physicochemical characteristics, the TR fruits at maturity of consumption had greater intensity of the green of the skin, greater firmness, soluble solids content (SST) and °Brix/acidity ratio.

Keywords: *Annona muricata* L., firmness, seeds, soluble solids, yield pulp, size.

Reception date: May 2019
Acceptance date: August 2019

Introduction

The soursop (*Annona muricata* L.) is a species native to Central America, with great potential and in constant growth both in the Caribbean regions and in the equatorial belt of the Americas (Pinto *et al*., 2005). In Mexico, the reported established area of this crop in 2017 is 3 527 43 ha, with a production of 28 853 66 t, with the main producing states Nayarit, Colima, Veracruz, Michoacán and Guerrero.

The largest area and production of soursop occurs in the state of Nayarit with 2 529 94 ha and 21 810 86 t respectively (SIAP, 2018), where the last five years has increased the area of the crop to 28%, since it represents an important alternative of culture for the producers of the coast, as much by its value in the market for fresh consumption as the potential in the industry, as well as the demand that has arisen by its nutraceutical and medicinal properties.

At the moment there is no botanical description regarding soursop varieties, but generally the farmers make selections of the best trees according to the quality of the fruit by size and thickness of the skin, as they do in Chile and Spain (Cerdas *et al*., 2007). In Puerto Rico, the individual selection of trees for yield and interest in the industry classifies them by the taste of pulp (sweet and sour), the shape of the fruit and the consistency of the pulp (Evangelista *et al*., 2003).

In Mexico, the morphological and biochemical variability in regional germplasm is notable between and within producing orchards and is fundamentally due to the fact that soursop spreads through seeds (Evangelista *et al*., 2003). This propagation by seed from natural pollinated fruits (entomophilic and aerobic) has given rise to many soursop materials, which does not allow the homogenization of the orchards, thus having a heterogeneous development in terms of flowering, production and susceptibility to pests and diseases are concerned.

In recent years, in the producing areas of Nayarit, materials have been identified with outstanding characteristics such as productivity, fruit weight ≈3.2 kg, pulp content, fiber, juice and tolerance to pests and diseases; nevertheless, the lack of improved varieties and technified production systems has led to a crop of underutilized soursop (Hernández *et al*., 2017). In this investigation the fruits of the outstanding accessions were characterized morphologically and physicochemically to determine the predominant characteristics that will allow the producers to establish better soursop materials with fruit quality and according to their market needs.

Materials and methods

Location of study areas

The fruit collection was carried out in two zones of the state of Nayarit. The first zone was identified in the municipality of Compostela at 824 masl, 21° 18’ 42’’ north latitude and 104° 54’ 26’’west longitude where the accession identified as TR was obtained. The second zone identified in the municipality of Venustiano Carranza at 933 masl, 21° 32’ 02.2’’north latitude and 104° 58’ 40.6’’ west longitude where the accessions VCA1, VCA4, VCA5 and VCA10 were obtained. The characterization analysis was carried out in the Post-Harvest and Safety Laboratory of the Santiago Ixcuintla Experimental Field of the National Institute of Forestry, Agriculture and Livestock Research of Nayarit.

Vegetative material

Each accession was represented by variable numbers of trees (2-4) where the fruits to be characterized were obtained. The collection of fruits of each accession was made during the productive period (March-November 2017), in a state of physiological maturity with the criterion of light green peel color, firm pulp and separated spines (Castillo-Animas *et al*., 2005), free of physical damage and diseases. To eliminate field dirt and reduce the development of postharvest diseases, the fruits were washed with a chlorine solution (200 mg L^{-1}) and submerged in fungicide (0.05% Benlate), subsequently kept under ambient conditions (25 ±2°C, 70 ±10% HR) until consumption maturity. For the morphological and physicochemical characterization 10 fruits of each accession were obtained.

Morphological characteristics

The morphological characterization was carried out based on descriptors (qualitative, quantitative and pseudo-qualitative) of the driving guide of the distinction, homogeneity and stability tests of the international union for the protection of cherimoya (*Annona cherimola* Mill.) they belong to the same family and botanical genus as the soursop (*Annona muricata* L.) and the lack of soursop guide. There were only 23 characters of the UPOV (Table 1) observed in fruits obtained at harvest maturity.

At the time of harvest, the characterization of some external physical variables such as the size of fruits in weight and length, color and brightness of the epidermis, shape of the fruit, type of segmentation and protuberances on the surface was determined. In the ripeness of consumption, the internal characteristics of the fruit were determined, such as the transverse diameter of the fruit, bark thickness, pulp color, pulp texture, amount of fiber, amount of bony locule, succulence of the pulp, content of soluble solids, acidity, aroma, number of seeds, seed shape, length and width of seed, adherence of the seed to the pulp.

Table 1. Morphological characteristics evaluated in fruits of soursop accessions in Nayarit.

Descriptor	Type (character)
Length	QN (short, medium, long)
Cross section diameter	QN (small, medium, large)
Fruit shape in side view	PQ (circular, codiform, conical, wide conical, trapezoidal)
Shine of the epidermis	QL (absent, present)
Epidermis color	PQ (pale yellowish green, pale green, grayish green)
Bark thickness (mm)	QN (thin, medium, thick)
Surface segmentation	QL (absent, present)
Surface bumps	QL (absent, small, medium, large)

Descriptor	Type (character)
Pulp color	PQ (white, cream)
Pulp texture	QN (soft, medium, firm)
Fiber quantity	QN (little, medium, much)
Amount of bone locule	QN (small, medium, high)
Pulp succulence	QN (low, medium, high)
Soluble Solids Content	QN (low, medium, high)
Acidity	QN (low, medium, high)
Aroma	QL (weak, medium, high)
Number of seeds	QN (low, medium, high)
Seed length	QN (short, medium, long)
Seed width	QN (narrow, medium, wide)
Seed length / width ratio	QN (small, medium, large)
Seed form	QN (narrow, medium, wide)
Seed shine	QL (absent, present)
Adhesion of the seed to the pulp	QL (weak, medium, strong)

Character type: QN= quantitative; QL= qualitative; PQ= pseudoqualitative.

Physicochemical characteristics

The fruits collected were determined at the ripeness of consumption: husk and pulp color, the firmness of the fruit with husk and without peel (pulp), content of total soluble solids (SST), titratable acidity (ATT), ratio of SST/ATT of each of the accessions.

Description of physicochemical and fruit performance analyzes

The size of the fruits (length and diameter) was determined with a digital vernier and a tape measure. The number of seeds was made by manual counting. The weight of the fruits, seeds, pulp and husk was made with an Ohaus digital scale with a capacity of 6 000 g and a precision of 0.01 g. The weight of pulp, seed and husk is expressed as a percentage of the total weight of the fruit. The firmness in Newtons (N) was determined with a penetrometer (Chantillon DFE-050, Ametek Instruments, Largo, FL.) of cylindrical strut of 10 mm in diameter in three parts of the fruit (upper, middle and lower) with husk and without husk (pulp).

The color in the husk was measured with a Minolta CR-400 colorimeter with standard C lighting, using the CIE L*a*b* color space with readings on the top, middle and bottom of the fruit. For the color in pulp the coordinates L*C*h were used. The total soluble solids (°Brix) were determined with an Atago digital refractometer with temperature correction, where a drop of fruit juice was placed (AOAC, 1998). The titratable acidity was carried out with a semiautomatic titrator Dosimat Plus with 0.1 N NaOH solution and phenolphthalein as indicator (AOAC, 1998), the results were expressed as percentage of malic acid.

For the yield of the fruit, weighed and performed the separation of the husk, pulp, central lobe and seeds, obtaining the percentage of each part of the fruit with respect to the weight of the fruit. The juice was extracted from the pulp without seeds and the fiber was separated with a juice extractor and the percentage was determined with respect to the weight of the pulp.

Statistical analysis

This is a descriptive and comparative study between the characteristics of the accessions evaluated. The fruits collected from each accession were analyzed independently as a unit of study. In the quantitative characteristics, a descriptive analysis was carried out to determine the average, the standard deviation, coefficient of variation and the maximum and minimum values for fruit accessions. For the qualitative and pseudo-qualitative descriptors, the frequency distribution was obtained as a percentage of the total sample (population).

Also, the information of the characteristics evaluated in the fruits of the accessions was subjected to a variance analysis of a single factor to determine if the means of the accessions differ, using the comparison of Tukey with level of significance $p \leq 0.05$. Minitab® statistical software version 17 was used to analyze the data.

Results and discussion

Qualitative and quantitative morphological descriptors

The qualitative and pseudo-qualitative descriptors of UPOV characterized in the fruits of the accessions are shown in Table 2.

Table 2. Frequency in percentage of the qualitative and pseudo-qualitative morphological characteristics in soursop accessions.

Descriptor	Character	TR	VCA1	VCA4	VCA5	VCA10
Epidermis color	Pale green	57	0	15	14	40
	Pale yellowish green	29	75	54	57	0
	Gray green	14	25	31	29	60
Epidermis shine	Present	0	0	0	0	0
	Absent	100	100	100	100	100
Fruit shape	Conical	29	75	85	57	40
	Trapezoidal	71	0	15	43	40
	Cordiform	0	25	0	0	20
Surface segmentation	Reticulated	100	100	100	100	100
	Overlapping segments	0	0	0	0	0
Surface bumps	Very small	0	0	0	86	40
	small	71	25	0	14	60
	Medium	29	75	15	0	0
	Big	0	0	85	0	0

Descriptor	Character	TR	VCA1	VCA4	VCA5	VCA10
Pulp color	White	0	25	8	29	20
	Cream	100	75	92	71	80
Aroma	Medium	86	50	54	43	100
	Strong	14	50	46	57	0
Seed shine	Absent	0	0	0	0	0
	Present	100	100	100	100	100
Seed adhesion to the pulp	Weak	0	25	8	0	0
	Median	86	75	84	100	60
	Strong	14	0	8	0	40

The fruits of the accessions evaluated at maturity had a light green color with a decrease in the brightness of the epidermis, becoming a matte color. 57% of the fruits of the TR accession presented a pale green color and in the accessions, VCA1, VCA4 and VCA5, the predominant color was the pale yellowish green, while in the VCA10 the grayish green was 60%.

The fruits during their development have a bright dark green epidermis color and at harvest maturity it becomes matte (Worrel *et al*., 1994). It should be mentioned that the fruits that acquire sufficient development for harvest and reach maturity of consumption, lose the dark green color becoming a light green throughout the fruit, but the brightness can still be present, as well as the firmness.

Of the fruits harvested, more than 60% had an absence of brightness in the epidermis at the time of harvest and the rest with the presence of brightness matured adequately. These characteristics of color change and loss of brightness in the skin of soursop fruits when they are suitable for harvesting are mentioned by Castro *et al*. (2008) because the annonaceae exhibit important metabolic changes, manifested as variations in color and brightness, as well as decreased green color as a result of the degradation of chlorophyll.

The evaluated accessions presented different forms of predominant fruit. The TR fruits presented fruits of trapezoidal shape in 71% and the rest conical, while in the accessions VCA1 and VCA4 the predominant form was conical and for VCA5 and VCA10 both conical and trapezoidal forms were presented in a similar percentage. The soursop is described as an oval-heart shaped fruit according to Lawrence (2007), in some fruits it has an irregular, asymmetrical shape curved due to its inappropriate development of the carpel or voids produced by insects.

All the accessions presented fruits with segmentation of defined reticulated surface, but with differences in the size of the protuberances (flexible and slightly curved spines presented in the center of each reticulated segment). The size of the spines distinguished externally the fruits of one accession and another. The fruits of TR and VCA10 showed small spines in 71 and 60% respectively, in the VCA5 the very small spines (86%) predominated, in the VCA1 the spines were medium (75%) and in the VCA4 the spines were larger (85%) with an elongated shape, more curved and fleshy.

As described by Schultes and Raffauf (1990) to soursop fruits with a reticulated cover, with a smooth skin appearance, with many protuberances that protrude little or are squat and with flexible spines elongated and slightly curved.

According to Lawrence (2007), the aromatic soursop pulp, similar in texture to cotton, is white, creamy, juicy and smooth. In the characterized accessions the predominant pulp color was cream, very few fruits had white pulp. The aroma presented by the fruits was the characteristic of the fruit; however, in the fruits of the TR and VCA10 accessions, the intensity was medium and the other accessions presented both fruits with strong and medium aroma. The seeds presented brightness and their adhesion to the pulp was medium in most of the fruits of the characterized accessions, which indicates a uniform maturation in all fruits.

In the quantitative descriptors that involve fruit size, other characteristics that identify the accessions evaluated are shown (Table 3 and Figure 1).

Table 3. Quantitative descriptive characteristics of fruit size of soursop accessions.

Accession	TR	VCA1	VCA4	VCA5	VCA10
Fruit weight (g)					
Mean	1 828 a^{z}	1 135 a	1 933 a	720.4 a	1 252 a
Minimum	901	482	304	429.1	825
Maximum	3 808	2 126	5 200	1 078.1	1 906
CV	47.2	57.19	74.12	28.14	36.36
Fruit length (cm)					
Mean	20.29 a	19.03 a	21.82 a	14.91 a	16.72 a
Minimum	16.5	13.9	11.9	11.6	14.2
Maximum	26.6	26.8	33.2	17.2	19.8
CV	17.34	27.07	14.64	33.63	12.37
Fruit diameter (mm)					
Mean	117.96 a	93.07 ab	109.04 ab	86.34 b	111.42 ab
Minimum	92.16	74	67.2	68.33	98.5
Maximum	154.28	116.4	144.51	97.84	131.81
CV	16.23	17.4	21.6	15.79	11.39
Bark thickness (mm)					
Mean	2.24 a	0.92 b	1.31 b	0.94 b	2 a
Minimum	2.02	0.49	1.02	0.52	1.35
Maximum	2.59	1.23	1.6	1.43	3.24
CV	9.45	29.69	12.26	34.92	38.27
CV	58.92	119.98	82.62	75.94	59.08

^{z}= means with different letters, are statistically different (Tukey, $p\leq 0.05$).

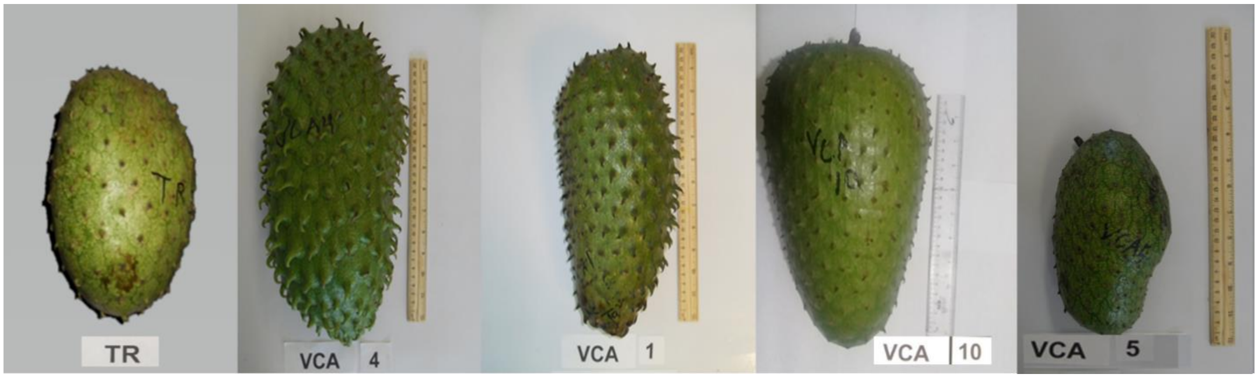

Figure 1. Fruits of soursop accessions: size, shape, color and thorns.

In all the accessions large and small fruits were found, without statistical differences in their weight and average length; however, the VCA5 accession presented the fruits with smaller size due to their weight and length, which is reflected in their coefficient of variation (28.14) with less dispersion in the weights, while those of VCA4 and TR presented greater number of large fruits, with weights higher than 1 500 g in 50 and 44.4% respectively. While the VCA5, 71.4% of the fruits had between 500 and 1 000 g, without fruit weighing more than 1 500 g.

On the other hand, VCA1 and VCA10 had weights greater than 1 500 g in 33 and 40% respectively, but without fruits with weights above 2 000 g. It is mentioned that the average weight of the soursop in Mexico, Nicaragua and Venezuela has ranges between 0.4 and 1 kg (Pinto *et al*., 2005; Coria-Téllez *et al*., 2018). Ávila *et al.* (2012) reported a minimum weight of 547 g and a maximum of 1 249 g. Regarding the diameter of the fruits, there were significant differences, where VCA5 presented fruits with a smaller diameter (86.34 mm) and TR those with a larger diameter (117.9 mm) because the trapezoidal shape predominated in the fruits, but were higher than those reported by Ávila *et al.* (2012) to the because they are larger fruits.

In thickness of bark or peel there were significant differences, fruits TR and VCA10 had greater thickness (2 and 2.2 mm, respectively), which would indicate greater resistance to the penetration of pests and diseases, as well as postharvest handling, while the other accessions its bark was thinner.

The amount of seeds average in the fruits was from 41 to 111, without showing significant differences as in the weights of the fruits; however, high CV resulted from the dispersion of the values when having both large and small fruits (Table 4).

Table 4. Quantitative descriptive characteristics of the seeds of soursop accessions.

Accession	TR	VCA1	VCA4	VCA5	VCA10
			Number of seeds		
Mean	102.8 a[z]	88.3 a	103.6 a	40.6 a	110.8 a
Minimum	28	13	17	12	52
Maximum	218	288	316	86	223
CV	58.92	119.98	82.62	75.94	59.08

Accession	TR	VCA1	VCA4	VCA5	VCA10
			Seed weight (g)		
Mean	67.9 a	47.2 a	66.7 a	25.31 a	75.9 a
Minimum	24	7.8	6.4	7.52	38.9
Maximum	121.4	161.1	188.4	61.72	153.6
CV	55.55	125.73	84.62	80.59	60
			Seed length (mm)		
Mean	16.77 a	12.16 b	12.2 b	14.11 ab	13.48 b
Minimum	13.16	10.8	9.3	13	10.12
Maximum	21.16	13.75	16.18	15.55	15.39
CV	14.59	9.77	15.7	6.68	15.14
			Seed width (mm)		
Mean	12.27 a	11.16 a	10.98 a	11.68 a	11.08 a
Minimum	10.21	10.1	8.3	10.36	10.74
Maximum	14.93	12.2	13.1	12.48	11.4
CV	11.95	6	10.76	6.93	2.77
			Seed thickness (mm)		
Mean	6.31a	5.29 b	5.68 ab	5.74 ab	5.59 ab
Minimum	5.02	4.5	3.82	5.03	5.07
Maximum	7.77	5.9	6.3	6.35	6.04
CV	14.26	11.81	10.96	7.77	6.67
			Seed length/width ratio		
Mean	1.37 a	1.09 b	1.12 b	1.21 ab	1.22 ab
Minimum	1.2033	0.9558	0.8319	1.0915	0.9396
Maximum	1.7039	1.2443	1.4408	1.4073	1.433
CV	11.25	8.86	15.94	9.3	15.05

^{z}= means with different letters, are statistically different (Tukey, $p \leq 0.05$).

Lawrence (2007) mentions that soursop can have up to 200 seeds and Pinto *et al*. (2005) that depending on the size of the fruit can contain between 127 and 170 seeds; on the other hand, Ávila *et al*. (2012) reported a minimum of 51 and a maximum of 145 seeds and Okoro and Osunde (2013) an average of 81 seeds per fruit. Soursop is considered a multiple fruit, a berry product of multiple ovaries (Méndez, 2003) so, if one considers that each seed is covered by a pulpy sac, it would be expected that large fruits had more seeds and vice versa.

Therefore, the fruits TR, VCA4 and VCA10 had the highest number of seeds and VCA5 the least number of seeds. The correlation of the fruit weight with respect to the number of seeds was directly proportional with r= 0.814 and highly significant (p= 0.00); Therefore, the greater the size of the fruit, the greater the number of seeds and also the total weight of the seeds (r= 0.861). The seed weight varies between 0.54 and 0.69 g, without differences between accessions. It is mentioned that soursop seeds are black with weights between 0.33 and 0.59 g and length of 1 to 2 cm, with a dark brown color (Pinto *et al*., 2005; Lawrence, 2007; Coria-Téllez *et al*., 2018).

In the length and thickness of seed there were differences, but not in width (10.98 -12.27 mm). The fruits of TR had large seeds with 16.77 mm in length, 12.27 in width and 6.31 mm in thickness, which is reflected in the high ratio of length and width of seed of 1.37. The seeds that remain in size were VCA5 and VCA10 and the smaller ones were VCA1 and VCA4 (Table 4 and Figure 2).

Figure 2. Seeds of the fruits of soursop accessions.

The study by Davies *et al*., 2014 in seeds reports averages of length, width and thickness of 13.25 ±0.65 mm, 8.97 ±0.87 mm and 5.63 ±0.12 mm, respectively. Okoro and Osunde (2013) mention that the seeds have an oval shape, with a bright dark brown color when they are just removed, but gradually they turn brown, until they acquire a light brown color.

Fruit yield

In the fruits of the evaluated accessions no significant differences were found in the pulp content, with averages of 68.65 to 72.42%, a minimum of 46.8 and a maximum of 80.6%. Márquez *et al*. (2012) reported percentages of 60%, below those obtained, Camacho (1995) of 74% and Ávila *et al*. (2012) between 62 and 82% close to those found. Machado *et al*. (1998) mentions that the percentage of pulp and the weight of the fruit are inversely proportional to the number of seeds; that is, the greater the number of seeds, the lower the proportion of the pulp; however, in this study the weight of the fruit is directly proportional to the number of seeds (r= 0.814) and to the percentage of pulp (r= 0.532) with $p< 0.001$, which would indicate that the greater the weight of the fruit the greater the number of seeds and pulp percentage, which is observed for TR, VCA4 and VCA10.

The seeds represent a low percentage, between 3.3 to 6.5%, with significant differences between accessions. VCA10 fruits had a higher percentage (6.48%) because they had a higher number of seeds and weight, while TR and VCA4 had a lower percentage (3.57 and 3.29% respectively). On the other hand, the rind represented more than twice the number of seeds, between 14 and 19.9%, without significant differences between accessions. Ojeda *et al*. (2007) reported percentages of bark between 18.5 and 20% and Márquez *et al*. (2012) 22% of husk and 5.4% of seeds, these values do not differ so much from those found, while Ávila *et al*. (2012) reported from 12 to 36% of husk and from 2 to 12% of seeds.

Regarding fiber content in the pulp, if there were differences between the accessions, the VCA10 fruits had higher content (43.13%) without differences with the other accessions VCA, but with respect to TR, which had the lowest fiber content (25.93 %). Both in percentage of seeds and fiber the TR fruits had the lowest content, while for the VCA10 that was the highest percentage, this is because each of the seeds is surrounded by a fibrous and pulpy sac and that between more seeds It would be considered a higher fiber content and vice versa.

The juice that was obtained in the extraction process from the pulp with fiber elimination did not present significant differences, the content varied between 51 and 57% of the total of the pulp and it is considered that in the extraction process there were losses that they are reflected in these values (Table 5).

Table 5. Yield of the fruits of soursop accessions.

Accession	TR	VCA1	VCA4	VCA5	VCA10
			(%) pulp		
Mean	72.23 a[z]	68.58 a	71.15 a	68.85 a	72.42 a
Minimum	65.87	58.96	46.76	63.75	67.65
Maximum	79.55	77.89	80.56	75.08	80.31
CV	7.97	10.44	13.22	5.21	6.61
			(%) husk		
Mean	14.08 a	19.92 a	17.75 a	19.87 a	14.77 a
Minimum	17.53	28.29	28.2	29.44	19.05
Maximum	8.33	13.29	17.67	15.77	8.79
CV	20.48	24.58	32.32	27.54	21.68
			(%) seeds		
Mean	3.57 b	3.7 ab	3.29 b	3.78 ab	6.48 a
Minimum	2.01	0.93	2.11	1.48	4.91
Maximum	5.25	7.68	4.54	8.65	9.34
CV	28.71	7.07	21.25	66.92	29.8
			(%) fiber		
Mean	25.93 b	39.28 a	38.16 a	38.47 ab	43.13 a
Minimum	18.68	27.64	30.28	30.86	40.76
Maximum	33.37	54.68	53.18	42.63	45.01
CV	23.71	32.84	20.05	11.67	4.08
			(%) juice		
Mean	52.64 a	57.06 a	56.19 a	55.46 a	51.07 a
Minimum	44	45.03	35.66	49.61	46.32
Maximum	75.33	65.85	68.92	60.54	58.51
CV	20.31	16.98	19.81	7.56	9.18

[z]= means with different letters, are statistically different (Tukey, $p \leq 0.05$).

Physicochemical characteristics of the fruits

In the physicochemical characteristics, the fruits of the accessions presented differences in some of the variables evaluated (Table 6).

Table 6. Physicochemical characteristics of the fruits of the accessions to consumption maturity.

Accession	TR	VCA1	VCA4	VCA5	VCA10
			Husk color (a*)		
Mean	-6.85 b[z]	-3.93 ab	-3.85 a	-4.80 ab	-5.63 ab
Minimum	-8.667	-6.503	-7.487	-6.547	-7.537
Maximum	-5.527	-0.08	1.187	-3.5	-3.843
CV	-18.05	-54.49	-70.89	-27.22	-25.45
			Pulp color (°Hue)		
Mean	96.89 a	92.38 a	96.5 a	95.95 a	95.46 a
Minimum	92.46	79.59	79.34	84.85	93.73
Maximum	102.69	98.35	102.08	99.28	97.26
CV	3.43	9.42	6.16	5.2	1.71
			Firmness with husk (N)		
Mean	42.98 a	25.09 a	27.44 a	27.68 a	32.02 a
Minimum	15.03	15.97	11.23	3.57	14.87
Maximum	67.87	36.33	92.43	44.43	46.9
CV	52.27	35.23	81.1	56.18	36.73
			Firmness in pulp (N)		
Mean	11.54 a	8.45 a	10.69 a	7 a	9.52 a
Minimum	7.4	5	4	2	4.5
Maximum	19.5	12.9	41.5	11.7	13.9
CV	34.08	37.41	93.15	48.8	37.64
			Soluble solids (°Brix)		
Mean	17.66 a	12.96 b	12.88 b	11.32 b	12.32 b
Minimum	14.3	9.4	10.1	10.8	10.8
Maximum	22.8	16.1	16.4	12.2	14.2
CV	15.1	20.63	13.08	4.27	11
			Titratable acidity (% ac. citric)		
Mean	0.68 a	0.86 a	0.71 a	0.71 a	0.59 a
Minimum	0.42	0.51	0.42	0.57	0.48
Maximum	0.96	1.06	1.34	0.88	0.68
CV	25.93	27.38	35.29	17.57	13.84
			°Brix/acidity ratio		
Mean	27.81 a	17.06 ab	19.68 ab	16.49 b	21.09 ab
Minimum	14.96	8.84	10.82	12.53	16.48
Maximum	43.36	31.71	29.88	21.37	25.73
CV	33.82	53.1	30.57	19.42	17.37

[z]= means with different letters, are statistically different (Tukey, $p \leq 0.05$).

In husk color (a*) the accession TR at maturity of consumption had greater intensity in the green color (a*= -6.85), presenting a light green matte, while the rest presented a less intense green color (a*= -3.85 to -4.8), which indicates greater degradation of chlorophyll and development of a green-yellow color, as mentioned by Castro *et al*. (2008) that the annonaceae during the ripening process show variations in color and brightness, as well as decrease in the angle of the green color, the coloration of the husk changes from dark green to a light yellowish green indicating that the chlorophyll has lost the carotenoids which are the main contributors to the color of the husk (Badrie and Schauss, 2010).

The luminosity L* had values between 31 and 45, where TR had the highest values (43 and 45) while the VCA had lower values indicating lower light in the green color. In soursops evaluated in maturity of consumption until senescence (6, 7, 8 and 9 days after harvest) they reached values of a*= -4, -2.2, 0.2 and 2 respectively and luminosity (L*) decreased intensely in those days, as well as the b* coordinate associated with chlorophyll a that confers a key with less clarity (Márquez *et al*., 2012).

Soursop pulp describes it as juicy and white (Coria-Téllez *et al*., 2018); however, the intensity of the white color may vary, since the fruits of the accessions evaluated had values of 92.38 to 96.89 °Hue, which indicates a creamy white color, this is also due to a decrease in the brightness of the pulp throughout of the ripening of the fruit (Márquez *et al*., 2012).

In the firmness of the fruit with rind, the TR showed greater firmness (42.98 N) and the other accessions had less firmness, between 25 and 32 N, which would indicate a state of more advanced maturity; however, the firmness of the fruit without peel, practically firmness of the pulp, indicate that there were no significant differences in the degree of ripeness of the fruit (7 to 11.5 N), but rather that the thickness of the peel or rind of the fruit have greater opposition to penetration and therefore greater resistance during its postharvest handling. Márquez *et al*. (2012) reported a firmness of 79.43 N and 3.62 N after 9 days.

The changes associated with the softening of the soursop during its maturation, implies the decrease in content of starch and total pectin due to the high enzymatic activity of amylase and polygalacturonase respectively (Lima *et al*., 2006). The high enzymatic activity of α and β amylase is related to the hydrolysis of high molecular weight carbohydrates to simple compounds such as disaccharides and monosaccharides (sucrose, glucose and fructose) [Kader, 2002], which increases total soluble solids during maturation, some studies mention maximum values of 12.8 °Brix (Márquez *et al*., 2012) and 16 °Brix (Badrie and Schauss, 2010), others from 13 to 24 °Brix (Ávila *et al*., 2012) and Colombian standards (ICONTEC, 2003) establish a minimum of 13.5 °Brix.

The TR fruits presented the highest content of total soluble solids 17.66 °Brix, which coincide with those reported by Ojeda *et al*. (2007) between 14 and 17 °Brix, while the VCA accessions did not show significant differences between them, with values between 11.3 and 12.9 °Brix. In titratable acidity the accessions did not have significant differences, with values between 0.59 to 0.86% of malic acid.

In the ratio of °Brix/acidity, which indicates the flavor and sweetness of the fruit, the TR presented greater sweetness in the TR fruits (27.81 °Brix) with an acidity (0.68% malic acid) that provides the balance between sweet and acid own of the fruit; however, the VCA, due to its lower content of soluble solids, provides a more acidic flavor to the fruit, thus presenting a pleasing mixture of sweetness and medium acidity that characterizes soursops (Pinto *et al*., 2005). Márquez *et al*. (2012) reported maximum acidity values of 0.74% as malic acid on day 6 post-harvest and Ávila *et al*. (2012) between 0.67 and 1.04%, which are very similar to those determined in the accessions evaluated.

Conclusions

The fruits of the evaluated accessions showed morphological differences in qualitative and quantitative descriptors, such as size and shape of fruits, color from peel to maturity, size of thorns, quantity and size of seeds. In the physicochemical characteristics, the fruits presented significant differences in the color of peel to ripeness of consumption, firmness of peel, in the development of SST and the °Brix/acidity ratio. The differences found between accessions show that according to their characteristics the producer could determine which vegetative material to choose according to their market needs.

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