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MORPHOLOGICAL AND PHYSICO-CHEMICAL CHARACTERIZATION OF FRUIT OF *MELICOCCUS BIJUGATUS* JACQ.

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Abstract

Morphological and physico-chemical characterization of the fruit of *Melicoccus bijugatus* were studied. To estimate more accurate data of fruit of *Melicoccus bijugatus* 11 variables were valued in two different stages of maturity ripe and unripe: shelled weight, shell weight, juice weight, pulp weight, seed weight, fruit length (cm), fruit diameter (cm), thickness (mm), shell thickness (mm), seed color and seed shape. In order to obtain these analytical scales and calibrators data, the two maturity stages by tabulating and analyzing all the information collected were compared and taken into consideration the maturity index to determine the optimum point of harvest. The shell weight, juice weight, pulp weight, seed weight, fruit length, fruit diameter and shell thickness were obtained higher in the ripe fruit than the unripe fruit, when the fruits have reached 69% of maturity, recommended as optimal percentage of maturity.

Introduction

Melicoccus bijugatus is found in the catalog which enumerates all taxa of Gymnosperms, dicotyledons, and monocotyledons occurring in the West Indies archipelago. Type specimen citations are provided for accepted names and synonyms of Sapindaceae among them (Acevedo-Rodríguez 2012). The morphological characterization of a species is a procedure that is normally used to describe the morphological, size, shape, structure and productive characters that identify the species; the term refers to the general aspects of biological form and arrangement of the parts of a plant (Villee 2018); includes the study of morphology for example homogeneity, size, shape, color, opacity, and texture. Moreover, its observation of shape and size, mobility, etc. and also includes the determination of chemical characteristics (Meza-Vázquez and Lépiz-Ildefonso 2015). The main objective of the characterization is to measure morphologically and chemically the variability to determine the optimum harvest point. *M. bijugatus* is native to northern South America and naturalized in coastal and dry forest in Central America, the Caribbean, and parts of the Old-World tropics. It is believed to have been introduced into the Caribbean in pre-Columbian times and is also found in India. The fruit ripens during the warm summer months and it is very popular in El Salvador because of the variety of uses for the fruit, which are consumed fresh or preserved and canned fruits, mainly in Central and South America. *M. bijugatus* is consumed fresh and even used to prepare canned refreshing drinks, "specific phenolics or sugars in *M. bijugatus* fruits may contribute to their therapeutic uses, especially for gastrointestinal problems, and to some extent toxicological effects" (Bystrom 2008, 2012). *M. bijuga* was originated at the La Guajirita hamlet, neighboring El Tocuyo city, Lara State in western Venezuela (Pérez *et al.* 2008, 2009). In addition, in El Salvador and Nicaragua, the use of seed milk or “horchata” is reported to

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treat parasites. Usually, the seeds are roasted before consumption for either dietary or medicinal purposes, most likely to reduce the toxicity of the seeds or make them more digestible (López-Sáez 2010; Bystrom LM *et al.* 2009). The tree is of slow growth, erect, majestic, attractive; it can reach 25 m high, while the diameter of the trunk is 0.5 m; *Melicoccus* b. Jacq. (guinep) "is native to South America but grows in the Caribbean and parts of Central and North America. It is a small round fruit with a thick green rind covering a peach-colored pulp which has a jelly-like consistency with a taste ranging from sweet to sour" (Javain *et al.* 2019). However, this research seeks to demonstrate the significant differences that exist within the process of ripening the *Melicoccus bijugatus* fruit and thus determine the optimum harvest point taking into consideration the maturity index, the percentage of acidity, the morphology of the fruit, colorimetry among other data.

Materials and Methods

The study area was San Salvador in the Municipality of Santiago Texacuangos, where the samples were collected and the research laboratory was "The Quality Lab", Faculty of Agriculture and Research, Jose Matias Delgado University, where the analyses were done. An attempt was made to gather literary information of the *M. bijugatus*, which is of potential interest to agro-industry and constitute a possible source of income for the local population in the near future (Moo-Huchin *et al.* 2014). Moreover, the fruit consists of a single, large, yellowish-white seed. Due to leathery skin, the fruit remains fresh for a long time. In El Salvador, it is known or called "mamoncillo" and in the American continent it is generally known as "Honeyberry", "Guinep", "Spanish lime" which belongs to the class Magnoliopsida, order Sapindales, family Sapindaceae and species *bijugatus*.

The concept of "Mature is best defined by having completed natural growth and development for the fruit; it is defined in U.S. Grade standards that stage which will ensure proper completion of the ripening process" (Pérez *et al.* 2008). In this phase of the investigation, a survey was conducted on the Municipality of Santiago Texacuangos, where the varieties of the *M. bijugatus* is located. On the other hand, a comparison was made taking into consideration the existing varieties of the Puerto Rico area, which mentioned in particular the variety "*Melicoccus bijugatus*", "Las Cuevas" and "Cesar Ramos" which are the most similar by the characteristics of percentages of acidity which vary 1.04 to 1.28. Moreover, the physical characteristics of the *M. bijugatus* were considered for being a semi-round fruit, which has one seed and belongs to the dicotyledon group. Furthermore, the way of obtaining the fruit is harvesting it manually through a woven sack or hessian sacks which are subsequently transferred in agroindustrial plastic crates, placing it in pallets. Afterward, the samples were analyzed with the objective to perform physicochemical parameters such as the pH, characterization of the fruit, determination of maturity index and brix degrees (the highest pH that reaches the fruit is 4 in the same way, the maximum brix achieved was 24 at its optimum point of maturity). The classification of fruits was made and the characterization of the *M. bijugatus* fruit was the weight of the seed, the shape, the length, width, the color individual weights of the exocarp, pulp, juice, the thickness of the exocarp, the husk; both ripe and immature fruit. For the measurement of weight, an analytical balance was used and for the different measures of length, a vernier caliper was used.

This characterization was performed with 374 unripe fruit samples at in a box containing the number of 400 of which only of 34 were selected for each of the characterizations, giving a total sample of 4400 extracted. The same was considered for the characterization of the ripe fruit. It is necessary to clarify that after taking data extracted from the box containing 400 fruits was discarded and again it was filled up with another 400 fruits characterization again, the same was

for unripe fruits. Each characteristic, namely shelled weight, shell weight, juice weight, pulp weight, seed weight, fruit length (cm), fruit diameter (cm), husk thickness (mm), exocarp thickness (mm), seed color, seed shape of the fruit was carefully determined in both ripe and unripe conditions.

Basically it was determined: Seed weight, shape, length, width, color, individual weights of husk, exocarp, pulp, juice, husk thickness; both ripe and unripe fruit. The analytical balance was used to measure the weight and for the different length measurements a vernier caliper was used, the characterization averages on the ripe and unripe fruits (Table 1).

Table 1. Averages value of ripe and unripe fruit of *M. bijugatus*.

Description ripe	Values ripe	Description unripe	Values unripe
Shelled weight	13.3708 (g)	Shelled weight	7.5121 (g)
Shell weight	4.3608 (g)	Shell weight	2.3309 (g)
Juice weight	5.6275 (g)	Juice weight	1.8228 (g)
Pulp weight	1.6817 (g)	Pulp weight	0.2811 (g)
Seed weight	4.6036 (g)	Seed weight	2.4140 (g)
Fruit length	3.8253 (cm)	Fruit length	2.8582 (cm)
Fruit diameter	2.5388 (cm)	Fruit diameter	2.0438 (cm)
Thickness	3.8824 (mm)	Thickness	4.8235 (mm)
Shell thickness	15.0882 (mm)	Shell thickness	12.6765 (mm)
Pulp color	Salmon	Pulp color	White
Seed shape	Semi oval	Seed shape	Oval

Results and Discussion

Results obtained from the analyses of the fruit of Melicoccus *bijugatus* ripe versus unripe stages through the characterization are presented in the Table 1 which shows that the higher weight was obtained by the juice of the ripe fruit than the optimal state, although apparently the liquid varies between an average of 5.6275 g. with compared to the other pulp averages weight which was 1.6817 g. For the seed, the average was 4.6036 g. and the shell the average was 4.3608 g. which confirms that the highest weight was in the juice of the ripe fruit.

Furthermore, the average weight juice of unripe fruits. was 1.8228 g, for the pulp was 0.2811 g, for the seed was 2.4140 g. and the shell weight of the unripe fruit on average was 2.3309 g. Therefore, all those results confirm the differences between the fruit in unripe state, which gets a lower weight compared to the ripe fruit state. On the other hand, the fruit in unripe state is oval while the fruit in ripe state is semi oval (it tends to be round or with circular symmetry); a very special characteristic is the color which takes the ripe fruit, turning to salmon color while the unripe state the color is white. In addition to the morphological characterization, 126 samples were taken, those samples including the % of titratable acidity (TA) and °Brix Maturity Index (MA). All information are presented in Table 2.

The first-trimester started at the beginning of March, in which 27 samples of % of TA, MI, and °Brix were taken (9 samples for each analyses). In the second trimester (May - July) another 27 samples of % TA, MI, and °Brix were taken into consideration. The third trimester the last 27

Table 2. Result of the samples of % of titrable acidity, °brix and maturity index of *Melicoccus bijugatus*.

First trimester			Second trimester			Third trimester		
% Titratable acidity	°Brix	Maturity index	% titratable acidity	°brix	Maturity index	% titratable acidity	°Brix	Maturity index
1.006653309	14.5	14.5981646	0.31918476	21	65.9866154	0.30080745	24	79.9792571
0.990051107	14.5	14.8397086	0.32149521	21	65.5137915	0.29578229	24	81.3347611
0.957627188	14.5	15.3355918	0.3203181	21	65.7538286	0.29445994	24	81.6991439
0.995695989	14.5	14.7566779	0.297925	21	74.038089	0.53354675	16.5	31.119125
0.983180114	14.5	14.9420607	0.29279028	21	75.3331065	0.52879214	16.5	31.3971867
0.99218716	14.5	14.8081782	0.29331183	21	75.1994995	0.53380244	16.5	31.1043121
0.989717601	14.5	14.8446438	0.31366957	21	67.1434345	0.42730677	21.5	50.5091398
1.005674037	14.5	14.6121906	0.31940803	21	65.9406259	0.43848668	21.5	49.2262758
0.989976975	14.5	14.8408053	0.3188409	21	66.0575707	0.44542642	21.5	48.4623536
0.990084831	14.5	14.8420024	0.31077152	21	68.9962846	0.42204565	20.67	53.8701728

Table 3. Independent samples test.

		Levene's test for equality of variances		t test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	99% confidence interval of the difference	
									Lower	Upper
(i)	Equal variances assumed	2.772	0.101	61.05	66	0	5.85869	0.09597	5.60413	6.11325
	Equal variances not assumed			61.05	63.465	0	5.85869	0.09597	5.60383	6.11355
(ii)	Equal variances assumed	0.312	0.579	30.87	66	0	2.0299	0.06576	1.85549	2.20431
	Equal variances not assumed			30.87	65.972	0	2.0299	0.06576	1.85548	2.20431
(iii)	Equal variances assumed	10.547	0.002	58.36	66	0	3.80474	0.06519	3.63182	3.97766
	Equal variances not assumed			58.36	56.397	0	3.80474	0.06519	3.63095	3.97854

samples were taken at the end of August, again the °Brix, PA and MI were measured. In a period of 6 months, all this served to determine the optimal harvest point of the *M. bijugatus* fruit and thus determine the MI, which showed that the % of TA and the number of soluble solids varied from the state of maturity of the fruit of *M. bijugatus*, which showed us that Unripe state the percentage of titratable acidity is higher than °Brix which is smaller. Table 2 shows that the highest % of TA - 1.006653309 reached, meanwhile the soluble solids in the unripe state was ° Brix = 14.5. The results change radically, raising the °Brix to 24 and decreasing the % TA = 0.297925, this being the lowest value obtained which presented in Fig. 2.

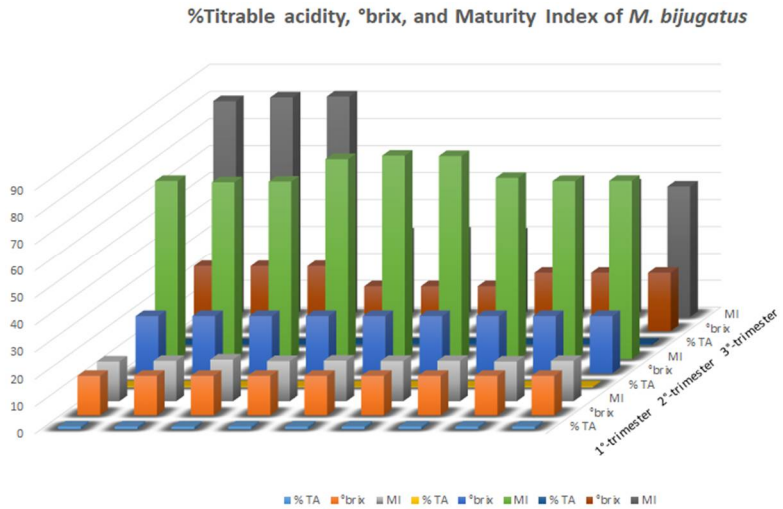

Fig. 1. % titratable acidity, °Brix and maturity index of *M. bijugatus*.

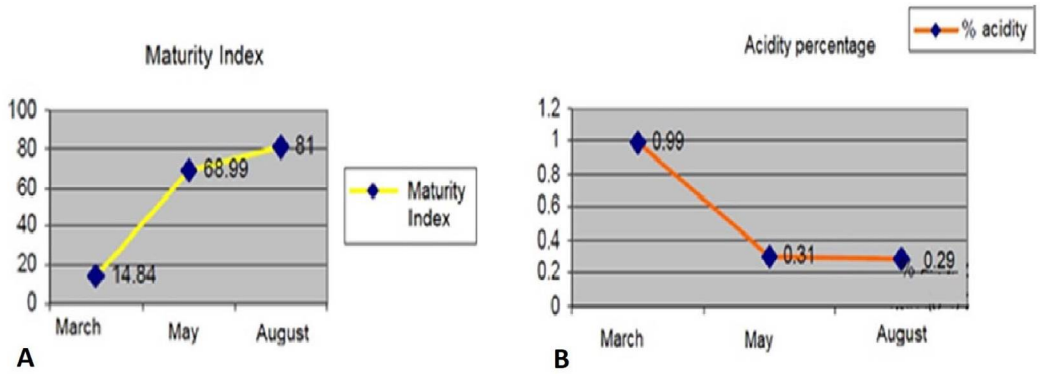

Fig. 2. A. Maturity index and B. acidity percentage graph.

Moreover, to verify these representative differences obtained through data collected from the characterization of the fruit of the mamoncillo and tabulated them using the ANOVA method, it is a statistical tool for the analysis of data and consists of analyzing two samples of two in two through a multiple table of ranges to determine significant differences between treatments or variables. Therefore, the data obtained by tabulation and the use of the F test for variance of two samples; t test for two samples assuming unequal variances and t test for two samples assuming equal variances. The last t test is only done when in the f test there are no significant differences

and the "t" test for the same variance shows that in averages if there are significant differences for the treatments (Table 3).

The MI was measured; in a period of 6 months, all this served to determine the optimum point of harvest of the mamoncillo fruit and thus determine the MI, which showed that the % of acidity and the number of soluble solids vary according to the state of maturity of the fruit of the *M. bijugatus* which showed that in an unripe state the percentage of acidity was higher and the % of ◦Brix lower, which changes radically, raising the ◦Brix to 24 and the % of titratable acidity in average decreased to 0.42204565. The data obtained by the analyses made in mid-March and subsequently, the second data collection was taken at the end of June when this point had reached a lower level of % titratable acidity, therefore, the number of soluble solids was higher. The reached Brix was 21 and the % of titratable acidity on an average was 0.31077152, meanwhile, the maturity index reached an average of 68.9962846, however, this continued increasing, in fact, the analyses show that exceeded in more than 50% maturity. Once the fruit has reached to 69% of maturity; is this point this study recommend as optimal % of maturity. The highest ◦ Brix reached was 24, this is the maximum amount of soluble solids that reached the fruit in ripe state, from this point the fruit begins to fall and decompose, it can also been observed that the % of acidity in average was: 0.42204565 which shows that at this point the % of titratable acidity has dropped considerably while the average value of maturity index was 81.0043873 taking into account the first three samples of MI (79.9792571, 81.3347611, and 81.6991439), since the others using simple random sampling there was a small portion of ripe fruits which gave an average maturity index of: 53.8037967 the last 27 samples were tken at the end of July and August (Fig. 3).

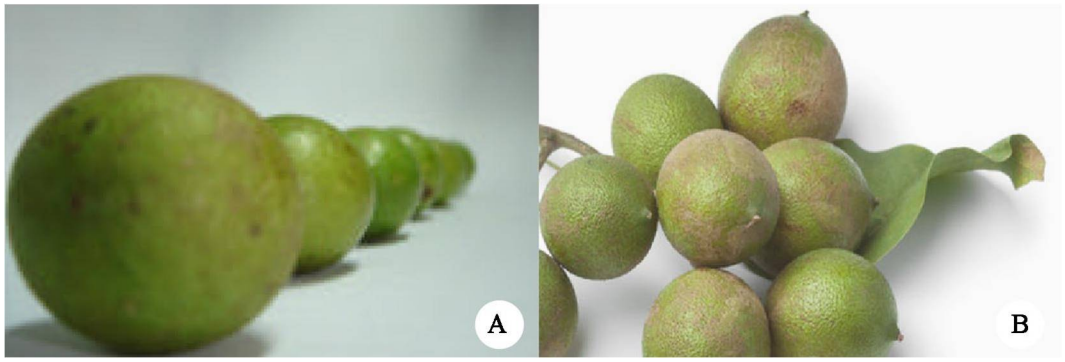

Fig. 3. *M. bijugatus* exocarp colors change from a slight color (A) to bright green or dark (B).

Moreover, it can be noticed how the percentage of citric acid present in the fruit decreases considerably once the fruit reaches its maximum state of physiological maturity. However, this does not occur in the maturity index, which shows how gradually increases over the 6-month period as shown in Fig. 2.

Through the analyzes and tests performed, the differences between ripe and unripe stage of the *M. bijugatus* fruit were verified, also there was a particular case which went through the exocarp undergoes changes from a slight color to bright green or dark green until it reached its optimum harvest point which shows a color hue of olive green or green moss.

This study sought to analyze the morphological characteristics of the *M. bijugatus* fruit, to determine its optimum harvest point. Once the fruit has reached to 69% of maturity this study recommends as optimal % of maturity because allows the farmer to extend the shelf-life taking

into consideration the distribution of this fruit in the local market, at the same time the fruit continues the maturing process for a period of two or three months more after this period of time it starts the senescence stage. The greater weight obtained was the weight of the juice because of large amount of pulp is concentrated; it has an average of 5.6275 g. The color of the fruit in a mature state was very striking and appetizing unlike it in other states of maturity. There was a significant difference or variability between the data group of characterization of the thickness of the shell of the ripe fruit vs. immature fruit. The fruit presents a smaller size in an immature state, which also changes its shape and color, making it difficult to consume and process it. In addition, the amount of pulp was very low, obtaining little raw material.

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