Australian Journal of Crop Science AJCS

Aust J Crop Sci. 18(09):564-573 (2024) ISSN:1835-2707
https://doi.org/10.21475/ajcs.24.18.09.p91

Sensory and organoleptic assessment from the byproducts of mamoncillo or quenepa *Melicoccus bijugatus Jacq*: Alternative food processing and morpho-physiological characterization of the fruit

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PUBLONS: https://publons.com/researcher/2976510/juan-carlos-calderon-lopez/

Submitted: ***10/01/2024***

Revised: ***25/04/2024***

Accepted: ***28/04/2024***

Abstract: This research aims to analyze the morpho-physiological characteristics of ripe fruit and assess the feasibility and acceptability of agro-industrial byproducts derived from mamoncillo or quenepa (*Melicoccus bijugatus Jacq*) fruit. In addition to this, it was considered to be the optimal harvest point, which begins at 69% of the Maturity Index. In addition, evaluations of the chemical and morphological characteristics were carried out. To gather analytical scales and calibrator data, the two ripeness phases were analyzed and compared, using the maturity index to establish the optimal harvest point. Ripe fruits have increased shell, juice, pulp, seed, length, width, and thickness than unripe fruits, with 69% maturity being best. Further, it is possible to use the pulp of *Melicoccus bijugatus* to make syrup, jam, or jelly among other things. For this reason, the hedonic test was conducted with panelists who had not received any prior training in order to ascertain the level of acceptance of these innovative products. The analyses showed that the highest rank given through the panelists by the hedonic test and ranks of taste was "P-2 Pattern-2" with an X = 55.5 (Rank) which is a substitute pattern "Lychee in syrup", the second-highest was X = 52 which is "T-1 Treatment i.e. *Melicoccus bijugatus* Jelly"' followed by "T-2 Treatment i.e. *M. bijugatus* in syrup" with X = 51 Rank. According to the findings of the statistical analysis, the various agro-industrial byproducts derived from *Melicoccus bijugatus* were positively received.

Keywords: *Melicoccus bijugatus Jacq*, Optimal harvesting time, Morpho-Physiological characterization, Determination of titratable acidity and Maturity Index, Bromatological analyses, Sensory analyses, Agro-industrial byproducts.

Introduction

The fruit of “mamoncillo” or “quenepa” *Melicoccus bijugatus*, which is typically consumed fresh or for medicinal purposes, is not yet exploited in the agro-industrial sector. In El Salvador, the fruit is commonly called "mamoncillo," but in the Americas continent it is often referred to as "Honeyberry," "Guinep," “Guenepa” or "Spanish lime." It belongs to the class Magnoliopsida, order Sapindales, family Sapindaceae, and species bijugatus. It is available in local markets throughout Asia, North America, Central America, and South America (Laura M, 2012; Laura M et al., 2008; Laura M et al., 2009; Martínez-Castillo et al., 2019). Consequently, this presents an opportunity to expand processing options and gain a greater understanding of the optimal harvest point or ripe stage (JCC Lopez et al., 2021). In actuality, there is considerable scope for inquiry regarding plant varieties that have yet to undergo industrialization. This study describes the by-products that can be obtained during the agro-industrial processing of *Melicoccus bijugatus* fruit. In addition to microbiological, organoleptic, and sensory analyses, the research provides information regarding the fruit's general characteristics (Acevedo-Rodríguez, 2003; Pérez C et al., 2008).
For the purpose of implementing Good Manufacturing Practices (GMP), it is required to guarantee that the fruit satisfies the requirements of harvesting. As a result, good harvest practices (GHP) are an absolute necessity (Fontana et al., 2012; Nunes et al., 2015). This study involves documenting the potential industrial procedures for processing the fruit of *Melicoccus bijugatus*. The research includes conducting microbiological and sensory examinations and providing information on the overall characteristics of the fruit (Victor M Moo-Huchin et al., 2014; Pérez C et al., 2009). The procedures that follow will be used to determine the optimal harvest point: maturity index and morphological characterization. Once harvested, the product will undergo microbiological analyses to ensure safety. Its acceptability will be determined through a hedonic test, which will be evaluated using parametric and

non-parametric tests such as ANOVA, Kruskal-Wallis by ranks, multiple comparisons, and Friedman test. Furthermore, significant data was gathered from government agencies such as the Inter-American Institute for Cooperation on Agriculture (IICA), the Food and Agriculture Organization (FAO), and literatures on the agro-industry of *Melicoccus bijugatus* fruit (Cruz and Deras, 2000; Nations, 1995).

The data and information regarding the agro-industrial process of *Melicoccus bijugatus* in El Salvador are restricted to a small number of authors, these authors have recorded botanical data and taxonomy, which has been used to conduct the research. To address the aforementioned issues, it is imperative to design effective processing protocols right from the starting point of the process. Furthermore, each product met stringent quality and safety criteria, necessitating the consideration of physicochemical and microbiological variables to ensure the consumption and safety of these products.

This study, on the other hand, aims to demonstrate alternatives for the agro-industrial processing of the quenepa fruit and validate its acceptance through untrained panelists. Additionally, the study intends to demonstrate the significant differences that exist within the process of ripening the Melicoccus bijugatus fruit and, as a result, determine the optimal harvest point by taking into consideration the maturity index, the percentage of acidity, the morphology of the fruit, and colorimetric, among other data.

Results and Discussion

Morpho-Physiological characterization of ripe fruit of Melicoccus bijugatus

In order to evaluate morphological and physiological parameters, the samples of Melicoccus bijugatus fruit were analyzed. These parameters included pH, fruit characteristics, measurement of maturity index, and brix degrees. During the fruit's optimal maturity stage, the pH level reached a maximum of 4, and the brix level reached its highest point at 24. Several characteristics, including seed weight, shape, length, width, color, separate weights of the outer layer, pulp, and juice, as well as the thickness of the outer layer and the husk, were used to classify the fruits. These characteristics were taken into consideration when they were classified. The features of both ripe and immature fruit of *Melicoccus bijugatus* were evaluated. A precision balance was used to measure weight, while a vernier caliper was used for measuring various lengths.

The characterization process entailed the analysis of 374 immature fruit samples out of a total of 400 fruits contained in a box. A total of 34 fruits were chosen for each characterization, resulting in a grand total of 4400 extracted samples. Comparable assessments were done regarding the attributes of the fully developed fruit. It is crucial to highlight that after gathering data from a container containing 400 fruits, those fruits were disposed of and replaced with another set of 400 fruits for the purpose of characterizing immature fruits. Precise measurements were taken for the shelled weight, shell weight, juice weight, pulp weight, seed weight, fruit length (cm), fruit diameter (cm), husk thickness (mm), exocarp thickness (mm), seed color, and seed shape of the fruit in both ripe and unripe conditions. The evaluation primarily focused on the weight, shape, length, width, color, and individual weights of the husk, exocarp, pulp, juice, and husk thickness of both ripe and unripe fruit. The weight was determined using an analytical balance, while the length measurements were obtained using a vernier caliper. Table 1 displays the average attributes of both mature and immature fruits (Table 1).

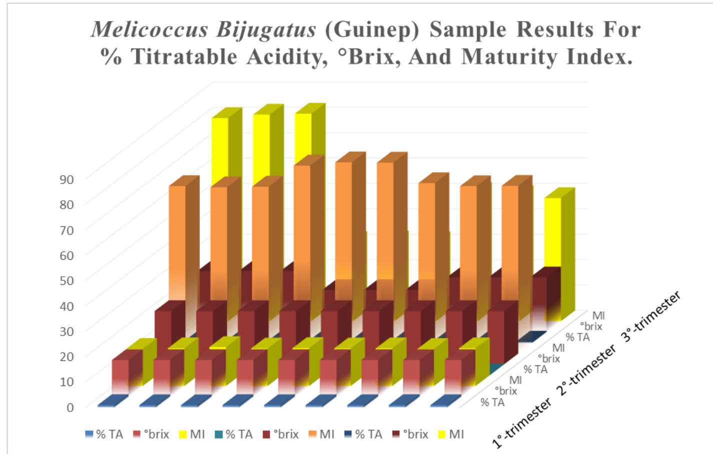

Figure 1. Chart element 3D Column: *Melicoccus bijugatus* (Guinep) sample results for % Titratable Acidity, °Brix, and Maturity Index.

Assessment and findings of the optimal timing for harvesting of Melicoccus bijugatus fruit

The results of the analyses comparing the ripe and unripe stages of *Melicoccus bijugatus* fruit are presented in Table 1. The data shows that the juice of the ripe fruit had a higher weight compared to the optimal state. However, the liquid content varied with an average of 5.6275 g, while the average weight of the other pulp was 1.6817 g. The average weight of the seed was 4.6036 g, whereas the average weight of the shell was 4.3608 g. This demonstrates that the mature fruit's fluid had the maximum weight.

In addition, the average weight of unripe fruits' juice was 1.8228 g, the pulp weighed 0.2811 g, the seed weighed 2.4140 g, and the average weight of the unripe fruit's shell was 2.3309 g. Thus, all of these findings validate the disparities between the immature fruit, which has a lesser weight in comparison to the ripe fruit. Conversely, the unripe fruit has an oval shape, whilst the ripe fruit has a semi-oval shape, often appearing round or with circular symmetry. A notable feature is the color transformation of the fruit: when ripe, it turns a salmon hue, whereas in its unripe state, it is white. Furthermore, with the morphological characterisation, a total of 126 samples were collected. These samples encompassed the percentage of titratable acidity (TA) and the °Brix Maturity Index (MA). (Table 2)

Furthermore, 27 samples of %TA, °MI, and °Brix were taken during the first trimester, which began at the beginning of March. Nine samples were taken for each analysis. Between May and July of the second trimester, 27 more samples of %TA, °MI, and °Brix were examined at. The last 27 tests for the third trimester were taken at the end of September. The °Brix, PA, and MI were measured once more. Over the course of 7 months, all of this helped us figure out the best time to harvest the *Melicoccus bijugatus* fruit and, by extension, the MI. The % of TA and the number of soluble solids changed depending on how ripe the fruit was, showing that when the fruit is not ripe, the % of titratable acidity is higher than the °Brix, which is lower. Table 2 shows that the highest level of TA was 1.006653309, and the highest level of soluble solids in the raw state was ° Brix = 14.5. The results are very different now; the °Brix goes up to 24 and the % TA goes down to 0.297925, which is the lowest number that was found and shown in Figure 1.

Table 1. The overall average value of ripe and immature fruits of Melicoccus bijugatus (Guinep).

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	7.8228 (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

Table 2. *Melicoccus bijugatus* (Guinep) sample results for % titratable acidity, °brix, and maturity index.

First sample collection			Second sample collection			Third sample collection		
% 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
Average % Titratable acidity	**Average °Brix**	**Average Maturity Index**	**Average % Titratable acidity**	**Average °Brix**	**Average Maturity Index**	**Average % Titratable acidity**	**Average °Brix**	**Average Maturity Index**
0.990085	14.5	14.842	0.310772	21	68.99628	0.422046	20.667	53.87017
MAX	**MAX**	**MAX**	**MAX**	**MAX**	**MAX**	**MAX**	**MAX**	**MAX**
1.006653309	14.5	15.3355918	0.32149521	21	75.3331065	0.53380244	24	81.6991439
MIN	**MIN**	**MIN**	**MIN**	**MIN**	**MIN**	**MIN**	**MIN**	**MIN**
0.957627188	14.5	14.5981646	0.29279028	21	65.5137915	0.29445994	16.5	31.1043121

Furthermore, in order to validate the distinct variations observed in the collected data from the characterization of the mamoncillo fruit, the ANOVA method was employed. ANOVA is a statistical technique used to analyze data by comparing two samples at a time through a multiple range table. This analysis helps determine significant differences between treatments or variables. Thus, the data is collected through tabulation and analyzed using statistical tests such as the F test for comparing variances of two samples, the t-test for comparing means of two samples with unequal variances, and the t-test for comparing means of two samples with equal variances. The final t-test is conducted only if the f-test reveals no significant differences and the t-test for equal variances indicates significant differences in means for the treatments. (Table 3)

Assessment and findings of Maturity Index (MI)

The maturity index (MI) of the mamoncillo fruit was measured over a 7-month period to determine the optimal harvest time. The MI revealed that the acidity percentage and the number of soluble solids varied depending on the fruit's maturity state. In the unripe state, the acidity percentage was higher and the Brix percentage was lower. However, as the fruit matured, the Brix percentage increased to 24 while the average titratable acidity percentage decreased to 0.42204565. The data collected during the mid-March analyses and subsequent data collection in late June indicated a decrease in % titratable acidity and an increase in the quantity of soluble solids. The Brix level attained was 21 and the average titratable acidity percentage was 0.31077152. Additionally, the maturity index averaged at 68.9962846. However, it continued to increase, with the analysis indicating that it exceeded maturity by more than 50%. According to this study, it is recommended to harvest the fruit after it has achieved 69% of maturity, as this is considered the optimal percentage of maturity. (Figure 2) (Figure 3)

The highest Brix value recorded was 24, indicating the maximum amount of soluble solids present in the ripe fruit. Beyond this point, the fruit starts to deteriorate and decompose. Additionally, the average acidity level was found to be 0.42204565, suggesting a significant decrease in titratable acidity. The average maturity index was calculated to be 81.0043873, considering the first three samples of MI (79.9792571, 81.3347611, and 81.6991439). However, for the remaining samples, which were obtained through simple random sampling, only a small portion of ripe fruits were included, resulting in an average maturity index of 53.8037967. The last 27 samples were collected at the end of August and the first week of September. (Figure 4)

Table 3. Statistical analysis using 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

Table 4. Results of the Microbiological analyses.

Microbiologic analyses	Jelly from *Melicoccus b*	Syrup from *Melicoccus b*
MPN	- 3 NMP/ml	- 3 NMP/ml
Total Counting of Bacteria	Negative	Negative
Total coliforms	Negative	Negative
Fecal Coliforms	Negative	Negative
Escherichia coli	Negative	Negative
Salmonella typhosa	Negative	Negative
Staphylococcus aureus	Negative	Negative
Non-pathogenic bacteria	Negative	Negative

The Graphical Abstract illustrates the ideal time to harvest based on the Titratable Acidity, °Brix, and Maturity Index. The Graphical Abstract depicts the mature stage of Melicoccus bijugatus, when the fruit reaches 69% of MI. Additionally, the acidity decreases to 0.42% and the °Brix levels increase to 24. (Figure 5)

Results of microbiological analysis

The analyses were performed as a quality control measure on three samples of the same lot, which consisted of ten cans for each processed product. A total of six cans were selected at random for the collection of the samples. The fungus environmental pollutants and pathogenic fungi were found to be "Negative" in both examinations. Additionally, the organic characteristics of the samples were found to be aroma, texture, and taste. The taste of both samples was sweet, and the color of the jelly from *M. bijugatus* was orange, while the color of the syrup from *M. bijugatus* was peach. *Melicoccus b* gelatin and syrup samples were examined, and the results revealed that neither bacterial nor fungal growth was present: (Table 4)

As a result of the production process being in accordance with the hygienic and sanitary rules, an outstanding quality control result was achieved.

Experimental design

The experimental design constituted countable random replicate samples to assess the acceptability of a product derived from the fruit of Melicoccus bijugatus. These samples underwent sensory evaluation and were subsequently compared to "Treatments" or products (from Melicoccus bijugatus) denoted by the letter "T" and a comparable "Pattern" (similar product) represented by the letter "P". Therefore, P-1 = Honeybee, T-2 = Melicoccus b jelly, P-2 = Lychee in syrup, T-2 = Melicoccus b in syrup. Through the hedonic test the acceptance of each treatment was determined, as well as for each attribute, the scale was the following: 1 = I dislike it very much, 2 = I dislike it very much, 3 = I dislike it moderately, 4 = I dislike it a little, 5 = I neither like nor dislike it, 6 = I like it a little, 7 = I like it moderately, 8 = I like it a lot and 9 = I like it. The attributes to evaluate were: taste, color and aroma. The number of evaluating judges was: 20 (Table 5)

Statistical analysis

Test procedure; (i) Exposure of the hypothesis:

Ho: The four treatment have the same effects in terms of taste (no significant differences between the elaborated products versus patrons).

H1): There are at least one treatment with different effects in terms of taste. (there is a significant difference between the elaborated products versus patrons)

Therefore, after to assign the ranks R (Xij) the rank which is assigned to the observation “Xij” inside of the block “j” obtained “Ri” which is the sum of the ranks assigned from the sample “i” in the following formula:

$$A = \sum_{i=1}^{k} \sum_{j=1}^{b} \left[R\,(X_{ij})\right]^2$$

$$A = [(1)^2 + (3.5)^2 + (3.5)^2 + (2)^2 + (2)^2 + (3)^2 + (1)^2 + (4)^2 + (2)^2 + (2)^2 + (4)^2 + (2)^2 + (1.5)^2 + (3.5)^2 + (1.5)^2 + (3.5)^2 + (2.5)^2 + (2.5)^2 + (2.5)^2 + (2.5)^2] + [(4)^2 + (1.5)^2 + (3)^2 + (1.5)^2 + (1.5)^2 + (3.5)^2 + (3.5)^2 + (1.5)^2 + (1)^2 + (3)^2 + (3)^2 + (3)^2 + (1.5)^2 + (3.5)^2 + (1.5)^2 + (3.5)^2 + (3.5)^2 + (1.5)^2 + (1.5)^2 + (3.5)^2] + [(2)^2 + (3.5)^2 + (3.5)^2 + (1)^2 + (3.5)^2 + (1)^2 + (3.5)^2 + (2)^2 + (2.5)^2 + (2.5)^2 + (4)^2 + (1)^2 + (1.5)^2 + (1.5)^2 + (4)^2 + (3)^2 + (1.5)^2 + (3)^2 + (4)^2 + (1.5)^2] + [(2)^2 + (3.5)^2 + (1)^2 + (3.5)^2 + (2.5)^2 + (1)^2 + (2.5)^2 + (4)^2 + (1)^2 + (2.5)^2 + (2.5)^2 + (4)^2 + (1)^2 + (3)^2 + (2)^2 + (4)^2 + (3.5)^2 + (2)^2 + (3.5)^2 + (1)^2]$$

A = [1 + 12.25 + 12.25 + 4 + 4 + 9 + 1 + 16 + 4 + 4 + 16 + 4 + 2.25 + 12.25 + 2.25 + 12.25 + 6.25 + 6.25 + 6.25 + 6.25] + [16 + 2.25 + 9 + 2.25 + 2.25 + 12.25 + 12.25 + 2.25 + 1 + 9 + 9 + 9 + 2.25 + 12.25 + 2.25 + 12.25 + 12.25 + 2.25 + 2.25 + 12.25] + [4 + 12.25 + 12.25 + 1 + 12.25 + 1 + 12.25 + 4 + 6.25 + 6.25 + 16 + 1 + 2.25 + 2.25 + 16 + 9 + 2.25 + 9 + 16 + 2.25] + [4 + 12.25 + 1 + 12.25 + 6.25 + 1 + 6.25 + 16 + 1 + 6.25 + 6.25 + 16 + 1 + 9 + 4 + 16 + 12.25 + 4 + 12.25 + 1]

A= [141.5 + 144.5 + 147.5 + 148]

A = 581.5

$$B = \frac{1}{b}\sum_{i=1}^{k} R_1^{\,2}$$

$$B = \frac{1}{20}\left[(41.5)^2 + (51)^2 + (55.5)^2 + (52)^2\right]$$

$$B = \frac{1}{20}\left[(10107.5)\right]$$

$$B = 505.375$$

Statistic proof

$$\chi^2\, proof / F_r = \frac{(k-1)\left[bB - \frac{b^2 k(k+1)^2}{4}\right]}{A - \frac{bk(k+1)^2}{4}}$$

$$\chi^2\, proof / F_r = \frac{(4-1)\left[(20)(505.375) - \frac{(20)^2(4)(4+1)^2}{4}\right]}{581.5 - \frac{(20)(4)(4+1)^2}{4}}$$

$$\chi^2\, proof / F_r = \frac{(3)\left[(10107.5 - 10000)\right]}{581.5 - 500}$$

$$\chi^2\, proof / F_r = \frac{322.5}{81.5}$$

$$\chi^2\, proof / F_r = 3.9570552147\ 239$$

$$\chi^2\, proof / F_r = 3.96$$

Critical Statistic F_r critical or X^2critical. The Critical value of the statistic for a significance level of 5 %, where: α = (5%); α = 0.05 & υ = (k-1) (4-1); υ = 3

X 2critical = (0.05, 3)   X 2critical = 7.81

Searching for the X 2critical (0.05, 3) in the table of chi-square of 5% significance the following data was obtained: (Figure 6)

Conclusion: F_r is smaller than X^2 critical (3.96 < 7.81) the Null hypothesis (Ho) is accepted. In other words, the four treatments have the same effects in terms of taste; there is not significant different.

Multiple comparisons. Consequently, if the Null Hypothesis (Ho) is rejected in Friedman test, we present a procedure to compare the treatments by pairs, the treatments i and j differ significantly if the following is satisfied inequality:

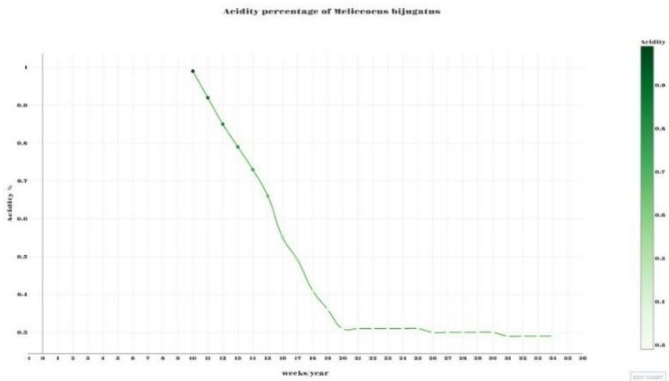

Figure 2. Acidity percentage graph: https://plot.ly/~jccharlies/13.embed

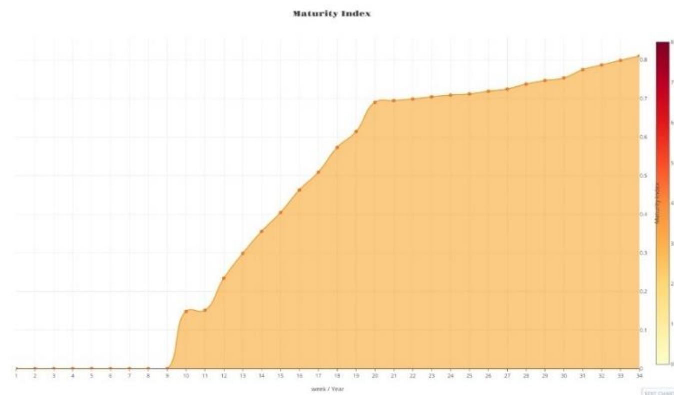

Figure 3. Maturity index graph: https://plot.ly/~jccharlies/15.embed

Figure 4. Level of acidity and maturity index plotted graphically: https://plot.ly/~jccharlies/11.embed

$$|\,R_i - R_j\,| > t = \frac{\alpha}{2}, \upsilon \sqrt{\frac{2b\,(A-B)}{(b-1)(k-1)}}\,;$$

$$\frac{\alpha}{2} = Right\ area \qquad \frac{\alpha}{2} = \frac{0.05}{2} = 0.025$$

The freedom degrees for "t" paired test is: υ = (b – 1) (k – 1); υ = (20 – 1) (4 – 1); υ = 57

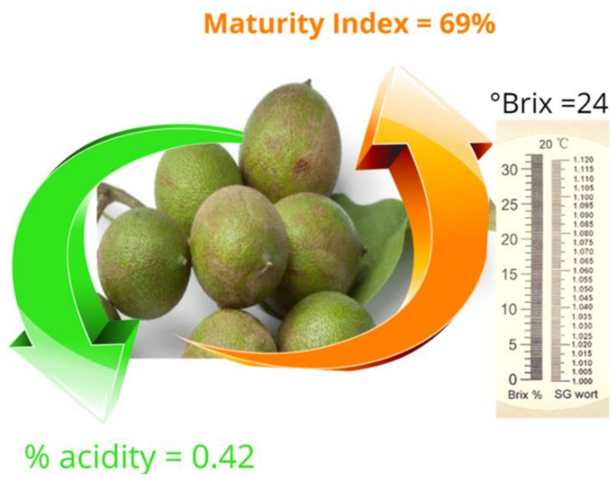

Figure 5. Graphical Abstract; optimum harvest point by the Titratable Acidity, °Brix and Maturity Index. The Graphical Abstract shows the ripe stage of the Melicoccus bijugatus, when the fruit reach to 69% of MI, additional to this the % of acidity decrease to 0.42 and the levels of °Brix increase to 24.

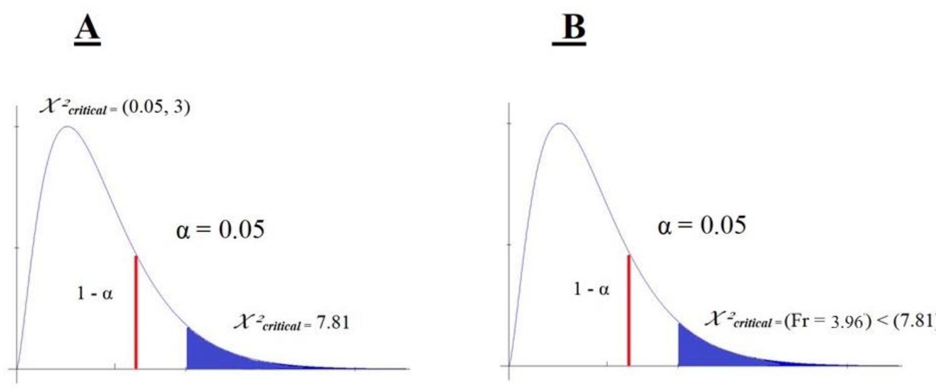

Figure 6. Results Gallus curve $X^2_{critical}$(0.05, 3) by the chi-square of 5% significance.

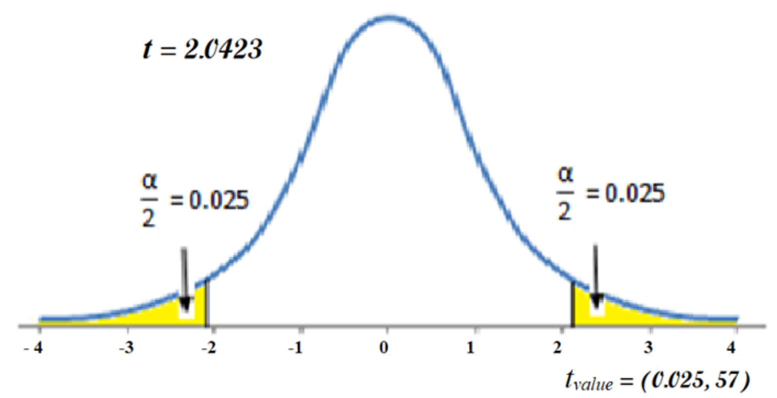

Figure 7. Results Gallus curve Fisher's exact test or Student's t-test

Therefore: $t = \frac{\alpha}{2}, \upsilon$; $t = \frac{0.05}{2}, 57$; t = (0.025, 57)

Consequently, searching for the data in Fisher's exact test or Student's t-test, the result is the following:
Therefore, as a result t = 2.0423 (Figure 7)

$$| R_i - R_j | > t = \frac{\alpha}{2}, \upsilon \sqrt{\frac{2b\,(A-B)}{(b-1)(k-1)}}$$

$$R_{value} > t(0.025, 57)\sqrt{\frac{2(20)\,(581.5-505.375)}{(20-1)(4-1)}}$$

$$R_{value} > t\,(2.0423)\sqrt{\frac{3045}{57}}$$

R_{value} = 7.308970696
R_{value} = 7.31

As a result, several comparisons of treatments were performed using the Friedman test. (Table 6)
Therefore, R_{value} 7.31 > t 2.0423; The honey bee is the product with the highest acceptance and qualifications. However, there is no significance in some attributes as aroma, color, and flavor. Treatment 3 was taken as the best treatment for taste "Flavor", followed by 4"*Melicoccus b.* in syrup".

Materials and Methods

The study was conducted in the Municipality of Santiago Texacuangos, located in San Salvador, El Salvador. The samples were transferred and analyzed at "The Quality Lab," situated in the Faculty of "Agricultura e Investigacion Agricola" at Jose Matias Delgado University.
The term "ripe" pertains to the stage of a fruit's life cycle where it has completed its natural growth and development and is suitable for consumption. According to the U.S. Grade standards, this stage is characterized as the one that ensures the proper culmination of the ripening process (Biale, 1964; Pérez et al., 2008). Furthermore, the *Melicoccus bijugatus* is distinguished by its somewhat circular form, solitary seed, and categorization as a dicotyledonous organism. In addition, the fruit is obtained through manual harvesting, using either a woven sack or hessian sacks. Subsequently, these sacks are transferred into agro-industrial plastic containers and positioned on pallets.

Maturity Index (MI).
Important aspects were measured such as the pH of the harvested products, the amount of soluble solids content (SSC), °brix, and titratable acidity (TA) (Ahmed et al., 2014).

Soluble solids content (S.S.C).
The soluble solids content is determined by the refractometry method, according to methods used by A.O.A.C. which it is expressed in Brix concentration (Helrich, 1990; Tobaruela et al., 2018; Ventura et al., 1998). The interpretation and study must be corrected using the percentage of citric acid determined, through the following equation:
S.S.C.COR = O.194*A + S.S.C.
Where A = % citric acid. & S.S.C. = Brix Level or Concentration.

Titratable acidity (T.A.)
The titratable acidity is determined by the base acid titration method (according to A.O.A.C. methods), with a NaOH standard solution (previously standardized) of approximately 0.1N concentration and using phenolphthalein as an indicator. It is expressed as a percentage of citric acid and is calculated by the following equation:
Alternative formula:
Where:
V1 = volume of NaOH consumed (ml / L)
V2 = volume of the sample (5.0 ml)
Vb = volume of the target (L)
N = normality of NaOH (0.1 meq / ml)
K = equivalent weight of citric acid (0.064 g / meq).

Agro-industrial and food processing of *Melicoccus bijugatus.*
Two agro-industrial products (by-products) a light syrup and jelly with pulp from *Melicoccus bijugatus* were elaborated, considering the agro-industrial procedures, processing manuals, GAP and GMP (Cheftel et at., 1992; Permuy and Prego, 1975; Figuerola et at., 1997). In addition to this, the proper harvest time to collect the fruits were an intervening period of the end of May and first week of June, taking into consideration the physiological morphological characteristics (Moo-Huchin et al., 2020; Pérez C. et al., 2009; Goldson-Barnaby and Bailey, 2020).

***Process and preparation of jelly based in pulp from Melicoccus* bijugatus.**
The gathered fruits were washed and sorted. A total of 2060 g of fruits were picked and disinfected using 1.2 g of chlorine dissolved in 6000 ml of water with a concentration of 200 ppm. The fruits were then soaked for 10 minutes before being thoroughly rinsed with water.
Pulped refers to the process of extracting the mucilaginous component from a pot using water and a 2% concentration of citric acid to prevent oxidation. The syrup was made using the pulp at a concentration of 76 °brix, which was then deposited for the boiling procedure.
The jelly was prepared by heating the pulped product to a temperature between 90 °C and 100 °C. Three applications of saccharose were added to achieve a concentration of 73° Brix. Only a 2% concentration of citric acid and pectin were used. The saccharose concentration was continuously measured using a refractometer. Afterwards, the mixture was filtered and left undisturbed for the pulp particles to settle (Edwards, 2001). To ensure sterility, the cans and containers were subjected to a temperature of 100 °C for 5 minutes, which effectively sterilized them. Subsequently, the sterilized cans and containers were packaged and sealed. After the cans were disinfected and achieved the necessary Brix degrees, they were promptly packaged following the bottling process. The specimens were immersed in a vessel containing water heated to a temperature of 100 °C in order to ensure their preservation and simultaneously create a vacuum environment.

Processing of Melicoccus bijugatus in syrup.
The reception and weighing process involved first selecting the ripe fruit and measuring its weight for the formulation. Afterwards, the peel was removed, resulting in a total of 300 g of seeds and pulp. Additionally, 500 ml of water and 200 g of saccharose were used.
We prepared a solution of *Melicoccus b.* in syrup and then heated it for 10 minutes to sterilize the product. The syrup was developed with the intention of being combined with the product in the glass container simultaneously, while keeping a pH of 3 in order to balance the saccharose content. To achieve a concentration of 26° Brix, citric acid and two doses of saccharose were added. The concentration of citric acid was 2%, and the refractometer was used to quantify the value. The concentration of the final product was 26 °Brix, which was necessary to achieve a liquid consistency.
To ensure sterility, the cans and containers were subjected to a temperature of 100 °C for 5 minutes, which effectively sterilized them. Subsequently, the sterilized cans and containers were packaged and sealed. After the cans were sterilized and had attained the necessary concentration of Brix degrees, they were promptly packaged following the bottling process. The specimens were immersed in a pot containing water heated to a temperature of 100 °C in order to ensure their safety and simultaneously create a vacuum. Containers filled with chilled water were employed to decrease the interior temperature and induce pasteurization of the product. The syrup was prepared by incorporating the fruit juice and used citric acid as a preservative (Desrosier, 1983, 2019).

Table 4. Results of the Microbiological analyses.

Microbiologic analyses	Jelly from *Melicoccus b*	Syrup from *Melicoccus b*
MPN	- 3 NMP/ml	- 3 NMP/ml
Total Counting of Bacteria	Negative	Negative
Total coliforms	Negative	Negative
Fecal Coliforms	Negative	Negative
Escherichia coli	Negative	Negative
Salmonella typhosa	Negative	Negative
Staphylococcus aureus	Negative	Negative
Non-pathogenic bacteria	Negative	Negative

Table 5. Ranks of taste.

RANKS FOR TASTE				
No	P-1	T-1	P-2	T-2
1	**1**	**3.5**	3.5	2
2	**2**	**3**	1	4
3	**2**	**2**	4	2
4	**1.5**	**3.5**	1.5	3.5
5	**2.5**	**2.5**	2.5	2.5
6	**4**	**1.5**	3	1.5
7	**1.5**	**3.5**	3.5	1.5
8	**1**	**3**	3	3
9	**1.5**	**3.5**	1.5	3.5
10	**3.5**	**1.5**	1.5	3.5
11	**2**	**3.5**	3.5	1
12	**3.5**	**1**	3.5	2
13	**2.5**	**2.5**	4	1
14	**1.5**	**1.5**	4	3
15	**1.5**	**3**	4	1.5
16	**2**	**3.5**	1	3.5
17	**2.5**	**1**	2.5	4
18	**1**	**2.5**	2.5	4
19	**1**	**3**	2	4
20	**3.5**	**2**	3.5	1
Ri	**45.1**	**51**	**55.5**	**52**

Ranks obtained through the hedonic test, to determine the degree of acceptability using quantitative units (Pattern and Treatment).

Table 6. Multiple comparison of the treatments by Friedman test.

Treatments compared	**|Ri – Rj|**	**P-VALUES P(T<=t) two-tail**
I-II	(41.5-51) = 9.5 > 7.31	$8.65 x10^{-12}$*
I-III	(41.5-55.5) = 14 > 7.31	$1.70 x10^{-11}$*
I-IV	(41.5-52) = 10.5 > 7.31	$1.43 x10^{-10}$*
II-III	(51-55.5) = 4.5 < 7.31	$2.26 x10^{-11}$*
II-IV	(51-52) = 1.00 < 7.31	$4.02 x10^{-10}$*
III-IV	(55.5-52) = 3.5 < 7.31	$2.02 x10^{-09}$*

The results denote the larges value of correlation coefficient and significance with *p<0.05 two tail. All significance levels are assessed at $\alpha < 0.05$.

Microbiological analyses were conducted to ensure the food safety of processed items derived from Melicoccus bijugatus pulp, which is a by-product. Adhering to the appropriate protocols. The quantification of these microorganisms, up to a specified numerical threshold, suggests the presence of circumstances that could facilitate the growth of harmful or disease-causing microbes. This serves as an indication of both the microbiological safety and the effectiveness of sanitary measures in place. (Downs et al., 1933; Tobaruela et al., 2018). The enumeration of these microorganisms is conducted by employing a methodology that involves plating samples on agar plates. The Most Likely Number technique is utilized; wherein bacterial colonies are selected at various dilutions to estimate the number of bacteria present. This method is also employed for bacterial identification (Roberts and Greenwood, 2008).

Organoleptic and sensory analysis.

The sensory and organoleptic analyses were performed and evaluated by the non-trained consumer panel through a hedonic test considering qualitative and quantitative aspects (Delle et al., 2011). It consisted of testing and evaluating the perceived quality through appearance, texture, taste, aroma, the color of the d products to determine its acceptance by the consumer panel.

Statistical analyses

The significant differences between ripe and unripe fruits of *Melicoccus bijugatus* Jacq., were evaluated by applying ANOVA and the organoleptic and sensory analyses were evaluated by parametric and non-parametric test such as: Kruskal–Wallis by ranks, Multiple comparisons & Friedman test, with α = 0.05 (significance level).

Data

The model and statistical analyses for the data which the component is "k" this, in turn, belongs to the "k treatments", for each size in "b" that is equal to the number of blocks; where "Rank 1" is assigned to the smallest observation, followed by the "Rank 2" which is next major to minor observation and then until reach to the highest, which for this case is the "Rank 4". However, if a tie result occurs, the corresponding average ranks will be used.

Therefore, "R (Xij)" is the rank assigned to the observation "Xij" within block "j" and "Ri" is the sum of the assigned ranks of sample I:

$$R_i = \sum_{j=1}^{b} R\,(X_{ij})$$

Assumptions.

i) The results within a block do not influence the results within the others because the "b" blocks are mutually independent.

ii) The observations are arranged within each block.

Proof procedure;

Hypothesis:

H0): There is no significant difference between treatments (products elaborated) versus patrons (similar product in the local market).

H1): There is a significant difference between treatments because at least one of the treatments has a different effect. (products elaborated versus patrons).

Statistic Test; first, the values of parameters "A" and "B" are calculated (Friedman, 1937).

$$A = \sum_{i=1}^{k} \sum_{j=1}^{b} \left[R\,(Xij)\right]^2 \qquad B = \frac{1}{b}\sum_{i=1}^{k} R_1^{\,2}$$

The statistic test:

$$\chi^2\, proof \,/\, F_1 = \frac{(k-1)\left[bB - \dfrac{b^2 k(k+1)^2}{4}\right]}{A - \dfrac{bk(k+1)^2}{4}}$$

Multiple comparisons; if the null hypothesis is rejected, the Friedman test presents a procedure to compare the treatments by pairs. It means that the treatments **"i"** and **"j"** differ significantly if they satisfy the following inequality.

$$|\,R_i - R_j\,| > t\;\frac{\alpha}{2},\upsilon\,\sqrt{\frac{2b\,(A-B)}{(b-1)(k-1)}}$$

Friedman application test for each characteristic. Calculations: being a: the level of significance and n = (b-1) (k-1) the degrees of freedom of the comparison test. Next, the following statistical operations applied to the results obtained of the organoleptic tests of this investigation, applying the method of Friedman mentioned above. Note that each product (P-1 = Honey bee, T-1 = Melicoccus b. Jelly, P-2 = Lychee in syrup, T-2 = Melicoccus bijugatus in syrup) were the analyzed treatments.

Conclusion

It is recommended that whenever the fruit of *Melicoccus bijugatus* achieves sixty percent of its Maturity Index, the harvesting process should start. If the Brix value of the fruit is larger than twenty-nine to twenty-four and the pH is between three and four, it is essential to take into consideration the morphological qualities of the fruit. These characteristics include the color of the pulp and the sweetness of the fruit. The amount of acidity decreases when the fruit reaches its optimal level of maturation, which is between sixty percent and eighty percent. Additionally, the fruit undergoes a drop-in acidity that ranges from one percent to two point nine percent as it reaches this stage. In addition to this, the amount of total solids being present rises. The processed products, which were by-products of *Melicoccus b*ijugatus, were accepted by the panellists, and then these were placed through sensory evaluations using the Friedman technique in order to determine the degree of variability that exists between the treatments. Following the completion of the evaluation, it was concluded that the P-2 treatment, which received a score of 55.5, was the most successful product. On the other hand, the product that achieved the highest ranking was the jelly that was produced using Melicoccus bijugatus (x = 52), which was then followed by the *Melicoccus bijugatus* syrup.

Data Availability Statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Conflict of Interest

The authors report no conflicts of interest; declare that they have no known competing for financial interest or personal relationships that could have appeared to influence the work reported in this paper.

Author Contributions

JCC Lopez contributed to the overall design, literature review, and writing about the current manuscript and was instructed and revised by K Bhaktikul and S Thepanondh. Both authors contributed to the article and approved the submitted version.

Funding

This part of the study it was self-funded. However, the sensory analysis and physico-chemical characterization of the fruit was carried out in the Lab of the Faculty of "Agricultura e Investigacion Agricola" Jose Matias Delgado University.

Acknowledgments

The authors would like to thank the Faculty of "Agricultura e Investigacion Agricola", Jose Matias Delgado University and Faculty of Environment and Resource Studies, Mahidol University for the information and data sets used in this study.

Reference

Pedro AR (2003) Melicocceae (Sapindaceae): Melicoccus and Talisia. New York: Organization for Flora Neotropica New York Botanical Garden.

Ahmed OK, Ahmed SE (2014) Determination of optimum maturity index of mango fruits (Mangifera indica, L.) in Darfur. Agriculture and Biology Journal of North America. 5(2): 97-103.

Biale JB (1964) Growth, maturation, and senescence in fruits: Recent knowledge on growth regulation and on biological oxidations has been applied to studies with fruits. Science. 146(3646): 880-888.

Bystrom LM (2012) The potential health effects of Melicoccus bijugatus Jacq. fruits: phytochemical, chemotaxonomic and

ethnobotanical investigations. Fitoterapia. 83(2), 266-271. doi:10.1016/j.fitote.2011.11.018
Bystrom LM, Lewis BA, Brown DL, Rodriguez E, Obendorf RL (2008) Characterization of phenolics by LC-UV/vis, LC-MS/MS and sugars by GC in Melicoccus bijugatus Jacq. 'Montgomery' fruits. Food Chemistry. 111(4): 1017-1024. doi:10.1016/j.foodchem.2008.04.058
Bystrom LM, Lewis BA, Brown DL, Rodriguez E, Obendorf RL (2009) Phenolics, sugars, antimicrobial and free-radical-scavenging activities of Melicoccus bijugatus Jacq. Fruits from the Dominican Republic and Florida. 64(2): 160-166.
Carpenter RP, Lyon DH, Hasdell TA (2000) Guidelines for sensory analysis in food product development and quality control (2 ed.). Gaithersburg, Md: Aspen Publishers.
Cheftel JC, Cheftel H, Besancon P, Desnuelle P, López CF (1992) Introducción a la bioquímica y tecnología de los alimentos. Zaragoza, España: Acribia.
Cruz E, Deras H (2000) Collection of tropical fruit in El Salvador. Agronomía Mesoamericana. 11(2): 97-100.
Delle Fave A, Brdar I, Freire T, Vella-Brodrick D, Wissing MP (2011). The eudaimonic and hedonic components of happiness: Qualitative and quantitative findings. 100(2): 185-207.
Desrosier NW (1983). Elementos de tegnología de alimentos / editado por Norman W. Desrosier.
Desrosier NW (2019) The technology of food preservation / Norman W. Desrosier.
Chairman PD, Hammer BW, Cordes WA, Chairman HM (1933) Bacteriological methods for the analysis of dairy products. Journal of Dairy Science. 16(277):10.
Edwards WP (2001) Sweet science: The science of sugar confectionery (Vol. 37).
Fontana M, Somenzi M, Tesio A (2012) Cultivation, harvest and postharvest aspects that influence quality and organoleptic properties of hazelnut production and related final products. Paper presented at the VIII International Congress on Hazelnut 1052.
Formoso Permuy A, Formoso Prego A, Formoso Prego J (1975) 2000 procedimientos industriales al alcance de todos. La Coruña: Formoso.
Friedman M (1937) The Use of Ranks to Avoid the Assumption of Normality Implicit in the Analysis of Variance. Journal of the American Statistical Association. 32(200): 675-701. doi:10.1080/01621459.1937.10503522
Helrich K (1990) Official methods of analysis of the Association of Official Analytical Chemists: Association of official analytical chemists.
López JCC, Sachdev H, Thepanondh S, Herrera YA (2021) Morphological and physico-chemical characterization of fruit of *Melicoccus Bijugatus* Jacq. 50(2), 387-394.
Martínez-Castillo J, Arias RS, Andueza-Noh RH, Ortiz-García MM, Irish BM, Scheffler BE (2019) Microsatellite markers in Spanish lime (*Melicoccus bijugatus* Jacq., Sapindaceae), a neglected neotropical fruit crop. Genetic Resources and Crop Evolution. 66(7): 1371-1377. doi:10.1007/s10722-019-00815-4
Moo-Huchin VM, Ac-Chim DM, Chim-Chi YA, Ríos-Soberanis CR, Ramos G, Yee-Madeira HT, Ortiz-Fernández A, Estrada-León RJ, Pérez-Pacheco E (2020). Huaya (*Melicoccus bijugatus*) seed flour as a new source of starch: physicochemical, morphological, thermal and functional characterization. 14(6): 3299-3309.
Moo-Huchin VM, Estrada-Mota I, Estrada-León R, Cuevas-Glory L, Ortiz-Vázquez E, y Vargas MD, Betancur-Ancona D, Sauri-Duch E (2014) Determination of some physicochemical characteristics, bioactive compounds and antioxidant activity of tropical fruits from Yucatan, Mexico. Food Chemistry. 152, 508-515. doi:https://doi.org/10.1016/j.foodchem.2013.12.013
Moo-Huchin VM, Estrada-Mota I, Estrada-León R, Cuevas-Glory L, Ortiz-Vázquez E, y Vargas MD, Betancur-Ancona D, Sauri-Duch E (2014) Determination of some physicochemical characteristics, bioactive compounds and antioxidant activity of tropical fruits from Yucatan, Mexico. 152: 508-515.
Food and Agriculture Organization of the United Nations (1995) Report of the International Expert Consultation on Non-Wood Forest Products, Yogyakarta, Indonesia 17-27 January 1995. Rome, Italy.
Nunes AA, Favaro SP, Galvani F, Miranda CH (2015). Good practices of harvest and processing provide high quality Macauba pulp oil. 117(12): 2036-2043.
Paltrinieri G, Figuerola F, Rojas L (1997) Technical manual on small-scale processing of fruits and vegetables. Retrieved from Santiago, Chile:
Pérez HC, Gómez M, Vila J (2009) Características físicas de frutos de mamón (*Melicoccus bijugatus* jacq.) según su ubicación en el árbol y el almacenamiento. Bioagro, 21(3): 6.
Pérez HC, Gómez M, Vila J (2008) Evaluación de los parámetros de calidad en frutos de mamoncillo (Melicoccus bijuga L.). Características químicas. Revista Iberoamericana de Tecnología Postcosecha. 9(1): 7-15.
Roberts D, Greenwood M (2008). Index. In Practical Food Microbiology: Blackwell Publishing Ltd.
Tobaruela ED, Santos AD, de Almeida-Muradian LB, Araujo ED, Lajolo FM, Menezes EW (2018) Application of dietary fiber method AOAC 2011.25 in fruit and comparison with AOAC 991.43 method. Food Chemistry. 238: 87-93. doi:https://doi.org/10.1016/j.foodchem.2016.12.068
Ventura M, de Jager A, de Putter H, Roelofs FP (1998) Non-destructive determination of soluble solids in apple fruit by near infrared spectroscopy (NIRS) 14(1): 21-27.
Wilson J, Goldson-Barnaby A, Bailey D (2020) *Melicoccus Bijugatus* (guinep): Phytochemical Properties, Associated Health Benefits and Commercial Applications. 20(4): 659-666.