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Study of the oenological properties of naranjilla for gastronomy uses, Pacto-Pichincha province

Estudio de las propiedades enológicas de la naranjilla con fines gastronómicos en Pacto-Pichincha

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Abstract

The present study sought to provide an economic alternative to the inhabitants of the Pacto parish, as an initiative for production, postharvest optimization and industrialization of the local fruit growing area, also considering the tourist potential of the area, where wine tourism represents an opportunity for the area. The aim was to find the technical viability for the elaboration of wine from naranjilla. The applied research approach was mixed, and an exhaustive literature review was made on the winemaking techniques. The test evaluated number of sugars in the must (18, 21 and 24 ° Brix), addition of water (4:1) (Ma) and whole must (Mo). Yield, fermentation time, organoleptic properties of the final product (color, smell and flavor) were determined using a 5-point hedonic scale and physicochemical characteristics of wines with better acceptance. Commercial Saccharomyces cerevisiae was used as inoculum. The average yield for Ma was 70.6% w/w and Mo 45.0% w/w, fermentation was observed up to 288 hours. The addition of water adversely affected the taste; however, the general organoleptic evaluation had a weighting between 3 and 4 out of 5 points. Wines with the best acceptance were Mo24 and Ma21, adhering to the requirements of the Ecuadorian Technical Standard for fruit wine, characterized as semi-sweet. It is necessary to work on the improvement and transfer of the established technical process, especially to obtain higher yields, decrease acidity and incorporate new studies with tropical fruits for the benefit of agriculture, gastronomy, tourism and local development.

Keywords: *Solanum quitoense Lam*, lulo, tourism, fruit wine.

Resumen

El presente estudio buscó brindar una alternativa económica a los pobladores de la parroquia Pacto, como iniciativa a la producción, optimización en postcosecha e industrialización del área frutícola local, considerando además las potencialidades turísticas de la zona, donde el enoturismo representa una oportunidad. El objetivo planteado fue encontrar la viabilidad técnica para la elaboración de vino a partir de la naranjilla. El enfoque de investigación aplicado fue de carácter mixto, y se hizo una exhaustiva revisión bibliográfica sobre las técnicas de elaboración del vino. El ensayo evaluó la cantidad de azúcares en el mosto (18, 21 y 24 °Brix), adición de agua (4:1) (Ma) y mosto íntegro (Mo). Se determinó el rendimiento, el tiempo de fermentación, y las propiedades organolépticas del producto final (color, olor y sabor) mediante una escala hedónica de 5 puntos y características fisicoquímicas de vinos con mejor aceptación. Como inóculo se utilizó *Saccharomyces cerevisiae* comercial. El rendimiento promedio para Ma fue 70,6% p/p y Mo 45,0% p/p, y se observó fermentación hasta 288 horas. La adición de agua afectó negativamente al sabor; sin embargo, la valoración organoléptica general tuvo una ponderación entre 3 y 4 de 5 puntos. Los vinos con mejor aceptación fueron Mo24 y Ma21, apegados a requisitos de la Norma Técnica Ecuatoriana para vino de frutas, caracterizándose como semidulce. Es necesario trabajar en la mejora y la transferencia del proceso técnico establecido, especialmente para obtener mayores rendimientos, disminución de la acidez e incorporar nuevos estudios con frutas tropicales en beneficio del agro, gastronomía, turismo y desarrollo local.

Palabras clave: *Solanum quitoense Lam*, lulo, turismo, vino de fruta.

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1 Introduction

The humid subtropical zone of Ecuador allows to have biodiversity of crops, especially fruit trees between native crops and those crops that have adapted easily to the micro region of the Chocó Andino in various areas (Endara, 2017), as is the case of the northeastern area of Pacto parish, known as an area of greater fruit biodiversity and agro-productive potential (GAD parroquial de Pacto, 2012). The diverse production, high annual yields and the lack of industrialization processes of fruit in this area generates instability in the commercialization of these products, causing economic losses for the farmers and their easy decoupling of this activity, as well as their migration to the city.

Taking advantage of the nutritional characteristics of natural or processed fruits, not only improve the quality of the diet but they are also essential to maintain health (Swami and Divate, 2014), because they are source of vitamins, minerals, carbohydrates and active biological compounds. Various studies show that fermentation of fruits and vegetables can be a viable technique to create new processed products, with modified chemical and organoleptic physical characteristics with great acceptance by the consumer (Swami and Divate, 2014). The product obtained is called fruit wine (Fracassetti et al., 2019), specifying the fruit used for its production (Matei, 2017).

Excepting grapes, fruits that have been investigated for the production of wine are apples, apricots, berries, cherries, plums, strawberries, oranges, mangoes, bananas, pineapples, pears, papayas, jaca juice, melons (Veeranjaneya and Reddy, 2009; Swami and Divate, 2014; Ogodo et al., 2015; Fracassetti et al., 2019); optimization process for mulberry wine (Wang et al., 2013); from cocoa pulp (Dias et al., 2007); sour sop (Ho et al., 2020); coconut with bee honey (Balogu and Towobola, 2017), among others; in addition to fermentations with mixtures between fruits and grape must. As a result, a variety of alcoholic beverages can be classified as natural wine (9 - 14 % alcohol), dessert wines and appetizer wines (15 - 21 % alcohol), among others. Wine varieties will depend on the region and climate for the fruits produced, types of fermentation and additives included to improve flavor (Matei, 2017). Better organoleptic characteristics and wine yields can be established by studying different strains of fermenting microorganisms (Veeranjaneya and Reddy, 2009; Ogodo et al., 2015; Baidya et al., 2016; Fracassetti et al., 2019).

Among the fruit production of Pacto stands out the cultivation of lulo (*Solanum quitoense* Lam.), which is a hybrid that has been the most cultivated nationally (60 % of the total) (Revelo and Sandoval, 2003), but its price is low on the market and its use depends on the preference of the consumer, being the highest consumption for the so-called "common" varieties (Guayasamín, 2015). Generally, people like this fruit by its citrus flavor (Gancel et al., 2008; Loizzo et al., 2019), giving it different gastronomic uses due to its bioactive compounds like polyphenols, with antioxidant capacity superior to Kiwi, melon or watermelon, among others (Acosta et al., 2009), especially in overmature-maturity phase (Cerón et al., 2010). Currently, research for the production of wine from lulo is limited, with only one online study carried out by (Granados et al., 2013) for a wine snack.

Because of the latter, this work aims to find the technical feasibility for the elaboration of wine from lulo cultivated at Pacto parish, as an initiative to the production, post harvest optimization and industrialization of the local fruit area, also considering the tourist potential of the area, where wine tourism represents an opportunity (Montaner Montejano, 1996) and (Tresserras et al., 2011), in which the idea of wine tourism combines oenology with gastronomy to guide the view toward places of culinary and oenological culture, where these aspects are important when deciding on a tourist trip. Similarly, the aim is to evaluate the performance of the final product obtained by conditioning the must to different amounts of fermentable sugars and dilution with water, the organoleptic characteristics (taste, color, odor) in treatments with better acceptance and to analyze the physico-chemical properties established by the Ecuadorian regulations in force for fruit wine.

2 Materials and Methods

2.1 Raw material

50 kilogramos (kg) of *S. quitoense* Lam. fruits were obtained from farms in the parish of Pacto, Qui-

to, province of Pichincha and were taken to the bromatology laboratory of the Faculty of Agricultural Sciences of the Central University of Ecuador. Healthy fruits were chosen regardless their size, in maturity state 4 and 5 (yellow-orange color in fruit = 75 and 100%, respectively) according to (Andrade et al., 2015), subsequently, cleaning and washing was carried out.

To obtain the must, the fruit was crushed and the pulp was separated by sieving, leaving bark and seeds as residue, as shown in Figure 1.

2.2 Initial characterization of the must

pH, titratable acidity and total dissolved solids or brix degrees (°Bx) were analyzed. All determinations were made in triplicate.

2.3 pH

20 mL of homogenized filtered must were added, which were previously in a 25 m beaker and then the pH reading was carried out with a digital potentiometer horiba – Laqua brand, equipped with a glass electrode and calibrated previously with standard solutions 4.0; 7.0 and 10.0 pH at 20 °C.

2.4 Total soluble solids

Using a dropper, 4 drops of must were added to the optical reader of a digital refractometer, Milwaukeebrand (reading 0 to 85 °Bx) previously soaked with distiled water, and °Bx was read.

2.5 Titratable acidity

In a 50 mL precipitation vessel, 5 mL of must was weighed, a similar amount of distiled water was added and placed in a magnetic stirring system. A potentiometric titration was performed with a sodium hydroxide solution (NaOH) of normal concentration equal to 0.0445, the volume of the titrant obtained (graduated buret ± 0.05 ml) was recorded at a pH reading equal to 8.3 (digital potentiometer brand Horiba – Laqua). The titratable acidity value was expressed as a percentage of citric acid.

2.6 Fermentation of the must

Orange juice must (1 kg/bottle) was placed in 18 amber glass bottles of 4 L capacity, with two thin plastic hoses for gas evacuation and sampling. Then, the must of 9 containers was diluted with 250 mL of water (Ma) (ratio 4:1), while the rest remained untouched (Mo). Additionally, both the Ma and Mo musts were adjusted with sucrose to a final concentration of 18, 21 and 24 °Bx. The calculation was performed using the following equation and verified with the same procedure used to determine the soluble solids.

$$Grams\,of\,sugar = \frac{(final\ {}^{\circ}Brix - initial{}^{\circ}Brix) \times Grams\ of\ initial\ must}{100 - final\ {}^{\circ}Brix}$$

Once the initial conditions of the must were established, 6 treatments were obtained (Table 1) with three replications, obtaining a total of 18 experimental units.

In each experimental unit (1 kg of must) 50 mg of potassium metabisulfite was added, it was stirred and set aside for 20 minutes. Subsequently, 1 g of dry granulated commercial yeast *Saccharomyces cerevisiae* (live cells > 85%) was inoculated, which was activated for 15 minutes in 10 mL of a sucrose solution (1.7% p/p) at a temperature of 38 °C according to the manufacturer's recommendation; in addition, 20 mg ammonium phosphate was added.

All the bottles were stirred, capped and placed on a shelf at random with the tip of one of the hoses on a water container and the other sealed hermetically. The test was covered with black plastic and kept for 480 hours (h) at room temperature.

Table 1. Treatments for wine making from naranjilla juice (*Solanum quitoense* Lam.).

Treatments	Combination
1	Mo18
2	Mo21
3	Mo24
4	Ma18
5	Ma21
6	Ma24

Mo= whole must
Ma= must with water in 4:1 relation
18, 21, 24= different concentrations of soluble solids (°Brix) of the must

2.7 Fermentation dynamics of soluble solids

To observe the fermentation dynamics of sugar, the amount of °Bx remaining within 72, 168, 288 and 480 hours was followed. For this, 2 mL of fermented product was extracted. The °Bx analysis was performed in triplicate, similar to that described for the initial must.

2.8 Decanting and clarification

After the fermentation time, the fermented product of each treatment was transferred with the aid of the sampling hose, avoiding dragging sediments (decanting 1) and was set aside for 12 hours. A second decanting was performed and flavored-free gelatin (0.08 g/L) was added, it was homogenized and maintained for 24 hours at 8 °C without moving it. Then, the precipitates were separated by filtration (Whatman N° 1 qualitative filter paper and vacuum filtration system), packed in 750 mL wine bottles with potassium metabisulphite (100 mg/L) added and sealed.

2.9 Sensory evaluation

The evaluation of the acceptance degree of the final product (naranjilla wine) was determined by sensorial-descriptive analysis (Pszczólkowski and Ceppi De Lecco, 2016) of color-limpidity, odor and taste-tact-end of mouth by 20 untrained judges but who normally taste fermented drinks. The evaluation initiated with Mo treatments and the following day Ma was used. For the test, 3 wine glasses with 5 ml of wine, coded according to °Bx and a sheet with a 5-point hedonic scale (Table 2), were presented to each panelist for the assessment of each sensory characteristic.

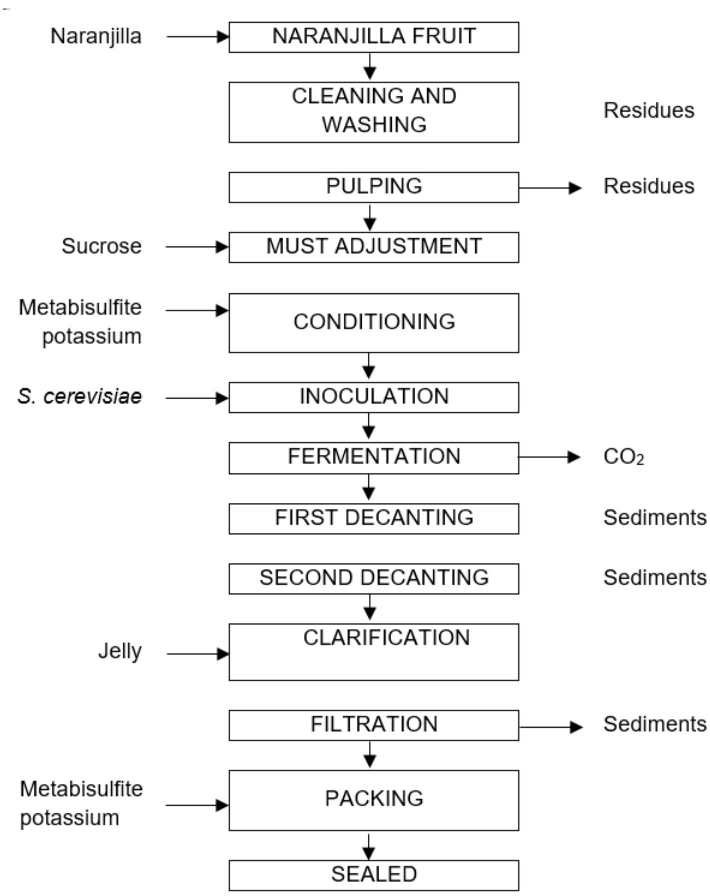

Figure 1. Flowchart for the elaboration of naranjilla wine (*Solanum quitoense* Lam.)

Table 2. Hedonic scale for the evaluation of color, flavor and smell of naranjilla wine (*Solanum quitoense* Lam.).

Perception	Weighting
I like it very much	5
I like it	4
I don't like it or dislike it	3
I dislike it	2
I dislike it very much	1

2.10 Statistical analysis

The effect of water to must dilution and °Bx on wine yield and acceptance degree was determined by a 2 × 3 multifactorial analysis (must:water and full must × °Bx). Mean separation in both cases was performed using Tukey ($p < 0.05$).

2.11 Physico-chemical evaluation of the final product (naranjilla wine)

Wines with the highest acceptance were physically evaluated to verify compliance with the requirements established by the Ecuadorian Technical Standard (INEN, 2016) for fruit wine. The parameters analyzed were alcoholic degree, total acidity (tartaric acid) and volatile acidity, total sulfur dioxide, methanol and total sugars. All the analyses were carried out in the laboratory of the Public Service Agency (OSP) of the Faculty of Chemical Sciences of the Central University of Ecuador.

3 Results and Discussion

3.1 Characterization of naranjilla must

Table 3 shows the pH, titratable acidity and °Bx values of *S. quitoense* Lam. must found in this study and also in literature reports from previous research on this fruit. The pH of the must is similar to the one found in other investigations; however, titratable acidity and soluble solids were lower. This variation may be related to factors specific to the cultivation where the research and the maturity of the fruit were carried out (González et al., 2014).

The pH of the must (3.13) was within the range (3.0 to 4.0) that according to (Dias et al., 2007; Swami and Divate, 2014) is considered suitable for good fermentation depending on the fruit and inoculum; in addition, the pH value found guarantees an acidic medium to yeasts and metabolite yield (Matei, 2017), so no adjustments were necessary (Coronel, 2008).

The titratable acidity showed to be relatively high in relation to other fruits used for the elaboration of wine, such as strawberries, blackberries, plums, apples, among others, where the value does not exceed 1 % (Matei, 2017); therefore the same author recommends its regulation with chemical compounds such as calcium carbonate to avoid sour flavors in the final product. However, this treatment was not conducted in this research because it was necessary to evaluate characteristics of naranjilla wine with its natural properties.

Furthermore, the °Bx found in the must (6.3) were not suitable for alcoholic fermentation, where the range fluctuates between 16 to 20 °Bx (Coronel, 2008), hence adjustments were needed by adding sucrose to complete the proposed values to be evaluated.

3.2 Fermentation dynamics

Figures 2a and 2b show the sugar fermentation dynamics of naranjilla must in Mo and Ma treatments, respectively, based on the °Bx determined during the process. A significant reduction in °Bx was observed up to 288 h in all treatments; however, from that time the concentration of °Bx remained constant until 480 h except for Ma24 which showed a slight decrease. All this indicates that there would be no need to ferment *S. quitoense* Lam. must for a time greater than 288 h for wine production, at a temperature between 16 to 19 °C which corresponded to fluctuation during the process.

In addition, it was observed that the final °Bx was greater than 6 %, which vary in relation to the initial °Bx, which demonstrates the cessation of fermentation of sugars without their entire consumption. This fact may be related to the inactivation of yeasts by the effect of alcohol concentration and nutrient balance (Swami and Divate, 2014).

Table 3. Physico-chemical characteristics of naranjilla must (*Solanum quitoense* Lam.) presented in the literature.

Parameter	Value found	Other reports		
		(Acosta et al., 2009)	(Brito et al., 2012)	(González et al., 2014)
pH	3.13	3.20 ± 0.04	3.00	2.89–2.94
Titrable acidity (gram of citric acid/100 g)	2.02	2.63 ± 0.07	2.56	3.78–3.21
Soluble solids (°Brix)	6.3	9.1 ± 0.5	10.8	6.58–9.04

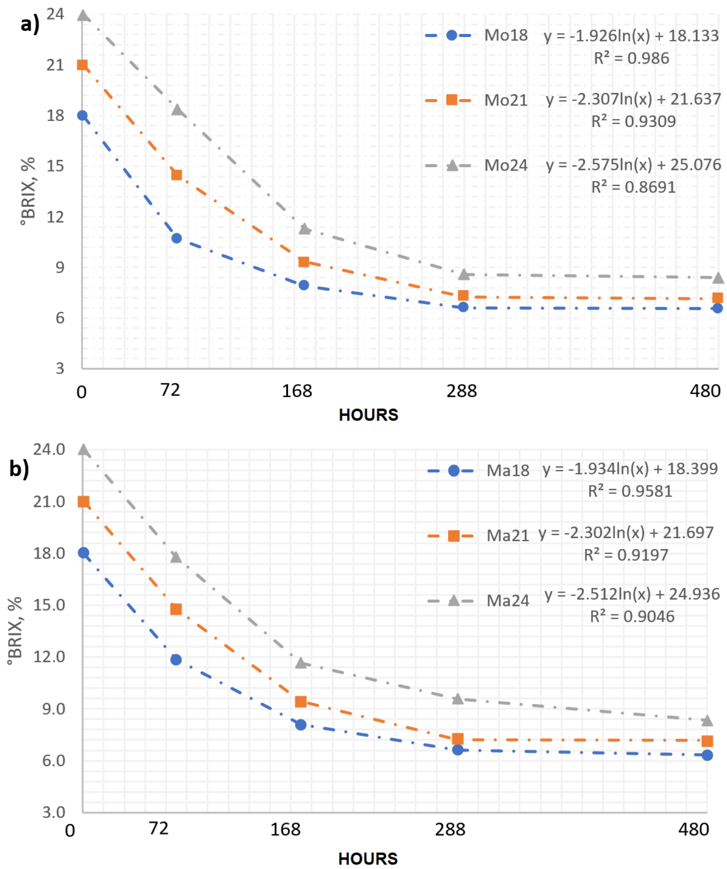

Figure 2. Dynamics of the fermentation of sugars in the production of naranjilla wine (*Solanum quitoense* Lam.) (a) Treatments without having added water to the must, (b) Once water was added to the must (ratio 1:4)

3.3 Yield of the final product (naranjilla wine)

Adding water to the naranjilla must before fermentation resulted in more wine (70.6 %p/p), compared to the non diluted must that showed a yield of 45.0 %p/p (Figure 3). But in addition to improving the yield with the amount of water to be added, juice can be easily extracted from some fruits and can decrease strong astringent flavors or acidity (Matei, 2017). In addition, it was observed that the percentage of sugars also influences the yield of wine, where the highest quantity was obtained at 21 and 24 °Bx with 58.8 and 61.1 %, respectively. In general, yields found are similar to studies on other fruits, such as mango wine that reports yields up to 60 % but with incorporation of pectinases that improve fermentation conditions (Veeranjaneya and Reddy, 2009).

The high amount of waste obtained in the first decanting, and the low yield in must without water at 18 °Bx allow considering the use of enzymes during maceration of the must (Romero, 2008) as an alternative for wine of *Solanum quitoense* Lam.

Figure 4 shows the yield of wine with respect to treatments. The results corroborate the above (Figure 3), where Ma in the different concentrations of °Bx shows better yields than Mo; however, in Mo as °Bx increases, more wine was obtained.

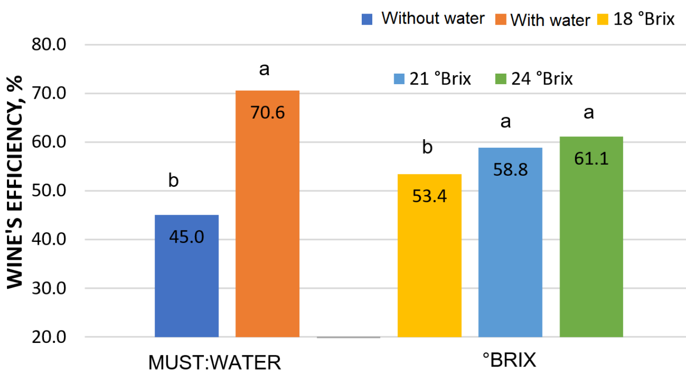

Figure 3. Effect of the addition of water and °Brix on the yield of naranjilla wine (*Solanum quitoense* Lam.). (Distinct letters show statistical differences, Tukey $p < 0.05$)

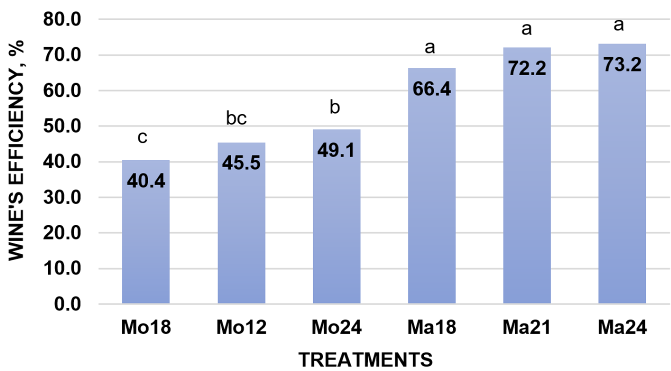

Figure 4. Yield of naranjilla wine (*Solanum quitoense* Lam.) according to the treatments. (Distinct letters show statistical differences, Tukey $p < 0.05$)

3.4 Sensory evaluation of naranjilla wine

It was found that the addition of water to naranjilla must negatively affects the taste of wine (Figure 5a), as well as the color and smell; although according to the established hedonic scale, the average wine taste rating is "I don't like or dislike", unlike the color and smell that obtained "I like it" on wine without water. These results would demonstrate a decrease in aromatic compounds in the beverage, as found by (Dias et al., 2007) where the addition of water decreased the flavor of cocoa-based wine.

Also, it was found that °Bx statistically influence the smell of the final product, where wines with 21 and 24 °Bx reach "moderately acceptable" to the consumer as opposed to 18 °Bx, while the color and taste of wine does not vary at different initial °Bx in the must with average ratings of "I like it" and "I do not like or dislike", respectively. In general, the low level of acceptance of taste was related to observations noted by some tasters at the feeling of acidity in the wine, related with the initial acidity of the must, which was not adjusted in this study.

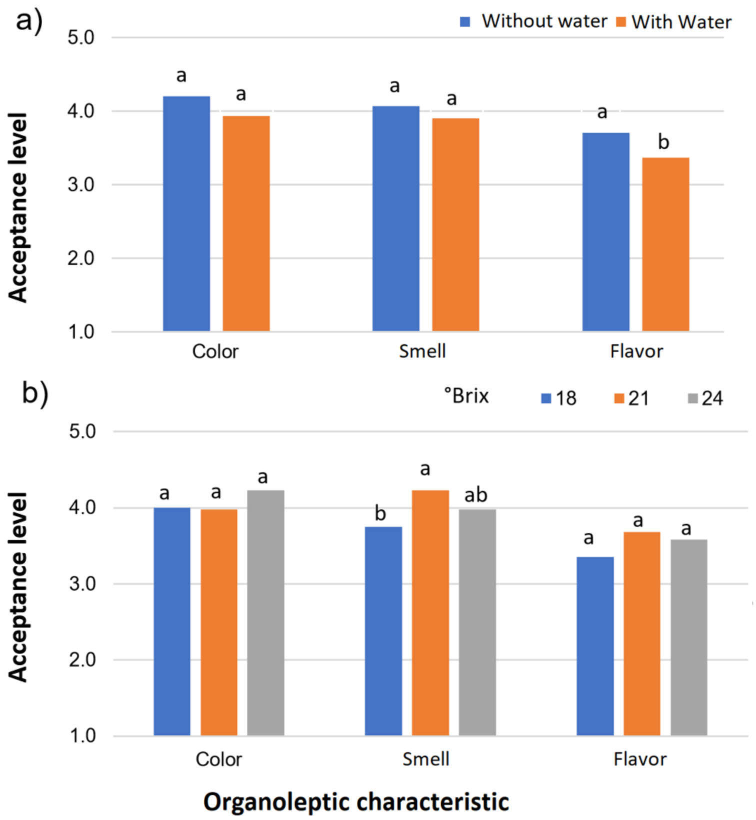

Figure 5. Level of acceptance of naranjilla wine (*Solanum quitoense* Lam.) according to color, smell and flavor, (a) Valuation according to the addition of water, (b) °Brix. (Distinct letters show statistical differences, Tukey $p < 0.05$)

An interaction was found (Figure 6) between the addition of water and 24 °Bx on the taste of wine, showing a deterioration in this attribute under these initial conditions of the must, generating a feeling of "moderate dislike" unlike the taste of wine without addition and with the same °Bx amount that "moderately likes". This effect may be related to cessation of fermentation by alcohol concentration or decreased nutrients as the source of nitrogen (Swami and Divate, 2014), with subsequent lysis of yeasts and dissolved cell wall components, as noted in (Vasantha et al., 2017). This fact was corroborated by the high turbidity presented in the wine that after the filtration treatment had organic residues that caused unpleasant taste, which could indicate that adding water should not only increase sugars, but also nutrients to achieve stable cell growth.

Table 4 shows the acceptance of the consumed naranjilla wine with respect to the sensory attributes evaluated and generally in the different treatments. No statistical differences were found for color and smell, but for general taste and acceptance with the same classification ranges. Thus, wines with greater acceptance were in Mo24 and Ma21 treatments, and for Ma24; while the rest remained in the same category at intermediate level.

According to the hedonic scale proposed for the assessment of wine acceptability, treatments Mo24 and Ma21 had values higher than 4 for almost all sensory characteristics, excepting the flavor of Ma21 which obtained an average of 3.9. This shows that the acceptance of wine produced under these conditions is in a weighting of "I like it"; similarly, the general acceptability in the other treatments shows that *S. quitoense* Lam. can be a fruit with great potential for wine making, because its consumption does not produce feelings of displeasure; however, more works should be conducted for Mo24 and Ma21 to improve the yield and decrease of acidity, which is the factor that influences taste.

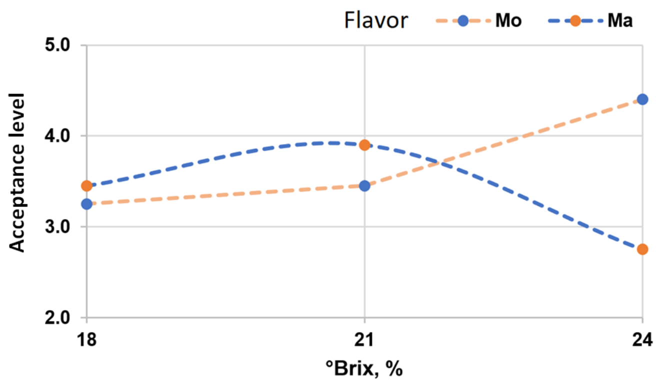

Figure 6. Interaction between the addition of water to the must and °Brix on the flavor of naranjilla wine (*Solanum quitoense* Lam.).

Table 4. Sensory evaluation of naranjilla wine (*Solanum quitoense* Lam.) according to treatments.

Treatment	Color	Smell	Flavor	General Acceptance
Mo18	4.1^{a}	3.8^{a}	3.3^{bc}	3.7^{bc}
Mo21	4.0^{a}	4.3^{a}	3.5^{bc}	3.9^{bc}
Mo24	4.6^{a}	4.2^{a}	4.4^{a}	4.4^{a}
Ma18	4.0^{a}	3.8^{a}	3.5^{bc}	3.7^{bc}
Ma21	4.0^{a}	4.2^{a}	3.9^{ab}	4.0^{ab}
Ma24	3.9^{a}	3.8^{a}	2.8^{c}	3.5^{c}

Means in the same column with distinct letters are significantly different ($p < 0.05$) according to Tukey.

3.5 Physico-chemical analysis of the final product (naranjilla wine)

According to the sensory analysis (Table 4), wines with the highest acceptance (Mo24 and Ma21) had a physico-chemical analysis (Table 5) to verify compliance with the requirements of NTE INEN 374-3 for fruit wine.

The results showed that the alcohol percentage in wines was 15%v/v in Mo24 and 13%v/v in Ma21, values that would be directly related to the initial concentration of fermented sugar in must (Matei, 2017). These concentrations are accepted by the NTE INEN which does not specify a maximum in the alcoholic degree. According to the classification of fruit wines described by (Joshi and Attri, 2005; Swami and Divate, 2014) the product obtained in treatments Mo24 would be called a dessert wine and aperitif, and wine Ma21 as a natural wine. The total acidity expressed as tartaric acid was 23.2 and 19.4 g/L for Mo24 and Ma21, respectively, showing that the wine obtained was acid, which is consistent with the observations found during the testing of the initial acidity of the must, which was not adjusted. This process was omitted to evaluate a procedure that does not imply greater use of economic resources, but considers the technicality, such as the addition of acidity deregulators, use of yeast varieties that allow to minimize this parameter (Joshi and Attri, 2005) or the use of naranjilla in combination with other fruit. The low volatile acidity found 0.18 g/L in Mo24 and 0.09 g/L in Ma21 represents adequate fermentation in both treatments and the organoleptic characteristics of wine are not altered by acetic acid. The concentration of total sulfur dioxide was 17.9 and 21.8 g/L in Mo24 and Ma21, respectively, values that are within the permitted range, and the quantities found are low and will not influence the sensory characteristics of wine (Dias et al., 2007). The non-detection of methanol ensures the fermentation quality of naranjilla wine under the established conditions. Finally, according to the amount of total sugar found in treatments Mo24 (34.9 g/L) and Ma21 (30.5 g/L), the established standard categorizes these fruit wines as semi-sweet.

Table 5. Physico-chemical characteristics of naranjilla wine in treatments with better acceptance-requirements of the Ecuadorian Technical Standard for Fruit Wine.

PARAMETERS	UNIT	NARANJILLA WINE		REQUIREMENTS*	
		Mo24	Ma21	Minimum	Maximum
Alcoholic degree at 20 °C	% (v/v)	15.0	13.0	6.0	–
Total acid (tartaric acid)	g/L	23.2	19.4	3.5	–
Volatile acid (acetic acid)	g/L	0.18	0.09	–	1.5
Sulfide total sulphur dioxide	mg/L	17.9	21.8	–	400.0
Methanol	mg/L	0.01	0.01	–	1000.0
Total sugar	g/L	34.9	30.5	25.0 (semi-sweet)	50.0

Mo24= naranjilla wine from must without added water and 24 °brix
Ma21= naranjilla wine from must with added water (4:1) and 21 °brix
*NTE INEN 374-3 Alcoholic beverage requirements. Fruit wine.

4 Conclusions

A viable technique was established for the production of semi-sweet wine from naranjilla, since good acceptance was demonstrated in relation to the sensory characteristics, and the wine obtained meets all the requirements established in the corresponding Ecuadorian Technical Standard. Hence, this fruit is proposed in enology on a small or medium scale, because of its low cost, availability and pleasant aromas, which would greatly help to link new economic activities, generating opportunities for territorial development by the possibility of increasing tourism due to the conjunction of wine production with gastronomy.

It is necessary to work on the improvement and transfer of the established technical process to obtain higher yields, decrease acidity and conduct new studies with tropical fruits and integrate them into the development of oenological proposals with the participation of the community and visitors.

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