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Mango Wine Production, by an Easy Fermentation and Distillation Procedure, Using the Surplus or Rejected Fruit, Produced in Sinaloa, Mexico

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

The aim of this work, was elaborate mango wines using rejected or surpluses fruit. Every year in Sinaloa, Mexico, there is 15-20% unutilized mango due to these causes, generating economic losses to producers. Mango juice was prepared crushing fruit slices, cane sugar and drinking water for obtain a juice with 17-19 ^{o}Brix of soluble sugars; after, juice was pasteurized. Yeasts were added to pasteurized juice, pH adjusted to 3.5-4.0 and fermented in a 3.78 litre (L) glass fermenter until alcohol production ended. Fermented liquid was distilled into glass distiller. To optimize this process several assays were performed and then, process was scaled to 50 L, using a stainless steel fermenter and a distiller attached to fermenter. To eliminate methanol, formaldehyde, and some superior alcohols, column temperature was controlled; into 75 to 82^{o}C. After, these compounds were analysed by GC. Bottles of 250 and 500 ml were partially filled with distilled, then full with mango extract and drinking water at diverse proportions; so, wines of 13 and 18% (alcohol vol.), were obtained. A sensory panel was performed to evaluate wines attributes: colour, clarity, aroma, flavour, etc. Results ranged from good to very good. Also, alcohol amount/mango kg was 67 to 72 ml; higher than obtained from papaya, banana and watermelon. A gross economic analysis, gave a gains around $ 4 US; since from 1 distillate L, 3 or 5 bottles of wines 18 or 13% (alcohol vol.) were obtained, using surplus or rejected fruit, and so decreased losses for producer.

Keywords: Postharvest surpluses; rejected fruit; mango wines; Sinaloa Mexico.

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1. INTRODUCTION

The mango is one of the most delicious and important fruits in the world. The global mango production for 2018 was estimated in 52.08 million tons, and Mexico occupied fifth place in the world, preceded by India, China, Thailand, and Indonesia. [1]. However, in same year, Mexico was positioned as the first worldwide exporter, with 382,000 tons, while Thailand ranks second with 257,600 tons [2]. This indicates the good quality of Mexican mango. In same year, the estimated mango production in Mexico was around 1.9 million tons [1], and 20% of this production was exported to different countries like the United States, Canada, countries of the European Union; and the rest was consumed locally.

In Mexico, the states with more mango production are as follows: Guerrero, with 388.5 thousand tons (t $x10^3$); Sinaloa, 381.3 (t $x10^3$); Nayarit, 350.9 (t $x10^3$); Chiapas, 279 (t $x10^3$); Oaxaca, 169 (t $x10^3$); and Michoacan, 160.4 (t $x10^3$), dates estimated by [3], which represent 8.83 % of fruit production in the country [4]. In Sinaloa, the area employed for mango cultivation in 2017 was estimated in 32,278 ha [5], being 63% of these fields in the southern region of the state [6]. The most important cultivated varieties are: Haden, Kent, Keitt, Ataulfo and Tommy Atkins [7]. Despite that Sinaloa is the second place in mango production, it is the state with more mango exportation in the country, with an estimate exportation value of $ 40 million USD [6]; however, in order to achieve this position, the importer countries establish strict phytosanitary controls, optimal maturity, aesthetic aspects, and other fruit features; otherwise, mango shipments are rejected at border points, which result as important losses for producers. On the other hand, at the end of mango harvest, price falls to such low levels, that producers choose to abandon the mango orchards. These two problems give as results losses ranging from 15 to 20 % of total production (personal comment from mango producer Ernesto Rivera by 11th Oct. 2019). Therefore, in order of facing these problems, an option is to elaborate some products with the mango rejected or surpluses at end of harvest period, and so, offer to market new products with an aggregated value, such as mango wines (liquors)[1], dehydrated slices and so on. Consequently, the aim this work was designing an easy method, for elaborates mango liquor, which could be carried on by mango producers without excessive technology and a moderate inversion. In addition, this product is less perishable and could sold at better price than fresh mangoes, which might improve the region economy, by generating jobs and a more diversified market whit new products elaborated from mango.

2. MATERIALS AND METHODS

2.1 Mango Juice Preparation

The mango juice was prepared from slices of ripe fruit previously washed, peeled and crushed in a blender. Other authors have used enzymes for obtain mango juice, reporting that Pectinase gave higher quantity of juice [8]; however, that method has not been sufficiently accepted, because is more expensive and by production of cloudy mango juice [9,10]. Water and cane sugar were added to the crushed fruit to obtain a homogeneous mango juice with a concentration of soluble sugar (SS) between 17-19 ^{o}Brix. Sugar content was measured using a portable refractometer (Hanna model HI96801). The mango juice was pasteurized by heating to 75-80^{o}C and then fast cooled to 25-27^{o}C. At same time, dehydrated yeast, *Saccharomyces cerevisiae* (supplied by Fleischmann de Mexico®) was hydrated and activated into a flask by adding sterilized water and stirred constantly until a homogeneous suspension was obtained. The yeast suspension was added to pasteurized mango juice to reach a concentration of 4-5 g/juice L. Finally, small portions of lemon juice were added to adjust pH at 3.5-4.0; the pH was measured with an Orion pH-meter model Star A-211. .

2.2 Fermentation and Distillation

In order to optimize the fermentation conditions, several assays were carried on, using a 3.785 L (1 gallon) glass fermenter and mango juice added with yeast as above indicated. The variables assayed were: temperature from 21 to 31^{o}C, pH from 2.0 to 4.0 and (SS) from 13 to 22 ^{o}Brix. The fermentation time was until ethanol production finished; i.e., not more CO_2 was generated, just by observation, no bubbles in air trap attached to fermenter, and (SS) dropped to 4-5 ºBrix. During this time, temperature, pH and (SS) were measured periodically every 12 h, using the same pH meter and portable refractometer.

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[1] *In Mexico, wine is the fermented product from grapes; whereas liquor is the word used for wines obtained by fermentation of other fruits; therefore, this term will be used in this work.*

Theoretically, the alcoholic fermentation is one of next metabolic route of glycolysis, or Embden-Meyerhof-Parnas metabolic pathway, where one glucose molecule is converted in two pyruvate molecules and then, in two ethanol and two CO_2 molecules. The yeasts perform this process in the absence of oxygen; i.e., alcoholic fermentation is an anaerobic process [11]. Therefore, all fermentation process must be based in this theoretic principle.

$C_6H_{12}O_6$ + 2 Pi + 2 ADP + 2 NADH + 2H+ → 2 CH_3-CH_2OH + 2 CO_2 + 2 ATP + 2 NAD

At the end of the fermentation process, which taken around 72 h, the fermenter was left resting in the dark at 22-24°C during 24 h. Next, the upper layer was filtered through a sock-shaped filter, made of nylon mesh 200 µm of size pore; then the filtered product was distilled by fractional distillation using a glass distillation apparatus. Once the best fermentation conditions (pH, temperature, and SS) were determined in the 3.785 L fermenter, the process was scaled up to 50 L, using a stainless steel fermenter and a distillation unit, which could be attached easily to the fermenter container once the fermentation process has finished. The amounts of mango pulp, cane sugar, yeast etc., were increased proportionally to those used in the 3.785 L fermenter; also a stainless steel juice extractor machine, similar to designed by other author, was used for obtain the mango juice [12]. This machine is made up of a perforated drum inside which three helical blades rotate impelled by an electric motor. The drum is inside a shell, through which the mango slices are introduced, and at bottom of this, there is a tube where mango juice drains into a container placed at apparatus base. Once the fermentation is finished in the 50 L fermenter, the fermented liquid was left resting during 24 h at 22-24°C, temperature, and then filtered through a similar filter that previously used, but of higher size. Subsequently, the filtered liquid was distilled using the stainless steel distilling unit, attached to the 50 L fermenter.

In order to obtain a distillate with higher ethanol purity, during distillation process the firsts and finals compounds (known as heads and tails) were discarded. This was performed controlling the temperature in distillation column; i.e., those compounds lower to 75 and higher to 82°C were discarded; in this way, some toxic compound such as formaldehyde, methanol, etc., which are produced during alcoholic fermentation, were substantially eliminated.

Once the distillate was obtained, it was poured into 250 and 500 ml glass bottles, but without filled totally. At same time, a mango extract was prepared introducing small mango slices into a 500 ml flask and 400 ml of distilled were added. After 72 h, mango slices were taken out manually using a dissecting forceps, and the liquid filtered through a 0.5 µm pore size filter, for discarding small mango detritus; then this clarified extract was combined with 1 g of sweetener per L of drinking water and used to fill totally the bottles. In this way, could be obtained mango liquors with different alcoholic graduations 12-13 and 18-19% (alcohol vol.) and enriched with the flavors and aromas from mango and slight sweet.

To calculate the amounts required of distilled, mango extract and sweetened potable water to obtain a 250 ml bottle of mango liquor, with 13% (alcohol vol.); the following mathematical procedure was applied

$$a + b + c = 250 \text{ ml} \quad (1)$$

$$(a + b) \times 0.57 = 250 \times 0.13 \quad (2)$$

Where,

a=ml of distilled; b= ml of mango extract and c=ml of sweetened potable water.

0.57 is % (alcohol vol.) in distilled, and mango extract, whereas 0.13 is % (alcohol vol.) in mango liquor.

If b=20 ml, and since total alcohol must be same in both side of eq. (2), then,

$$\text{ax}(0.57) + 11.4 = 250 \text{ ml x } 0.13$$

Therefore; $\text{ax}(0.57) - 11.4 = 32 \text{ ml}$; and then,

$$a = (32 - 11.4)/0.57 = 36.1 \text{ ml}$$

Substituting the value of a in eq. (1)

$$36.1 + 20 + c = 250$$

Therefore, $c = 250 - 56.1 = 193.9$
Then, $a + b + c = 36.1 + 20 + 193$ .9; where: 36.1= ml of distilled, 20= ml of mango extract,

and 193.9= ml of sweetened potable water, are the amounts required to obtain 250 ml of mango liquor with 13% (alcohol vol.).

At same way, to obtain a 500 ml bottle of mango liquor with 18% (alcohol vol.), the mathematical procedure was similar, but equations were the following:

$$a+b+c= 500 \text{ ml} \quad (3)$$

$$(a+b)\, x0.57= 500x0.18 \quad (4)$$

Therefore, the required amounts of distilled, mango extract, and sweetened potable water were the next: 137.9 ml, 20 ml and 342.1 ml respectively.

2.3 Analysis of Alcohol and Related Compounds

Finalized the distillation, the distilled liquid (spirit) was analyzed to quantify the amount of alcohol as % (alcohol vol.) using a densitometer (alcohol meter) whereas the analysis of related compounds was performed by gas chromatography (GC), using a HP 5890 Series II chromatograph® (Palo Alto, CA), in splitless mode, a fused silica capillary column of dimethyl polysiloxane cross-bond, Restek® of 30 m long, 0.53 mm ID (Bellefonte, PA) and a flame ionization detector (FID). The operating conditions were as follows: Initial oven temperature 50°C, during 2.5 min, a ramp of 10°C/min, final temperature 280°C and final time 3 min; the Injection and detector temperature were 250°C and 320°C respectively. Nitrogen (purity ≥99.7%) was used as carrier gas at a constant flow rate of 2.5 ml/min, and constant pressure (15 PSI) during all run. Hydrogen was used as fuel gas with a flow rate of 40 ml/min and dry air as oxidant gas, with a flow rate of 450 ml/min. A reference standard was prepared mixing 0.5 ml of following compounds: acetaldehyde ≥99.5%, methanol ≥99.8%, ethanol ≥ 97%, 2-propanol ≥ 99.5 %, Isobutanol ≥ 99.2%, ethyl acetate ≥ 99.5%, 2-butanol ≥99%, pentanol ≥99%, ethyl lactate ≥98% and isoamyl alcohol ≥98 % purity respectively; all them, purchased in Sigma-Aldrich® of Mexico (Mexico City).

The related compounds were identified comparing the retention times (RT) peaks in chromatograms of distilled, with corresponding RT peaks, in chromatograms of prepared standard. The quantification of identified compounds was performed considering respective area of each peak, using an Agilent ChemStation® software, purchased in Agilent Technologies of Mexico (Mexico City).

The maximums permissible values of related compounds, were those established in the Mexican normativity for the distillation industry of alcoholic beverages [13].

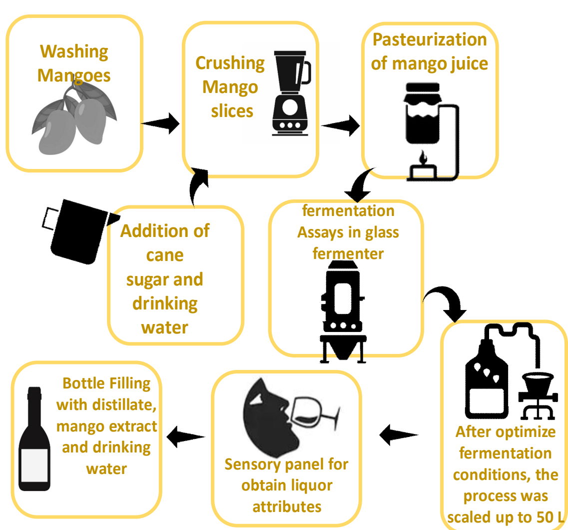

Fig. 1. Flow diagram showing the steps followed for elaborate mango liquor

Other related compound is glycerol, which is produced during alcoholic fermentation. The glycerol is a non-volatile compound, without aromatic proprieties but contributes significantly to the quality of different wines, providing sweetness and fullness [14] however, this compound was not analyzed in this work.

2.4 Sensory Panel

Formerly, sensory panels included thirty three attributes or features like those reported by [15], [16]. In these works, attributes comprise three sensory groups; five visual, sixteen olfactory and twelve gustatory. However, in this work, attributes considered for mango liquor, only were: color, clarity, aroma, taste, alcohol strength and palate fullness, using the following scores for this attributes 1= very bad, 2= bad, 3= acceptable or good, 4= very good and 5= excellent.

A group of 12 voluntary panelists (made up of 8 men and 4 women) were randomly selected from students and university staff, taking into accounts their availability and familiarity with wines and alcoholic beverages. Also, this sensory analysis replaced (at least partially) the analysis of volatile aromatic compounds such as, ethyl esters, acetates, phenols, trephines, etc., in mango liquor, which were not analyzed in this work, but are reported by other authors [17,18,19].

The Fig. 1 shows a flow diagram, where the stages of production of mango liquor are shown. Note that the details of each stage are not indicated; they are explained in detail in the methodology.

3. RESULTS AND DISCUSSION

The amount of distillate obtained after fermentation, in the 3.785 L fermenter such as in 50 L fermenter, was similar; this ranged from 67 to 72 ml per kg of mango. That is a very acceptable amount compared to amount obtained using other tropical fruits like papaya, banana and watermelon, or other process conditions [20].

The results of assays to know the best fermentation conditions are shown in Table 1. As can observed, the best ranges for temperature, pH and SS, were: 25 to 27°C, 3.5 to 4.0 and 17 to 19 °Brix respectively.

Other authors performed assays with mango juice using similar fermentation conditions, but they focused their work on the effect of fermentation conditions on yeast growth duration, and the volatile compounds in mango wine [21]; however, their outputs were similar to the results obtained in this work.

In Table 2, are shown the results obtained from chromatographic analysis of distillate. As can be observed, the quality of distillate obtained was very acceptable, because the formaldehyde, methanol and other no desirable compounds, were considerable below of permissible maximums, established by Mexican regulations.

The Mexican regulations, establish as maximum permissible values for some undesirable compounds in alcoholic beverages, the following (expressed in mg/ml): Aldehydes 0.4, Esters (Ethyl acetate) 2.5, Superior Alcohols, 5.0 and Methanol 3.0 (values for the other compounds are not indicated). On the other hand, some volatile compounds found in this work, such as Acetaldehyde, Methanol, Ethyl-acetate, Isobutanol and isoamyl alcohol were similar, and in some cases light higher in concentration to those of mango wines obtained from several varieties of mangoes from India [22].

Table 1. Amount of distillate obtained after fermentation assays performed at different temperatures (°C), amount of SS (°Brix) and pH. The best ranges were: 25-27°C, 17-19 SS and pH 3.5-4.0

Variables assayed, and amount of distillate obtained.	First assay	Second assay	Third assay	Fourth assay	Fifth assay	Best range
Temperature (0C)	21	23	25	27	31	
Soluble sugars (SS)	13	15	17	19	22	
pH	2.0	2.5	3.0	3.5	4.0	
Amount of distillate (ml), keeping constant SS and pH	50 ml. SD±4.0	53 ml. SD±5.58	60 ml. SD±4.0	72 ml. SD±3.46	55. ml. SD±2.64	25-27°C
Amount of distillate (ml), keeping constant T (^{0}C) and pH	47 ml. SD±3.0	54 ml. SD±4.0	65 ml. SD±1.0	68 ml. SD±2.64	57 ml. SD±3.6	17-19 SS
Amount of distillate (ml). keeping constant T (^{0}C), and SS	46 ml. SD±3.6	54 ml. SD±4.58	58 ml. SD±4.3	67 ml. SD±4.0	62 ml. SD±3.0	3.5-4.0 pH

Table 2. Amount of related compounds in mango distillate obtained by gas chromatography. The values are the mean of five experiments and their standard deviations

Compound analysed	Mean value (mg/ml)	Standard deviation
Acetaldehyde	0.015	±0.001
Methanol	0.38	±0.021
*Ethanol	57.3	±3.820
Ethyl acetate	0.49	±0.035
2-Propanol	0.24	±0.018
Isobutanol	0.61	±0.043
2-Butanol	0.013	±0.009
Pentanol	1.29	±0.085
Isoamyl alcohol	0.19	±0.078
Ethyl lactate	0.39	±0.088

**The ethanol was quantified by densitometry (alcohol-meter) and also by Gas Chromatography together to related compounds in mango distilled. As can be see, the amount obtained by both methods was very similar*

Table 3. Sensory panel for evaluate some mango liquor attributes such as color, clarity, aroma, flavor, alcohol strength and palate fullness; using scores from 1 to 5 for this attributes. 1 = very bad, 2 = bad and 3 =acceptable or good, 4= very good and 5 = excellent

Panelist	Color	Clarity	Aroma	Flavor	Alcohol strength	Palate fullness
1^{th}	4	3	4	5	3	4
2^{th}	3	3	4	4	3	5
3^{th}	4	4	3	4	4	5
4^{th}	3	4	4	4	4	4
5^{th}	4	4	4	5	3	5
6^{th}	5	4	4	3	4	5
7^{th}	4	4	4	4	5	4
8^{th}	3	3	3	4	2	3
9^{th}	4	3	4	5	4	3
10^{th}	4	4	4	4	4	4
11^{th}	4	3	3	5	4	4
12^{th}	3	4	4	3	5	5
Average	3.75	3.6	3.75	4.16	3.6	4.25

Concerning to some superior alcohols, there is no consensus about their toxicity levels vs. flavor. Some authors declare that scientific data are not sufficient to consider higher alcohols as a cause of adverse effects in alcoholic beverages [23], whereas other say that superior alcohols are important flavoring compounds, because they commonly account for about 50% of flavoring substances in wines and spirits [24].

The results obtained in sensory panel, ranged from good to very good (Table 3), since average values of attributes were: 3.75, 3.6, 3.75, 4.16, 3.6 and 4.25 for color, clarity, aroma, flavor, alcohol strength and palate fullness respectively. This indicates that mango liquor quality is very acceptable.

On the other hand, this sensory panel is considerably easier to carry out, compared with procedures to evaluate the liquors attributes, used by other authors [25].

3.1 Economic Benefices

Without intending to perform a detailed economic analysis of mango liquor production, an approximate cost to benefit is presented. Therefore, to obtain 1 L of distillate (58% alcohol vol.), around 14.3-15 kg of mango, 1.75-1.85 kg of sugar and 121-126 g of yeast and 3 or 5 plastic bottles are required, with an approximately total cost of $ 3.5 US dollars. 1 L of distillate is sufficient to prepare either 3 bottles of 500 ml, or 5 of 250 ml of mango liquor, of 18% and 13% alcohol vol. respectively. The approximate price in the market would be of $2.5 and $1.5 US dollars per bottle respectively; i.e., $ 7.5 US per L of distillate. Therefore, the utility will be $7.5-$3.5 = $ 4 US. However, production and marketing costs must be discounted, which should not be very high, because the production and commercialization will be carried out by mango producers. Also, a scaling-up cost, will be necessary to obtain a more precise cost-benefit of mango liquor production.

Concerning to commercialization problems of fresh mango in the southern of Sinaloa State, Mexico, other author declares similar problems of exportation in Ecuador [26]; i.e., around 10-15% of total fruit production is rejected by several problems; therefore, he suggest to growers, the production of mango liquor with the mango surplus. In same work, the author report that amount of distillate obtained per mango kg, was 28.57 ml, with 60% (alcohol vol.), whereas in this work, the quantity of distillate obtained per mango kg was from 67 to 72 ml, with 57% (alcohol vol.); i.e., 2.5 times more distilled than in that work. On the other hand, the sensory panel, Indicated that mango liquor obtained in this work, was very acceptable by people who tried it, since the scores values are higher to 3.5 in a scale from 1 to 5 for attributes evaluated.

4. CONCLUSION

Finally, in base to results obtained, it can be conclude that the objective of this work was reached satisfactorily, since the surplus of mangoes was used to obtain a product with an added value; i.e., a mango liquor, with an attractive market price, and so, horticulturists could reduce traditional losses (15-20%) due to decreased price at the end of the harvest, or by the rejected mango in frontier ports. On the other hand, from results of economic analysis, can be conclude, that elaboration of mango liquor using the leftover or rejected fruit, is totally viable utilizing the methodology presented in this work, since it is a procedure relatively easy and economical, to be performed by the mango producers.

Other authors arrived to similar conclusions, reporting that tropical fruits can be used in production of wines, as an alternative to utilize the surpluses harvest and other underused fruits such as cacao, cupuassu, gabiroba, etc and so the introduction of new products into the market [17].

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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