

**PRODUCTION AND CHARACTERIZATION OF WINE FROM MANGO
FRUIT (*MANGIFERA INDICA*) VARIETIES IN KENYA**

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Abstract

Mango is one of the most important tropical fruit. In Kenya, increased production has been observed over years paralleled by large postharvest losses which are partly attributed to poor value addition practices. This study sought to investigate the suitability of mango fruit for wine production and characterization of the wine produced. Six mature and unripe mango fruits were harvested three times from a farm in Katheka Kai Division, Machakos County of Kenya. The ripened fruits were screened for their suitability to produce wine based on juice yield, °brix (°Bx), pH, reducing sugars and titratable acidity (TTA). The wine produced was analyzed for the chemical properties whereas characterization of the major volatile compounds was determined by GC-FID. Sensory evaluation was done using a nine point hedonic scale with a reference commercial grape wine (chardonnay). Juice recovery was dependent on variety with Kent yielding 72.8%, Apple 71.3% and Ngowe 67.6%. The extracted juice had a high sugar content ranging from 17.0 to 23.9°Bx. Apple and Ngowe variety had the most suitable properties for wine production based on sugar levels and juice yield. The ethanol content of the wines produced was between 8.9-9.5 %v/v, the range acceptable for table wine. The methanol content (128-129mg/l) was however higher than grape wine (100mg/l) although it was within the acceptable limits for wine. The sensory evaluation indicated that mango wine exhibited similar sensory characteristics with those of grape wine. This study provides evidence that mango fruits are suitable for wine processing.

Introduction

Mango (*Mangifera indica*) of the family Anacardiaceae is a tropical, subtropical and frostfree fruit (Bally et al., 2009). It is the fifth largest fruit crop produced worldwide after banana, grapes, apples and oranges. It is the second most important tropical fruit with 27 million tons being produced annually worldwide (Bally et al., 2009). It originated from the foothills of the Himalayas of India and Burma and has been cultivated in that region for at least 4,000 years. In Kenya, it has been the third most important fruit in terms of area and production for the last ten years after banana and pine apple (HCDA, 2010). The hectares under mango production, production output (ton) and the revenue earned have continued increasing over years. In 2010, hectarage increased from 36,304 to 59,260 (Ha); production increased from 528,815 to 636,585(MT) and revenue earned increased from 104,616,297 to 139,836,268 USD (HCDA, 2011).

There are two types of mango grown in Kenya, the local (including Ngowe, Dodo, Boribo and Batawi) and the exotic or improved (including Apple, Kent, Keit, Tommy Atkins, Sabine, Van dyke, Hadden, Sensation) varieties (Okoth et al., 2013). The exotic varieties are of superior market quality - they have higher juice yields, no strings, more preferred colour and flavor. They are grown targeting the export market (Okoth et al., 2013). The local varieties grown in Kenya are high in fiber hence "stringy"; with the exception of Ng'owe variety, and thus are less preferred for fresh, processing and export markets (Okoth et al., 2013). Postharvest losses of mango fruits in Kenya are estimated to be 40-50% through its market value chain to consumption and less than 1% is processed to value added products (FAO, 2006). Minimal value addition technologies and lack of viable markets of the fresh fruit as well as high competition of the processed mango products from local and imported juices is the main challenge in mango production. Value addition of mango fruits to curb high losses may be utilized to offer high priced products and alleviate poverty through enhanced food and nutrition security in terms of quantity, quality, safety, and variety (Abe et al., 1997). This can be done by using applicable postharvest technologies which preserves the fruits' qualities. The value-added products offer higher return, open new markets, create brand recognition, and add variety to a farm operation (Bachmann, 2001). Mango fruits can be processed into various products: the unripe mangoes can be processed to pickles, preserves, dessert and chutneys whereas the ripe mangoes can be processed into dried chips, wine, juice, concentrate, jam, jelly, syrup and canned mango. Despite this great diversity in mango products, most of the mangoes produced are channeled towards the production of juice and concentrate. This is attributed to the fact that most farmers have limited information on the processing skills of other mango products.

Although grapes are the main raw material used for wine production, there is an increasing interest in the search of other fruits, such as apricot, apple and palm sap, suitable for wine making. In countries where grapes are not abundantly available,

local fruits that are cheap and readily available are used as an alternative (Reddy, 2005). Mango wine is a potential value added product; however, in Kenya there is no published information regarding the suitability of mango fruit varieties for wine production and information on the characterization and sensory attributes of the produced wine. This study aims at production and characterization of mango wine as a value added product.

2.0 Materials and Methods

2.1 Sample Collection

Six mature and healthy mango fruit varieties, Apple, Ngowe, Tommy Atkins, Kent, Vandyke and Sabine were obtained from a farm in Katheka Kai Division, Machakos County of Kenya and transported to Jomo Kenyatta University of Agriculture and Technology, Department of Food Science and Technology. The fruits were then washed with tap water and a detergent (easy foam) and stored in a cold room (controller, MCU-2260C-S, Sanyo Electric Co., Ltd. Japan) at 20°C and 85-90% relative humidity to ripen.

2.2 Extraction of Pulp

Ripened mango fruits of the six varieties were sorted, washed and peeled manually using a knife.

Ripeness was indicated by a rapid decline in fruit firmness using a rheometer. The flesh was cut away from the seed using a knife and then homogenized using a pulp extractor. Juice was obtained by passing the pulp through a muslin cloth. Juice obtained in this manner was then subjected to physicochemical analysis.

2.3 Analysis of Physicochemical Properties

2.3.1 Determination of Juice Yield

Three mango fruit samples from each variety were weighed and the juice extracted measured (Musyimi, et al., 2013). The percentage juice recovery was calculated as:

$$\text{Juice recovery} = \frac{\text{juice yield}}{\text{weight of sample}} \times 100 \dots\dots\dots 1$$

2.3.2 Determination of Reducing Sugars

Quantification of reducing sugars present was determined using High Performance Liquid chromatography (HPLC) method as outlined in AOAC (1996). A sample of 10 g each of fruit pulp was refluxed in 96% ethanol for 1 hour. The extract was filtered using cotton wool and concentrated by rotary evaporator. This was then diluted with 80% acetonitrile in the ratio of 1:1 which was used as the mobile phase. Standard solutions of sucrose, fructose and glucose were prepared at varying concentrations, 2mg/ml, 4mg/ml, 6mg/ml and 8mg/ml and injected together with

the sample extracts into HPLC (LC- 10AS, Shimadzu Corp., Kyoto, Japan) fitted with Refractive Index Detector (RID). The HPLC conditions were as follows: oven 35°C, flow rate: 0.8 ml/min, injection volume: 20 µl, column (NH2P-50 E). The standard curves were drawn and used to quantify the reducing sugars of the samples.

2.3.3 Determination of pH

The pH was determined by the method of Ofori and Hahn (1994). The pH was determined by the method of Ofori and Hahn (1994).

2.3.4 Determination of Total Soluble Solids (TSS)

The TSS was determined using an Atago hand refractometer (RX 5000, Atago, Tokyo, Japan) (AOAC, 1995). A drop of well homogenized mango pulp was placed at the screen of a calibrated hand refractometer. The readings were taken and results expressed in °Bx.

2.3.5 Determination of Total Titratable Acidity (TTA)

Total titratable acidity analysis was done according to AOAC, 1995 method. Calculations of TTA was determined and expressed as follows;

$$\% \text{ malic acid} = A \times 0.009 \times \frac{100}{V} \dots\dots\dots 2$$

Where: A = ml of 0.1 NaOH required for the titration

V = ml of sample taken for the test. 0.009 is a Constant

2.4 Fermentation of Mango Wine

Two mango varieties with the most suitable physicochemical characteristics for wine production were selected for the subsequent study. After extraction, the juice was pasteurized at 65±4°C for 10 minutes and cooled immediately with cold tap running water to 27±2°C. The pH of the mango juice was adjusted to 4.5 by addition of calcium carbonate, CaCO₃ (food grade) and citric acid, C₆H₈O₇ (food grade) respectively. The mango juice was not added with any sugar prior to fermentation. The treated juice was fermented with wine yeast from Kenya Wine Agencies Limited (KWAL) at a concentration of 0.05% at 25°C (Musyimi, et al., 2013). Fermentation was allowed to proceed until the °Bx could not change any further. After fermentation, the wine samples were centrifuged (Centrifuge Model H-2000C Shimadzu Corp., Kyoto, Japan) at 7,000 rpm for 5 minutes prior to analysis. The clear supernatant samples were kept in air tight glass jars and stored at -8°C (Chester freezer, model: K302) until the physicochemical analyses were completed. At the end of fermentation, the wines were stabilized with the addition of 30 mg SO₂/l and preserved.

2.5 Characterization of Mango Wine

The chemical properties analyzed were: ethanol content, pH, TTA, residual °Bx and volatile acidity and the major volatile compounds were: acetaldehyde, ethyl acetate, 1-propanol, isobutanol, isoamyl alcohol, phenyl ethanol, acetic acid and methanol.

2.6 Determination of TTA

This was determined according to AOAC, 1995 where 5 ml of wine was drawn into a pipette and the sample titrated with 0.1 N sodium hydroxide (NaOH) solution. Titration was stopped when the sample turned to a faint pink.

TTA Calculations

When a 5-milliliter sample and 0.1N NaOH are used, titratable acid is calculated using the following formula:

$$TTA(\%) = 0.15 \times \text{ml of NaOH used} \dots\dots\dots 5$$

2.7 Determination of Volatile Acidity (VA)

This was determined by taking 10ml of the wine sample and collecting 75ml of the distillate in a 250 ml conical flask. The distillate was titrated against 0.1N NaOH in the presence of 1% phenolphthalein until a pink colour persisted. The amount of NaOH used was noted and used for calculation as described using AOAC (2000) method as follows:

$$VA \text{ in g/l of acetic acid} = (\text{ml NaOH used}) \times (0.06) \dots\dots\dots 6$$

2.8 Determination of Ethanol

Ethanol was determined as described in AOAC, 1995 by putting 100 ml of the sample into a flask and adding 50ml of distilled water. A portion of 100ml of the distillate was collected under ice. The distillate was filled into a pre-weighed pycnometer (25ml) and cooled to 14°C. The reading of the balance was tarred and the pycnometer weighed at 15.5°C. This measurement was repeated using distilled water. The specific gravity of the distillate was determined using water as the reference at 15.5°C as follows:

$$Sg = \frac{\text{weight of sample}}{\text{weight of an equal volume of water}} \dots\dots\dots 7$$

Where Sg = specific gravity

Using the conversion tables, the specific gravity value was converted to the corresponding percentage ethanol content.

2.9 Determination of Major Volatile Compounds

Wine samples were collected 6 months after winemaking and then analyzed. The major volatile compounds were determined according to AOAC (1995) methods. The distillates were prepared by putting 100 ml of the sample into a flask and adding 50ml of distilled water. A portion of 100 ml of the distillate was collected under ice. Standard solutions of known alcohols were prepared and 0.2 µl injected in a Gas Chromatograph fitted with a Flame Ionization Detector (FID) (GC-9A, Shimadzu

Corporation, Kyoto, Japan). The conditions were as follows: glass packed column: diethyleneglycol succinate 15% (3m x 3 mm i.d); injector/detector temperature: 220°C and N₂ was the carrier gas with a flow of 20 ml/min. The eluted compounds were detected by FID where the fuel gas was hydrogen with a flow rate of 40 ml/min and the oxidant was air with a flow rate of 40ml/ min. Appropriate dilutions were made were the curves were too big. One µl of the distilled samples was injected into the GC-FID under the same conditions as of the known standards. Esters as ethyl acetate and volatile acids were also determined using GC – FID according to established methods (AOAC, 1995). Identification of the sample peaks was done by comparing the retention time of the samples with those of authentic standard compounds injected under the same conditions. The compounds to be identified were preliminarily identified from (Reddy and Reddy, 2005; 2009).

$$\text{Conc. (ppm)} = \frac{\text{peak area of compound}}{\text{total area of peaks}} \times \frac{(\text{alcohol content})}{100} \times \text{density at } 20^{\circ}\text{C} \times 10^6 \quad \dots\dots\dots 8$$

2.10 Sensory Analysis

Mango wine was compared with a commercial grape wine (Changli Chardonnay wine 2010, Yueqiannian Winemaking Company, Changli County, China) as the reference wine for colour, clarity, mouth feel, aroma and general acceptability by a panel of 30 untrained panelists using a nine point hedonic scale as described by Ihekoronye, et al., (1985) where 9 denoted; like extremely and 1; dislike extremely.

2.11 Statistical Analysis

Sample collection was done three times and analyses were done in duplicate. Data was assessed using Genstat 12th edition by one way analysis of variance. Significance was determined at p≤0.05. For sensory analysis, statistical analysis for the two wines was done using a t-test to compare the means of the five parameters.

3.0 Results and Discussion

3.1 Screening Mango Varieties for their Suitability for Wine Production

The results of juice yield and chemical composition of mango juice is presented in Table 1. The fruits of different varieties were found to vary in sugar concentrations and other chemical characteristics.

Kent variety had the highest juice yield whereas Sabine had the lowest. Juice yield is an important parameter in wine production as it reflects on the final quantity of the wine. Fruits with high juice yield are preferred for wine production relative to low yielding fruits for economical purposes.

The main prerequisite character of juice for fermentation is sugar content. The total soluble solids (TSS) of the mango ranged from 17.0°Bx (Sabine) to 23.9°Bx (Apple). For wine production, a minimum of 18.0°Bx is required thus Apple, Ngowe, Vandyke and Kent were within the acceptable range. The variability in total soluble solids of different cultivars at different stages of ripeness are attributed to the alteration

occurring in structure during ripening processes (Saeed, et al., 2009; Rathore, et al., 2007)

The simple sugars found in mango fruit are glucose, fructose and sucrose. These were in the range of 16.95% (Sabine) to 23.78% (Apple). Fructose and glucose are the products of sucrose hydrolysis, glucose also being produced by starch hydrolysis (Saeed et al., 2010). Fructose sweetness is more pronounced than the other sugars, and thus accounts for a significant part of the sweet taste of mango (Rathore, et al., 2007). The sugar content of a given fruit is essential for wine production as these sugars are utilized during fermentation to yield alcohol. The higher the sugar content the higher the alcohol yield.

Mango variety	Juice Yield (%)	$^{\circ}\text{Bx}$	Reducing Sugars (%w/v)	pH	Titrateable Acidity (%)
Apple	71.3±1.59 ^c	23.9±0.21 ^e	23.8±1.24 ^b	4.25±0.04 ^c	0.46±0.04 ^c
Ngowe	67.6±5.70 ^{bc}	23.1±0.42 ^d	22.2±0.23 ^b	4.89±0.03 ^f	0.35±0.03 ^a
Tommy Atkins	67.3±0.94 ^{bc}	17.0±0.12 ^a	16.9±1.73 ^a	4.54±0.04 ^d	0.39±0.02 ^b
Vandyke	58.9±7.27 ^{ab}	21.8±0.06 ^c	21.6±0.06 ^b	4.74±0.05 ^e	0.37±0.01 ^a
Kent	72.8±7.04 ^c	18.0±0.15 ^b	17.0±0.15 ^a	4.03±0.03 ^b	0.55±0.03 ^d
Sabine	52.9±4.93 ^a	17.0±0.14 ^a	16.9±1.13 ^a	3.92±0.03 ^a	0.82±0.04 ^e

Means within the same column sharing the same superscripts were not significantly different ($p>0.05$) Values are presented as mean \pm SD. n = 3

Sucrose, glucose and fructose are the main sugars in ripened mango fruit. Fructose and glucose are the products of sucrose hydrolysis, glucose also being produced by starch hydrolysis. Fructose sweetness is more pronounced than the other sugars, and thus accounts for a significant part of the sweet taste of mango. The pH increases during the maturation and ripening of the fruit. Malic acid which is the main acid in ripe mango fruit ((Ueda et al., 2000) is synthesized when fruit growth becomes slower and when energy demand is low (Selvaraj and Kumar, 1994).

These results suggest that mango juice has a potential for producing good quality wine based on its chemical composition. From the six varieties, Apple and Ngowe exhibited the most suitable properties for wine production and as a result, were selected for the subsequent studies.

3.2 Characterization of Mango Wine

3.2.1 Chemical Properties of Mango Wine

The chemical properties of Apple and Ngowe mango wine fermented with wine yeast at 25°C, pH 4.5 and yeast concentration of 0.05% are shown in Table 2. The percentage of ethanol produced from the mango wines was between 8.9 and 9.5% v/v, comparable with moderate grape wines (Reddy, 2005). At 25°C and 0.05% yeast concentration, mango wine was found to produce the highest ethanol yield compared to other fermentation temperatures and yeast concentrations (Musyimi et al., 2013). The TTA increase corresponded with the fall in pH value as fermentation progressed. The final acidity ranged from 0.81 to 0.96% (v/v) as tartaric acid.

Volatile acidity measures the degree of sourness of wine. The volatile acidity (as acetic acid) of the wine was between 0.37 and 0.49% v/v which is within the acceptable range of 0.3 to 0.6% reported for wines (Amerine, et al., 1980). The volatile acidity (as acetic acid) has been reported to be low at a fermentation temperature of 25°C and 0.05% yeast concentration (Musyimi et al., 2013). Acetic acid was used as the reference acid because about 90% of the volatile acids consists of acetic acid (Yannam, et al., 2009).

Table 2: Chemical characteristics of mango wine from Apple and Ng'owe varieties at 25°C and 0.05% yeast concentration

Mango variety	Ethanol content (% v/v)	Residual °Bx	pH	TTA (%)	Volatile acidity (g/l)
Apple	9.47±1.24 ^b	5.4±0.04 ^a	3.98±0.21 ^a	0.96±1.24 ^b	0.37±0.04 ^a
Ngowe	8.89±1.46 ^a	5.4±0.03 ^a	4.06±0.42 ^a	0.81±0.23 ^a	0.49±0.03 ^b

Means within the same column sharing the same superscripts were not significantly different ($p>0.05$). Values are presented as mean \pm SD. $n = 3$

The principal metabolite produced from the wine is ethanol. In general, the concentration of ethanol contributes to the whole characteristic quality and flavour of the produced wine. According to Michael (2000), a good table wine must have alcohol content ranging from 8 to 14%. The mango wines produced had ethanol contents within this range.

Acidity plays a vital role in determining wine quality by aiding the fermentation process and enhancing the overall characteristics of the wine. Lack of acidity will suggest a poor fermentation (Berry, 2000). On the other hand, the decrease in pH has been observed for wines produced from other tropical fruits (Aderiye et al.,

1990). This decrease in pH was desirable as it helped to maintain the acidity of the wine high enough to inhibit the growth of undesirable micro-organisms. Fermentation of the juice resulted in residual °Bx of 5.4. The sugars were utilized for alcohol and organic acid production (Akubor, 1996).

3.2.2 Volatile Composition of Mango Wine

The volatile profile is important in wine, as it contributes to the quality of the final product. It is due to the combined effects of several volatile compounds, mainly alcohols, aldehydes, esters, acids and other minor components already present in the grapes as well as those that are being formed during the fermentation and maturation process (Verzera et al., 2008). The volatile composition of Apple mango wine is illustrated (see plate 1).

From Table 3, it was observed that the wine produced had their methanol content varying between 126 mg/l to 129 mg/l. This was significantly higher when compared to grape wine. However, Craig 1998 and Soufleros et al., 2001, reported that methanol levels from 100 mg/ml to 300mg/ml are not potentially injurious to health. More so, Reddy et al., 2009, reported that the human oral lethal dose for methanol is 340 mg/kg body weight. Therefore, the methanol content produced by mango wine is not harmful to humans. Methanol is formed from the enzymatic hydrolysis of the methoxy groups of pectin during fermentation, and its content depends on the extent to which the solids, especially the skins, which have high pectin content, are macerated (Peinado et al., 2004). Therefore, the differences in the concentrations of methanol between Apple and Ng'owe varieties could be related to the pectin content of each fruit.

Isoamyl alcohol is the major higher alcohol found in wines (>50%), and its concentration has been reported in the range of 90 to 292 mg/L (Useeaglio, 1975; Boulton et al., 1996).

In this study, isoamyl alcohol was in the range of 112.4 to 119.2 mg/l. The other higher alcohols like 1-propanol concentrations were in the medium range, as in the case of grape wine 60–80 mg/l (Reddy, 2005).

Acetaldehyde content varied between 18 to 21mg/l. This was relative to acetaldehyde content in wine produced from grapes which is usually in the range of 13–30 mg/l. (Longo et al., 1992). At low levels, acetaldehyde gives a pleasant fruity aroma to wines, but in higher concentrations, it has a pungent, irritating odor (Miyake and Shibamoto, 1993). The other aldehydes were not identified in the mango wine.

The concentration of esters (ethyl acetate) was between 27 and 33 mg/l. Ethyl esters are some of the most important groups of aroma compounds in wine, and their concentrations depend on several factors, such as yeast strain, fermentation

temperature, aeration, and sugar content. These compounds contribute positively to the overall wine quality, and most of them have a mature flavor and fruity aroma that contribute to the “fruity” and “floral” sensory properties of wines (Perestrelo et al., 2006). Consequently, ethyl acetate adversely affects the quality of wine due to its unpleasant flavor in high concentrations. On the other hand, at very low concentrations (50-80 mg/L) it has a positive impact on the flavour (Tesevic et al., 2009). The concentration of this compound varied significantly among the two varieties.

Table 3: Composition of major volatile compounds by Gas Chromatography–Flame Ionization Detector (GC-FID) from two mango varieties (Apple and Ngowe) fermented at 25°C and pH 4.5 for 16 days at 0.05% yeast concentration with reference to the acceptable limits (grape wine)

Name of the Compound	Apple	Ngowe	Acceptable limits*
Metabolites (mg/l)			
Ethanol (% v/v)	9.47± 1.24 ^b	8.89± 1.46 ^a	8-13
1-Propanol	66.1± 1.21 ^b	61.3± 0.54 ^a	<400
Isobutyl alcohol	105.4± 0.87 ^a	111.1± 0.76 ^b	<400
Isoamyl alcohol	119.2± 0.62 ^b	112.4± 0.25 ^a	<400
Phenyl-ethanol	24.2± 0.41 ^a	26.2± 0.31 ^b	<400
Methanol	129.2± 5.34 ^b	126.2± 6.11 ^a	<100
Acetaldehyde	18.2 ± 0.51 ^a	21.4± 0.33 ^b	<100
Ethyl acetate	73.2± 0.73 ^b	62.4± 0.82 ^a	<100
Acetic acid (g/l)	0.37± 0.96 ^a	0.46± 0.55 ^b	0.3-0.7

*Means within the same row sharing the same superscript were not significantly $p > 0.05$ different. Values are presented as mean ± SD. n=3 < means less than *source: Chemistry in wine making (2003)*

Acetic acid concentration was in the range of 0.37 to 0.46 in the two varieties. Acetic acid in high concentrations (>0.7 g/ L) might give a taste and odour of vinegar (Whasley, et al., 2010).

Phenyl ethanol was in the range of 24.15 and 26.15 in the two varieties. Phenyl ethanol is an aroma carrier and its presence may contribute to the floral nuance of wines (Wondra and Berovic, 2001). The aroma character of this compound changes

with its oxidation from rose to a hyacinth bouquet. Further oxidation produces esters with a fine honey nose.

The main groups of compounds that form the fermentation bouquet are organic acids, higher alcohols, esters and to a lesser extent, aldehydes (Lambrechts and Pretorius, 2000).

Mango fruit is known to have good aroma and flavour. The flavour of mango fruit is due to the volatile components that are present. The flavour of wine depends on many varietal or fermentative compounds, which are present in highly variable amounts and are mainly alcohols, esters, sulfur compounds and acids (Rapp 1988; Nobel 1994). Volatile aroma compounds are present in fruit juices and many are synthesized by wine yeast during wine fermentation. The aroma and flavor of wine are among the main characteristics that determine its quality and value (Mauricio et al., 1997; Swiegers et al., 2005; Molina et al., 2007). The aroma complexity dramatically increases during alcoholic fermentation because of the synthesis of important volatile compounds by the wine yeast and the release of some varietal aroma precursors (Mauricio et al., 1997; Swiegers et al., 2005). The nature and the amount of the synthesized volatile compounds depend on multiple factors, such as the nitrogen content of the must, the temperature of fermentation, and the yeast strain (Lambrechts and Pretorius 2000; Swiegers et al., 2006). The volatile compounds synthesized by wine yeasts include higher alcohols, medium and long-chain volatile acids, acetate esters, ethyl esters and aldehydes (Stashenko et al., 1992).

Statistical analysis of the concentrations of the major volatile compounds in the two varieties showed significant differences ($p < 0.05$) in their concentrations except for methanol. This implied that different mango varieties have varying concentrations of volatile compounds.

3.3 Sensory Properties of Mango Wine

The results for sensory evaluation of mango wine are presented in Table 4. There was no significant difference ($p \geq 0.05$) in clarity and general acceptability between apple mango wine and the reference wine from grapes. However, the reference wine received higher ratings for clarity than the mango wine.

Table 4: Sensory evaluation for mango wine and a reference wine from grapes

	Sensory parameters				
	Colour	Mouth feel	Aroma	Clarity	General acceptability
Mango wine (Apple variety)	7.6 ^b	6.8 ^a	8.6 ^b	6.8 ^a	6.8 ^a
	Sensory parameters				
	Colour	Mouth feel	Aroma	Clarity	General acceptability
Grape wine (Chardonnay)	6.9 ^a	7.2 ^b	7.4 ^a	7.0 ^a	7.0 ^a

Means within the same column with the same superscript were not significantly different $n=3$

The preliminary test investigation characterized the new wine as a novel, special type of wine, with a pleasant soft aroma and fruity taste. This wine had light golden yellow colour with clarity and possessed good body. The results have shown that the wine produced from mango is very similar to the commercial grape wine in terms of aroma and taste.

The aroma of mango wine was significantly higher ($p \leq 0.05$) than that of grape wine. Significant changes in wine aroma occur during maturation and aging. These include the loss of certain grape or yeasty aromas, retention of the varietal aroma, formation of new aromas, and above all, integration of all flavour to produce a harmonious and pleasing fragrance (Buglione and Lozan, 2002). Many esters and higher alcohols formed by the yeast's metabolic activity contribute to the fermentation aroma. During wine storage, the esters are hydrolyzed and the fresh and fruity aroma is lost. This was evidenced in the produced mango wine. Concurrent with the degradation of esters, a synthesis of new esters occurs. For example, the formation of isoamyl acetate and diethyl succinate (Coulter, et al., 2005). During maturation and aging, the concentration of monoterpene alcohol declines and monoterpene oxides are formed. This leads to the loss and alteration of floral aroma. The terpene compound gives a floral aroma to the wine (Coulter, et al. 2005). The oxide terpene derivatives, such as alpherpineol, have a pine like odor; whereas, its precursor linalool has a floral fragrance. In an acidic medium, such as wine, the bound terpenes are slowly converted to free volatile terpenes over time. When these reactions occur, the fruity aroma of a wine is enhanced during maturation (Coulter, et al. 2005). This was experienced in the mango wine.

Colour is one of the most appealing properties of a wine. The colour of mango wine is light yellow. During maturation, when the wine is exposed to air, the colour becomes darker, and with over-aeration, becomes brown (Castellari, et al., 1998). Several phenolic compounds are involved in oxidative reactions. To minimize oxidation and browning, mango wines are generally treated with minimum oxygen

exposure. Besides phenolic oxidation, other reactions such as the Maillard reaction and sugar caramelization contributed to colour in mango wine during fermentation (Buglione and Lozan, 2002).

Many compositional changes contribute to the taste and mouthfeel of mango wine. The important changes include polymerization of phenolic compounds and reduction in acidity (Godden, 2001). Phenolic compounds play an important role in the taste and flavour of wine. Mango wines contain mostly non-flavonoid phenols. Bitterness is primarily attributed to flavonoid phenols (Lubbers, et al., 2001). As flavonoid phenols polymerize, they become less bitter and more astringent (Lubbers, et al., 2001). During maturation, oxidative and non-oxidative polymerization and precipitation of phenolic compounds occurs. This results in a wine with a smoother and softer taste (Buglione and Lozan, 2002). Another factor which contributed to improved mouthfeel was loss of acidity. This occurred due to acid precipitation and ester formation. Acidity enhances the taste and loss of acidity makes wine taste mellow (Coulter, et al., 2005).

4.0 Conclusion

This study demonstrates that mango juice can be used successfully in the production of wine. The best varieties for wine production are Apple and Ngowe due to the high juice content, low acidity and high sugar content. Contrary, Sabine variety is not suitable for wine production, it is suggested that alternative uses should be sought for its utilization. Sensory evaluation results indicated that mango wine possesses a pleasant aroma and mouthfeel and is comparable to grape wine. This study has demonstrated that it is possible to produce wines from locally available mango fruits with acceptable characteristics.

5.0 Recommendations

It is recommended that the output of this research be disseminated to relevant stakeholders within Kenya including farmers, cooperatives, processors and policy makers. Further work is needed to refine the quality of the wine for commercial production.

Acknowledgements

The authors wish to thank Jomo Kenyatta University of Agriculture and Technology (JKUAT) for funding this project and the Department of Food Science and Technology, JKUAT for availing Laboratories for this research work.

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