PRODUCTION, OPTIMIZATION AND CHARACTERIZATION OF MANGO FRUIT WINE: TOWARDS VALUE ADDITION OF MANGO PRODUCE

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Abstract
Mango is commercially grown in more than 90 countries world wide and is consumed both in fresh or processed form. In Kenya, its production has greatly increased for the last ten years leading to a 45% post harvest loss and the main reason being excess fruits in the market during the peak seasons. As a way of mitigating these losses, mango fruits can be processed into various products. Mango wine is a potential value added product; however, there is no proper documentation on information regarding the technological aspects of its production. This study sought to elucidate the scientific and technological approaches in the production of mango wine through optimization of fermentation conditions and appropriate selection of yeast and mango varieties produced in Kenya. Six mango varieties which are abundantly available in the region were screened for their suitability for wine production. Optimization of the fermentation conditions was carried by optimizing the yeast types, inoculum sizes and temperatures by use of fermentation kinetics where as, production of higher alcohols and other volatile compounds during wine fermentation were determined using GC-MC. Effects of storage and browning index of stored wines were determined as wine intensity. For sensory evaluation, wines were compared for color, aroma, taste, and general acceptability on a scale of 1 to 10. It was found that the mango juices were similar to grape juice in terms of sugar and acidity. The sugar content of must ranged from 17.0 to 23.9°brix with Apple variety giving the highest sugar content (23.9°brix) followed by Ng'owe (23.1°brix). Kent gave the highest juice yield (72.83%) followed by Apple (71.34%) and Ng'owe (67.64%) varieties. Fermentation temperature of 25°C and inoculum size of 0.05% gave the best physicochemical characteristics of the wine. After fermentation, the ethanol concentration ranged from 8.89–9.47% w/v, the methanol concentration (129.23 mg/l) was slightly higher than that of grape wines (< 100 mg/l) and other volatile compounds were present in comparable amounts. Apple and Ng'owe varieties gave the most suitable characteristics for mango wine production. Fermentation temperature of 25°C and inoculum size of 0.05% were optimal for wine production using wine yeast. The sensory evaluation showed no significant difference (p=0.05) in the colour, mouth feel, aroma and general acceptability between mango wine and a reference wine.

Key words: Wine production, fermentation, optimization, *Saccharomyces cerevisiae*

1 Introduction

Mango (*Mangifera indica L.)* is one of the most important fruits in the tropics and subtropics. It originated from the Indian subcontinent and reached East Africa by 10th Century. It's commercially grown in more than 90 countries world wide and is consumed both in fresh or processed form. In Kenya, it is the third most important fruit in terms of area and production for the last ten years after banana and pine apple (FAO 2005). In 2007, it was estimated that the area under mango production was 14,387 Ha with an output of 280,884 MT (MoA, 2007). In 2008, HCDA reported 250,000MT of mango production; however, this number greatly increased to 450,000 MT in 2010. This is a clear indication that mango production has tremendously expanded. Gathambiri (2009) reported a percentage post harvest loss of 45% and the main reason cited was excess fruits in the market during the peak seasons.

Postharvest value addition technologies would reduce these losses giving farmers high returns for their crop. Mango fruits can be processed into various products: For instance, the unripe mangoes can be processed to pickles, preserves, dessert and chutneys whereas the ripe mangoes can be processed into dried mango chips, mango wine, mango juice, mango concentrate, mango jam, mango jelly, mango syrup and canned mango.

Despite this great diversity in mango products, most of the mangoes produced are channeled towards the production of mango juice. This can only be attributed to the fact that most farmers have limited information on the processing skills of other mango products. For instance, mango wine is a potential value added product; however, there is no proper documentation on information regarding the technological aspects of its production.

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 (Onkarayya and Signk 1986; Reddy and Reddy, 2005).

Limited research and value addition options for mango juice are available in Kenya. Only one relatively large-size mango processing firm, Milly Fruit Industries, based in Coast Province processes local products. Other local juice and jam makers import mangoes in the form of concentrates mainly from Mauritius, Egypt and South Africa. (Gitonga *et al*, 2009). In principle, therefore, there is a potential for increasing the processing options for mangoes into a variety of high value added shelf stable products. This study explores how scientific and technological approaches can be used for optimal production of high quality shelf stable mango wine.

2 Materials and Methods

2.1 Sample Collection

Six mature and healthy mango varieties, Apple, *Ngo'we*, Tommoy 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. They were then left at an ambient temperature of 25ºC±2 to ripe

2.2 Juice Extraction

Ripened mango fruits were sorted, washed and peeled manually using a knife. 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 Juice Preparation

After extraction, the juice was pasteurized at 60ºC for 10 minutes and cooled immediately with cold tap running water to 25ºC. The pH of the mango juice was adjusted to 4.5 by addition of calcium carbornate and citric acid respectively. None of the varieties was ameliorated with fermentable sugars prior to fermentation.

2.4 Preparation of Yeast Culture

Active dried wine yeast obtained from Kenya Wine Agencies Limited (KWAL) was used. The yeast inoculum size was varied in concentration from 0.0065% (control), 0.01%, 0.05% and 0.1% levels. Prior to inoculation, the yeast strain was rehydrated by adding it in the mango juice at 35ºC for 10 minutes. After 10 minutes, the slurry was allowed to cool and attain the same temperature as of the juice which was at 24ºC±2.

2.5 Fermentation of the Mango Juice

The treated juice was divided into different portions of 500 ml and put in sterile fermentation jars. In order to determine the optimum yeast inoculum size and temperature, the experiments were carried out by incubating the appropriate number of inoculated flasks at different temperatures, 20°C, 25°C, 30°C and 35°C and varying inoculum sizes and the jars shaken intermittently to evolve dissolved CO_2 thus facilitating the fermentation process. The jars were closed using a rubber stopper fitted with a bend tube to release carbon dioxide. Fermentation rate was monitored every 24 hours by checking the ºBx change. End of fermentation was determined when the ºBx could not change any further. After fermentation, the wine samples were centrifuged (Centrifuge Model H–2000C Shimadzu Corp., Kyoto, Japan) at 5,000 rpm for 5 minutes prior to analysis. All the determinations were done in triplicates and the mean values determined. The clear supernatant samples were kept at 0°C for a few weeks until the physicochemical analyses were completed. At the end of fermentation, the wines were stabilized with the addition of 30 mg SO_2/l and preserved. Except for the variables being studied, other procedure of wine fermentation remained the same.

2.6 Effect of Temperature and Inoculum Size on Chemical Characteristics

Juice from Apple mango variety, was used for studying the effects of temperature and inoculum size on the physicochemical properties of wine. The wine was fermented at 25°C and pH 4.5 for 16 days. Composition of volatiles from two mango varieties (Apple and *Ng'owe*) fermented under the same conditions as stated above were also studied.

2.7 Analytical Methods

2.7.1 Juice Yield

This was determined by weighing each mango variety prior to juice extraction and quantifying the juice recovered after extraction as a percentage based on weight basis.

2.7.2 Reducing Sugars

Quantification of reducing sugars present were determined using High Performance Liquid chromatography (HPLC) method as outlined in AOAC (1996). The standard solutions and the sample extracts were injected into HPLC Model LC- 10AS, Shimadzu Corp., Kyoto, Japan fitted with refractive index detector under the following conditions: oven 35°C, flow rate: 0.5-1.0 ml/min, injection volume –

20 µl, column - NH_2P-50 E.A standard curve was drawn and used to quantify the sugar contents of the samples.

2.7.3 pH

This was done by the method of Ofori and Hahn (1994). The pH meter was standardized using buffer solutions of acidic and basic values of 4.01 and 9.08 at 25°C (TOA pH Meter HM–7B, Tokyo, Japan).

2.7.4 Total Soluble Solid (TSS)

The TSS was determined as the total sugars using an Atago hand refractometer (model RX 5000, Atago, Tokyo, Japan). The readings were expressed in ºBx

2.7.5 Total Titratable Acidity (TTA)

The TTA was determined by titrating with 0.1N NaOH in the presence of phenolphthalein indicator as described using AOAC, 1995 method. TTA results were expressed as % citric acid which is the main organic acid in mango fruit (Ueda *et al*, 2000).

2.7.6 Residual Sugars (AOAC 2000)

Residual sugars were determined in °brix using an Atago hand refractometer (model RX 5000, Atago, Tokyo, Japan).

2.7.7 Volatile acidity (VA)

This was determined by titrating the distillates against 0.1N sodium hydroxide (NaOH) and the results expressed as acetic acid (g/l) as described using AOAC, 2000 method.

2.7.8 Analysis of Ethanol and Other Volatile Metabolites

Ethanol was determined by use of a pycnometer where the specific gravity was compared to the corresponding percentage alcohol content. Higher alcohols were determined according to AOAC 1995 established method using Gas Chromatograph (GC - FID) GC-9A, Shimadzu Corporation, Kyoto, Japan model). The conditions were as follows: (glass packed column: diethyleneglycol succinate 15% (3m x 3 mm i.d); injector/detector temperature: 220°C. Nitrogen was used as a carrier gas with a flow of 20 ml/min and the eluted compounds were detected by flame ionization detection (FID) where the fuel gas was hydrogen with a flow rate of 40 ml/min and the oxidant was aired with a flow rate of 40 ml/ min. Glycerol, esters and volatile acids were also determined using GC – FID according to established methods (AOAC, 1995). The compounds to be identified were preliminarily identified from (Reddy and Reddy, 2009). All the analyses were determined in triplicate and the mean ± SD calculated.

2.8 Sensory Analysis

Mango wine was compared with a commercialized grape wine 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 where 9 denoted like extremely and 1 denoted dislike extremely. The ratings for the sensory attributes were analyzed as described by (Ihekoronye, *et al,* 1985).

2.9 Statistical Analysis

All tests were run in triplicate, and analyses of all samples run in triplicate and averaged to determine the mean and standard deviation. The figures were then averaged using Microsoft Excel. Data was assessed using Analysis of Variance (ANOVA) with the Statistical Analysis Software (SAS) Genstat. Standard deviation (S.D) is given by: $\{\Sigma (x-x')^{2,}\}/ (n-1)$. Where Σx is the sum of the sample, x is sample

mean, x' is population mean and n is the number of sample in the population. Significance was accepted at $p \leq 0.05$.

The results were analysed using Genstat 12th edition for Analysis of Variance (ANOVA). Correlation analysis was also done with the same statistical package.

3 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 below. The fruits of different varieties were found to vary in sugar concentrations and other chemical characteristics.

Kent variety gave the highest juice yield (72.83%) followed by Apple, Ng'owe, Tommy Atkins, Vandyke and Sabine. The main prerequisite character of juice for fermentation is sugar content. The total soluble solids (TSS) of the mango ranged from 17.0 to 23.9 ºBx, the highest being exhibited by Apple (23.9 ºBx) whereas the lowest being Sabine and Tommy Atkins.

Table 1: Chemical characteristics of mango juice of different mango varieties

Mango variety	Juice yield (%)	ºBx	Reducing sugars (% w/v)	*p*H	Titrable acidity (%)
Apple	71.34±1.59	23.9±0.21	23.78±1.24	4.25±0.04	0.46±0.04
Ng'owe	67.64±5.70	23.1±0.42	22.23±0.23	4.89±0.03	0.35±0.03
Tommy atkins	67.28±0.94	17.0±0.12	16.94±1.73	4.54±0.04	0.39±0.02
Vandyke	58.92±7.27	21.8±0.06	21.68±0.06	4.74±0.05	0.37±0.01
Kent	72.83±7.04	18.0±0.15	17.91±0.15	4.03±0.03	0.55±0.03
Sabine	52.93±4.93	17.0±0.14	16.95±1.13	3.92±0.03	0.82±0.04

Values are presented as mean ± SD.

n = 3

The titratable acidity as citric acid ranged from 0.35 to 0.82% (w/v). The pH of the juice was 3.92 to 4.89. The lowest pH (3.92) was recorded in Sabine variety which had a sour taste. It was found that the mango juices were similar to grape juice in terms of sugar and acidity. These results suggest that mango juice has a potential for producing good quality wine.

3.2 Optimization of the Fermentation Conditions

3.2.1 Temperature on Chemical Properties of Mango Wine

Alcohol yield was highest when fermentation was conducted at 25ºC for all inoculum sizes. This was also true for the fermentation rate (Table 2). At the same temperature, there was maximum conversion of sugars and fermentation took 16 days to completely utilize the available sugars in the mango juice at 0.05 % yeast inoculum size.

It can also be noted that, although 30 ºC and 35ºC had the highest fermentation rates respectively, the alcohol content was low. Fermentation temperatures of 20°C and 25°C had the highest alcohol yield. The concentration of alcohol decreased as the temperature increased, which has been related to a drop in the ethanol yield and a reduced use of substrate.

Table 2: Physicochemical properties of mango wine at different temperatures at 0.05% S. Cerevisiae inoculum size

parameters	20ºC	25ºC	30ºC	35ºC
Alcohol content (% v/v)	8.07±1.42^{c}	9.44±1.74^{c}	7.20±1.69^{b}	6.93±1.72^{a}
pH	4.09±0.04^{b}	4.08±0.03^{b}	3.98±0.03^{b}	3.98±0.04^{b}
TTA	0.93±0.23^{a}	0.93±0.22^{a}	0.94±0.24^{b}	0.96±0.22^{b}
Residual ºBx	5.5±0.11^{a}	5.3±0.10^{a}	6.4±0.10^{b}	7.4±0.10^{c}
Volatile acidity (g/l as acetic acid)	0.27±0.17^{a}	0.27±0.17^{a}	0.28±0.18^{a}	0.29±0.17^{a}
Fermentation rate *(k)* (º Bx/day)	0.84±0.06^{b}	1.03±0.06^{c}	1.08±0.05^{c}	1.21±0.07^{d}

Means within the same row with different superscripts were significantly different (p<0.05)
Values are presented as mean ± SD
n=3

3.2.2 Temperature on Volatile Compounds

The effect of temperature on the volatile composition of mango wine is presented in Table 3. From the table, all the secondary metabolism products increased as fermentation temperature increased from 20°C to 35°C. Glycerol concentration increased as temperature increased (6.4 g/L at 20°C and 8.9 g/L at 35°C. The concentration of acetaldehyde decreased as the temperature increased. The concentration of ethyl acetate ranged from 9.5 to 35.7 mg/L, as the lowest values were observed in experiments with high temperature (35°C). The acceptable range of acetaldehyde and ethyl acetate is 13 to 40 g/L and 50 to 75 mg/L, respectively (Adsule, *et al*., 1992). The concentration of higher alcohols increased with temperature. The total concentrations of higher alcohols were 286 mg/L at 20°C and 380 mg/L at 30°C; in contrast, the concentration decreased to 350 mg/L at 35°C as compared with 30°C.

Table 3: Effect of temperature on volatile compounds production (mg/L) of mango wine from apple variety fermented at 25°C and pH 4.5 for 16 days at 0.05% inoculum size

Metabolite (mg/l)	20°C	25°C	30°C	35°C
Ethanol (% v/v)	8.07± 0.53	9.44± 0.42	7.20± 0.65	6.93± 0.51
Acetaldehyde	17.4 ± 0.51	18.2 ± 0.51	25.0 ± 1.15	25.5 ± 1.15
Ethyl acetate	35.7 ± 1.28	35.2 ± 1.28	22.1 ± 0.78	9.8 ± 0.63
1-Propanol	43.9 ± 2.45	44.6 ± 2.45	52.3 ± 1.53	41.9 ± 3.60
Isobutanol	91.4 ± 1.31	93.9 ± 1.31	110.7 ± 1.98	93.2 ± 1.88
Isoamyl alcohol	123.8 ± 5.78	124.2 ± 5.78	204.1 ± 5.68	154.6 ± 7.49
Phenyl ethanol	28.1 ± 1.23	28.8 ± 1.23	26.5 ± 0.58	22.2 ± 1.83
Glycerol (g/l)	6.4 ± 0.38	7.0 ± 0.38	7.8 ± 0.56	9.0 ± 0.67

Acetic acid	0.16 ± 0.04	0.16 ± 0.04	0.47 ± 0.03	0.54 ± 0.05
Methanol	126.8 ± 6.12	129.3 ± 6.12	118.1 ± 5.42	123.7 ± 6.86

Values are presented as mean ± SD
n=3

In general, the threshold value of higher alcohols was 200 to 400 g/L. Temperature affected not only the fermentation kinetics (rate and length of fermentation) but also the yeast metabolism, which determined the chemical composition and in turn the quality of wine.

The alcohol concentration decreased as the temperature increased, which is due to the increase in the concentration of products from other metabolic pathways such as glycerol and acetic acid (Reddy and Reddy, 2005). It was found that ester formation was greatly influenced by temperature.

3.2.3 Temperature on Fermentation Kinetics

Figure 1 shows the effects of temperature on the fermentation kinetics at 0.05% inoculum size.

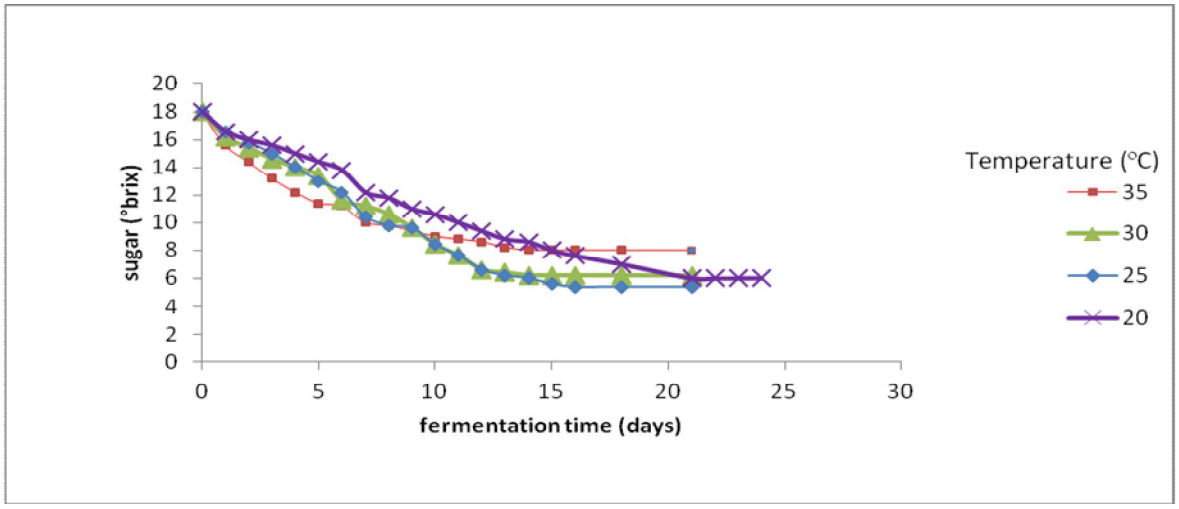

Figure 1: Effects of temperature on substrate utilization at 0.05% inoculum size

Initial fermentation rates increased as the temperature increased due to the high temperature which increased the enzyme activity. At 20 ºC the fermentation rate was slow; it took 21 days to completely utilize the sugars, as compared to 25 ºC where fermentation took 16 days.

3.2.4 Yeast Inoculum Size on Physicochemical Properties of Mango Wine

From Table 4, it can be implied that the level of inoculum size had no effect on pH, titrable acidity and volatile acidity of the mango wine. Inoculum size of 0.05 % gave the highest alcohol yield as compared to the rest of the inoculum sizes. There was no significant difference (p>0.05) in the physico-chemical properties of mango wine produced from 0.1% and 0.05% yeast inoculum sizes. As a result, inoculum size of 0.05% was selected for the remaining studies.

Alcohol production increased with increase in inoculum size up to 0.05%. Higher levels of inoculum gave almost same amount of alcohol content, such as 0.05% inoculation gave 9.44% of alcohol content, while

0.1% inoculum concentration gave 8.67% alcohol. From this, it can be shown that as the concentration of yeast inoculum is increased, yeast converted more sugars to alcohol, while at higher concentration yeast was not able to utilize more sugar for conversion as in the case of 0.1%.

Table 4: Chemical properties of mango wine at different inoculum sizes at 25ºC

Parameters	0.1%	0.05%	0.01%	0.0065% (control)
Alcohol content (% v/v)	8.67±0.04^{c}	9.44±0.04^{c}	7.20±0.04^{b}	6.93±0.04^{a}
pH	4.09±0.02^{b}	4.08±0.02^{b}	4.05±0.02^{b}	4.08±0.02^{b}
TTA	0.93±0.06^{a}	0.93±0.07^{a}	0.94±0.06^{a}	0.93±0.07^{a}
Residual ºBx	5.4±0.10^{a}	5.4±0.10^{a}	6.0±0.20^{b}	7.4±0.10^{c}
Volatile acidity (g/l as acetic acid)	0.27±0.14^{a}	0.27±0.13^{a}	0.28±0.13^{a}	0.29±0.13^{a}
Fermentation rate*(k)* º Bx/day	1.23±0.06^{b}	1.16±0.05^{d}	1.05±0.06^{c}	0.97±0.06^{d}

Means within the same row with the same superscript were not significantly different (p>0.05)
Values are presented as mean ± SD
n=3

3.2.5 Yeast Inoculum Size on Substrate Utilization

As it can be seen from Figure 2, the higher the inoculum size, the higher will be the initial fermentation rate. At 0.0065% inoculation it was slowest and decrease in sugar level is from 18 to 15ºBx after initial four days of fermentation. At 0.1% inoculum it was fastest indicating a decrease in sugar concentration from 18ºBx to 12.4 after initial four days. Experiments with higher inoculum size rapidly reached the completion of fermentation and at the later stage of fermentation the decrease in ºBx were slower and it was more or less equal in all the cases.

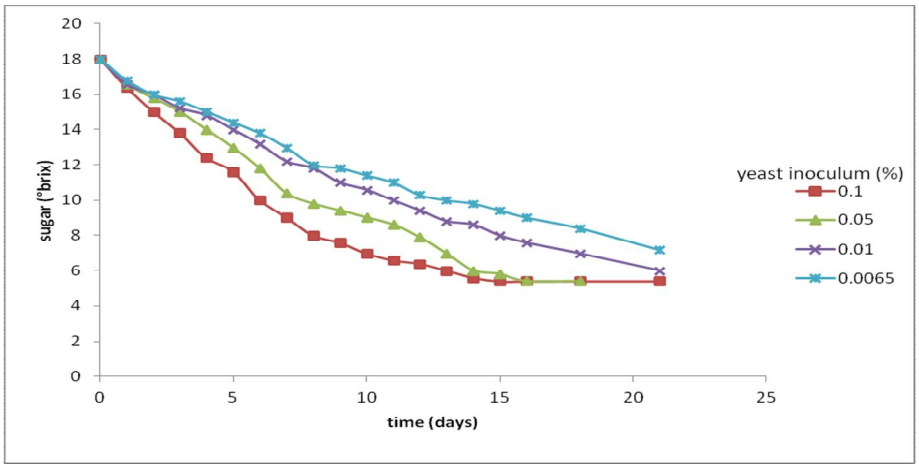

Figure 2: Substrate utilization during the fermentation of mango juice from apple variety at 25ºC

3.3 Characteristics of the Mango Wine

3.3.1 Physicochemical Properties

The physicochemical properties of mango wine fermented with wine yeast at 25^{o}C, pH 4.5 and inoculum size of 0.05% are shown in Table 5. The principal metabolite produced from the mango juice was ethanol. In general, the concentration of ethanol contributes to the whole characteristic quality and flavour of the produced wine. The percentage of ethanol produced from the mango juices was between 8.89 and 9.47% w/v, comparable with moderate grape wines.

Table 5: Physico-chemical characteristics of mango wine from apple and Ng'owe varieties

Mango variety	Alcohol content (% v/v)	Residual ^{o}Bx	pH	TTA (%)	Volatile acidity (v/v)	Colour OD (420 nm)
Apple	9.47±1.24	5.4±0.04	3.98±0.21	0.96±1.24	0.37±0.04	0.22±0.01
Ng'owe	8.89±1.46	5.4±0.03	4.06±0.42	0.81±0.23	0.49±0.03	0.20±0.01

Values are presented as mean ± SD.
n=3

According to Michael (2000) a good table wine must have alcohol content between 8 and 14%, which is within the range obtained for mango wines. The acidity of mango wine ranged from 0.81 to 0.96% (v/v) (as tartaric acid). 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 mean a poor fermentation (Berry, 2000). The volatile acidity (as acetic acid) of the wine was between 0.37 and 0.49%(v/v) which is within the range of 0.3 to 0.6% reported for wines (Amerine *et al*, 1980).

3.3.2 Volatile Composition

From Table 6 below, it was observed that the wine produced had their methanol content varying between 126 mg/l to 129 mg/l. The methanol produced in the mango wine was significantly higher when compared to the grape wine. Grape wine normally contains less than 100 mg/ l methanol content. (Reddy and Reddy, 2005). According to previous reports these methanol levels are not potentially injurious to health (Craig 1998; Soufleros *et al.* 2001). The human oral lethal dose for methanol is 340 mg/kg body weight (Reddy and Reddy, 2009). 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 and Reddy, 2005).

Table 6: Composition of volatile compounds by Gas Chromatography–Mass Spectroscopy (GC-MS) from two mango varieties (Apple and Ng'owe) fermented at 25ºC and pH 4.5 for 16 days at 0.05% inoculum size of wine yeast

Name of the Compound	Apple	*Ng'owe*
Metabolites (mg/l)		
Ethanol (% v/v)	9.47± 1.24	8.89± 1.46
1-Propanol	56.11± 1.21	38.32± 0.54
Isobutyl alcohol	105.40± 0.87	111.14± 0.76
Isoamyl alcohol	119.2± 0.62	112.40± 0.25
Phenethyl alcohol	24.15± 0.41	26.15± 0.31
Methanol	129.23± 5.34	126.15± 6.11
Aldehydes		
Acetaldehyde	18.2 ± 0.51	21.42± 0.33
Esters		
Ethyl acetate	33.15± 0.73	27.42± 0.82
Acids		
Acetic acid	0.198± 0.96	0.167± 0.55
Propanoic acid	0.139± 0.78	0.217± 0.47
Butanoic acid	0.936± 0.13	0.751± 0.18

Values are presented as mean ± SD.
n=3

Acetaldehyde content varied between 18 to 21 mg/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. The volatile acids present in the mango wine were acetic acid, propanoic acid, and benzoic acid.

3.4 Wine Colour Determination and Sensory Analysis

Wine stored in brown bottles at low temperature showed low browning indices (0.23) when compared to wine stored in green and clear white bottles (0.25). Wine intensity increased with time and storage temperatures. Mango wine in clear white bottles stored at 20°C and 25°C had a higher browning index (0.29).

The results for sensory evaluation of mango wine are presented in Table 7. There was no significant difference (p=0.05) in clarity and general acceptability between the mango wine and the reference wine from grapes. However, the reference wine received higher ratings for clarity (7.0) than the mango wine (6.8).

Table 7: Sensory evaluation for mango wine and a reference wine from grapes
Sensory parameters

Wine sample	Colour	Mouth feel	Aroma	Clarity	General acceptability
Mango wine (Apple variety)	7.2^{a}	6.8^{b}	7.8^{b}	6.8^{a}	6.8^{d}
Grape wine (reference)	6.9^{b}	7.2^{c}	7.4^{c}	7.0^{a}	7.0^{dc}

Means within the same column with the same superscript were not significantly different (p=0.05)

4 Conclusion

Based on these studies, it can be concluded that a 16 day fermentation at 25°C and pH 4.5 and inoculum size of 0.05% yields optimal fermentation characteristics for mango wine production using wine yeast. The sensory evaluation has indicated that mango wine possesses novel characteristics in aroma and taste and good acceptability. Therefore, as mango production is tremendously increasing in Kenya, their use in wine production would greatly reduce the cases of post harvest losses and thus go a long way in contributing considerably to the economy of not only Kenyans but also international mango producers. More so, information on adequate process for both juice and wine production from mango and other tropical fruits can be of valuable reference to the wine industry.

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