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Production of Mixed Fruit Wine Using *Saccharomyces cerevisiae* from Palm Wine

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This study aimed to produce mixed fruit wine from watermelon (*Citrullus vulgaris* L.), apple (*Malus domestica*), banana (*Musa acuminata*), and avocado (*Persea americana*) using *Saccharomyces cerevisiae* isolated from palm wine. Fruits were sourced from Oba Market, Edo State, Nigeria, and fresh palm wine was obtained from Aruogba community for yeast isolation. *Saccharomyces cerevisiae* was identified, cultured on potato dextrose agar (PDA), and used to initiate must fermentation with palm wine sediments. A yeast starter culture was prepared, followed by primary fermentation and racking into secondary fermentation for 21 days. Bentonite was used for clarification, and proximate and physicochemical analyses were performed. Results indicated the highest heterotrophic fungi count (64 CFU/ml) in Palm Wine 3 and the lowest (12 CFU/ml) in Palm Wine 2. The total heterotrophic bacterial count was highest in Fruit Blend 2 (40 CFU/ml) and lowest in Fruit Blends 1, 3, and 4 (20 CFU/ml). Proximate analysis showed watermelon with the highest moisture content (95.11%), avocado with the highest ash content (0.65%), and fat content ranging from 0.13–4.17%, with mixed fruit wine at 1.01%. Protein content was highest in bananas, with mixed fruit wine recording 4.78%. Nutrient analysis revealed elevated levels of sodium, potassium, zinc, manganese, and iron in the mixed fruit wine. Sensory evaluation indicated Wine 3 as the most preferred, achieving a 100% flavour score, underscoring the influence of fruit combinations on acceptability. These findings suggest that mixed fruit wine formulation can be optimized for enhanced sensory appeal and nutritional quality, with potential for further research into specific fruit proportions to improve production outcomes.

Keywords: fruit blend, fermentation, wine, yeast, starter culture.

Introduction

Fruit wine production plays a crucial role in the beverage industry, offering a diverse and refreshing alternative to traditional grape wines (Saranraj et al., 2017). With their unique flavours and aromas derived from various fruits such as apples, berries, and tropical fruits, fruit wines have gained popularity among consumers seeking novel taste experiences. Moreover, fruit wines cater to a wider audience by accommodating those with dietary restrictions or preferences, as they are often gluten-free and vegan-friendly. The significance of fruit wine production lies not only in its ability to satisfy the evolving palates of consumers but also in its contribution to the economic growth of regions known for their fruit cultivation. *Saccharomyces cerevisiae*, commonly known as brewer's yeast, plays a crucial role in fermentation processes for fruit wine production (Walker and Stewart, 2016). This versatile yeast strain is well-suited for converting sugars into alcohol and carbon dioxide, making it an ideal choice for wine-making. Its ability to efficiently metabolise sugars and produce desirable flavours and aromas contributes to the overall quality of fruit wines.

Wines can occasionally be made from a variety of fruits, including pawpaw, mango, pineapple, banana, lemon, and watermelon. Here, the wine created in this manner carries the name of the fruit or fruit blend that was employed in its production (Alba-Lois and Segal-Kischinevzky, 2010). Wine is a good source of vitamins, numerous vital amino acids, minerals, fatty acids, and other nutrients, but other fruits with similar properties have been found and are also useful for making wine. During fermentation, microscopic single-celled organisms known as 'yeast', such as *Saccharomyces cerevisiae*, use the sugar contained in fruit juice as a source of carbon, producing alcohol and carbon dioxide gas in the process. According to Okoro (2017), wines are categorised according to a range of factors such grape variety, place of origin, colour before fermentation, and production methods (Amerine et al., 2012). Wine has been produced and enjoyed by many people, from peasants to kings, for thousands of years. For example, the consumption of red wine is known to have a remarkable protective effect against oxidative stress in blood plasma (Banc et

al., 2022). Most wines consumed in Nigeria are fermented, aged, bottled, and largely imported (Michelle et al., 2007). However, the high tariffs on imported goods (including fermented foreign wines/beverages) in Nigeria have made them very expensive and unaffordable in some cases, thus increasing the demand for locally fermented wines.

Globally, microbial cultures are employed to produce fermented foods and alcoholic beverages. Bacteria, yeast, and mixed cultures are used exclusively in the preparation of fermented foods (Djegui et al., 2014). Many of the world's traditional fermented staple foods and beverages depend heavily on yeast for their manufacturing, with the primary substrates for fermentation being grains (Jimoh et al., 2012; Djegui et al., 2014). Palm wine is prepared from the sap of many palm trees, including the palmyra and the coconut palm. In the western part of Nigeria, this is frequently referred to as "emu" and "oguro", with microorganisms such as *Candida pelliculosa*, *Rhodotorula glutinis*, *Cryptococcus albidus*, *Trichosporon asahii*, *Rhodotorula mucilaginosa*, *Candida magnolia*, *Candida utilis*, and *Candida colliculosa* being among the yeast species isolated from palm wine (Nwachukwu et al., 2008; Jimoh et al., 2012). This study aims to bridge the gap in current knowledge by exploring the potential of indigenous *Saccharomyces cerevisiae* from palm wine in mixed fruit wine production. The findings are expected to enhance the quality and diversity of fruit wines, provide economic benefits to fruit-producing regions, and contribute to sustainable and culturally rich production practices.

Materials and Methods

Collection of Samples

Fresh matured ripe banana (*Musa acuminata*), watermelon (*Citrullus vulgaris* L.), apple (*Malus domestica*), and avocado (*Persea americana*) were purchased from Oba Market in Oredo Local Government Area, Edo State, Nigeria. Fresh palm wine was obtained from palm trees in Aruogba community, in Oredo Local Government Area, Edo State, within one (1) hour of tapping. Palm wine was extracted from a mature palm tree using a sterile plastic jug and a small tube. The sap was collected in the early morning to ensure maximum yield and freshness. The sap was then transferred into sterilised glass bottles, sealed to prevent contamination and retain its freshness. The bottles were placed in an ice box to preserve quality during transportation to the laboratory for further analysis.

Study Design

Isolation and Identification of Yeast from Palm Wine

Culturing of the fresh palm wine was done on Potato Dextrose Agar (PDA) and incubated at room temperature for 24 h. Nineteen (19) microorganisms were obtained and sub-cultured on fresh medium to obtain pure culture. The yeast cultures were transferred to PDA containing yeast extract and 2% glucose and then incubated for another 24 h. The yeast isolates were characterized considering cultural, morphological, and biochemical properties by standard methods described by Igiebor and Osarumwense (2021), and identification followed the keys of Kurtzman and Fell (1998). *Saccharomyces cerevisiae* were further screened for their ability to tolerate different concentrations of sugar and alcohol by inoculating in PDA supplemented with 10–60% and 5–30% sucrose and ethanol, respectively. The isolate with the highest sugar and alcohol tolerance was selected and used as the starter culture. The identified organism was maintained on nutrient agar (NA) slant.

Multiplication of Starter Culture

The isolated organism was multiplied prior to fermentation by culturing them on malt extract broth (MEB) using a centrifuge at 2000 revolutions per minute (rpm) for 10 min and incubated for 48–72 h at 27 °C. The sediments were collected and used for must fermentation.

Preparation of Must for Mixed Fruit Fermentation

The must was prepared from four mixed fruits for fermentation. The fruits were washed thoroughly with distilled water and then peeled. The four fruits were weighed individually: apple (50 g), banana (150 g), watermelon (400 g), and avocado (200 g), then chopped into smaller pieces using a clean knife before transferring them separately into a blender for blending. The crushed sample was transferred into clean bowls separately; 2000 ml (2 L) each of the crushed fruit was transferred into a transparent bucket and stirred. Exactly four grams (4 g) of sodium metabisulphite ($Na_2S_2O_5$) was dissolved in 400 ml of water and poured in 100 ml (0.1 L) aliquots to the mixture and stirred properly. Sodium metabisulphite served as a stabilizer and prevented fermentation before the addition of the yeast starter.

Preparation of Yeast Starter Culture

The method of Thungbeni et al. (2020) was adopted with slight modifications. The yeast starter culture was prepared from a 2000 ml (2 L) quantity of the must for fermentation, 2 g of sucrose, 1 g of yeast, and 500 ml of water. The mixture of all these was treated with yeast nutrients and allowed to stand for 24 h. Approximately 200 ml of water was boiled and allowed to attain 37 °C, and 200 ml of the mixture of must (banana, apple, avocado, and watermelon) was treated with 1 g of sucrose. A 5 g of citric acid was added to each preparation and then stirred for proper mixing. Precisely 2 g each of the yeast nutrients, namely potassium phosphate, ammonium sulphate, and magnesium sulphate, was dissolved in 100 ml of water and poured into the must mixture. Exactly 3.7 ml, representing approximately cfu/ml (measured using McFarland standard), of the yeast (*Saccharomyces cerevisiae*) isolated from palm wine after centrifugation was added to each mixture, stirred properly, and allowed to stand for 24 h before use.

Fermentation

This was carried out using the method of Thungbeni et al. (2020) with slight modifications. The primary fermentation was initiated by the addition of the 200 ml starter culture. Precisely, 4 L of the must was stirred every 12 h with subsequent readings of the specific gravity, pH, temperature, and alcohol content for 4 days. After 4 days, the wine was racked into the secondary fermenter. The secondary fermentation was done in an airtight

container in which a tube was passed into a clean bottle containing clean water. The essence was to monitor the fermentation process. This was allowed until completion of fermentation, as evidenced by the lack of appearance of bubbles in the container, usually within 3 weeks. Secondary fermentation was done for 21 days. When fermentation stopped, the wine was promptly racked off the lees, ensuring minimum exposure to oxygen. After secondary fermentation, the wines were clarified using bentonite (a clarifying/fining agent) to remove any remaining particles and sediment. This process helped improve the wine's clarity and stability, ensuring a clean and crisp final product for bottling. Precisely, 500 g of bentonite was dissolved in 2 L of boiling water and stirred properly to a gel form. This was allowed to stand for 24 h. Then, 250 g of the gel-like bentonite was transferred into each of the wines, followed by stirring to dissolve properly. A 200 ml of the mixture was collected in a 250 ml conical flask, which was covered tightly and used to monitor the process of clarification, which was done for a period of 3 months. Filtration was done after the wines had completed clarification using muslin cloth, sieve, and syphon tubes sterilized by 70% alcohol. The wine was syphoned into the sieve containing four layers of muslin cloth. The residues were removed, and the filtrates were allowed to mature for a period of 6 months before other chemical analyses were carried out.

Isolation of Microorganisms from the Fermentation Broth

The microbial analysis of fermentation broth mixtures was conducted using the method described by Fleet (2003). The total heterotrophic count (THC) for bacteria was determined using the pour plate method, using nutrient agar (NA) medium supplemented with fulcin (50 mg/20 ml of NA) to suppress fungal growth. Enteric bacteria were enumerated using MacConkey Agar (MA) medium, and colonies formed were counted. Fungal (yeast) count was determined using the spread plate method, using Potato Dextrose Agar (PDA) supplemented with 50 μg/ml of chloramphenicol to suppress bacterial growth. Serial dilutions of the broth were prepared, and a specific volume of each dilution was spread evenly on the surface of solidified PDA plates. The plates were incubated at 25 °C for 3–5 days, and colonies formed were counted to determine the fungal count. The results of these analyses provide valuable insights into the microbiological composition and growth of fermentation broth mixtures. Pure cultures were obtained by streaking and identified based on colonial characteristics, microscopy, and biochemical tests (Fawole and Oso, 1988; Onyeagba, 2004). The fungi were identified only on the basis of their spore morphology (Isitua and Ibeh, 2010; Barnett et al., 2000).

Chemical Analysis of the Wines

The volatile acidity was determined using the method described by McClements (2003), total acidity of of the wines was determined by titration, and the concentration of the acid was calculated. The residual acidity of the wines was also determined as described by McClements (2003), while the alcohol content was determined using the density method as described by McClements (2003). The specific gravities of the wines were determined using the hydrometer method, and the results were determined from the reading on the stem (Awe, 2011). The total solid and total sugar content of the wines were determined using the method of McClements (2003), and the pH and temperature were determined using a digital pH meter (PHS-25C, China) and an analytical thermometer (Traceable™ Platinum High-Accuracy Thermometer, USA), respectively.

Determination of Alcohol Content During the Production of the Wine

One hundred (100) ml of the produced fruit juice in a capacity graduated cylinder (Pyrex® Glass Graduated Cylinder) were refrigerated for 15 min until the temperature of the wine reached 15 °C. The alcohol meter was allowed to float freely on the sample, and then the alcohol content was recorded. The reading was expressed as percentage (%) alcohol (Chim et al., 2015).

Proximate Analysis

The proximate composition of the fruit and the produced wine were analyzed using the Association of Official Analytical Chemists (AOAC) method, and selected parameters (titratable acidity, pH, and temperature) were determined using the Association of Official Analytical Chemists (AOAC) method as described by Balogu et al. (2016). The percentage proximate parameters analyzed include moisture content, ash, protein, crude fibre, crude fat, and carbohydrate as described by Moronkola et al. (2011).

Mineral Analysis

The minerals in the fruits and wine samples were analyzed using a spectrophotometer. The sample (2 ml) was collected in a 50 cm^3 volumetric flask, followed by 2 ml of perchloric acid, 1 ml of H_2SO_4, and 5 ml of HNO_3. The mixtures were placed on a water bath and evaporated almost to dryness. The solution was cooled and filtered into a 100 ml standard flask and diluted to volume with distilled water. An atomic absorption spectrophotometer was used to analyze the minerals separately.

Microbial Analysis of the Produced Fruit Wine

The microbial quality of the fruit wine was evaluated by inoculating the wine on PDA (yeast) and incubating it at 25 °C for 3–5 days. Whereas, in nutrient agar, the bacterial isolates were incubated at 37 °C for 24 h to determine the total heterotrophic yeast and bacteria, respectively. Upon establishment of viable growth, it was thereafter subcultured, and Gram staining and relevant biochemical assays (catalase test, coagulase test, oxidase test, indole, motility, and sugar fermentation/utilisation test) were performed in accordance with the method of ISO (International Standard Organisation) (Balogu and Towobola, 2017).

Sensory Evaluation of the Fruit Wine

A total number of 25 panelists amongst Wellspring University staff and students were selected to carry out sensory evaluation of the wine on a 9-point hedonic scale, and the methodology for monitoring the performance of the sensory panel followed.

Result

Table 1 shows the total fungal count from palm wine culture. The highest fungal count was recorded in Palm Wine 3 with 64 CFU/ml, followed by Palm Wine 1 with 20 CFU/ml. However, the lowest count was observed in Palm Wine 2 with 12 CFU/ml.

Table 1 Total fungal (yeast) count from fresh palm wine

Samples	Potato Dextrose Agar ($\times 10^3$ cfu/ml)
PW1	20
PW2	12
PW3	64

Key: PW1 = Palm wine 1; PW2 = Palm wine 2; PW3 = Palm wine 3.

Table 2 shows the total heterotrophic bacterial counts from the fruit blend. For total heterotrophic bacterial counts, the highest counts was observed in Fruit blend 2 with 40 CFU/ml while the lowest growth was recorded in Fruit blend 1, 3 and 4 with 20 CFU/ml.

Table 2 Total heterotrophic bacterial counts from the fruit blend

Samples	Nutrient Agar ($\times 10^3$ cfu/ml)
MT1	20
MT2	40
MT3	20
MT4	20

Key: MT1 = Fruit blend 1; MT2 = Fruit blend 2; MT3 = Fruit blend 3; MT4 = Fruit blend 4.

Table 3 shows the morphological and cultural characteristics of bacteria isolated from fermented broth. The isolates identified were Escherichia coli, Lactobacillus specie, Micrococcus specie, Staphylococcus aureus, Bacillus subtilis, Lactobacillus specie.

Table 4 shows the biochemical characteristics of the yeast isolated in this study. Saccharomyces cerevisiae was isolated and identified according to standard procedures.

Table 5 shows the proximate analysis of selected fruit and mixed fruit wines. The moisture content of banana, avocado, apple, and watermelon was 66.10, 67.21, 84.20, and 95.11 %, respectively. Watermelon had the highest moisture content (95.11 %), compared to banana, which had the lowest content (66.10 %). Ash content ranged from 0.18–0.65 %. The highest content was recorded in avocado with 0.65 %, while the lowest was recorded in watermelon with 0.18 %. Fat and lipid content ranged from 0.13–4.17 %. The lowest content was recorded in watermelon with 0.13 %, while the highest was recorded in avocado with 4.17%. However, the fat and lipid content in the mixed fruit wine was 1.01 %. Crude fiber content ranged from 0.44 % to 16.46 %. The highest content was observed in avocado with 16.46 %, while the lowest was observed in watermelon with 0.44 %. Carbohydrate contents ranged from 3.89 to 21.57 %. The lowest content was reported in watermelon with 3.89%, while the highest was reported in banana with 21.57 %. However, the carbohydrate content of mixed fruit was 10.89 %. The protein content in bananas was the highest with 7.40 %, while the lowest content was reported to be in watermelon with 0.31 %. However, the protein content of the wine was 4.78 %. The vitamin C contents of apples, avocados, mixed fruit wine, watermelon, and bananas were 4.91, 5.31, 5.45, 7.31, and 8.26 mg, respectively. The vitamin B2 content ranged from 1.02 to 3.30 mg. The highest content was reported in mixed fruit wine with 3.30 mg, while the lowest was reported in avocado with 1.02 mg. Vitamin B3 contents ranged from 1.17 to 4.22 mg. The highest was observed in mixed fruit wine with 4.22 mg, compared to apple with the lowest content of 1.10mg. Vitamin B6 content ranged from 1.07 to 2.60mg. The lowest content was reported in apples with 1.07 mg, whereas the highest was reported in mixed fruit wine with 2.60 mg.

Table 6 shows the nutrient composition of selected fruits and mixed fruit wine. Sodium concentration ranged from 6.08 – 8.53 mg/l, with the highest recorded in avocado with 8.53 mg/l while the lowest was reported in banana with 6.08 ppm. Potassium content ranged from 186.37 – 390.22 mg/l. The highest content was observed in 390.22 mg/l while the lowest content was observed in 186.37 mg/l. However, the potassium content in mixed fruit wine was 288.83mg/l. Zinc concentration ranged from 0.15 – 0.45 mg/l. The highest concentration was observed in mixed fruit wine with 0.45 mg/l while the lowest was observed in apple with 0.15 mg/l. Manganese content was highest in banana with 1.24 mg/l whereas it was lowest in avocado with 0.13 mg/l. Iron content across the samples ranged from 0.30 – 4.30 mg/l. The highest content was observed in avocado with 4.30 mg/l while the lowest value was observed in watermelon with 0.30 mg/l. However, the value observed in the mixed fruit wine was 3.21 mg/l. Figure 1 shows the physicochemical properties of the must during primary fermentation for 4 days. The duration is 12 hours for this exercise. The specific gravity of the must during this period decreases from 30 to 1.Temperature remain constant at 25℃. The Alcohol (%) content decreased from 35 to 10. The pH reading was decreased from 3:30 to 3.40 maintaining the norm and pH level of wine from 3.0 to 3.50 during production Table 7 shows the physiochemical parameters after 3 weeks of secondary fermentation. The specific gravity is 1, the alcohol content (%) is 10, and the temperature remains 25 °C. Total pH which is high, making total acidity low. pH was 4.80, total acidity was 2.15, and total sugar was 10.89.

Table 8 shows the sensory evaluation of wine using the hedonic scale. Wine 1 scored the highest for pale wine (88 %), followed by wines 2 (64 %), 3 (60 %), 4 (8 %), and 5 (4 %). There were similar responses (12 %) in wines 2, 3, and 4, respectively, in terms of midstraw appearance. Deepstraw had responses of 16 % in wines 3 and 4. However, yellow and gold colours had variegated reposes for wines 4 and 5. In terms of brilliance, it was observed that wine 2 scored 78% (opaque) when compared to other wines with opacities of 8% and 68% across the wines. However, wines 4 (80 %) and 5 (72 %) scored higher in terms of clarity. For texture, it was observed that the score for oily wine ranged from 16 to 32 %. Creamy texture ranged from 8 to 28 %, crunchy texture ranged from 4 to 44 %, with wines 4 and 5 scoring the highest point of 44 %. However, 20–48 % of the respondents did

Table 3 Morphological and Cultural Characteristics of bacteria isolated from fermented broth

Samples	Shapes	Colour	Elevation	Margin	Surface	Opacity	Gram reaction	Isolates
MT1	Irregular	Pink	Flat	Entire	Dry	Opaque	-ve	*Escherichia coli*
	Irregular	Milky	Raised	Entire	Moist	Opaque	+ve	*Lactobacillus* specie
MT2	Irregular	Milky	Raised	Entire	Moist	Opaque	+ve	*Micrococcus* specie
	Regular	Milky	Flat	Entire	Moist	Opaque	+ve	*Staphylococcus aureus*
MT3	Irregular	Milky	Flat	Entire	Wet	Opaque	+ve	*Bacillus subtilis*
	Irregular	Milky	Raised	Entire	Moist	Transparent	+ve	*Lactobacillus* specie
MT4	Irregular	Milky	Flat	Entire	Moist	Opaque	+ve	*Staphylococcus aureus*

Key: MT1 = Fruit blend 1; MT2 = Fruit blend 2; MT3 = Fruit blend 3; MT4 = Fruit blend 4; +ve = positive; -ve = negative.

Table 4 Morphological and biochemical characteristics of *Saccharomyces cerevisiae* isolated from palm wine

Characteristics	Result
Colony features	Smooth, moist, cream, coloured colonies
Microscopy	Spherical, elongated cells with multilateral budding
Gram reaction	Positive, ascospore negative
Ascospore	+
Growth at 25°C on PDA	+
Germ tube	-
KNO_3	-
Glucose	+
Dextrose	+
Maltose	+
Sucrose	+
Galactose	+
Raffinose	+
Trehalose	+
Lactose	-
Mannitol	-
Melibiose	-
Cellobiose	-
Xylose	-
Ducitol	-
Budding cells	+
Surface	Moist
Pellicle formation	-

Key: + = positive; - = negative.

not respond. For aroma, 56–68 % of the respondents liked the aroma of wines 3–5, whereas 78 % disliked the aroma of wine 1. In terms of taste, wine 3 scored the maximum of 100 % (sweet), while wine 4 and 5 both scored 60 %. However, wine 1 and wine 2 scored 92 and 60 %, respectively, for having a sour taste.

Discussion

It is well known that the fermentation of wine involves a variety of ecological and biochemical processes involving yeast strains (Fleet, 2003). The ability of the yeast to convert sugar into alcohol and esters is believed to be a key factor in the fermentation process used to create beverages. According to Duarte et al. (2010), the flavour and aroma of the finished product are determined by the many species of yeast that emerge during fermentation. *Saccharomyces cerevisiae* was discovered to be positive for glucose, sucrose, mannitol, maltose, galactose, trehalose, rafinnose, and dextrose after the traditional sugar fermentation and characterization.

In this study, the moisture content of mixed fruit wines was found to be slightly lower compared to the individual fruits, with an average of 60.85%. This suggests that the fermentation process used in wine production reduces the moisture content of the fruits. The result obtained in this study is contrary to the report of Mohammed et al. (2022), who reported about 100% moisture content in their mixed fruit wine samples. This discrepancy could be due to variations in fermentation techniques or differences in the types of fruits used in the study. Further research is needed to explore these factors and their impact on moisture content in mixed fruit wines. Also, it is worth noting that watermelon had the highest moisture content among all the fruits analysed, indicating its high water content.

The variation in ash content among the fruits could be attributed to differences in mineral composition. However, this is close to the range of 0.38% reported by Mohammed et al. (2022) in green grape wine. Avocado, known for its high fat content, may have higher ash content due to the presence of minerals in its fatty tissues. On the other hand, watermelon's low ash content could be indicative of its relatively lower mineral composition compared to the other fruits.

The fat and lipid content varied significantly among the fruits, with watermelon having the lowest content of 0.13% and avocado having the highest content of 4.17%. However, the mixed fruit wine had a moderate fat and lipid content of 1.01%. Furthermore, the crude fibre content in the fruits also varied greatly, with avocado having the highest content of 16.46%. In addition to the varying fat and lipid content, the fruits also exhibited different carbohydrate contents. Watermelon had the lowest carbohydrate content at 3.89%, while banana had the highest at 21.57%. On the other hand, the mixed fruit had a moderate carbohydrate content of 10.89%. The report of this study is contrary to the report by Balogu and Towobola (2017), who reported lower carbohydrate levels of 4.9 and 6.17%, respectively. The varying carbohydrate and protein contents of the fruits suggest that they can provide different nutritional benefits. For example, watermelon's low carbohydrate content makes it a suitable option for those following a low-carb diet, while bananas' high

Table 5 Proximate composition of selected fruits and mixed fruit wine

Parameter	Banana	Apple	Watermelon	Avocado	Mixed fruit wine
Moisture content (%)	66.10	84.20	95.11	67.21	60.85
Ash content (%)	0.36	0.59	0.18	0.65	0.35
Fat/Lipids (%)	2.89	0.29	0.13	4.17	1.01
Crude fibre (%)	1.64	0.87	0.44	16.46	4.85
Carbohydrates (%)	21.57	12.28	3.89	8.40	10.89
Protein (%)	7.40	0.87	0.31	3.11	4.78
Vitamin C (mg/100g)	8.26	4.93	7.31	5.31	5.45
Vitamin B2 (mg/100g)	2.20	1.40	2.21	1.02	3.30
Vitamin B3 (mg/100g)	1.67	1.10	1.17	2.80	4.22
Vitamin B6 (mg/100g)	2.04	1.07	1.45	1.50	2.60

Table 6 Nutrient composition of selected fruits and mixed fruit wine

Parameter (mg/l)	Banana	Apple	Watermelon	Avocado	Mixed fruit wine
Sodium (Na)	6.08	8.12	7.71	8.53	6.64
Potassium (K)	269.81	186.37	304.89	390.22	288.83
Zinc (Zn)	0.16	0.15	0.40	0.32	0.45
Manganese (Mn)	1.24	0.57	0.31	0.13	0.63
Iron (Fe)	1.90	1.20	0.30	4.30	3.21

protein content makes them a good choice for individuals looking to increase their protein intake. Furthermore, the moderate carbohydrate content in the mixed fruit suggests that it can be a balanced option for those seeking a well-rounded nutritional profile.

The vitamin C contents reported in this study suggest that bananas have the highest vitamin C content among the fruits mentioned. Vitamin C is an essential nutrient that plays a crucial role in supporting immune function and promoting overall health. Furthermore, the vitamin B2 content of the fruits mentioned varied significantly, with mixed fruit wine having the highest content at 3.30 mg and avocado having the lowest at 1.02 mg. Vitamin B2, also known as riboflavin, is important for energy production and maintaining healthy skin and eyes. Vitamin B3, also known as niacin, plays a crucial role in converting food into energy and supporting proper brain function. The significant variation in vitamin B3 content among the fruits mentioned highlights the importance of incorporating a diverse range of fruits into one's diet to ensure adequate intake of this essential nutrient. Vitamin B6, also known as pyridoxine, is involved in over 100 enzymatic reactions in the body, including the metabolism of amino acids and the production of neurotransmitters. The wide range of vitamin B6 content observed among these fruits emphasises the need for a varied diet to meet the recommended daily intake of this important nutrient.

The nutrient composition of the selected fruits and mixed fruit wine also revealed variations in other nutrients. For instance, potassium content ranged from 186.37 to 390.22 mg/l, with the highest found in avocado and the lowest in apple. These findings highlight the diverse nutritional profiles of different fruits and their potential health benefits. Potassium is known to play a crucial role in maintaining proper heart and muscle function as well as regulating blood pressure. Therefore, the consumption of mixed fruit wine can contribute to overall health and well-being.

The variations in manganese content emphasise the need to select fruits carefully for individuals looking to increase their manganese intake. Moreover, individuals with manganese deficiency may find it beneficial to drink mixed fruit wines, which are a good source of this essential mineral. It is important to note that manganese plays a crucial role in supporting healthy brain function and metabolism. Therefore, individuals who are specifically aiming to boost their manganese levels should consider adding mixed fruit wines to their diet, as they contain higher amounts of this essential mineral compared to watermelon alone.

In this study, the physiochemical parameters indicate that the secondary fermentation process has resulted in a significant decrease in total acidity compared to initial measurements. The pH value of 4.80 suggests a slightly acidic environment, which is similar to the report of Ogodo et al. (2015), while the relatively low total acidity of 2.15 indicates a well-balanced and less acidic product. The total acidity of the mixed fruit wines reported in this study is higher than that reported by Ogodo et al. (2015), who reported the total acidity of the final wine to be between 0.5 and 1.0%. Interestingly, the temperature during secondary fermentation and primary fermentation was constant (25 °C) throughout the entire process. This consistent temperature allowed for optimal yeast activity and fermentation efficiency. The controlled environment ensured that the flavours and aromas developed harmoniously, resulting in a well-balanced and flavourful end product. This is not in line with the reports by Balogu and Towobola (2017), who reported variability in temperature.

The sensory analysis of mixed fruit wine reveals its acceptability and dislike using the hedonic scale. Wine 2 has the highest opacity score, while wines 4 and 5 have higher clarity scores. Variations in colour responses for wines 4 and 5 suggest differences in

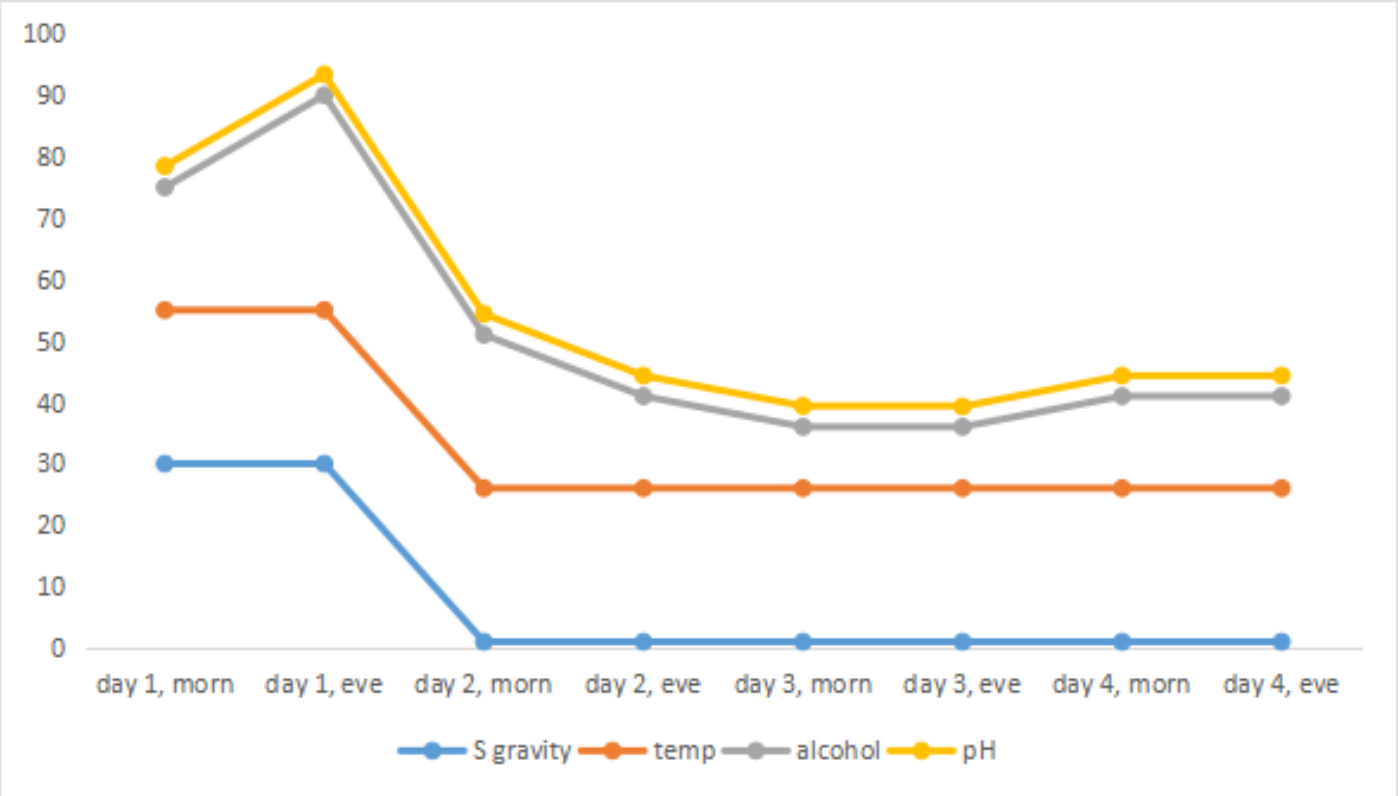

Figure 1 Specific gravity, alcohol reading (%), temperature (°C), and pH level during primary fermentation.

Key: s gravity = specific gravity; temp = temperature; morn = morning; eve = evening.

Table 7 Specific gravity, alcohol reading, temperature and pH level after secondary fermentation

Specific gravity	Alcohol (%)	Temperature (°C)	pH	Total acidity (%)	Total sugar (%)
1	10	25.0	4.80	2.15	10.89

production or ageing processes. A significant portion of respondents did not provide a response for texture, indicating potential inconsistencies in perception. Wines 3, 4, and 5 have distinct aroma and taste characteristics compared to wine 1. Wine 1 has a high score of 92%, suggesting a strong sour taste, while wine 2 scores lower at 60%, indicating a less pronounced sour taste. The good aroma may be due to alcohol content, while oxygen presence is crucial for ageing potential in bottled wine. Out of 25 tasted participants, 5 disliked the fruit wine, while 20 liked it. Further investigation is needed to understand the specific factors influencing these differences.

Conclusion

This study has demonstrated that mixed fruit wine has a better flavour, as evidenced by its highest score of 100%. This might be explained by the particular mix of fruits that was employed in the production of the wine. In terms of flavour and aroma, Wine 3 was preferred by the vast majority of respondents. The distinctive fruit combination produced a sensory experience that was highly enjoyable for the majority of respondents. It is therefore recommended that mixed fruit wine be further explored and potentially marketed as a popular choice among wine enthusiasts. Additionally, further research could be conducted to identify the specific fruits and their proportions that contribute to the superior flavour profile of mixed fruit wine, allowing for more targeted production methods and potentially even more favourable results.

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Table 8 Sensory evaluation of mixed fruit wine using hedonic scale

Appearance	Wine 1 (%)	Wine 2 (%)	Wine 3 (%)	Wine 4 (%)	Wine 5 (%)
Colour					
Pale	88	64	60	8	4
Mid straw	12	12	12	0	4
Deepstraw	0	16	16	0	0
Yellow	0	0	0	56	28
Gold	0	0	0	32	60
No response	0	8	12	4	4
Brilliance					
Clear	16	12	20	80	72
Opaque	68	76	68	8	8
No response	16	12	12	12	20
Texture					
Creamy	12	24	28	8	12
Oily	32	24	28	28	16
Crunchy	8	4	8	44	44
No response	48	48	36	20	28
Aroma					
Like	4	8	68	56	68
Dislike	76	40	12	12	4
No response	20	52	20	32	28
Taste					
Bitter	4	8	0	20	16
Sweet	4	32	100	60	60
Sour	92	60	0	20	8
No response	0	0	0	0	16

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