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Production and quality evaluation of banana wine using *Saccharomyces cerevisiae*

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Abstract

This study was conducted to investigate yeast dynamics, the impact of physicochemical conditions on yeast, the identification of microorganisms during fermentation, and the overall quality of banana wine production. The results revealed surprising trends. After a plateau of 48-120 hours, yeast cell counts increased to $2.52x10^6$ cfu/ml at 144 hours. As fermentation progressed, the total aerobic count in the treated sample declined from $5.6x10^2$ to $2.0x10^2$, and comparable declines were found in the other samples. The alcohol concentration varied, with a sample of a known yeast strain measuring 10.5%, illustrating the importance of yeast strains and fermentation circumstances. The pH levels constantly fell and temperature changes (25°C to 24.5°C) indicated a dynamic fermentation environment. Titratable acidity increased (0.98g/100ml to 1.48g/100ml), affecting sensory properties, whereas specific gravity decreased (1.090 to 1.040). The microbial composition revealed *Saccharomyces cerevisiae, Bacillus sp, Lactobacillus sp*, and *Penicillium sp*. Sensory evaluation results showed substantial acceptability in terms of scent, texture, taste, color, and overall acceptability, with the panelists favoring the sample containing a pure and well-known yeast strain. These findings highlight the necessity of matching sensory features to the yeast strain used. In conclusion, this study increases our understanding of banana wine production and quality assessment, with implications for the beverage industry's further growth.

Keywords: Banana wine; *Saccharomyces cerevisiae*; Fermentation; Quality evaluation; Microbial composition

Introduction

Food preservation techniques have been a cornerstone of human civilization, enabling the extension of food shelf life and protection against spoilage by microorganisms (Rahman, 2020). These methods have evolved significantly over time, ranging from traditional practices such as drying, salting, and smoking to modern techniques like refrigeration, freezing, pasteurization, and fermentation (Ghoshal, 2018). Among these, fermentation holds a unique place due to its dual role in food preservation and production of value-added products, including alcoholic beverages (Kaur *et al*. 2019).

Fermentation is a metabolic process where microorganisms, particularly yeasts and bacteria, convert sugars into other products such as alcohol, acids, and gases under anaerobic conditions (Maicas, 2020). This process has been utilized for millennia to produce various alcoholic beverages, including beer, wine, and spirits. The use of fermentation for alcoholic beverage production, such as converting grains and fruits to beer and wine, has been well-documented (Anagnostopoulos and Tsaltas, 2019; Berenjian, 2019). Alcoholic fermentation, primarily mediated by yeasts like *Saccharomyces cerevisiae*, involves the enzymatic conversion of sugars to ethanol and carbon dioxide, forming the basis of beverages like palm wine, beer, stout, and wine (Medina, 2019).

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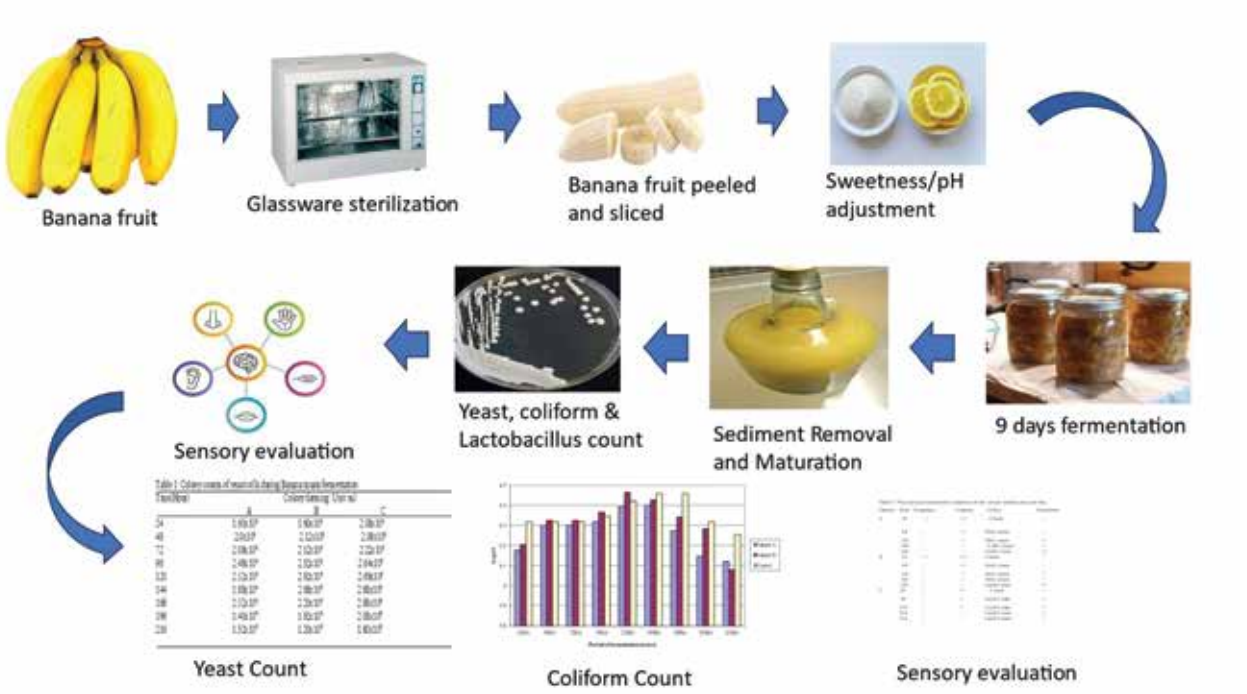
Graphical Abstract:



$$C_6H_{12}O_6 + \text{yeast} \longrightarrow 2C_2H_5OH + 2CO_2$$

Sugar Ethanol Carbon dioxide

While sugars are the most common substrate for fermentation, it can produce a variety of compounds like butyric acid and acetone. Yeast is often used to produce ethanol in alcoholic beverages, which generates a substantial amount of carbon dioxide. Wine is an alcoholic beverage made by fermenting ripe grapes or other sugar-rich fruits with yeast (Nya and Etukudo, 2023). It is a high-value fruit-based product that can also be used to make vinegar.

Banana (*Musa spp.*) is one of the most consumed fruits globally due to its nutritional value, natural sweetness, and widespread availability. Rich in fermentable sugars such as glucose, fructose, and sucrose, banana serves as an excellent substrate for alcoholic fermentation (Maseko *et al*. 2024). However, bananas are highly perishable, with significant postharvest losses reported in tropical and subtropical regions where they are cultivated. Converting excess bananas into value-added products like banana wine offers a sustainable solution to reduce waste while providing economic and nutritional benefits (Al-Dairi *et al*. 2023).

The production of fruit wines has gained increasing attention worldwide due to their distinctive flavors, health benefits, and market demand (Joshi *et al*. 2017). Research on fruit-based wines has expanded to include non-traditional substrates such as pineapples, oranges, apples, and mangoes, highlighting their potential as alternatives to traditional grape wines (Kumari *et al*. 2021). Studies on banana wine production have demonstrated its feasibility, with *Saccharomyces cerevisiae* emerging as the yeast of choice due to its high ethanol yield, ability to ferment diverse sugar substrates, and tolerance to the fermentation conditions typical of fruit musts (Matei and Kosseva, 2017; Onyema *et al.* 2023).

Despite its potential, limited studies have systematically evaluated the quality parameters of banana wine, including physicochemical properties, sensory attributes, and nutritional content. Addressing this gap, the present study investigates the production and quality evaluation of banana wine using *Saccharomyces cerevisiae*. This work aims to optimize fermentation conditions, analyze the physicochemical and sensory characteristics of the wine, and establish its potential as a commercially viable product. By exploring banana wine production, this study contributes to the growing body of research on alternative fruit wines and sustainable approaches to managing postharvest fruit losses.

Materials and methods

Flow Chart of Banana Wine Production Process

Sample Collection
↓
Fresh banana fruits purchased from Faringada market, Jos Plateau state. Transported to laboratory for juice extraction.
↓
Sterilization
↓
Glassware sterilized in oven at 160°C for 1 hour. Inoculating loops sterilized by red heat. Spatulas dipped in 70% alcohol and ignited.
↓
Preparation of Banana Juice (Must)
↓
Bananas washed, disinfected with ethanol, peeled, sliced, blended with hot water, filtered, and juice (must) collected.
↓
Adjustment of pH and Sweetness
↓
pH measured, specific gravity adjusted with sugar, and lemon juice added to fine-tune pH.
↓
Fermentation Setup
↓
Vessels filled with banana must mixtures. Vessel A with sodium metabisulphite, vessel B without it, vessel C as control. Yeast added to A and B.
↓
Fermentation
↓
Fermentation for 9 days at ambient temperature. Samples drawn daily for microbiological and physicochemical analysis.
↓
Sediment Removal and Maturation
↓
After 9 days, wines racked, transferred to clean containers. Left to age in a dark cupboard for 7 weeks.
↓
Final Product
↓
Clear, matured wine with mellow taste. Corked, labeled, and stored (Machamangalath *et al*. 2016)

Sample collection

Fresh banana fruits were purchased at the 'Faringada' fruit market, Jos Plateau state. The orange fruit were then transported to the laboratory for extraction of the juice.

Sterilization

The glass ware was first washed with detergent, rinsed properly in water until all the detergent is completely rinsed off the material, then left to dry. They were then sterilized in the oven at 160^{o}C for 1 hour. Metals like inoculating loop and needle were sterilized by using red heat from Bunsen burner flame. Spatulas were sterilized by dipping them into 70% alcohol and igniting them in the Bunsen flame. The Petri dishes used were disposable plastics ones which had been pre-sterilized.

Preparation of banana juice (Must)

Ripe bananas are washed meticulously with distilled water to eliminate any external impurities. Furthermore, the disinfection of the bananas is carried out using ethanol-soaked cotton wool. Precise quantities of banana pulps (2.00kg), yeast cells (5.00g), sugar (1.02kg), lemon juice (1.5kg), and sterile distilled water (3L) are measured and recorded. The bananas are then individually hand peeled, revealing the edible portion within. Subsequent to peeling, the edible portion of the bananas is sliced using a sterile stainless-steel knife. The uniformity of the slices is essential for consistent processing and end-product quality. The blending process involves combining the sliced bananas with 100°C hot water in a Super Mark blender. The slurry is then carefully filtered through a double-folded cheese cloth. This filtration process separates the juice, referred to as "must," from any solid components. This meticulous separation is vital in achieving the desired clarity and consistency of the final product. The pH of the banana must is measured using a digital pH meter. In addition to pH, the specific gravity of the must is measured using a hydrometer within a specified range (1.000-1.100). To achieve the desired level of sweetness, granulated sugar is added, with the amount (1.02grams) determined based on the measured specific gravity. Lastly, the pH of the mixture is further fine-tuned by incorporating lemon juice (citric acid), which weighs 1.5grams. This adjustment plays a crucial role in achieving the optimal pH level, which affects not only the taste but also the safety and stability of the final product (Dhar *et al*. 2013).

Banana wine fermentation

For the fermentation experiments, a 10-litre vessel (A) and two 4-litre vessels (B and C) were used. Vessel A contained 4 litres of prepared must (banana juice, sugar,

lemon juice, and sodium metabisulphite), vessel B held 1.5 litres of the same mixture without sodium metabisulphite, and vessel C was the control with only banana must. Each vessel was securely covered to prevent contamination from Bacteria, Fungi, or fruit flies during fermentation. A thermometer was used to monitor daily temperature changes in the fermenting musts. Samples were drawn aseptically, daily through the tap head for microbiological and physicochemical analysis. Yeast was carefully introduced into vessels A and B to initiate fermentation. This process, known as pitching, ensured even distribution of yeast cells throughout the must for consistent and efficient fermentation. The experiment spanned nine days, at ambient temperature. After nine days of primary fermentation, the sediment was removed from each vessel, and the racked wines were transferred to clean, sterile storage containers with tight covers. The wines were left to mature and age at room temperature in a dark cupboard. After seven weeks, the wines were considered matured, possessing a light, mellowed taste, and were clear and brilliant. No clarifying agents were used. The wines were then corked, appropriately labeled, and stored until needed (Idise and Odum, 2011).

Media preparation

All the media were prepared according to the manufacturer's instructions. An aluminium foil was used to weigh powdered media on a weighing balance. These were then transferred into different 250ml conical flasks. The suspension in each flask was stirred to dissolve the solid and heated to homogenize. After heating the mouth of the conical flask were plugged with cotton wool and wrapped with aluminum foil. The medium was sterilized in the autoclave at 121^{o}C for 15 minute and allowed to cool to about 47^{o}C.

Determination of yeast count

A stock solution was prepared daily from each of the fermenting samples by the addition of 1ml of the sample into 9ml of sterile distilled water. These were serially diluted up to the 6th dilution factor. 1ml of the 10^{-2} and 10^{-4} were inoculated onto sterile media plates. 20ml of already Prepared SDA (cooled to about 45^{o}C) was then poured onto the plates. The plates were the swirled gently right, forward and backward. The incubated plates were inverted and incubated at 37^{o}C for 24 hours. The total yeast populations were determined from the visible growth on the media (Entonu *et al*. 2023).

Determination of total aerobic counts and coliform counts

A stock solution was prepared daily from each of the fermenting samples by the addition of 1ml of the sample into 9ml of sterile distilled water. These were serially diluted up to the 6th dilution factor. 1ml of the 10^{-2} and 10^{-4} were inoculated onto sterile media plates. 20ml each of already Prepared Nutrient agar and MacConkey agar (cooled to about 45^{o}C) respectively were then poured onto the plates. The plates were the swirled gently right, forward and backward. The incubated plates were inverted and incubated at 37^{o}C for 24 hours. The total aerobic and coliform counts were determined from the visible growth on the media (Aycicek *et al*. 2006).

Detection of lactobacillus sp.

A stock solution was prepared every 72 hours from each fermenting sample by adding 1ml of the sample into 9ml of sterile distilled water. These solutions were serially diluted up to the 6th dilution factor. From the 10^$^{-2}$ and 10^$^{-4}$ dilutions, 1ml was inoculated onto sterile media plates. De Man's Rogosa Sharpe's agar (previously cooled to approximately 45^{o}C) was poured onto the plates (20ml per plate) and swirled gently to ensure even distribution. The plates were then inverted and placed inside an anaerobic jar with a gaspak kit. The jar was incubated at 37°C for 72 hours to allow for the growth of lactic acid bacteria, which were then identified based on their growth characteristics on the media (Ngene *et al.* 2019).

Subculturing

Colonies with distinct morphologies were subcultured. An inoculating loop or needle was sterilized using an open flame until it became red-hot. The agar plate was opened, exposing the solid surface. With the sterilized loop or needle, a dense concentration of microorganisms was streaked across the surface to create an initial streak. Without re-sterilizing the loop, subsequent streaks were made through the end of the previous ones, diluting the concentration of microorganisms. For the final streak, the loop was again dragged through the end of the previous streak, aiming to isolate individual microbial cells and enable distinct colonies to develop. The agar plate was then placed in suitable conditions for the specific microorganism being cultured to facilitate the growth of individual colonies from the isolated cells.

Identification of bacterial and fungal isolates

Gram staining technique

A thin smear of each pure 24-hour-old culture was prepared on clean, grease-free slides and fixed by passing over a gentle flame. Each heat-fixed smear was stained by adding a few drops of crystal violet solution for 60 seconds and rinsed with water. The smears were then flooded with Lugol's iodine for 30 seconds, rinsed with water, decolorized rapidly with 70% alcohol, and rinsed with distilled water. They were counter-stained with 2 drops of Safranin for 60 seconds, rinsed with water, and allowed to air dry. The smears were mounted on a microscope and observed under an oil immersion objective lens (X100 magnification) (Cheesbrough, 2000).

Lactophenol cotton blue staining

A small piece of the fungal specimen was placed on a clean slide. A drop of Lactophenol cotton blue solution was added to cover the specimen and left for about 5 minutes. Excess solution was gently blotted using absorbent paper, and a cover slip was carefully placed over the specimen. The slide was observed under a microscope (X10 and X40 Objective lenses) to visualize fungal structures such as spores and hyphae (Cheesbrough, 2000).

Biochemical characterization

Bacterial isolates were characterized using biochemical tests following the method described by Cheesbrough (2000).

pH Determination

The pH of the samples was measured using a standard pH meter. The pH meter was calibrated using buffer solution with a pH of 4.0, prepared by dissolving pH buffer powder in distilled water. 10 mL of the juice was placed in a sterile beaker, and the pH meter electrode was immersed in the juice to take readings (Egbere *et al*. 2021).

Total titratable acidity determination

Total titratable acidity was determined following the method by Egbere *et al*. (2021). 5 mL of the sample was pipetted into 100 mL beakers and treated with 3 to 5 drops of 1% phenolphthalein indicator. A burette containing 0.1N sodium hydroxide was used to titrate the sample until a pale color appeared, indicating the end point. The titratable acidity was calculated with reference to tartaric acid.

Alcoholic content determination

The alcoholic content in the wine was determined using a wine hydrometer. The specific gravity before and after fermentation was measured, and the difference was multiplied by the factor 131.25 to obtain the alcohol content (Mamauag, 2022).

Specific gravity determination

The specific gravity of the wine was determined using a pycometer bottle. The weight of the bottle was recorded before and after filling it with the sample. The specific gravity was calculated based on the weight difference.

Temperature determination

The temperature of the sample was measured using a thermometer and a measuring cylinder.

Bottling and packaging

After aging for 6 weeks, the wine was bottled in sterilized bottles of various sizes and shapes. The bottled wine was pasteurized at 90^{o}C for 2 mins, and stored at a 4^{0} C temperature, following the method described by (Ramesh, 2020).

Sensory evaluation

Sensory evaluation was conducted using questionnaires to assess the color, clarity, flavor, taste, odor, and texture of the banana wine. The overall acceptance of the wine was also evaluated, following the methods described by Egbere *et al*. (2021), and Onyimba *et al.* (2022).

Statistical analysis

Statistical analysis was performed using independent sample T-test in SPSS version 23 to analyze the sensory evaluation results (taste, aroma, color, overall acceptability) of the banana wine.

Results and discussion

Table I shows that the yeast cell counts exhibited significant fluctuations during banana wine fermentation across all samples. In Sample B, yeast counts increased rapidly from 48 to 120 hours, peaking at 2.92 x 10^{6} cfu/ml at 144 hours before declining to 1.2 x 10^{6} cfu/ml at 216 hours. In Sample A, yeast counts rose from 1.60 x 10^{6} cfu/ml at

the 24th hour to a peak of 2.52 x 10^6 cfu/ml, then declined to 1.32 x 10^6 cfu/ml. Similarly, in Sample C, counts increased from 2.08 x 10^6 cfu/ml to a peak of 2.88 x 10^6 cfu/ml at 144 hours, before declining to 1.80 x 10^6 cfu/ml.

Table I. Colony counts of yeast cells during banana musts fermentation

Time (Hrs)	Colony forming Unit /ml		
	A	B	C
24	1.60 x10^6	1.60 x10^6	2.08 x10^6
48	2.00 x10^6	2.12 x10^6	2.08 x10^6
72	2.08 x10^6	2.12 x10^6	2.22 x10^6
96	2.48 x10^6	2.32 x10^6	2.64 x10^6
120	2.52 x10^6	2.92 x10^6	2.68 x10^6
144	1.88 x10^6	2.68 x10^6	2.88 x10^6
168	2.52 x10^6	2.20 x10^6	2.88 x10^6
196	1.40 x10^6	1.92 x10^6	2.08 x10^6
216	1.32 x10^6	1.20 x10^6	1.80 x10^6

Key,
A = Fermenting wine containing only pure strain of wine yeast
B= Fermenting wine containing wine yeast and wild yeast
C= Fermenting wine containing only wild yeast/Control

Table II. Colonial, morphological characteristics of bacterial and fungal isolates

Isolates	Size	Shape	Colour	Type
Bacillus sp.	Medium	Convex	Whitish	Round
Lactobacillus sp.	Small	Convex	Creamy	Round
S. cerevisiae	Moderate	Convex	Creamy	Circular
Penicillium sp.	Large	__	Dark Green	Round

Table II shows that microbiological examination identified various organisms present during the fermentation of banana wine, including *Bacillus* sp., *Lactobacillus* sp., *Penicillium* sp., and *Saccharomyces cerevisiae*.

Table III presents the biochemical and metabolic reactions of the organisms isolated during banana wine fermentation, including *Bacillus* sp., *Lactobacillus* sp., *Penicillium* sp., and *Saccharomyces cerevisiae*.

Table IV presents the varying differences between the physical and organoleptic properties of the various banana wine samples over time. Throughout the fermentation process, sweetness was observed to decrease in all samples. During the first two days of fermentation, there was a lot of foaming, indicating that the yeast was active and releasing carbon dioxide. However, this foaming decreased rapidly and became eliminated near the end of primary fermentation. The color of the wine changed from dark cream to lighter and brighter cream. Furthermore, sediments, which were not present on the first day, began to accumulate as fermentation progressed and became well established by the final days.

Table III. Biochemical and metabolic reaction of the isolated organisms

Most Probable Organism	NA	GR	Morphology	Cat	MR	Coa	Ind	Urs	Oxi	Cit	SFT			
											Lac	Glu	Suc	Fru
Bacillus sp	+	+	Rod	+	-	-	-	-	-	+	-	+	+	+
Lactobacillus sp	-	+	Short Rods	-	-	-	-	-	-	+	+	+	+	+
Saccharomyces cerevisiae	-	-	Oval	-	-						+	+	+	+
Penicillium sp	-		Conidia seen											

Key
NA= Growth in NA; Oxi = Oxidase; GR=Gram; reaction; Cit = Citrate utilization; MR=Methyl Red; SFT= Sugar; fermentation test; Morph =Morphology; Lac=Lactose; Cat = Catalase; Glu= Glucose; Coa = Coagulase; Suc= Sucrose; Ind = Indole test; Fru= Fructose; Urs = Urease; - = Absent; + = Present;

Table IV. Physical and organoleptic properties of the arious samples per unit time

Sample	Hour	Sweetness	Frothing	Colour	Sediments
A	24	+ +	+++	Cream	-
	48	-	++	Dirty cream	-
	120	-	+	Dirty cream	+
	168	-	-	Light Cream	+
	226	-	-	Light Cream	++
B	24	+ +	+++	Cream	-
	48	-	++	Dirty cream	-
	120	-	+	Dirty cream	+
	168	-	-	Dirty cream	+
	226	-	-	Light Cream	++
C	24	+	++	Cream	-
	48	-	+	Light Cream	+
	120	-	+	Light Cream	+
	168	-	-	Light Cream	+
	226	-	-	Light Cream	+

Key
Where; - = absent, + = slightly present, ++ = moderately present
+++ =highly present

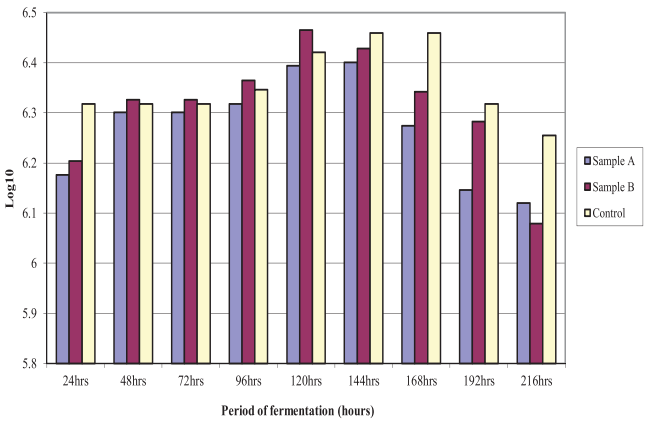


Fig. 1. Colony counts (Log CFU/ml) of yeast cells during banana musts fermentation

Figure 1 shows that the yeast cell counts exhibited significant fluctuations during banana wine fermentation across all samples. In Sample B, yeast counts increased rapidly from 48 to 120 hours, peaking at 2.92 x 10^6 cfu/ml at 144 hours, before declining to 1.2 x 10^6 cfu/ml at 216 hours. In Sample A, yeast counts rose from 1.60 x 10^6 cfu/ml at the 24th hour to a peak of 2.52 x 10^6 cfu/ml, then declined to 1.32 x 10^6 cfu/ml. Similarly, in Sample C, counts increased from 2.08 x 10^6 cfu/ml to a peak of 2.88 x 10^6 cfu/ml at 144 hours, before declining to 1.80 x 10^6 cfu/ml.

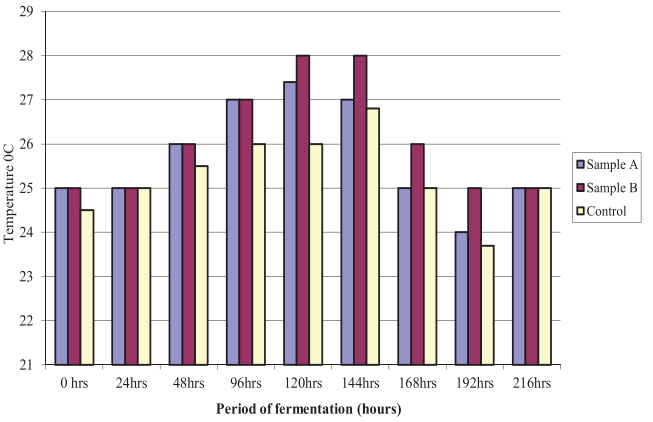


Fig. 2. Illustrates daily temperature variations during the fermentation process

Figure 2 illustrates the performance of three samples (A, B, and C) during the fermentation period, highlighting distinct variations in their parameters over time. Sample A consistently exhibits the highest values across most stages, indicating superior fermentation efficiency. Sample B follows a similar trend but with moderately lower values, suggesting less optimized fermentation conditions. In contrast, Sample C demonstrates the lowest values throughout, reflecting the challenges associated with wild yeast fermentation, including reduced efficiency and environmental influences.

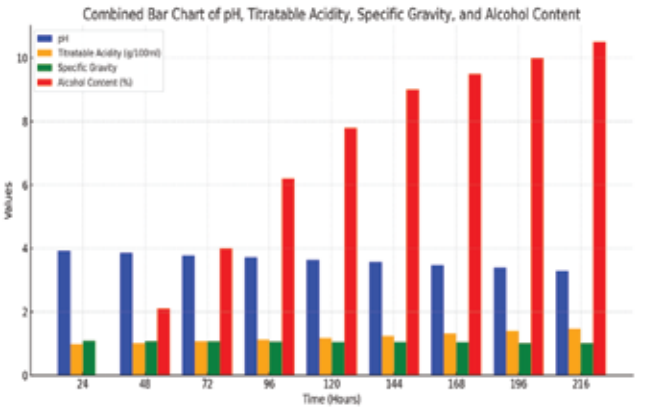


Fig. 3. Combined bar chart of PH, titratable acidity, specific gravity, and Alcohol Content

Figure 3 illustrates the dynamics of pH, titratable acidity, specific gravity, and alcohol content during the fermentation process over 216 hours. The pH shows a steady

decline from approximately 4.0 to 3.2, indicating increasing acidity due to organic acid production by fermenting microorganisms. Titratable acidity increases correspondingly, reflecting the accumulation of these acids, which contribute to the tangy flavor of the wine. Specific gravity decreases steadily throughout fermentation, signifying sugar consumption by yeast to produce ethanol and carbon dioxide. Alcohol content exhibits a consistent upward trend, peaking at around 10% by the end of fermentation, showcasing the efficiency of Saccharomyces cerevisiae in converting sugars to ethanol.

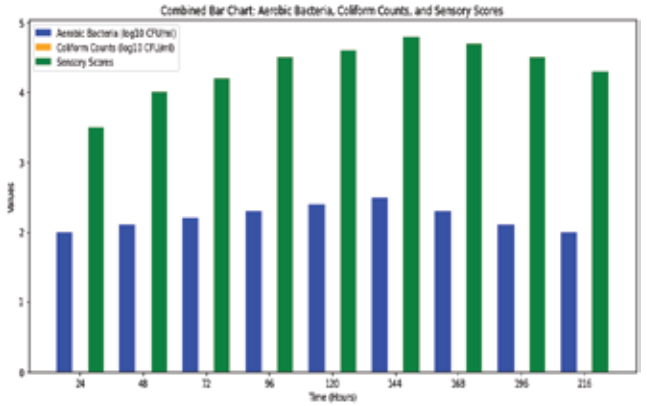


Fig. 4. A combined chart of aerobic bacteria, coliform counts, and sensory scores

Figure 4 presents a comparative overview of microbial activity and sensory evaluation during banana wine fermentation; Aerobic bacteria (log10 CFU/ml): The fluctuation reflects microbial dynamics during fermentation, with a peak followed by a decline due to the inhibitory effects of alcohol and acidity. Coliform counts: The absence of coliforms throughout the process suggests effective sanitation and proper fermentation practices. Sensory Scores: These steadily increase, peaking near the end of fermentation, indicating improved taste, aroma, and overall acceptability as the wine matures.

The results of this study provide valuable insights into the complex dynamics of banana wine fermentation, highlighting the interplay between microbial activity, physicochemical changes, and sensory properties in determining wine quality. The pivotal role of Saccharomyces cerevisiae in efficiently converting sugars into ethanol during fermentation is evident from the observed yeast dynamics, with cell counts peaking between 120 and 144 hours. This aligns with prior studies, such as Zhao *et al.* (2022), which emphasized the significance of specific yeast strains in achieving high ethanol yields while maintaining desirable sensory characteristics.

The characteristic lifecycle of yeast, marked by a decline in cell counts post-stationary phase due to nutrient limitations, corroborates earlier findings (Ezenwa *et al.* 2020). The steady decrease in specific gravity, unaffected by yeast strain or fruit variety, further supports the metabolic activity of yeast in converting sugars to ethanol and carbon dioxide. These results are consistent with Ezemba and Archibong's (2017) report on similar patterns in fruit wine fermentation.

The progressive decline in pH from 3.93 to 3.23 reflects the production of organic acids by fermenting microorganisms, primarily S. cerevisiae and lactic acid bacteria. This acidic environment is crucial for microbial stability and flavor enhancement. Additionally, the increase in titratable acidity from 0.98 g/100 mL to 1.48 g/100 mL underscores the accumulation of organic acids, contributing to the wine's tangy taste. These findings align with Fu *et al.* (2022), who demonstrated the influence of acidity on the sensory profiles of fruit wines, including the possible role of malolactic fermentation.

The increase in alcohol content, reaching 10.5% (v/v) in Sample A, validates the effectiveness of S. cerevisiae in fermenting banana must. The higher alcohol content observed in Sample A highlights the positive impact of sodium metabisulphite, which inhibited competing microorganisms and enhanced fermentation efficiency. In contrast, the lower alcohol content in the control sample (Sample C) suggests that relying solely on wild yeast may lead to less efficient fermentation, as environmental factors can inhibit wild yeast activity. This observation is consistent with Steensels and Verstrepen (2014), who reported the challenges of achieving optimal fermentation using wild yeast.

Microbiological analyses revealed a diverse microbial community, including Bacillus sp., Lactobacillus sp., Penicillium sp., and S. cerevisiae. The presence of these microorganisms underscores the complexity of interactions during fermentation, where both beneficial and spoilage organisms coexist. Notably, the absence of coliform bacteria throughout fermentation highlights the effectiveness of the applied sanitary practices, ensuring microbiological safety, as supported by Lyumugabe *et al.* (2010).

Sensory evaluation showed significant differences in consumer preferences, with Sample A receiving the highest scores for taste, texture, and overall acceptability. The controlled fermentation conditions in Sample A optimized alcohol production and acidity balance, enhancing its sensory appeal. These findings suggest that optimizing fermentation parameters, including yeast strain selection and nutrient adjustments, can significantly improve the quality of banana wine. Similar conclusions were drawn by Joshi et al. (2017),

who highlighted the importance of tailoring fermentation processes to improve fruit wine quality.

This study highlights the intricate interplay between microbial dynamics, physicochemical changes, and sensory attributes in banana wine production. The findings emphasize the potential of S. cerevisiae and sodium metabisulphite in achieving high-quality banana wine with desirable sensory characteristics, providing a foundation for further research into optimizing fermentation conditions for commercial applications.

Conclusion

This study highlights the critical role of yeast strain selection and fermentation management in producing high-quality banana wine. The results indicate that *Saccharomyces cerevisiae* is highly effective in converting banana must sugars into ethanol, yielding wines with superior sensory and physicochemical properties. The controlled use of sodium metabisulphite was instrumental in enhancing fermentation efficiency and alcohol yield, while maintaining microbial stability.

The findings also emphasize the importance of monitoring key parameters such as pH, titratable acidity, specific gravity, and alcohol content throughout the fermentation process. These parameters not only influence the sensory appeal of the wine but also its microbial safety and shelf stability. The absence of coliform bacteria throughout the fermentation process reinforces the importance of maintaining stringent sanitary practices.

Furthermore, the sensory evaluation revealed consumer preferences for wines produced with optimized fermentation conditions, suggesting that banana wine has significant potential for commercial production. By leveraging local resources and optimizing production techniques, banana wine can serve as a viable alternative to imported wines, contributing to economic growth and food sustainability.

This study underscores the potential of banana wine production as a sustainable and economically beneficial venture. Future research should focus on scaling up production processes, exploring additional fruit combinations, and further refining fermentation techniques to cater to diverse consumer preferences.

Conflict of Interest

The authors declare no conflict of interest

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Data availability statement

No date was used for research described in the article.

Author's Contribution

Entonu Entonu: Conceptualization, Methodology, Data curation, Writing- Original draft preparation, Writing-Reviewing; Olorunlaye Boluwatife: Conceptualization, Methodology, Data curation, Writing- Original draft preparation Anayochukwu Ngene: Methodology, Software, Data curation, Writing-Reviewing and Editing, Diagrams; John Egbere: Supervision.

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