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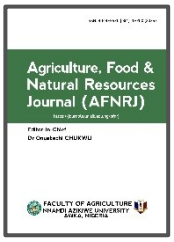

Original Article

Comparative evaluation of physicochemical and sensory properties of commercial wines and mixed-fruit wine fermented with indigenous stress-tolerant yeast

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Chukwuemeka Marcellinus EZEUKO, Sophina Ogonna UMEH, Chidimma Maryrose EZEUKO, Onyekachukwu Izuchukwu UDEMEZUE*& Glory Chinecherem UZOIGWE

Department of Applied Microbiology and Brewing, Nnamdi Azikiwe University, Awka, Nigeria

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A B S T R A C T

The use of indigenous yeast strains and underutilized fruits offers a sustainable pathway for local wine industry development. This study aimed to produce and comparatively analyze mixed-fruit wine from watermelon and pineapple using a previously isolated indigenous stress-tolerant Saccharomyces cerevisiae Y-03, benchmarked against commercial wines. A 50:50 (v/v) watermelon-pineapple must was fermented with strain Y-03 over 28 days. Fermentation kinetics were monitored weekly for pH, reducing sugar, titratable acidity, specific gravity, °Brix, and estimated alcohol content. The final wine was evaluated for physicochemical properties and sensory attributes including appearance, aroma, taste, mouthfeel and overall acceptability, assessed by a 20-member panel against two unnamed commercial wines. Data were analysed using descriptive statistics and analysis of variance at $p<0.05$. Results showed successful fermentation, with pH decreasing from 4.50 to 3.75, reducing sugar from 125.4 g/L to 9.8 g/L, and specific gravity declining, while titratable acidity and alcohol content increased to 11.5% v/v. The physicochemical profile of the final wine was comparable to commercial benchmarks. Sensory evaluation revealed high ratings for appearance (8.2 ± 0.9) and aroma/flavour (7.6 ± 1.1), attributed to desirable volatile esters, while taste (7.3 ± 1.3) was slightly lower due to perceptible acidity. Overall acceptability (7.7 ± 0.9) exceeded one commercial wine and was competitive with the second. Thus, the indigenous stress-tolerant strain Y-03 effectively produced a high-quality mixed-fruit wine with distinct sensory appeal, demonstrating the feasibility of valorizing local microbial resources and agricultural produce into competitive products.

K E Y W O R D S : *Fermented wine, Indigenous yeast, Sensory evaluation, Underutilised fruits*

INTRODUCTION

Wine can simply be defined as a fully or partially fermented grape juice. In the past, grape juice was fermented using wild yeast and endogenous bacteria found on grapes, to generate wine. Nowadays, *Saccharomyces cerevisiae* strains account for most commercial wine yeasts due to their higher aldehyde generation and rate of sugar utilization during fermentation. Fruit wine has numerous health advantages and has been praised for its medicinal or therapeutic benefits (Dalal & Sandeep, 2023).

Humans have been making and consuming wine from time immemorial. Most of the wines produced in the world are undoubtedly made from grapes and the technique of winemaking has developed with trial and error until the fundamental of microbiology, biochemistry, food science especially sensory science could be developed and applied. Fruits other than grapes are also used to make wine. Wines

*Corresponding author: io.udemezue@unizik.edu.ng

from many tropical fruits like mango, banana, pineapple, papaya, guava, custard apple, lychee, watermelon, coconut, sapota, and jamun have also been prepared and evaluated for their acceptability, especially that from mango (*Mangifera indica* L) (Vasantha *et al*., 2017).Wine is a calorie- and vitamin-rich beverage that is safe and beneficial. In an era when life was frequently demanding, it provided solace and pain relief. Additionally, because they retain the minerals of the fruits they are made from, wines in general are rich in nutrients (Sukhvir & Kocher, 2019).

A microbe with the following qualities is suitable for producing alcohol: ability to ferment quickly, better flocculation, significant osmo-tolerance, improved ethanol tolerance, and good thermo-tolerance. A small number of yeast strains have been identified to have notable properties for the generation of ethanol, despite the fact that no microbiological strain possesses all these desirable traits. Since industrial microorganisms' technological behaviour is still mostly kept a secret in the fermentation sector, the majority of them is patented and might not be usable outside of their nation of origin. This poses a severe threat to the economy since it prevents the fermentation businesses from growing quickly. As a result, it is necessary to find native yeast strains that are compatible with local substrates in order to produce ethanol sustainably (Brooks, 2008).

Winemaking involves mainly three categories of operations, namely, pre-fermentation, fermentation, and post-fermentation operations. In the case of wines made from grapes, pre-fermentation involves crushing the fruit and releasing juice. In case of white wine, juice is separated from the skin, whereas in red wine, the skins are not separated from the juice. Clarification of juice for white wine is usually achieved by sedimentation or centrifugation. Then, yeast is added to the clarified juice to initiate fermentation. In red winemaking, the pulp, skins, and seeds of grapes are kept together after crushing and during all or part of the fermentation. This is done to extract color and flavor. Yeast is added to mashed pulp (must) in red winemaking (Jackson, 2000; Gayon *et al*., 2000).

Fruit output value has lately grown as compared to prior years. However, because there were few opportunities for value addition during production gluts, this increase in output was accompanied by significant postharvest losses. The majority of fruits that are grown are eaten while still fresh, with the remainder being sold to enterprises that process them. These businesses turn the fruits into concentrates, juice, and jam. Nigeria lacks many of the additional creative value-adding choices that have been utilized in other nations, such as pickles, wine, nectar, and candy. Fruit growers continue to live in poverty as a result of low pricing and a lack of awareness about value-adding opportunities. The strict laws controlling its exports have a negative impact on the export market. Furthermore, there is a lack of knowledge regarding the characteristics, safety, and shelf life of fruit wine.

This study aimed to comparatively analyze the physicochemical and sensory properties of mixed-fruit wine fermented with indigenous stress-tolerant yeast versus commercial wines

MATERIALS AND METHOD

Sample Collection

The water melon (*Citrullus lanatus*) and pineapple (*Ananas comosus*) fruits used in this study were obtained from Eke Awka Market, Awka South Local Government Area, Anambra State, Nigeria, using different sterile polythene bags. They were transported to the Laboratory unit of Department of Applied Microbiology and Brewing, Nnamdi Azikiwe University, Awka for analysis. The ripe fruits were used within 24 hours after collection.

Characterization of Stress-Tolerant Yeast

The stress-tolerant yeast used in this study was obtained from stock-collection of Microbiology Laboratory unit, Nnamdi Azikiwe University, Awka. The isolate was re-identified using standard methods as described by Ezeuko *et al*. (2025).

"Must" Preparation

The watermelon and pineapple fruits were aseptically peeled, washed with sterile water and cut into smaller sizes. They were rewashed thoroughly with 0.1% sodium metabisulphite in water. The fruits were then manually deseeded, blended and filtered to obtain the juice. The watermelon and pineapple juice were mixed in a 50-50 ratio to obtain the must. The must was pasteurized at 75°C for 30 seconds (Okeke *et al*., 2015).

Inoculum Development and build-up

A 250ml of the juice was introduced into a clean sterile 500ml conical flask. Upon cooling, three (3) loopful of the yeast culture were used to inoculate the juice and incubated in a rotary shaker for 48 hours. The must was then transferred to another 1000ml conical flask containing 500ml of sterile must. All procedures were done under aseptic condition (Archibong *et al*., 2015).

Wine Production

This was done according to the modified method of Moreno-Arribas & Polo (2005). One liter (1L) of the must was poured into 5L fermenting vessel. The inoculum (500ml) was added into the fermenting vessel too. Sodium metabisulphite (1g) was added to inhibit the growth of microorganisms while 100g of sucrose was also added to fortify the must. The set-up was allowed to stay for 28 days and analyzed weekly for reducing sugar, titratable acidity, specific gravity and alcoholic content.

Ageing and Clarification

At the end of secondary fermentation, the wine was racked and allowed to age leaving the jar on a flat surface without shaking

at room temperature. The aged wine was subjected to clarification process since it was still cloudy and hazy by simply allowing the sediments, containing yeasts cells, as well as precipitated materials to settle naturally in the glass jar. The wine was then recovered from the sediments by decantation. A clear wine was obtained at the end of clarification (Vasantha *et al*., 2017).

Physiochemical Analysis of the Product Must and Wines

pH Determination

The pH of the "must" was determined using a digital pH meter (Model No: pH S-25). The same procedure was employed to determine the pH of the wine produced. The pH meter was standardized with buffer solution. The buffer solution was prepared with pH buffer powder of pH 4.00 at 25°C dissolved in 250ml distilled water. Ten ml (10ml) of the "must" and wine were put into sterile test tube. The electrode of the pH meter was immersed in the test tube and the pH recorded (Iland *et al*., 2000).

Determination of Reducing Sugar

The quantitative estimation of reducing sugar of the must and wine was done according to the modified method of Archibong *et al*., (2015). A 1ml of 3, 5-Dinitro Salicylic acid (DNS) was added to 1ml of supernatant of the sample in a test tube and the mixture heated in boiling water for 10mins. The test tube was cooled rapidly in tap water and the volume adjusted to 12ml with distilled water. A blank containing 1ml of distilled water and 1ml of DNS was also prepared. The Optical Density (OD) of the samples was read against the blank in a spectrophotometer at 540nm absorbance. The concentration of reducing sugar was estimated from a glucose standard curve.

Determination of Specific Gravity

A 50ml specific gravity bottle was thoroughly cleaned with distilled water, dried in an oven for 50°C and allowed to cool. The weight of the cooled dried bottle (W_1) was recorded. The dried bottle was filled with deionized water and surface of the bottle was cleaned with a cotton wool and weighed as (W_2). The bottle was cleaned twice with 10ml of the "must" and wine. It was thereafter filled to the brim with the "must", cleaned with cotton wool and weighed as (W_3). The specific gravity (S.G) was calculated as;

$$S.\ G = \frac{W3 - W1}{W2 - W1} = \frac{S}{W} \qquad (1)$$

Where; S= weight of volume of must (W_3 - W_1), W= weight of volume of water (W_2 - W_1) (Iland *et al*., 2000).

Estimation of Titratable Acidity

This was determined by the methods described by Ezemba *et al*. (2022). Aqueous alcoholic phenolphthalein indicator (1%) was added to 200ml of distilled water. It was titrated with 0.1m of NaOH. Titration was stopped when a faint but definite pink colour appeared. The titre was taken and served as the initial titre. The must and wine (5ml) were added to the neutralized solution and titrated against 0.1m NaOH. The titer was taken and recorded as the final titre. The titratable acidity was calculated with reference to tartaric acid:

$$\text{Tartaric Acid (g/100ml)} = \frac{V \times M \times 100}{100 \times V} \qquad (2)$$

Where; V= volume of NaOH (Final reading – initial reading), M = Molarity of NaOH, V = Volume of "Must".

Determination of Brix Value

The Brix value of the wine sample was determined using a handheld refractometer. The instrument was first calibrated with distilled water to ensure accurate measurement. Two drops of the wine sample were then placed on the prism surface of the refractometer, after which the cover plate was closed to spread the sample evenly. The instrument was held towards a light source and the Brix value was read directly from the scale at the boundary line (AOAC, 1990).

Alcohol Content Determination

The distillation method according to the Association of Official Analytical Chemists Methods of Analysis (1990) was used. The "must" and wine (100ml) were measured into a round-bottom flask with side arms and connected to the fractioning column. An anti-bumping chip was added to the wine to ensure adequate dispersal of heat in the wine. It was then heated and the distillate collected. The distillate was poured into a clean dry conical flask and made up to 100ml with distilled water and left to stand overnight on the bench. The specific gravity of the distillate was determined and the result taken to determine the alcoholic strength.

Sensory Evaluation

The sensory quality of the fruit wines was evaluated after fermentation by 20 trained panelists who are familiar with the product. The panelists were supplied with 30ml of the wine samples and water to rinse their mouths in between samples. They were also provided with 2 unnamed commercial wine samples for comparison. The samples were rated on a 9-point hedonic scale ranging from 1 (disliked extremely) to 9 (liked extremely). The parameters were assessed for flavor, taste, appearance, mouth feel, and overall acceptability (Kanwar, 2016).

Statistical Analysis

All the experiments were carried out in triplicate. The data obtained were analyzed using descriptive statistics and one-way Analysis of Variance (ANOVA) and significance accepted at p value < 0.05.

RESULTS

Isolation, Morphological and Biochemical Characterization of the Yeast Isolate

After purification and sub-culturing, the isolate (designated as Y-03) was identified and selected for further study based on their robust growth and distinct morphological characteristics. Microscopic examination revealed that the isolate was ovoid in shape and reproduced by multilateral budding, confirming them as yeast

Physicochemical Analysis during Fermentation

The results for the mixed "must" fermented with the selected isolate Y-03 are presented below in figures 1 and 2. The pH of the "must" decreased gradually over the fermentation period, while the titratable acidity (expressed as g/L tartaric acid) increased. This is a direct result of yeast metabolism, producing organic acids (e.g. succinic and acetic) and CO_2, which can form carbonic acid. A rapid decrease in reducing sugar content was observed in the fermentation within the first 7 – 14 days, coinciding with the most vigorous phase of yeast activity and CO_2 production. The residual sugar values indicate that the fermentation was nearly complete but not totally dry, which is desirable for palatability in fruit wines. The specific gravity of the must decreased steadily as denser sugars were converted into less dense ethanol and CO_2. There was also gradient decrease in the Brix value from 13.0 to 1.5.

Table 1: Identification of the yeast isolate

Isolate	Colony Morphology (Macroscopic and Microscopic)	Sugar Fermentation Test								Probable Identity
		Fru	Mann	Dex	Gala	Mal	Glu	Suc	Lac	
Y-03	Creamy-white, oval shape with raised elevation	AG	AG	AG	AG	AG	AG	AG	-	*Saccharomyces cerevisiae*

Key : Fru = Fructose, Mann = Mannose, Dex = Dextrose, Gala = Galactose, Mal = Maltose, Glu = Glucose, Suc = Sucrose, Lac = lactose, A = Acid Production, G = Gas Production, (-) = No Fermentation.

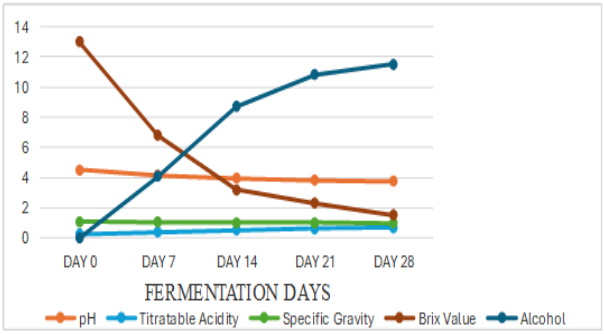

Figure 1: Physicochemical changes during Fermentation of Mixed-Fruit must

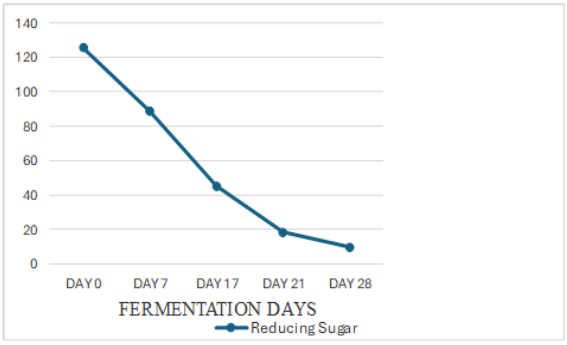

Figure 2: Reducing sugar changes during Fermentation of Mixed-Fruit must
[NB: y-axis represents reducing sugar in percentage (%)]

Comparison of Final Wine Parameters with Commercial wine

A comparison of the key physicochemical parameters of the final wines produced from the different fruit bases after 28 days of fermentation is shown in Table 2. The result showed that the mixed fruit wine produced compares positively with some of the commercial wines sold in the market.

Sensory Evaluation

The sensory attributes of the mixed fruit wine and two commercial wines were evaluated by a 20-member trained panel using a 9-point hedonic scale. The results are presented in Table 3.

The wine was highly rated for its intense and pleasant tropical aroma and flavor, a characteristic likely derived from ethyl esters and acetate esters produced by the yeast during fermentation from pineapple-derived precursors. However, its high acidity likely contributed to a slightly lower score in "taste" compared to "aroma." The highest rating of the mixed fruit wine was in its appearance. In overall acceptability, the mixed fruit wine was generally accepted more than commercial wine A and scored slightly lower than commercial wine B.

Table 2: Physicochemical Properties of Mixed-Fruit Wine Produced in Comparison with Commercial Wines

Parameter	Mixed Fruit Wine	Commercial Wine A	Commercial Wine B
pH	3.75 ± 0.04	3.80 ± 0.05	3.65 ± 0.04
Reducing Sugar (g/L)	9.8 ± 0.9	11.5 ± 1.1	8.2 ± 0.8
Titratable Acidity (g Tartaric/100ml)	0.68 ± 0.02	0.62 ± 0.03	0.75 ± 0.04
Specific Gravity	0.998 ± 0.001	0.999 ± 0.001	0.996 ± 0.001
Alcohol Content (% v/v)	11.5 ± 0.4	10.8 ± 0.5	12.5 ± 0.6

Values are mean ± standard deviation of triplicate determinations (n=3).

Table 3: Sensory Evaluation Scores of the Fruit Wines as Compared to Commercial Wines

Parameter	Mixed Fruit Wine	Commercial Wine A	Commercial Wine B
Appearance	8.2 ± 0.9	7.1 ± 1.2	7.8 ± 1.1
Aroma/Flavor	7.6 ± 1.1	6.5 ± 1.4	8.0 ± 1.0
Taste	7.3 ± 1.3	6.0 ± 1.5	7.9 ± 1.2
Mouthfeel	7.7 ± 1.0	6.8 ± 1.3	7.5 ± 1.1
Overall Acceptability	7.7 ± 0.9	6.6 ± 1.3	7.8 ± 1.0

Scores are mean ± standard deviation (n=20). Scale: 1 (Dislike Extremely) to 9 (Like Extremely).

DISCUSSION

The fermentation of the mixed watermelon-pineapple (WM-PN) "must" by isolate Y-03 proceeded predictably and efficiently. The physicochemical changes observed, a steady decrease in pH, reducing sugar, specific gravity, and °Brix, coupled with an increase in titratable acidity and alcohol content, are hallmarks of a successful alcoholic fermentation driven by yeast metabolism. The production of organic acids (e.g. succinic and acetic) by the yeast contributes to the increasing titratable acidity and falling pH, which enhances the microbiological stability and sensory profile of the wine. The rapid sugar utilization within the first 14 days indicates a vigorous fermentative phase, and the final residual sugar of 9.8 g/L suggests a nearly complete fermentation, leaving a touch of sweetness that is often desirable for fruit wine palatability. The steady decrease in pH and increase in titratable acidity due to the production of organic acids is a well-documented phenomenon, as reported by Hanifah *et al*. (2022). The rapid decline in reducing sugar content within the first 7-14 days coincides with the most vigorous phase of yeast activity and CO_2 production, which is typical. The final residual sugar of 9.8 g/L indicates a nearly complete fermentation, leaving a slight sweetness that is often desirable for palatability in fruit wines, a strategy also employed in the development of Nigerian banana wine. The correlation between decreasing specific gravity/°Brix and increasing estimated alcohol content is a standard observation and confirms the efficiency of the fermentation process.

The final wine produced from the mixed "must" compared favorably with commercial benchmarks. Its physicochemical parameters (pH: 3.75, alcohol: 11.5% v/v, reducing sugar: 9.8 g/L) fell well within the standard ranges for fruit wines and were strikingly similar to those of the commercial products. This indicates that the fermentation was technically successful and yielded a product with comparable core chemical properties. This successful benchmarking is a key outcome, as several Nigerian studies have aimed to produce wines from local fruits that can compete with imported products. For instance, Okeke *et al*. (2015) produced acceptable wine from pineapple and watermelon with similar physicochemical parameters, while Archibong *et al*. (2015) achieved success with a blend of orange and pineapple. This study adds to the body of evidence supporting the viability of blended fruit wines using locally isolated yeasts in Nigeria.

Sensory evaluation revealed the wine's key strengths and a minor limitation. The high scores for "Appearance" and "Aroma/Flavor" (7.6-8.2) suggest that the strain Y-03 effectively produced desirable volatile compounds, likely esters such as ethyl acetate and isoamyl acetate, which are known to confer fruity and tropical aromas, particularly from pineapple precursors (Saerens *et al*., 2010). Nigerian consumers are often drawn to products with familiar and intense fruity aromas (Oyeniyi *et al*., 2009). The slightly lower score for "Taste" (7.3) compared to "Aroma" can likely be attributed to the relatively high titratable acidity, a common trait in fruit wines that some consumers may find too sharp. The high overall acceptability score confirms that the complex aroma profile largely compensates for the sharp taste, resulting in a product with distinct character and strong market potential. Despite this, the overall acceptability score (7.7) was higher than that of Commercial Wine A and only marginally lower than that of Commercial Wine B, demonstrating strong consumer appeal and market potential. This demonstrates a strong market potential, particularly for consumers seeking novel, locally sourced alcoholic beverages.

CONCLUSION AND RECOMMENDATIONS

The use of stress-tolerant yeast in fermenting a mixed watermelon-pineapple must resulted in a wine with physicochemical properties that are competitive with commercial wines. The sensory profile of the wine was characterized by a highly appealing tropical aroma and flavor, although its taste was slightly impacted by perceptible acidity. Overall, the research successfully

demonstrates the feasibility of using locally isolated, stress-tolerant yeasts for the production of high-quality, acceptable fruit wine from underutilized fruits like watermelon and pineapple. This approach not only adds value to surplus produce but also promotes the use of indigenous microbial resources for sustainable bioprocessing.

There is a need to improve the Y-03 yeast strain to enhance its performance and overall yield. Further research on more efficient indigenous yeast strains and underutilized fruits for developing sustainable local wineries is very essential.

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Authors Contributions

OIU prepared the manuscript and involved in some analysis. CME, CME & SOU performed data collection and analysis. GCU assisted with some analysis. All authors read and approved the final manuscript.

Ethical Statement

The sensory evaluation was carried out following the principles for human experimentation as defined in the Declaration of Helsinki and International Conference on Harmonization, Good Clinical Practice guidelines and approved by the relevant institutional review boards.

AI Declaration Statement

The authors declare that no Artificial Intelligence (AI) tools were used in the generation, analysis, interpretation or writing of this manuscript.

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