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Comparative Exploration and Implications of Safety Profiles in Palm Wine and Raphia Wine for Economic Potential

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Abstract

The comparative exploration and implications of safety profiles in palm wine and raphia wine for economic potential provide insights into fermentation processes, microbial dynamics, and potential economic applications. This study compares the safety profiles of palm wine and raphia wine, over five days. Palm wine contained *Bacillus, Enterobacter*, and *Staphylococcus* species, along with *Saccharomyces cerevisiae*, *Fusarium*, and *Penicillium* species. Raphia wine had a broader microbial spectrum, including *Pseudomonas*, *Salmonella typhi*, and *Streptococcus* species, in addition to those found in palm wine. The microbial load increased over time, with bacterial counts peaking on day 3 and fungal counts on day 5. Raphia wine exhibited higher fungal counts (5.80×10^5 CFU/mL) than palm wine (5.10×10^5 CFU/mL). Sugar analysis showed raphia wine had higher glucose concentration, with higher levels of fructose (0.018 µg/mL), lactose (1.02 µg/mL), and xylose (0.054 µg/mL) than palm wine, indicating faster fermentation potential. These variations in safety profiles influence the taste, preservation, and health implications. The findings highlight distinct fermentation characteristics and economic opportunities for both wines, suggesting their suitability for specific commercial production and distribution strategies.

Keywords: Potentials, Safety, Quality, Fermentation, Dynamics

Introduction

Palm wine and raphia wine are traditional beverages derived from the sap of palm species, notably *Elaeis guineensis* and *Raphia hookeri*/ *R. vinifera,* respectively. These wines have cultural significance and potential economic value, owing to their unique flavors and nutritional properties (Aisien & Ghosh, 1978) [1]. The microbial diversity within each wine type plays a crucial role in the fermentation process, influencing the flavor, preservation, and safety of the product. Moreover, the sugar profile of the sap is pivotal in determining the alcohol content and overall flavor profile of the wine (Faparusi & Bassir, 1971) [8].

In traditional African societies, traditional wines play a significant role in customary practices, especially the distilled product from the wines, a potent gin called by various names in West Africa (Amoa-Awua *et al.,* 2006) [2]. Over ten million people consume traditional wines in West Africa (Onwuka, 2011) [13]. Traditionally, especially in Igbo land, it is believed that when taken by a nursing mother, palm/raphia wines stimulate lactation and also have a diuretic effect. Palm/raphia wines have also been used to enhance men's potency due to yeast cell concentration. They could also be used for leavening of dough and also used in African medicine, particularly in the treatment of measles and malaria (Onwuka, 2011) [13].

Despite all these good qualities of traditional wines, they are highly perishable due to fermentation activities which starts soon after the sap is collected, and within an hour or two becomes reasonably high in alcohol (up to 4%). If traditional wines are allowed to continue to ferment for more than 24 hours, it starts to turn into vinegar. This makes it unacceptable to consumers

and creates losses to the food service industries. Fermentation in palm/raphia wines are possible because they are good growth medium for numerous microorganisms especially for yeast, lactic acid and acetic acid bacteria (Bechem *et al*., 2007) [4]. *Saccharomyces cerevisiae* constitutes about 70% of the total yeast of traditional wines and the activities of these microbes are believed to be responsible for conversion of sugar to alcohol after a short time while bacteria induces the conversion of alcohol into vinegar (Onwuka, 2011) [13].

Earlier researchers on microbiology of traditional wines have isolated acid-producing bacteria and these bacteria are believed to be responsible for souring of traditional wines. However, there is need to establish succession pattern for other inherent microorganisms to enable appropriate preservation method to be developed. Hence, this study is aimed at comparing the safety profiles of palm wine and raphia wine, exploring their implications for commercial applications, which provides insight into fermentation dynamics and also highlights the potential economic benefits through enhanced product stability and marketability.

Materials and Methods

Study area

The study area is Owerri Metropolis, Imo State, in the South-Eastern Nigeria. The Owerri town is a major hospitality center ("Oriri na Onunu/ Igba Oringo" in Igbo) in Eastern Nigeria, of the Igbo tribe. The geographical coordinates are 5.1215ºN and 7.3732ºE.

Collection of samples

Two different traditional wine samples from *Elaeis guineensis* and *Raphia hookeri* were separately collected from local wine tappers from Owerri metropolis, Imo State, Nigeria. The freshly tapped samples were collected using 6 pre-sterilized labeled 100ml capacity sample bottles with perforated screw caps corresponding to 0, 24, 48, 72, 96 and 120 hours of fermentation respectively. The perforated screw caps were plugged with sterile non-absorbent cotton wool. The sample were transported to the laboratory in a cooler supported with packs of freezing mixture of salt and ice-block for analysis within 1 hour of collection. This was to reduce the rate of fermentation of the sample before analysis could began (Obire, 2005; Bassir, 1962) [11, 3].

Sample preparation

One milliliter each of palm and raphia wines was transferred to 9ml of sterile physiological saline. Ten-fold serial dilution of each test samples were done using sterile peptone water as diluent up to 10^{-10}. One milliliter (1 mL) each of the samples was aseptically transferred into a sterile test tube containing nine milliliters (9 mLs) of sterile peptone water, stirred with sterile glass rod and shaken vigorously to ensure adequate disengagement of entrapped microorganisms to obtain 10^{-1} dilution. Serial dilutions of the homogenates were continued and made step-wisely till the tenth (10^{th}) tube, to obtain dilutions of 10^{-1} to 10^{-10}.

Microbial analysis

An aliquot (0.1ml) of each of the 10^{-2}, 10^{-3}, 10^{-4}… 10^{-9} diluents of each test samples were used to inoculate plates of Nutrient agar plate, MacConkey agar, *Salmonella-Shigella* agar plate and Sabourand dextrose agar by spread plate technique of Cappucino and Sherman (2010) [6]. These plates were then incubated at 37 ºC for 24 hours for bacterial colonies and 25 ºC for 78 hours for fungal colonies. After incubation, colonies were observed, counted and recorded. The different colonies were sub-cultured on the media used for enumeration and incubated accordingly as described above. Pure bacterial isolates were identified using cultural, morphological and biochemical characterization. Identification of bacteria to genera level was based on the schemes of (Boone *et al*., 2005) [5]. The purified fungal isolates were identified on the basis of macroscopic and microscopic characteristics by slide culture technique and lactophenol staining. The scheme of Kidd *et al*. (2016) [9] was used for the identification.

Sugar analysis

The sugar profile was analyzed using colorimetric assays to measure concentrations of reducing sugars, fructose, sucrose, lactose, glucose, xylose, and maltose, following the methodology outlined by Okafor (1975) [12].

Statistical analyses

All data obtained in this study were analyzed using SPSS version 21 (Statistical Package for Social Sciences).

Results

Microbial counts

The total bacterial count (TBC) of the test samples ranged from 2.80 $x10^4$ CFU/ml (palm wine) to 5.00 $x10^4$ CFU/ml (raphia wine). Raphia wine had the highest total bacteria count (5.00$x10^4$ CFU/ml) and was significantly different ($p \leq 0.05$) from palm wine. The high bacteria count seen in raphia wine could be attributed to high sap yield recorded with raphia wine (Okafor, 1975) [12]. The total fungi count (TFC) was found to range from 4.00$x10^5$ CFU/ml (palm wine) to 5.80 $x10^5$ CFU/ml (raphia wine). There was significant difference ($p \leq 0.05$) between the test samples at the 5^{th} day. The total coliform count (TCC) significantly ranged from zero CFU/ml (raphia wine) to 0.10 $x10^2$ CFU/ml (palm wine). The fermentation activities created acidic conditions that inhibited the proliferation of coliforms as recorded on the 5^{th} day. The *Pseudomonas* species count (PSC) ranged from 1.05 $x10^2$ CFU/ml (palm wine) to 1.60 $x10^2$ CFU/ml (raphia wine). There were significant difference among values obtained across the fermentation days.

Microbial growth patterns across days 1, 3, and 5 (Table 3.1) revealed that raphia wine exhibited higher overall bacteria and fungi counts, with a peak in total bacterial count (TBC), and *Pseudomonas* Species Count (PSC) on day 3, while fungi count (TFC) extended increase to day 5. Palm wine only showed higher coliform count (TCC) on day 3 which depreciated as fermentation days prolonged. This rapid microbial growth suggests a shorter shelf life for raphia wine, corroborating the work of Faparusi and Bassir (1971) [8], who documented accelerated spoilage in high-sugar fermented beverages. Palm wine's stable microbial profile may indicate potential for longer storage.

Table 3.1: Results of Microbial Analysis on Palm and Raphia Wines

ISOLATE	DAY 1				DAY 3				DAY 5			
	TBC	TFC	TCC	PSC	TBC	TFC	TCC	PSC	TBC	TFC	TCC	PSC
Palm wine	$3.25x10^4 \pm 0.25^a$	$4.00x10^5 \pm 0.85^a$	$1.23x10^3 \pm 0.00^b$	$1.40x10^2 \pm 2.82^a$	$3.92x10^4 \pm 0.00^b$	$4.95x10^5 \pm 0.00^b$	$1.30x10^3 \pm 0.00^a$	$1.54x10^2 \pm 0.00^a$	$2.80x10^4 \pm 0.00^b$	$5.10x10^5 \pm 0.30^b$	$0.10x10^2 \pm 0.00^a$	$1.05x10^2 \pm 0.00^a$
Raphia wine	$5.00x10^4 \pm 0.00^a$	$5.06x10^5 \pm 1.41^a$	$1.18x10^3 \pm 0.00^a$	$1.60x10^2 \pm 0.09^a$	$4.40x10^4 \pm 0.00^a$	$5.70x10^5 \pm 0.00^a$	$1.22x10^3 \pm 0.00^b$	$1.80x10^2 \pm 0.00^b$	$2.84x10^4 \pm 0.23^b$	$5.80x10^5 \pm 0.00^a$	-	$1.20x10^2 \pm 0.00^a$
LSD	$5.11 x10^7$	$1.70x10^5$	0.00	$5.84 x10^4$	0.24	0.16	0.05	0.30	0.00	0.05	0.00	0.00

Legend: TBC - Total bacteria count, TFC – Total fungi count, TCC – Total coliform count, PSC – Pseudomonas species count

Microbial identifications

Six (6) bacteria species (*Bacillus* species, *Enterobacter* species, *Staphylococci* species, *Pseudomonas* species, *Salmonella typhi, Streptococcus* species) and three (3) fungi species (*Saccharomyces cerevisiae, Fusarium* species, *Penicillium* species) were identified. Table 3.2 illustrated that palm wine predominantly contained *Bacillus*, *Enterobacter*, and *Staphylococci* species, while raphia wine hosted *Pseudomonas*, *Salmonella typhi*, and *Streptococcus* species in addition to that hosted with palm wine. The presence of *Bacillus* and *Staphylococci* in traditional wines could contribute to enhanced flavor and preservation qualities, while *Salmonella typhi* in raphia wine raises potential safety concerns, aligning with prior studies indicating microbial risks associated with traditional fermentation (Okafor, 1975) [12].

Table 3.2: Results of Identification of Some Microbial Isolated from Palm Wine & Raphia Wine

Isolate	Day 1		Day 3		Day 5	
Palm wine	NA/ MA	*Bacillus* species *Enterobacter* species *Staphylococci* species	NA/ MA	*Bacillus* species *Enterobacter* species *Staphylococci* species	NA/ MA	*Bacillus* species *Enterobacter* species *Staphylococci* species
	SDA	*Saccharomyces cerevisiae* *Fusarium* species *Penicillium* species	SDA	*Saccharomyces cerevisiae* *Fusarium* species *Penicillium* species	SDA	*Saccharomyces cerevisiae* *Fusarium* species *Penicillium* species
Raphia wine	NA/ /MA/ CA/ SSA	*Pseudomonas* species *Salmonella typhi* *Bacillus* species *Enterobacter* species *Staphylococci* species	NA/ /MA/ CA/ SSA	*Pseudomonas* species *Salmonella typhi* *Bacillus* species *Enterobacter* species *Staphylococci* species	NA/ /MA/ CA/ SSA	*Pseudomonas* species *Salmonella typhi* *Streptococcus* species *Bacillus* species *Enterobacter* species *Staphylococci* species
	SDA	*Saccharomyces cerevisiae* *Fusarium* species *Penicillium* species	SDA	*Saccharomyces cerevisiae* *Fusarium* species *Penicillium* species	SDA	*Saccharomyces cerevisiae* *Fusarium* species *Penicillium* species

Legend: NA - Nutrient agar, MA - MacConkey agar, SSA - Salmonella-Shigella aga, CA - Cetrimide agar, SDA - Sabouraud dextrose agar

Sugar profile

Sugar analysis (Table 3.3) showed a significant difference in glucose levels, with raphia wine containing 1.02 µg/ml compared to lower levels in palm wine. Higher glucose content in raphia wine could enable faster fermentation, potentially leading to a stronger alcohol profile (Aisien & Ghosh, 1978) [1]. The presence of varied sugars, including fructose, lactose, and maltose, further influences the distinct flavor profiles between the two wines.

Table 3.3: Results of Sugar Analysis of Raphia and Palm Wines

Sample	Total reducing sugar (µg/ml)	*Fructose* (µg/ml)	Sucrose (µg/ml)	*Lactose* (µg/ml)	*Glucose* (µg/ml)	*Xylose* (µg/ml)	*Maltose* (µg/ml)
Palm wine	0.0025 ± 0.12^a	0.012 ± 0.07^b	0.003 ± 0.16^a	0.69 ± 0.0^a	0.001 ± 0.00^a	0.033 ± 0.05^a	0.014 ± 0.10^b
Raphia wine	0.003 ± 0.13^a	0.018 ± 0.00^a	0.003 ± 0.17^a	1.02 ± 0.45^a	0.003 ± 0.03^b	0.054 ± 0.01^b	0.019 ± 0.0^a
LSD	0.21	0.00	0.14	0.46	0.00	0.05	0.00

Discussion

The distinct microbial and sugar profiles of palm and raphia wines suggest different fermentation dynamics and economic potential. Raphia wine's higher glucose concentration, bacterial and fungal counts align with a rapid fermentation process, which may enhance its flavor but limit its shelf life, as noted in prior research (Nwachukwu & Ibekwe, 2007) [10]. Conversely, palm wine's stability and lower microbial counts make it a candidate for extended preservation and potential commercial scaling (Eze & Asamudo, 2007) [7].

The findings of this study highlight significant differences in microbial diversity and sugar composition between palm wine and raphia wine. The microbial analysis revealed that while both traditional wines contained *Bacillus* species, *Enterobacter* species, *Staphylococcus* species, and fungi such as *Saccharomyces cerevisiae*, *Fusarium* species, and *Penicillium* species, raphia wine exhibited a broader spectrum, including potentially pathogenic species like *Pseudomonas* species, *Streptococcus* species and *Salmonella typhi*. This suggests that raphia wine may pose a higher risk of microbial contamination and require additional safety measures during processing and consumption.

Microbial load dynamics showed an increase in total bacterial and fungal counts over time, which aligns with the natural fermentation process driven by indigenous microbes. Notably, raphia wine had a higher total fungi count (5.80 x 10^5 CFU/mL on day 5) compared to palm wine (5.10 x 10^5 CFU/mL), suggesting a more vigorous microbial activity. This could be attributed to environmental factors, nutrient availability, or differences in fermentation conditions.

Sugar analysis indicated variations in carbohydrate composition, which may influence the organoleptic properties and potential applications of these wines. Raphia wine exhibited higher fructose (0.018 µg/mL), lactose (1.02 µg/mL), and xylose (0.054 µg/mL) content, whereas palm wine had relatively lower sugar concentrations. The higher lactose and xylose levels in raphia wine may contribute to its distinct sweetness and fermentation characteristics. Additionally, the presence of reducing sugars plays a crucial role in the alcohol yield and flavor profile of these traditional beverages.

These findings have notable economic implications. The high microbial diversity and sugar composition of raphia wine with unique flavor may appeal to niche markets, and suggest its potential for bioethanol production, while palm wine, with its lower microbial risks and stability, could be more suitable for large-scale commercial distribution. Enhancing microbial safety and fermentation techniques can improve the shelf life and safety of these products, making them more competitive in global markets with increased market viability for both beverages. Furthermore, optimizing sugar utilization through controlled fermentation can improve alcohol yield, thereby increasing profitability for local producers. Future research should focus on refining fermentation techniques, exploring microbial inhibitors, examining the sensory properties and consumer preferences to understand potential product development pathways and enhancing preservation strategies to maximize the economic potential of these indigenous wines.

Conclusion

This study highlights key differences in diversity and sugar profiles between palm and raphia wines, influencing their fermentation dynamics, safety, and economic potential. Raphia wine's higher microbial load and sugar content contribute to its rapid fermentation and distinct flavor but may shorten its shelf life and increase contamination risks. In contrast, palm wine's lower microbial counts and stability makes it more suitable for extended preservation and commercial scaling. The findings suggest that raphia wine has potential for bioethanol production and niche markets, while palm wine holds promise for large-scale distribution. Enhancing microbial safety and fermentation techniques can improve product quality, competitiveness, and profitability in global markets.

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Disclosure of conflict of interest

There is no conflict of interest.

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