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Original Article

Aging of Palm Wine Source: Its Implication on the Physicochemical Properties and Vitamin Content of Palm Wine

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Abstract *- Palm wine, a traditional alcoholic beverage widely consumed in sub-Saharan Africa, is derived from the sap of various palm trees. This study investigated the effects of aging of the palm wine source on the physicochemical properties and vitamin content of palm wine for 30 days. Standard laboratory procedures were employed to analyze these parameters. The results revealed significant ($P<0.05$) changes in most physicochemical properties and vitamin levels during aging. The pH decreased from (4.95±0.07) on Day 1 to (3.60±0.12) on Day 30, indicating increased acidity. Viscosity declined from (10.12±0.01 mPa·s) on Day 1 to (7.16±0.07 mPa·s) on Day 30, while total solids reduced from (8.72±0.03%) to (6.99±0.01%). Alcohol content increased significantly from (2.88±0.04%) to (6.89±0.01%), and titratable acidity rose from (0.47±0.01%) to (1.20±0.02%), indicating active fermentation. Vitamin analysis showed a significant decline in vitamin A levels, from (6.05±0.02 mg/kg) on Day 1 to (2.30±0.01 mg/kg) on Day 30. Vitamins E and C also showed significant reductions, from (14.66±0.04 mg/kg) and (93.41±0.21 mg/kg) on Day 1 to (7.82±0.20 mg/kg) and (41.07±0.02 mg/kg), respectively, on Day 30. In conclusion, freshly tapped palm wine (aged 1–3 days) is rich in sugar and essential vitamins, making it suitable for casual consumption due to its refreshing taste and nutritional benefits. It supports cellular energy production, brain function, and muscle activity, while its vitamin content acts as cofactors in energy metabolism. These findings underscore the importance of aging in determining the beverage's physicochemical and nutritional qualities.*

Keywords *- Palm wine, Vitamins, Physicochemical properties, Aging period, Fermentation.*

1. Introduction

Palm wine, a traditional alcoholic beverage derived from the sap of palm trees such as *Elaeis guineensis* and *Borassus aethiopum*, is widely consumed across tropical regions, particularly in Africa, Asia, and parts of South America [1]. This sweet, fizzy, and alcoholic beverage is obtained from various palm species, including Raphia palm (*Raphia hookeri*), oil palm (*Elaeis guineensis*), nipa palm (*Nypa fruticans*), palmyra or borassus palm (*Borassus flabellifer*), and wild date palm (*Phoenix sylvestris*) [2, 3]. It is a naturally fermented drink, rich in sugars, organic acids, and minerals, making it both culturally significant and nutritionally valuable [4].

Palm wine undergoes spontaneous fermentation almost immediately after sap extraction due to its high sugar content and microbial activity. This fermentation process triggers significant changes in the beverage's chemical composition, flavor, and nutritional profile. As fermentation progresses, the alcohol content rises, while physicochemical properties such as pH, titratable acidity, and the concentration of volatile compounds evolve [5]. These transformations, driven by microbial metabolism, make palm wine a dynamic product with sensory and nutritional characteristics that vary depending on the aging period.

Previous research has extensively explored changes in sugar content, ethanol concentration, and microbial populations during palm wine fermentation [6, 7]. However, while these reports focused on the fermentation of already tapped palm wine, there is limited data on how the ageing of the source of the wine could influence the beverage's vitamin profile over time. Understanding the effects of aging on the physicochemical properties and vitamin content of palm

wine is critical for assessing how ageing of the source and timing of consumption impact its nutritional value. For instance, while palm wine is traditionally consumed fresh, aging introduces significant alterations that may either degrade or enhance its health benefits [7]. Given the nutritional importance of palm wine and the scarcity of data on the impact of aging on its vitamin profile, this study aims to investigate how the aging process affects its physicochemical properties and vitamin content. These insights will not only contribute to the scientific understanding of palm wine's nutritional dynamics but also guide consumers and producers on the optimal time to stop tapping from a source and consumption practices to maximize its health benefits.

2. Materials and Method

2.1. Sample Collection

The palm tree was cut down and allowed to ferment for 2 weeks, after which the samples (palm wine) were collected on day 1, 3, 7, 14, 21, and 30 and were taken to the laboratory for analysis. The Palm Wine was collected from the Aluu community in Ikwere LGA, Rivers State, Nigeria.

The study was conducted using a completely randomized design to evaluate the effect of aging period on the physicochemical properties and vitamin composition of palm wine. Samples were collected at predetermined intervals of Day 1, Day 3, Day 7, Day 14, Day 21, and Day 30 following tapping. All analyses were carried out in triplicate and results expressed as mean ± standard deviation. Quality assurance measures included proper calibration of analytical instruments, preparation of reagent blanks, adherence to standard laboratory protocols, and immediate transportation of samples to the laboratory to minimize contamination and biochemical alterations prior to analysis.

2.2. Determination of the Physicochemical Properties of Aged Palm Wine

2.2.1. Specify Gravity

Fifty milliliters of the pycnometer bottle was washed thoroughly with detergent water and petroleum ether. It was allowed to dry and weigh. The bottle was filled with water, and the weight was taken. The bottle was allowed to dry, and it was filled with the sample and weighed.

$$specific\ grafity = weight\ of\ Xml\ of\ sample \therefore weight\ of\ Xml\ of\ water$$

2.2.2. Viscosity

The dynamic viscosity (mpas. sec) of the sample was determined by using a Brookfield viscometer equipped with a thermo-container and programmable temperature controller (LV-DVIII, HT-60, HT-110FR, respectively). The thermo-container was equipped with a sample chamber and a spindle (HT-2 and SC4-18, respectively). Twenty milliliters of the sample was transferred into the sample chamber, and the viscosity was measured.

2.2.3. Moisture Content

A petri dish was washed and dried in the oven. Approximately 1-2g of the sample was weighed into the petri dish. The weight of the petri-dish and sample was taken before drying. The petri-dish and sample were put in an oven and were heated at 105 ˚C for 2hours, and the result was taken and heated for another 1hour until a steady result was obtained, and the weight was taken. The drying procedure was continued until a constant weight was obtained.

$$\%\ moisture\ content = W1 - W2 \therefore weight\ of\ petri - dish\ and\ sample\ after\ drying$$

2.2.4. Ash Content

An empty platinum crucible was washed, allowed to dry, and the weight was taken. Approximately 1-2g of the sample was weighed and put in the empty platinum crucible. It was then placed in a muffle furnace at 550 ˚C for 3hours. After this, the sample was cooled in a desiccator after burning and was weighed.

$$\%\ Ash\ content = W3 - W1 \therefore W2 - W1\ \times 100$$

Where W_1 is the weight of the empty platinum crucible, W_2 is the weight of the platinum crucible and the sample before burning, and W_3 is the weight of platinum and ash.

2.2.5. Sugar Content

Benedict's method was adopted for the determination of sugar content. Five milliliters of the sample was transferred into a volumetric flask [50ml], and then 2.5ml of sodium tungstate [10%] was added drop by drop with continuous mixing and then 5ml of 2/3N H_2S0_4 was added. The volume was made up with distilled water. The mixture was left in the flask for 10 minutes, and then filtered. The filtrate was transferred into a burette. 25ml of Benedict reagent with 30ml of distilled water was put in a beaker, and 2g of hydrous sodium carbonate was added to increase the alkalinity. The mixture was heated till a clear solution was gotten. Titration was performed while it was boiling. The ml of filtrate exhausted in the titration was then recorded.

$$\%\ reducing\ sugar = 0.0678 \therefore R\ \times 10 \times 100$$

2.2.6. Total Titrable Acidity

The titrimetric method was adopted for the determination of total titrable acidity. Ten milliliters of a 1 in 100 dilution of the sample was poured into a conical flask. 3 drops of phenolphthalein indicator were added. 0.1m sodium hydroxide was poured into a burette and used to titrate the solution to end point. Total titrable acidity [lactic acid]: 1ml of 0.1m NaOH = 0.0064g of lactic acid.

2.3. Determination of the Vitamin Content

2.3.1. Vitamin A

The Bayfield and Cole [8] method was adopted for the estimation of vitamin A. One gram of the sample was mixed with 1.0ml of saponification mixture and refluxed for 20 minutes at 60 $^{\circ C}$ in the dark. The tubes were cooled, and 20ml of water was added and mixed well. 10ml of (40 $^{\circ C}$ – **6**0 $^{\circ}$C) petroleum ether was used to extract vitamin A twice. The two samples were pooled and washed thoroughly with water. Anhydrous sodium sulphate was added to remove excess moisture. Standard vitamin A palmitate of concentrations ranging from 0 – 7.7 $\int g$ were pipetted out into a series of test tubes. The volume for all the test tubes was made up to 1.0ml with chloroform. TCA reagent (2.0ml) was added rapidly, it was mixed, and the absorbance was measured immediately at 620nm using a spectrophotometer (Genesys 10uv). Vitamin A content was expressed as mg/kg. Note: All procedures were carried out in the dark to avoid the interference of light.

2.3.2. Vitamin D

Brockmann & Chen [9] method was adopted for the estimation of vitamin D.

Standard Preparation: Twenty-five milligrams of vitamin D working standard was weighed accurately and put in a 25ml volumetric flask with a solution mixture (chloroform and methanol in a ratio of 1:9). It was dissolved and diluted with a solution mixture and made up to the mark for it to mix well.

Sample Preparation: 0.1ml of the sample was weighed accurately and taken into a 25ml volumetric flask with a solution mixture containing chloroform and methanol in a ratio of 1:9. It was dissolved and diluted with a solution mixture and made up to the mark for it to mix well.

1.6ml of 0.25N HCl, 0.5ml of 15.0% Tricholoracetic Acid (TCA) and 0.5ml of 0.375% of Thiobarbituric Acid (TBA) was added and the absorbance was taken at 464nm against blank.

2.3.3. Vitamin E

Extraction of Vitamin E: 2.5g of the sample was homogenized in 50ml of 0.1N sulphuric acid and was allowed to stand overnight. The contents of the flask were shaken vigorously and filtered using Whatman No 1 filter paper. After which, aliquots of the filtrate were used for the estimation.

Procedure: Emmeric – Engel reaction as reported by Rosenberg [10] was adopted for the estimation of vitamin E. 1.5ml of the sample, 1.5ml of the standard and 1.5ml of water were pipetted separately into 3 centrifuge tubes. 1.5ml of ethanol and 1.5ml of xylene were added to all the tubes, and it was mixed well and centrifuged. 1.0ml xylene was transferred into another tube. 1.0ml dipyridyl reagent was added to each tube and mixed thoroughly, then 1.5ml of the mixture was pipetted out into a cuvette and the absorbance was measured at 460nm.

2.3.4. Vitamin C

Extraction of Vitamin C: Ascorbate was extracted from 1g of the sample using 4% Tricholoracetic Acid (TCA), and the volume was made up to 10ml with the same. The supernatant obtained after centrifuging at 2000rpm for 10minutes was treated with a pinch of activated charcoal, it was shaken vigorously using a cyclomixer and allowed to stand for 5 minutes. The charcoal particles were removed by centrifugation, and aliquots were used for the estimation.

Procedure: The spectrophotometric method as described by Roe and Kenther [11] was adopted for the estimation of vitamin C. Standard ascorbate ranging between 0.2 – 1.0ml and 0.5ml and 1.0ml of the supernatant were taken. The volume was made up to 2.0ml with 4% Trichloroacetic Acid (TCA). 0.5ml of 2,4- Dinitrophenyhydrazine (DNPH) reagent was added to all the tubes, followed by 2 drops of 10% thiourea solution. The contents were mixed and incubated at 37 $^{\circ C}$ for 3 hours, resulting in the formation of osazane crystals. The crystals were dissolved in 2.5ml of 85% sulphuric acid, in cold. DNPH reagent and thiourea were added to the blank alone after the addition of sulphuric acid. The tubes were cooled in ice, and the absorbance reading was taken at 540nm using a spectrophotometer. A standard graph was constructed using an electronic calculator set to the linear regression mode. The concentration of ascorbate in the sample was calculated and expressed in terms of mg/kg of sample.

2.4. Determination of Vitamin B_1& B_2

One gram of the sample was weighed into a conical flask. This was dissolved with 100ml of deionized water. It was shaken thoroughly, heated for 5 minutes, allowed to cool, and then it was filtered. The filtrate was powered a cuvette, and its respective wavelength for the vitamins was set to read the absorbance using a spectrophotometer. Vitamin B_1 = 261nm and vitamin B_2 = 242nm.

$$Concentration\ (mg\ \%) = A \times D.F \times Vol.of\ cuvette \therefore E \quad (5)$$

Where A is absorbance, E is the extinction coefficient: 25 for B_1 and B_2, and D.F is the dilution factor.

2.5. Determination of vitamin B_3

Five grams of the sample was dissolved in20ml of anhydrous glacial acetic acid and was warmed slightly. Five milliliters of anhydride were added and mixed. 2-3 drops of crystal violet solution were added as an indicator. 0.1M perchloric acid was used to titrate it until a green colour endpoint was observed.

$$Vitamin\ B3 = titrevalue \times 0.0122 \therefore 0.1$$

2.6. Determination of Vitamin B_6

Five grams of the sample was dissolved in a mixture of 5ml of anhydrous glacial acetic acid and 6ml of 0.1M mercury II acetate solution. Two drops of crystal violet were added as an indicator. It was titrated with 0.1M perchloric acid until a green colour was observed.
Each ml of 0.1M perchloric acid is equivalent to 0.02056g of $C_8H_{11}NO_3HCl$

2.7. Determination of vitamin B_{12}

Spectrophotometric determination of cyanocobalamin in serum preparations by coupling reactions with pyridine. Sample Preparation: 0.1ml of the sample was weighed and taken into a separator. 5ml of water was added, mixed well with 5ml of chloroform in the separator. The water layer was discarded, and then chloroform was taken into a dry 50ml volumetric flask by passed through anhydrous sodium sulphate and made up to 50ml with chloroform.

Procedure: Two milliliters of the sample and blank solution were taken into test tubes. 2ml of 0.2% solution of phenyl hydrazine (in hydrochloric acid and alcohol in a ratio of 1:5v/v) was added to each test tube and mixed well. After which it was heated in a water bath to almost dryness and cool to room temperature. Two milliliter solution mixture (ammonia and alcohol in a ratio of 1:1) and 1ml of pyridine were added to each tube. The absorbance was recorded at 635nm against a blank. Standard cobalamine was also analyzed and treated the same as the sample.

A calibration curve was plotted, and the concentration of the sample was extrapolated.

Statistical analysis of the generated data was performed using one-way Analysis of Variance (ANOVA). Significant differences among means were determined at a confidence level of 95% ($P < 0.05$). Results were expressed as Mean ± Standard Deviation.

4. Result

Table 1. Effect of Aging Period on the Physicochemical Properties of Palm wine

PARAMETER(S)	DAY 1	DAY 3	DAY 7	DAY 14	DAY 21	DAY 30
pH	4.95 ± 0.07 bdfhj	4.21 ± 0.01 *adfhj	3.86 ± 0.08 *bcfgi	4.41 ± 0.02 *bdehj	3.84 ± 0.06 *bcfgi	3.6± 0.12 *bdfgi
Specify Gravity	0.99 ± 0.03	1.00 ± 0.03	1.01 ± 0.03	1.00 ± 0.01	1.07 ± 0.04	1.00 ± 0.02
Viscosity (mpas.sec)	10.12 ± 0.01 bdfhj	9.81 ± 0.03 *adfhj	8.90 ± 0.02 *bcfhj	7.80 ± 0.02 *bdehj	7.28 ± 0.02 *bdfgj	7.16 ± 0.07 *bdfhi
Moisture Content (%)	91.33 ± 0.05 adfh	91.62 ± 0.42 adfh	89.21 ± 0.04 *bcfh	92.94 ± 0.08 *bde	92.92 ± 0.11 *bdeg	93.00 ± 0.02 *bdeg
Total Solid (%)	8.72 ± 0.03 bdfhj	8.08 ± 0.02 *adfhj	10.87 ± 0.07 *bcfhj	7.13 ± 0.02 *bdehj	7.19 ± 0.03 *bdfgj	6.99 ± 0.01 *bdfhi
Ash content (%)	2.89 ± 0.00 bdfhj	1.85 ± 0.01 *acfhj	1.84 ± 0.03 *acfhj	2.57 ± 0.08 *bdehj	2.16 ± 0.02 *bdfgj	2.11 ± 0.01 *bdfhi
Sugar Content (°Bx)	10.30 ± 0.01 bdfhj	8.94 ± 0.01 *adehj	6.91 ± 0.02 *bcfhj	8.92 ± 0.03 *adehj	7.51 ± 0.05 *bdfgj	5.99 ± 0.01 *bdfhi
Alcohol Content (%)	2.88 ± 0.04 bdfhj	3.80 ± 0.03 *adfhj	4.94 ± 0.03 *bcfhj	5.21 ± 0.02 *bdehj	6.46 ± 0.08 *bdfgj	6.89 ± 0.01 *bdfhi
Total Titratable Acidity (% w/v)	0.47 ± 0.01 bdfhj	0.55 ± 0.01 *adfhj	0.63 ± 0.02 *bcfhj	0.96 ± 0.05 *bdehj	1.09 ± 0.02 *bdegj	1.20 ± 0.02 *bdfhc

This table presents the effect of aging period on the physicochemical properties of palm wine. A progressive decrease in pH, viscosity, total solids, ash content, and sugar content was observed as aging progressed. Conversely, alcohol content and titratable acidity increased throughout the aging period, indicating continuous fermentation and biochemical transformation within the palm wine matrix.

Values of Table 1 are expressed as mean ± standard deviation. * shows that the mean difference is significant at the 0.05 level when comparing day 1with other days and different superscripts (a'b), (c'd), (e,f), (g'h), (i'j) differ significantly at the 0.05 level when comparing day 3, day 7, day 14, day 21 and day 30 respectively with other days.

Table 2. Effect of Aging Period on the Vitamin Contents of Palm Wine

VITAMIN(S)	DAY 1	DAY 3	DAY 7	DAY 14	DAY 21	DAY 30
A (mg/kg)	6.05 ± 0.02 bdfhj	5.51 ±0.03*adfhj	5.04 ±0.01*bcfhj	4.24 ± 0.03*bdehj	2.92 ± 0.02*bdfgj	2.30 ± 0.01*bdfhi
D (mg/kg)	3.84 ± 0.03 bdfhj	3.33 ± 0.04 *adfhj	5.47 ± 0.02 *bcfhj	1.93 ± 0.02*bdchj	2.29 ± 0.01*bdfgj	2.57 ± 0.01*bdfhi
E (mg/kg)	14.66 ± 0.04 bdfhj	12.0 ± 0.03*adfhj	10.64 ±0.04*bcfhi	9.35 ± 0.03*bdehj	7.60 ± 0.04 *bdfgi	7.82 ± 0.2*bdfhi
C (mg/kg)	93.41 ± 0.21bdfhj	68.07± 0.02*adfhj	66.17± 0.06*bcfhj	57.24 ± 0.07*bdehj	44.89 ± 0.01*bdfgh	41.07 ± 0.02 *bdfhi
B_1 (mg%)	0.04 ± 0.00	0.03 ± 0.00	0.02 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.02 ± 0.00
B_2 (mg%)	0.01± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.01± 0.00	0.01 ± 0.00	0.02 ± 0.00
B_3 (mg%)	0.86 ± 0.01bdfhj	0.60 ± 0.04 *adfhj	0.51 ± 0.01*bcehj	0.50 ± 0.01*bcehj	0.46 ± 0.07*bdfgj	0.36 ± 0.00*bdfi
B_6 (mg%)	0.25 ± 0.01bdfhj	0.25 ± 0.01	0.26 ± 0.00c	0.21 ±0.00*bdehj	0.19 ± 0.07*bdfgj	0.17 ± 0.02*bdfhi
B_{12} (mg/kg)	3.98 ± 0.02bdfhj	3.36 ± 0.02*adfhj	2.86 ± 0.02*bcfhj	4.90 ± 0.02*bdehj	4.19 ± 0.02*bdfgh	3.90 ± 0.01*bdfhi

This table presents the effect of the aging period on the vitamin composition of palm wine. Vitamins A, C, E, B3, and B6 generally showed decreasing concentrations with increasing aging period, whereas vitamins B1 and B2 remained relatively stable. Variations observed in vitamins D and B12 may be associated with complex microbial activities occurring during fermentation.

Values of Table 2 are expressed as mean ± standard deviation. * shows that the mean difference is significant at the 0.05 level when comparing day 1with other days and different superscripts (a'b), (c'd), (e,f), (g'h), (i'j) differ significantly at the 0.05 level when comparing day 3, day 7, day 14, day 21 and day 30 respectively with other days.

5. Discussion

Palm wine undergoes significant physicochemical and nutritional transformations during aging. This study investigated changes in key parameters, including pH, specific gravity, viscosity, sugar content, alcohol content, total solids, ash content, titratable acidity, and vitamin composition, over a 30-day fermentation period. The fermentation process mostly entails the transformation of sugars, which are a kind of carbohydrate, into alcohol, carbon dioxide, and other metabolites. The complex reaction between microorganism (yeast) and carbohydrate catabolism during fermentation not only produces the alcohol but also coordinates a series of changes in its physical and chemical characteristics, which affect its taste, aroma, appearance, and duration of storage [12].

Table 1 shows physicochemical insights into this dynamic interaction. The result shows that the pH of the palm wine exhibited a general trend of decrease throughout the aging period when comparing day 1 to other days. The pH of the day 1 sample was 4.95, and it maintained a significant decrease as the wine aged, except for that of day 14, whose value was 4.41. However, it was significantly lower when compared with the value for the day 1 sample. This acidification (lowered pH) is primarily attributed to the metabolic activities of fermenting microorganisms, predominantly yeasts and bacteria. The decrease in pH not only contributes to the characteristic flavor of aged palm wine but also plays a crucial role in its preservation by inhibiting the growth of spoilage microorganisms. The observed pH decline aligns with findings from previous studies on palm wine fermentation, where a similar pattern of acidification has been reported [5, 6]. The reduction in pH observed in the present study is consistent with recent findings reported by Oluwole *et al* [4], who attributed increased acidity in fermented palm beverages to the metabolic activities of lactic acid bacteria and acetic acid bacteria. The production of organic acids during fermentation contributes significantly to the acidification process and enhances microbial stability of the beverage. The specific gravity of the palm wine showed no significant difference in samples, irrespective of the aging duration.

The relatively stable specific gravity may suggest that the overall density of the beverage remained fairly constant despite the ongoing biochemical transformations. At the same time, the viscosity (mpas.sec) of the palm wine decreased significantly in all samples on all days from 10.12 on Day 1 to 7.16 on Day 30. This reduction in viscosity can be attributed to the breakdown of complex carbohydrates and the hydrolysis of pectin by microbial enzymes during fermentation. Viscosity in palm wine reflects its freshness and fermentation, as higher viscosity means more sugar, while lower viscosity indicates higher alcohol. The results align with research done by Karamoko *et al* [7] on palm wine fermentation.

However, an increase in moisture content was observed when comparing day 1, which recorded 91.33%, with other days as the wine aged, except for that of day 7, whose value was 89.21%, which is significantly lower when compared with the values for other days. An increase in the moisture content of the palm wine as it ages is a result of the utilization of palm wine sugars by various microorganisms during fermentation. The fermentation of these sugars leads to the precipitation of the said sugars out of the solution that constitutes palm wine, leading to an increased value of moisture content of the palm wine. Also, the increase in water content of the palm wine during storage could be a result of the various microorganisms present inside it undergoing cellular respiration, which leads to the production of water as a byproduct of respiration [6]. A decrease in total solids was observed when comparing day 1 sample with value of 8.72% with other days as the wine aged except for that of day 7 whose value was 10.87% which is significantly higher when compared with every other day's values. The decrease in total solids aligns with previous research, which indicates that a decrease in total solids of palm wine as fermentation ages could be a result of the utilization of palm sap soluble solids (soluble sugars such as glucose, sucrose) by microorganisms present in the sap, leading to the reduction of the total soluble solids content of the palm wine as the aging period progresses [6]. Although this is contrary to the work of Nwachukwu *et al* [13], which revealed that the percentage total solids of the palm wine samples increased with the age of the wines. This could be due to microbial activity, as yeast and bacteria involved in fermentation produce organic compounds and residues that led to an increase in the total solids.

Similarly, a significant decrease in ash content was recorded for all sample days when compared to day 1, which recorded 2.89 percent as the highest and day 7 recorded the lowest. The decrease could be due to bacteria or yeast activity, temperature, or moisture during aging. A decrease in ash contents suggests a reduction in the total minerals (such as potassium, calcium, magnesium, zinc, and copper). The result aligns with the report of Titilayo & Temitope [6] research on palm wine, which also recorded a decrease in ash content. A significant decrease in sugar content was observed in all sample days from 10.30% on Day 1 to 5.99% on Day 30. This decrease is a direct consequence of the metabolic activity of fermenting microorganisms, which utilize sugars as a primary energy source for growth and reproduction. The conversion of sugars into alcohol and other byproducts results in a progressive reduction in the sweetness of the palm wine as fermentation progresses. Nwachukwu *et al* [13] revealed that the sugar content of the palm wine decreased with the age of the wine. However, a significant steady increase in alcohol content of the palm wine was observed in all sample days when comparing day 1 with a value of 2.88% to other days and a final value of 6.89% on day 30, which has the highest percentage. This increase is a hallmark of the fermentation process, as yeasts convert sugars into ethanol and carbon dioxide [6]. The gradual accumulation of alcohol contributes to the intoxicating properties of aged palm wine and also acts as a natural preservative. The observed reduction in sugar content alongside the increase in alcohol concentration agrees with the report of Sharma *et al* [14], who noted that fermentative microorganisms continuously convert fermentable sugars into ethanol and carbon dioxide. The findings further demonstrate the active fermentation processes occurring throughout the aging period. A steady significant increase in total titratable acidity (%w/v) of the palm wine was observed in all sample days when comparing day 1 with 0.47 to other days, and 1.20 was recorded on Day 30 as the highest value. This increase in acidity is primarily due to the production of organic acids, such as lactic acid and acetic acid, by fermenting microorganisms. The rising acidity contributes to the lowered pH, tart flavor of aged palm wine and also plays a role in its preservation [7].

Table 2shows the vitamin composition of palm wine. Vitamins are vital micronutrients with many functions in human health, and are naturally found in palm sap and may be further produced or altered by the microorganisms used in fermentation [13, 14]. The process of fermentation, mostly facilitated by yeasts and bacteria, entails an intricate interaction of metabolic processes that might impact the vitamin composition of palm wine [15].

From the result, Vitamin A (mg/kg) showed a significant decrease in all sample days, from 6.85 on day 1 to 2.30 on day 30. The subsequent decrease suggests the breakdown of vitamin A precursors (like beta-carotene) by the fermentation process. It has been established that fermentation increase alcohol content of palm wine, which can degrade vitamin A components [14]. During palm wine fermentation, an increase in TTA can lead to a decrease in vitamin A content due to the acidic environment, which can degrade the unstable vitamin A molecule (beta- carotene) [16]. Vitamin C (Ascorbic acid), renowned for its antioxidant properties, showed a significant decrease when comparing the day 1 sample with other days throughout the fermentation process. The decrease could be a result of decreased pH, leading to acidity of the medium and metabolic activity of microorganisms (yeast and bacteria). Aganbi *et al* [17] reported that fermentation reduces ascorbic acid concentration. Vitamin D content showed a significant decrease when comparing day 1 to other sample days, except for day 7, which showed a significant increase when compared to other days. This alteration could be due to several factors, such as sunlight exposure, fermentation process, storage conditions, and microbial flora. These factors interact in complex ways to influence the presence and stability of vitamin D. Vitamin E (Tocopherol), another potent antioxidant, showed a significant decrease when comparing day 1 to other days of fermentation. While relatively stable compared to Vitamin C, it is still susceptible

to oxidation, particularly at higher temperatures and prolonged storage. For instance, Hashem*et al* [18] noted that light and air can accelerate lipid oxidation, reducing the stability of tocopherols in oils. Similarly, Oluwalana *et al* [19] examined how storage conditions affect the stability of vitamins A and E in palm oil, emphasizing the role of environmental factors, such as sunlight, which can cause their degradation. The declining concentrations of vitamins A, C, and E during aging are consistent with observations reported by Sarma *et al* [14], who noted that prolonged fermentation and storage can result in oxidative degradation of antioxidant vitamins. Exposure to oxygen, enzymatic reactions, microbial metabolism, and acidic conditions may collectively contribute to the reduction of these vitamins during aging.

The B vitamins, a group essential for various metabolic processes, showed diverse trends. Vitamin B_1 (Thiamine) and B_2 (Riboflavin) showed no significant difference as the wine aged. While Vitamin B_3 (Niacin) showed a decreasing trend, suggesting its potential utilization or modification by microorganisms. Vitamin B_6 (Pyridoxine) showed no significant differences for values of day 1, 3, & 7; the values for day 14, 21, & 30 maintain a significant decrease when compared to the values of day 1, 3, & 7. This could primarily be due to its sensitivity to light and oxidation. Vitamin B_{12} (Cobalamin) showed a significant decrease when comparing day 1 value with day 3, 7, & 30. The values for days 14 & 21 were significantly higher than the values for other days. This could be due to its complex interactions within the fermenting matrix.

Compared with previously reported studies, the present findings generally follow similar fermentation trends but provide additional information on the dynamics of vitamin composition during extended aging periods. Variations between the present study and previous reports may be attributed to differences in palm species, environmental conditions, microbial populations, geographical location, storage conditions, and analytical methodologies employed. These factors may influence fermentation efficiency and nutrient stability.

The vitamin content of palm wine undergoes substantial changes during fermentation. While some vitamins, like B_1 and B_2, remain relatively stable, vitamin D, B_6 and B_{12} showed diverse trend others, particularly Vitamins A, C, E, and B_3 experience significant reduction. These changes not only impact the nutritional value of palm wine but also influence its flavor, aroma, and overall quality. The observed trends highlight the delicate balance between microbial activity and vitamin stability, emphasizing the need for further research to understand and potentially control these processes to optimize the nutritional and sensory attributes of fermented palm wine.

6. Conclusion

The study reveals that aging palm wine undergoes significant physicochemical and nutritional changes due to fermentation caused by microorganisms. This process leads to pH decreases, enhancing tartness and preservation, while viscosity drops, creating a smoother texture. Sugar conversion raises alcohol content and acidity, improving flavor stability. Some vitamins, like B1 and B2, remain stable, while others, especially A, C, E, and B3, decline. Findings suggest that freshly tapped palm wine (aged 1–3 days) is rich in sugar and essential vitamins, making it suitable for casual consumption due to its refreshing taste and nutritional benefits. The findings of the present study suggest that aging may significantly influence the physicochemical characteristics and vitamin composition of palm wine. The observed changes indicate progressive biochemical transformations associated with fermentation. Although freshly tapped palm wine demonstrated relatively higher concentrations of several vitamins and sugars, the results should be interpreted within the scope of the study conditions. Additional investigations involving microbial characterization, larger sample sizes, and different palm wine sources may further enhance understanding of the aging process.

Authors' Contributions

NN and CVO conceived and designed the research. NN, CVO and AUB conducted the experiments. COE and GS contributed the analytical tools. CVO and GS analyzed data. COE, CVO and AUB wrote the manuscript. All authors read and approved the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

References

[1] K. Chandrasekhar et al., "A Review on Palm Wine," *International Journal of Research in Biological Sciences*, vol. 2, no. 1, pp. 33-38, 2012. [Google Scholar]

[2] Onyeka Benjamin Onyeukwu et al., "Palm Wine: A Review on its Composition, Preservation, Health Benefits, and Market Value," *International Journal of Basic Science and Technology*, vol. 10, no. 1, pp. 71-80, 2024. [Google Scholar]

[3] V.P. Aparnna, Anil Kumar Kumar Chauhan, and Shubhendra Singh, "Palm-based Beverages Around the World: A Review," *Current Nutrition and Food Science*, vol. 20, no. 1, pp. 16-27, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[4] Oluwatoyin Oluwole et al., "Fermented Traditional Wine from Palm Trees: Microbial, Nutritional Attributes and Health Impacts," *Frontiers in Food Science and Technology*, vol. 3, pp. 1-15, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[5] W.K. Amoa-Awua, E. Sampson, and K. Tano-Debrah, "Growth of Yeasts, Lactic and Acetic Acid Bacteria in Palm Wine during Tapping and Fermentation from Felled Oil Palm (Elaeis Guineensis) in Ghana," *Journal of Applied Microbiology*, vol. 102, no. 2, pp. 599-606, 2007. [CrossRef] [Google Scholar] [Publisher Link]

[6] Folake Titilayo Afolabi, and Akeem Temitope Owoola, "Microbiological and Physicochemical Changes in Palm Wine Subjected to Spontaneous Fermentation During Storage," *The International Journal of Biotechnology*, vol. 8, no. 1, pp. 48-58, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[7] Detto Karamoko et al., "Biochemical and Microbial Properties of Palm Wine: Effect of Tapping Length and Varietal Differences," *Food and Nutrition Sciences*, vol. 7, no. 9, pp. 763-771, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[8] R.F. Bayfield, and E.R. Cole, "Colorimetric Estimation of vitamin A with Trichloroacetic Acid," *Methods in Enzymology*, vol. 67, pp. 189-195, 1980. [CrossRef] [Google Scholar] [Publisher Link]

[9] Hans Brockmann and Yun Hwang Chen, "On a Method for the Quantitative Determination of Vitamin D," *Biological Chemistry ,* vol. 241, no. 1-3, pp. 129-133, 1936. [CrossRef] [Google Scholar] [Publisher Link]

[10] H.R. Rosenberg, *Chemistry and Physiology of the Vitamins*, Interscience Publishers, Inc, New York, 1945. [CrossRef] [Google Scholar] [Publisher Link]

[11] J.H. Roe, and C.A. Kenther, "The Determination of Ascorbic Acid in whole Blood and Urine through the 2,4- Dinitrophenylhydrazine Derivative of Dehydroascorbic Acid," *The Journal of Biological Chemistry*, vol. 147, pp. 399-407, 1943. [Google Scholar]

[12] Ranjana Sharma et al., "Microbial Fermentation and its Role in Quality Improvement of Fermented Foods," *Fermentation*, vol. 6, no. 4, pp. 1-20, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[13] I.N. Nwachukwu, V.I. Ibekwe, and B.N. Anyanwu, "Investigation of some Physicochemical and Microbial Succession Parameters of Palm Wine," *Journal of Food Technology*, vol. 4, no. 4, pp. 308-312, 2006. [Google Scholar]

[14] Chayanika Sarma et al., "Anthology of Palm Sap: The Global Status, Nutritional Composition, Health Benefits and Value Added Products," *Trends in Food Science and Technology*, vol. 119, pp. 530-549, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[15] Pazhani Saranraj, Panneerselavam Sivasakthivelan, and Murugadoss Naveen, "Fermentation of Fruit Wine and its Quality Analysis: A Review," *Australian Journal of Science and Technology*, vol. 1, no. 2, pp. 85-97, 2017. [Google Scholar] [Publisher Link]

[16] Mapula R. Moloto et al., "Influence of Fermentation on Functional Properties and Bioactivities of Different Cowpea Leaf Smoothies During in Vitro Digestion," *Foods*, vol. 12, no. 8, pp. 1-20, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[17] Avwioroko J. Oghenetega et al., "Effect of Fermentation on Sensory, Nutritional and Antioxidant Properties of Mixtures of Aqueous Extracts of Hibiscus Sabdariffa (Zobo) and Raphia Hookeri (Raffia) Wine," *Nigerian Journal of Science and Environment*, vol. 15, no. 1, pp. 66-74, 2017. [Google Scholar] [Publisher Link]

[18] Hanafy A. Hashem et al., "Effect of Long-Term Storage in Light and Dark at Room Temperature on Physicochemical Characteristics of Some Vegetable Oils," *Egyptian Journal of Nutrition*, vol. 38, no. 1, pp. 182-197, 2023. [Google Scholar]

[19] I.B. Oluwalana et al., "Influence of Packaging Materials and Storage Conditions on the Vitamins A and E Storage Stability of Palm Oil in Nigeria," *Advances in Research*, vol. 4, no. 3, pp. 191-202, 2015. [CrossRef] [Google Scholar] [Publisher Link]