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Local Gin Distillation Methods and Health Impact: Evaluating Physicochemical Properties of Raffia Palm and Oil Palm Derived Distillates

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ABSTRACT

This study presents a comparative analysis between traditional gins produced from oil palm (Elaeis guineensis) and raffia palm (Raphia hookeri) sap. Physicochemical quantification revealed the raffia palm gin exhibited significantly lower moisture content (27.0%) yet higher total titratable acidity (0.134 g) compared to the oil palm gin (29.7% moisture; 0.014 g acidity). Mineral profiling indicated both gins were below established regulatory limits for toxic metals including lead (0.083 and 0.042 mg/kg) and cadmium (0.038 and 0.028 mg/kg) in oil palm and raffia palm gin respectively. Gas chromatographic analysis quantified higher concentrations of methanol (0.61 vs 0.04 mg/L), ethyl acetate (0.177 vs 0.025 mg/L), acetonitrile (0.396 vs 0.137 mg/L) and ethanol (10.39 vs 9.68 mg/L) in raffia compared to oil palm gin. The alcohol content ranged from 23.6-25.7% between the two beverages. While these traditional gins appear safe for consumption, compositional differences highlight the need for production standards and routine testing to ensure quality and safety. Adhering to regulations and safety standards can mitigate potential health hazards associated with these traditional alcoholic beverages. In conclusion, this work provides new comparative data on two understudied African fermented beverages, underscoring the importance of further characterization to assess microbiological and toxicological effects.

1. INTRODUCTION

Palm wine is a traditional alcoholic beverage derived from the sap of various palm tree species, commonly consumed in sub-regions of Africa (Falegan and Akoja, 2014). Palm wine encompasses all alcoholic beverages produced through the natural fermentation of sap obtained from different palm tree species.

In Nigeria, oil palm (*Elaeis guineensis Jacq*.) and raffia palm (*Raffia hookeria*) are the most economically important palm species for revenue generation, medicinal uses, and alcohol production (Ikegwu, 2014). Raffia palm tree wine is distinct from oil palm tree wine in terms of sweetness, milky nature, lower alcohol

content, and affordability throughout the year (Aiyeloja *et al.*, 2014). With fermentation, the alcohol content of fresh palm wine increases over time. The laboratory distillation process of local gin (dry gin) and other portable alcoholic beverages is similar, involving the use of fermented sap, a distillation apparatus, and temperature control (Idonije *et al.*, 2012).

Locally made alcoholic beverages, including ogogoro, pito, burukutu and palm wine among others are widely consumed in Nigeria (Dimelu *et al.*, 2011). Ogogoro is locally distilled from fermented palm sap from oil palms or bast palms and is often consumed at traditional social occasions (Obot, 2007; Idonije *et al.*, 2012). However, making local gin from oil palm and raffia sap raises health and safety concerns due to unregulated production, resulting in the production of inferior and potentially harmful products. Despite these concerns, the demand for locally produced gin remains high. Tragic incidents of deaths resulting from the consumption of locally manufactured gin have been reported in Nigeria, emphasizing the need for quality control and regulation (Sam, 2015). This study aims to evaluate the physicochemical properties and chemical content of locally distilled dry gin (ogogoro) produced from oil palm and raffia palm sap, comparing them with standard organizations' specifications. Understanding the production process and challenges involved in producing high-quality, safe local gin can provide insights into traditional practices.

2. MATERIALS AND METHODS

2.1. Equipment

For accurate measurements, controlled conditions, and safe handling of substances, this research work was conducted using a range of essential laboratory equipment and glassware which include:

i. Simple distillation apparatus for separating liquid components.
ii. Fractionating column, which aids in refining the separation of liquids.
iii. Fermenter used for the fermentation process.
iv. Thermometer with a temperature range of 1-110 °C to monitor temperature changes.
v. Electronic pH meter to measure and control the acidity or alkalinity of solutions.
vi. Electronic weighing balance for precise measurements.
vii. Conical flasks to hold and mix liquids.
viii. Beakers used for various purposes, such as mixing and holding substances.
ix. Measuring cylinder for accurate volume measurements.
x. Buckets for carrying and storing materials.
xi. Funnel for easy and controlled pouring of liquids or powders.
xii. Heating mantle for heating reactions or substances.
xiii. Water for various laboratory purposes.
xiv. Hose for fluid transfer if needed.
xv. Plastic containers for storage or collection of samples and materials.

2.2. Collection of Samples

The fresh sap of raffia and oil palms used for this research was procured from a local wine tapper in Ofagbe Town, Isoko North Local Government Area in Delta State, Nigeria. The juice samples were carefully collected in a securely sealed 10 litres plastic container and promptly taken to the SLT department laboratory, Delta State University of Science and Technology, Ozoro.

2.3. Sample Fermentation Process

Five (5) litres each of raffia palm tree sap and oil palm tree sap were measured and transferred into a fermenter. The fermenter, with the samples, was left open in a water bath at room temperature to expose them to the surrounding atmosphere. The samples underwent natural fermentation without the addition of yeast or sugar. This fermentation process occurred in a cupboard at room temperature for five days.

2.4. Distillation Procedure

The methodology by Viele *et al.* (2013) was followed in this study with some minor modifications. The fermented sap was first passed through a fine mesh or filter to remove impurities like dirt and insects. The clean sap was then subjected to distillation using a setup comprising a fractionating column, condenser, collection flask, and heat source. Initially, 500 mL of the fermented sample was heated in a round-bottom flask with a thermometer and condenser, using water cooling (Figure 1). Boiling chips were added to prevent shock. The heating temperature was maintained at 78-80 °C for ogogoro distillation. The distillate from the first round of distillation underwent a second distillation. It was transferred to a round-bottom flask with a fractionating column packed with raschig rings (Figure 2). The heating temperature was again set at 78-80 °C. The cooling water flow rate was adjusted for efficient condensation in the condenser. As the heat was applied, the fermented sample vaporized and ascended through the fractionating column, separating based on boiling points. The distillates were collected at 78 °C and carefully collected in separate flat-bottom flasks for oil palm and raffia palm sap. The process was repeated until enough distillates were obtained. The distilled ogogoro was stored in clean, airtight glass bottles, away from direct sunlight or extreme temperatures, to preserve its quality for further analysis and characterization.

Figure 1: Simple distillation process of fermented sap

Figure 2: Fractional distillation process of the product from the simple distillation of sample sap

2.5. Characterization of Local Gin

2.5.1. Determination of reducing sugar

The method described by Ivanova-Petropulos and Mitrev (2014) was employed to determine the reducing sugar content of the gin sample. The reducing sugar in the dry gin was estimated by diluting the sample, heating it with Fehling's solution to form a colored complex, adding potassium iodide and sulfuric acid for further color development, titrating with sodium thiosulfate until the color change occurred, and calculating the reducing sugar by determining the difference between the sample and blank titre volumes as presented in Equation 1.

$$V\ (Na_2S_2O_3) = V\ (Na_2S_2O_3) blank\ titre\ -\ V\ (Na_2S_2O_3)\ \ sample) \quad (1)$$

2.5.2. Determination of aldehyde content

The procedure for determining aldehyde contents in the alcohol followed the methodology described by Magda *et al.* (1991). Initially, a 0.5 ml portion of the aldehyde solution was meticulously transferred into a 5 ml volumetric flask. Subsequently, 1 ml of 3-Methyl-2-benzothiazolinone hydrazine (MBTH) solution was added to the flask, and the contents were thoroughly mixed and allowed to stand for 20 minutes. Following this, 1 ml of ferric chloride solution was added to the mixture, and the flask was again mixed and allowed to stand for an additional 10 minutes. The final volume was adjusted to 5 ml using water. The absorbance of

the supernatant fluid was then measured at 357 nm using a Shimadzu UV 2450 spectrophotometer. For the quantification of aldehyde concentration in the alcohol sample, calibration curves derived from the previous procedure were utilized, ensuring precise and accurate determinations.

2.5.3. Determination of total titrable acid (TTA)

A 10 mL aliquot of the alcohol sample is transferred to a 250 mL Erlenmeyer flask, and three drops of phenolphthalein indicator are added. A burette filled with 0.1 M sodium hydroxide (NaOH) is used to titrate the alcohol sample until a light pink hue appears. The volume of NaOH solution used and the weight of the alcohol sample in grams are recorded. This process is repeated three times for reliable results. The total titrable acidity (TTA) of the alcohol sample was calculated using Equation 2.

$$\text{TTA} = \frac{[(V1 + V2 + V3) \text{ x N x } 0.006]}{W} \quad (2)$$

Where V_1, V_2, and V_3 are the volumes of NaOH solution used in the three titrations, N is the normality of NaOH solution (0.1 M), 0.006 is the equivalent weight of acetic acid, and W is the weight of the alcohol sample in grams.

2.5.4. Moisture contents determination

A clean petri dish was washed, dried in the oven, and weighed (W1) to obtain its initial weight. Approximately 2 g of the alcohol sample was carefully measured and placed into the petri dish. The combined weight of the petri dish and sample was recorded as (W1 + Ws) before drying. The petri dish containing the sample was then placed in an oven set at 105 °C for 2 hours. After the specified time, the petri dish was removed from the oven, allowed to cool in a desiccator, and weighed again to obtain the new weight (W2). Subsequently, the petri dish with the sample was returned to the oven and heated until a constant weight (W3) was achieved. The moisture content of the sample was calculated using Equation 3.

$$\text{Moisture content (\%)} = \frac{(W2 - W3)}{(W2 - W1)} \text{x } 100 \quad (3)$$

Where; W_2 = combined weight of the dried sample and the petri dish, W_3 = constant weight of the petri dish with the sample, W_1= initial weight of the clean, empty petri dish before the sample is added.

2.5.5. Determination of pH

To determine the pH of the alcohol sample, a pH meter was employed. The pH meter was calibrated according to the manufacturer's guidelines to ensure accurate readings. Next, a clean and dry container was prepared, and a small amount of the alcohol sample was placed inside. The pH meter electrode was carefully immersed in the alcohol sample and allowed to stabilize for a few seconds. Once the pH meter displayed a stable reading, the pH measurement was recorded for further analysis.

2.5.6. Determination of colour

The colour was measured using a colourimeter and by visual inspection of the sample.

2.5.7. Determination of specific gravity

The specific gravity of the alcohol was determined following the methods outlined in FSSAI (2021) and FSSAI (2019) (FSSAI 02.002:2021-Determination of Specific Gravity). Specific gravity was calculated using Equation 4, as described in these FSSAI publications.

$$\text{Specific gravity} = \frac{(W2 - W1)}{(W3 - W1)} \quad (4)$$

Where; W_1 = weight of empty pycnometer bottle, W_2 = weight of pycnometer bottle filled alcohol sample, W_3 = weight of pycnometer bottle filled water sample

2.5.8. Determination of alcohol content

After determining the specific gravity as in above, the value obtained was used to calculate the volume of alcohol content in the sample using the formula in Equation 5.

$$\% \text{ v/v alcohol} = \frac{SG1 - SG2}{0.0074} \quad (5)$$

Where; SG_1 = specific gravity of the alcohol sample before distillation, SG_2 = specific gravity of the distillate obtained after sample distillation 0.0074 = constant that takes into account the density of H_2O and molecular weight of ethanol.

2.5.9. Determination of ester value

As soon as the acid value and saponification value were determined, the ester value was calculated using Equation 6.

$$\text{Ester value} = \text{saponification value} - \text{acid value} \quad (6)$$

2.5.10. Determination of acid value

To determine the acid value, a 1 g alcohol sample was measured and poured into a conical flask along with approximately 25 mL of diethyl ether and 1 mL of 1% phenolphthalein indicator. The mixture was titrated with 0.1 M NaOH solution, with constant shaking, until a pink color that persisted for 15 seconds was obtained. The volume of NaOH solution used was recorded. The acid value was then calculated using Equation 7.

$$\text{Acid value} = \frac{(V \times 5.61)}{W} \quad (7)$$

Where; V = volume of NaOH solution in (mL) required to neutralize the acid in the sample, 5.61 = constant factor that accounts for the molar mass and equivalent weight of KOH. W= weight of the sample used in grams (g).

2.5.11. Determination of nitrate

The nitrate determination was carried out according to established methods (Masime et al. 2013; Said and Mahmud 2013; Bulgariu and Bulgariu 2012; Narayana and Sunil 2009). Nitrate standard solutions (0.1–1.2 mL) were pipetted into dry glass flasks and diluted with double-distilled water to a total volume of 2.0 mL. 1-Naphthylamine reagent (1.0 mL, 0.05%) and concentrated sulfuric acid (3.0 mL, 95%) were added drop wise with gentle swirling. The solutions were allowed to equilibrate for 45 minutes at room temperature before measuring the absorbance at 540 nm compared to a blank. Nitrate concentrations in unknown samples were derived from a calibration curve constructed using nitrate standards as described.

2.5.12. Determination of heavy metals

The alcohol samples were tested for heavy metals using established procedures from Yahaya *et al*., (2022), Yahaya *et al.,* (2021), Yahaya *et al*., (2019) and Ogunlana *et al*., (2015). The sample was combined with nitric acid and distilled water in a beaker and heated to reduce volume and break molecular bonds, releasing metals into solution (noted by red fumes). The solution was filtered, diluted to a set volume, mixed completely, and settled before analysis. The prepared samples were analyzed using an atomic absorption spectrophotometer (AAS) of model Varian AA240 to determine the levels of selected heavy metals present in the alcohol samples.

2.5.13. Procedure for GC-FID analysis

The current study used gas chromatography with flame ionization detection (GC-FID) for sample analysis, following the methodology described by Okpo and Otaraku (2020). A Buck M910 GC-FID instrument with a calibrated capillary column was used to perform the analysis. The compounds were identified by comparing the retention indices with standards and by searching mass spectral libraries. Based on these identification

methods, quantification of the target analytes was performed to determine the concentrations in the studied local gin samples.

3. RESULTS AND DISCUSSION

Table 1 shows the physicochemical properties of the synthesized alcohol from oil palm and raffia palm sap. Oil palm alcohol and raffia palm alcohol were found to have a moisture content of 29.741% and 27.003%, respectively. The moisture levels reported in this present study were above 9.48%, 17.9% and 7.35% respectively for the local gins extracted from Opukushi, Warri and Rumuji by Adakporia (2021). High moisture content in alcohol affects its distillation, shelf life, taste/aroma and physical properties.

Table 1: Physicochemical properties of formulated local gin from oil palm and raffia palm tree sap

Properties	Oil palm alcohol	Raffia palm alcohol
Moisture (%)	29.741	27.003
Nitrate (mg/l)	6.642	8.128
Chloride (mg/l)	90.000	95.000
Total titrable acidity (g)	0.014	0.134
Specific gravity	0.995	0.983
Alcohol contents (%)	25.676	23.649
pH	4.900	5.700
Colour	Cloudy	Cloudy
Reducing sugar (g/L)	5.795	7.063
Ester value (mg/kg)	107.964	83.150
Acid value (mg/KOH)	12.436	9.390
Aldehyde (mg/kg)	0.677	0.444

The nitrate concentration indicates the number of nitrate ions present in the alcohol samples, expressed in milligrams per litre (mg/l). The results in Table 1 suggest that raffia alcohol has a higher nitrate concentration (8.128 mg/L) than oil palm alcohol (6.642 mg/L). Elevated levels of nitrates in beverages can be associated with potential health risks, such as the formation of nitrosamines, which are thought to be potentially carcinogenic (Tricker, 1997). However, Karwowska and Kononiuk (2020) state that nitrates and nitrites are not themselves carcinogenic but have the potential to react with other compounds to form carcinogens. The chloride concentration in both samples was 90 mg/L and 95 mg/L for oil palm alcohol and raffia palm alcohol, respectively. Chloride content is a measure of the concentration of chloride ions in a substance. The chloride content in the alcohol can provide information about the level of impurities present. In general, lower chloride levels are desirable as they indicate higher purity. Therefore, both oil palm alcohol and raffia palm alcohol have relatively low chloride levels, suggesting a reasonable level of purity. Higher chloride levels can increase the risk of corrosion, which can affect the overall quality and safety of the product. With chloride values of 90 mg/l and 95 mg/l, both alcohol samples are in a similar range and do not differ significantly in terms of the possible influence on taste. The chloride value of 17.5, 18.1 and 3.74 mg/l reported by Adakporia (2021) for local gins from Opukushi, Warri and Rumuji, respectively, was lower than the results reported in this present study.

Ogogoro is a locally distilled alcoholic beverage produced by fermentation of palm wine. Studies have detected elevated chloride concentrations likely originating from the soil where palm trees are cultivated (Dibofori-Orji and Ali, 2019). Nitrates, naturally occurring in plants, have also been found in concerning amounts (Bassir and Maduagwu, 1978). The source and point of entry of these chemicals requires further elucidation to mitigate potential health consequences (Nwaiwu and Itumoh, 2017). While chloride and nitrate contamination may arise from natural sources, production processes can also introduce hazardous chemicals. Pesticide residues on equipment may leach into the final product (Nwaiwu and Itumoh, 2017), indicating a need for stringent quality control from start to finish (Mbuagbaw and Noorduyn, 2012). Elevated chloride negatively impacts human health and product quality (Buldini et al., 1997; Jagadish and Shanmugaselvan, 2018). Specifically, high nitrate levels correlated to increased methemoglobinemia prevalence (Şimşek et al., 2020). Intake levels should be regulated through monitoring systems and adherence to established safety

guidelines, like the World Health Organization's recommended maximum dietary chloride intake of 9 mg/kg body weight for adults (WHO, 2003). A concerted effort is imperative to elucidate and control chloride and nitrate contamination pathways in locally produced alcoholic beverages.

The total titrable acidity for oil palm alcohol and raffia palm alcohol was 0.014 g and 0.134 g, respectively. This indicates that the acidity of oil palm alcohol is relatively low and raffia palm alcohol has higher acidity compared to oil palm alcohol. The presence of a higher TTA value indicates that raffia alcohol contains a relatively higher concentration of acids. Total titrable acidity is a measure of the total amount of acid present in the alcohol sample. The result obtained in this present study agreed with the range of 0.011 to 0.23 observed by Idonije *et al* (2012).

The specific gravity value for oil palm alcohol was 0.995 and that for raffia palm alcohol was 0.983. Both alcohol have specific gravities of less than 1, indicating they are lighter than water. It should be noted that specific gravity can vary depending on factors such as temperature and impurities in the alcohol. Additionally, specific gravity is just one property to consider when evaluating alcohol. The results also agree with the 0.93-0.94 reported for Ogogoro 1 and Ogogoro 2 by Idonije *et al.* (2012).

The alcohol content (%) of the oil palm and raffia palm alcohol were determined as 25.676% and 23.649%, respectively. Ethanol content is a critical parameter in alcoholic beverages as it directly affects the intoxicating effects and sensory characteristics of the product. The measured alcohol content in both oil palm and raffia palm alcohol indicates that they are within the typical range for distilled spirits. This disparity may result from variations in the raw materials, fermentation conditions, or distillation techniques employed during production. The reported results are below the range of 89.2-91.0 reported by Adakporia (2021) and 61-78% by Idonije *et al.* (2012). Both the oil palm alcohol and raffia palm alcohol fall below the required minimum alcohol content of 37.0% set by Spirit Drinks Regulations (2019) for distilled gin. The alcohol contents for oil palm alcohol and raffia palm alcohol are 25.676% and 23.649%, respectively. Therefore, neither of these components alone meets the minimum alcohol requirement for producing distilled gin. In contrast, under the Spirits Regulations 2019, alcoholic beverages must meet the mandatory criterion of a minimum alcohol content of 25% to be classified as sloe flavored spirits or pacharn. Consequently, it can be firmly assumed that the gin product in question developed clearly meets the classification as a sloe flavored spirit or pacharn in accordance with these regulatory guidelines.

The observed pH values were 4.90 and 5.70 for palm oil alcohol and raffia palm alcohol, respectively. These results conform to pH values obtained by Idonije *et al.* (2012). These pH values indicate that both samples are slightly acidic, although raffia palm alcohol is slightly less acidic than oil palm alcohol. Both oil palm alcohol and raffia palm alcohol were cloudy in colour. The cloudy appearance of the alcohol samples can be due to many factors, including the presence of suspended particles, contaminants, or compounds that do not completely dissolve in the alcohol.

As shown in Table 1, the reducing sugars (g/L) were 5.795 and 7.063 for palm oil alcohol and raffia palm alcohol, respectively. This indicates that there is a relatively higher amount of sugar in raffia palm alcohol compared to oil palm alcohol. Higher reducing sugar levels may be important in certain applications, such as the manufacture of alcoholic beverages, where sugar contributes to flavour, fermentation, or other desired properties. The reducing sugar content is a measure of the amount of sugar present in a substance that can undergo reduction reactions. Idonije *et al.* (2012) have reported a reduction in sugar levels in the range of 2-6%. Also shown in Table 1, oil palm alcohol has an ester value of 107.964 mg/kg while that of raffia palm alcohol is 83.15 mg/kg. The ester value is a measurement that indicates the concentration of esters in the alcohol sample. Esters are organic compounds responsible for providing aroma and flavour characteristics to various substances, including alcohol. The results indicate that the oil palm alcohol contains a relatively higher concentration of esters. This indicates that it may possess a more pronounced aroma and flavour profile compared to raffia palm alcohol. The specific esters found in the alcohol contribute to its sensory attributes.

Acid value, a measure of free fatty acid content, was determined for samples of oil palm alcohol and raffia palm alcohol. The results showed that oil palm alcohol had a higher acid value of 12.436 mg/KOH, indicating a higher concentration of free fatty acids compared to raffia palm alcohol with an acid value of 9.39 mg/KOH. This disparity in acidity suggests possible differences in quality and characteristics between the two alcohol samples. A higher content of free fatty acids in palm oil alcohol can affect the sensory properties, stability and shelf life. In the work by Idonije *et al.* (2012) reported acidity value of 0.0-0.2 was lower than the values reported in this present study.

The aldehyde content in oil palm alcohol (0.677 mg/kg) and raffia palm alcohol (0.444 mg/kg) indicates the presence of organic compounds that contribute to their aroma and flavour profiles. The aldehyde content provides valuable information about the sensory properties of these alcohol samples and their potential for specific aroma profiles. The aldehyde levels reported in this current study were below 1.76-3.15 reported by Idonije *et al.* (2012).

Table 2 presents the mineral composition of formulated local gin derived from oil palm alcohol and raffia palm alcohol. Heavy metal contamination in locally brewed beverages, notably local gins like ogogoro, primarily emanates from the vessels employed in fermentation, and to a lesser extent, the distillation equipment. This issue, as elucidated by Ibanez et al. (2008), results from various sources and stages in the production process, encompassing raw materials, brewing techniques, equipment, bottling, aging, and the potential for adulteration. The distillation of fermented palm wine, as commonly seen in local gin production, employs relatively uncomplicated equipment to maintain cost-efficiency, according to Opio et al. (2013). However, the materials used in this process, as indicated by Tulashie et al. (2017), can introduce heavy metal contaminants. Agbley et al. (2023) and Udota and Umoudofia (2011) has emphasized the presence of iron impurities, largely attributed to the use of iron tanks, as well as copper contamination arising from the employment of copper pipes in the condensation process.

Table 2: Mineral composition of formulated local gin from oil palm and raffia palm tree sap

Heavy metal	Composition (mg/kg)	
	Oil palm alcohol	Raffia palm alcohol
Lead	0.083	0.042
Arsenic	0.000	0.000
Mercury	0.010	0.019
Cadmium	0.038	0.028
Zinc	0.672	0.378
Copper	0.054	0.083
Iron	0.384	0.278

The analysis revealed that the oil palm alcohol sample contained a lead concentration of 0.083 mg/kg, while the raffia alcohol sample exhibited a slightly lower concentration of 0.042 mg/kg. Both samples demonstrated compliance with the recommended threshold of 0.2 mg/kg, as stipulated by Spirit Drinks Regulations (2019). These findings indicate that the lead content in both oil palm alcohol and raffia alcohol falls well below the permissible limit, making them safe for consumption from a lead contamination perspective.

Both oil palm alcohol and raffia palm alcohol exhibit non-detectable levels of arsenic, with a measurement of 0.00 mg/kg. This outcome is highly favourable since arsenic is a poisonous element, and the absence of it indicates a safer product. However, it's important to note that Spirit Drinks Regulations (2019) sets a maximum allowable limit of arsenic impurities in spirits at 0.2 mg/kg. Oil palm alcohol contains a mercury concentration of 0.010 mg/kg, whereas raffia alcohol has a slightly higher concentration of 0.019 mg/kg. Both samples demonstrate low levels of mercury, which is beneficial considering the potential health risks associated with high mercury concentrations. These findings are below the maximum limit of 0.1 mg/kg for mercury in spirits, as specified by Spirit Drinks Regulations (2019). Oil palm alcohol contains 0.038 mg/kg of cadmium, while raffia palm alcohol has a slightly lower concentration of 0.028 mg/kg. These levels of

cadmium are considered low, which is advantageous as higher concentrations of this element can have adverse effects on health. According to Spirit Drinks Regulations (2019) guidelines, the maximum allowable limit for cadmium in spirits is 0.1 mg/kg. Oil palm alcohol has a zinc content of 0.672 mg/kg, while raffia palm alcohol contains 0.378 mg/kg of zinc. Zinc is a vital mineral, and both samples have detectable but comparatively low levels. According to Spirit Drinks Regulations (2019) recommendations, the maximum allowable zinc concentration in spirits is 5 mg/kg. Oil palm alcohol contains 0.054 mg/kg of copper, while raffia palm alcohol contains a slightly higher concentration of 0.083 mg/kg. Both samples have detectable but relatively low copper values. The reported result is below the Spirit Drinks Regulations (2019) maximum limit of 5 mg/kg in spirits. Oil palm alcohol contains 0.384 mg/kg of iron, while raffia palm alcohol contains a slightly lower concentration of 0.278 mg/kg. Both samples show detectable but relatively low iron values. The reported result is below the Spirit Drinks Regulations (2019) maximum limit of 15 mg/kg for spirits.

Table 3 presents the results of the GC-FID analysis of alcohol components in oil palm and raffia palm gin samples. Both oil palm and raffia palm gins exhibit the presence of ethyl acetate, although the concentration is higher in raffia palm gin (0.1768 mg/l) compared to oil palm gin (0.1104 mg/l). The ethyl acetate detected in both samples was below the 50 mg/L permissible level set by Spirit Drinks Regulations (2019) for esters. Ethyl acetate is a common flavouring compound found in alcoholic beverages and is generally considered safe for consumption. At the levels observed in the analysis, it is unlikely to pose significant health risks. The results of this present study are also far less than the results of previous studies. According to Kostik *et al.* (2014), plum brandy has a range of ethyl acetate content from 48 to 454 mg/100 ml. Similarly, grape brandy, also studied by Kostik *et al.* (2014), has an ethyl acetate content ranging from 5.2 to 255 mg/100 ml. On the other hand, Gueven (2013) reported an ethyl acetate content varying from 12.8 to 292 mg/l for raki beverage. 2-butanol is detected only in raffia palm gin at a very low concentration (0.0011 mg/l). The 2-butanol detected in the sample was below the 50 mg/L permissible level set by Spirit Drinks Regulations (2019) for higher alcohol like 2-butanol, 2 – propanol etc. In the study conducted by Leon-Rodriquez *et al.* (2008), it was reported that the concentration of 2-butanol in agrave ranges from non-detectable (ND) to 59 mg/L. Similarly, in the study by Jung *et al.* (2010), the concentration of 2-butanol for plum wine samples ranged from 309 to 1092 mg/L. The concentration observed in this present study is minimal and is unlikely to contribute significantly to health risks.

Table 3: GC-FID analysis of alcohol from oil palm and raffia palm gin

Components	Oil palm alcohol (mg/l)	Raffia palm alcohol (mg/l)
Ethyl acetate	0.1104	0.1768
2-butanol	-	0.0011
Methanol	0.3529	0.6100
Acetonitrile	0.3167	0.3960
Benzoic acid	0.0023	0.0029
Ethanol	9.9246	10.3897
Total	10.7069	11.5765

Both oil palm and raffia palm gins contain methanol, with raffia palm gin showing a higher concentration (0.6100 mg/l) compared to oil palm gin (0.3529 mg/l). The levels detected in both gins are much lower than the acceptable limit of 5 mg/l set by Spirit Drinks Regulations (2019). These findings suggest that the levels of methanol in the samples are within safe limits and do not pose a health risk based on the Spirit Drinks Regulations (2019) The results of this present study are far lower than the 1.9483 mg/L, 2.4715 mg/L and 11.3746 mg/L previously reported by Anarado *et al.* (2019) respectively for local gin obtained from Okwagbe, Olomoro and Awba Ofemili. Also, another study has reported higher methanol content of 176.17 mg/L, 21.62 mg/L and 18.25 mg/L for three different samples of spirit (Osobamiro, 2013). Nevertheless, a study has shown that traditional fermented beverages are prone to methanol contamination due to the activities of pectinase-producing yeast, fungi and bacteria during the fermentation process (Ohimain, 2016; Osobamiro, 2013). Methanol contamination in alcoholic beverages is a complex issue with an elusive source, as highlighted by Ohimain (2016) and the notion that it may originate during fermentation (Tulashie et al., 2017). The involvement of pectinase-producing yeasts, fungi, and bacteria in methanol production in

traditional fermented beverages is well-documented (Ohimain, 2016). Saccharomyces cerevisiae typically dominates such beverages (Jespersen, 2003; Ogbulie et al., 2007; Karamoko et al., 2012), although the presence of other microbes, as demonstrated by Shale et al. (2013) and Kostik et al. (2014), can lead to the production of various compounds, including methanol. In essence, the presence of chemical compounds in alcoholic beverages results from a complex interplay of factors during fermentation, wherein Saccharomyces cerevisiae and coexisting microorganisms play pivotal roles. Methanol is a toxic compound that can have detrimental health effects, especially in high amounts. Consumption of methanol-poisoned gin can lead to severe health risks, including vomiting, abdominal pain, blindness, headache, dizziness and loss of consciousness, organ damage, and even death. According to Semiu (2015); Sam (2015) report, about 18-70 persons have died from consumption of locally brewed gin contaminated with methanol in Nigeria.

Both oil palm and raffia palm gins contain acetonitrile, with slightly higher levels observed in oil palm gin (0.3167 mg/l) compared to raffia palm gin (0.3960 mg/l). Acetonitrile is a toxic compound that can cause adverse health effects, particularly with prolonged exposure. While the concentrations observed here are relatively low, continued consumption of acetonitrile over time could potentially pose health risks. Both gins exhibit the presence of benzoic acid at very low concentrations (0.0023 mg/l for oil palm gin and 0.0029 mg/l for raffia palm gin). Benzoic acid is a commonly used preservative and is considered safe for consumption in regulated amounts. The levels detected in the analysis are negligible and are unlikely to contribute significantly to health risks. Ethanol is found in both oil palm and raffia palm gins, but raffia palm gin contains slightly higher levels of ethanol (10.3897 mg/l) compared to oil palm gin (9.9246 mg/l). Ethanol is the primary alcohol component responsible for the intoxicating effects of alcoholic beverages. Moderate alcohol consumption is generally deemed acceptable, but excessive or prolonged intake of ethanol can give rise to a range of health hazards. These risks include liver damage, addiction, and other disorders associated with alcohol.

4. CONCLUSION

Finally, this comparative study highlights the physico-chemical differences between locally distilled gins made from raffia and oil palm and emphasizes the importance of quality control during production. While both gins are within acceptable safety limits, variations in acidity, alcohol levels, reducing sugars and certain alcohol components require ongoing monitoring and safety compliance. To ensure safe and standardized production, strict quality control measures should be implemented. To ensure consumer well-being, further research into the long-term health effects and public awareness campaigns to promote responsible drinking habits are recommended.

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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