

Food Safety and Regulatory Compliance of Sachet Alcoholic Beverages: Evidence from Heavy Metals, Labelling and Alcohol Content Discrepancies

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Abstract

Background: Sachet alcohol beverages are widely consumed in Sub-Saharan Africa due to affordability and easy access. However, safety concerns exist regarding heavy metal contamination, inaccurate alcohol declaration, and non-compliance with regulatory labelling standards. Data on heavy metals, microelements, and labelling compliance in sachet alcoholic beverages remain limited. This study assessed heavy metals, micro-elements, alcohol by volume (ABV), and compliance with regulatory labelling requirements among sachet alcohol beverages marketed in Nigeria.

Method: A laboratory-based cross-sectional study was conducted. Fifteen (15) sachet alcohol brands were randomly selected from four major categories (gins, schnapps, bitters, and rum). Six micro-elements and 8 heavy metals were analyzed using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). Alcohol by volume was determined using Prelude Solid-Phase Liquid Chromatography and compared with labelled values. Product labels were evaluated for compliance with the National Agency for Food and Drugs Administration and Control (NAFDAC) regulation.

Result: Iron exceeded the World Health Organization's (WHO) maximum permissible limit (300µg/L) in 20% of the samples, while other micro-elements were within acceptable limits. All 8 heavy metals assessed were undetectable or below WHO limits. Significant discrepancies were observed between measured ABV (13.35%) and declared ABV (37.35%) ($P < 0.001$). Only 40% displayed valid NAFDAC registration numbers, and 26.7% included prohibited health claims.

Conclusion: Sachet alcohol beverages exhibited heavy iron contamination, regulatory non-compliance in some sachets, and significant ABV misrepresentation, underscoring the need for strengthened regulatory oversight and quality monitoring. By addressing these gaps, regulatory bodies, manufacturers, and healthcare professionals can mitigate the risks of heavy metal exposure and alcohol-related harm, ultimately safeguarding public health.

1.0 Introduction

In recent years, the widespread availability and consumption of sachet-packaged alcoholic beverages in Sub-Saharan African countries has raised substantial public health concerns. Sachet alcohol, including spirit-based alcoholic drinks, is typically packed in 30-mL to 200-mL sachets, plastic or glass bottles with ethanol contents up to 45% (Umarudeen et al., 2023). Medicinal plant extracts, widely believed to enhance physical or sexual vitality, are often added to sachet-packaged alcohol to increase sales and consumption. Sachet alcohols are easily affordable and widely available in various parts of the world, including Nigeria and other African countries (Rogers et al., 2024). The accessibility and affordability of sachet alcohol have potential health risks due to unregulated production processes and questionable ingredient quality. Adult mortality is increasing in sub-Saharan Africa, partly due to the region's high consumption of readily available and affordable spirit-based drinks (Ferreira-Borges et al., 2017; Otim et al., 2019).

One of the primary health concerns of sachet alcohol consumption is heavy metal contamination, which can lead to chronic toxicity (Pál et al., 2020). Heavy metals are naturally occurring elements with high atomic numbers, densities, and toxicity (Tchounwou et al., 2012). Examples of heavy metals include Lead (Pb), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Arsenic (As), Nickel (Ni), and Mercury (Hg) (Scutaruşu & Trincă, 2023). Iron, Manganese (Mn), Zn, Cu, Boron (B), Molybdenum (Mo), Ni, Co, and Cl are known as micro or trace elements, and are needed by living organisms in very small quantities. Micro-elements are generally beneficial but can pose a health risk when consumed at levels that exceed the maximum permissible levels (MPLs). Lead, Cd, Ni, As, and Hg are toxic at low levels of concentration, while Fe, Zn, Cu, Cr, and Co are intolerable at high levels of concentration. This study assessed the levels of heavy metals, micro-elements, and alcohol content in commonly sold sachet alcoholic beverages in Abeokuta, Nigeria.

Ethanol and its metabolite acetaldehyde are responsible for most of the harmful effects in alcoholic beverages. However, long-term exposure and accumulation of heavy metals are reported to impose detrimental and even lethal effects on humans (Fulke et al., 2024). Excess consumption of heavy metals has been linked with premature aging, neurological and

kidney impairment (Bouida et al., 2022; C. M. Iwegbue et al., 2013), lung damage, and even death (Izah et al., 2016). Toxic metals can pose major threats to human health, due to their ability to disrupt cellular membranes and DNA integrity, perturb protein structure and enzyme activity, leading to metabolic dysfunction (Shah & Lachenmeier, 2022; Witkowska et al., 2021).

The concentration of heavy metals in alcoholic drinks is assessed to ensure compliance with regulatory provisions and consumers' safety. Heavy metals can be introduced into alcoholic beverages during manufacturing and storage, particularly in beverages made in small-scale and household stills (Pál et al., 2020; Scutarașu & Trincă, 2023). Extant research has shown that beer and wine typically contain heavy metals, which are usually below the regulatory threshold (Scutarașu & Trincă, 2023). However, artisanal or unrecorded alcohol, such as homemade spirits, poses a higher risk due to unregulated production practices. For example, unrecorded fruit spirits in Central and Eastern Europe frequently exceed toxicological thresholds for lead and cadmium arising from improper distillation equipment and a lack of quality control (Lachenmeier, 2020). Pál et al. (2020) reported that unrecorded Hungarian spirits contained significantly higher levels of copper, zinc, and selenium, whereas recorded spirits had elevated iron, manganese, and nickel. Despite these differences, chronic heavy drinkers of recorded spirits face a higher cumulative risk due to prolonged exposure (Pál et al., 2020).

Studies have also examined heavy metal concentration in commercially available alcoholic beverages in Africa. Otim et al. (2019) assessed the health risk associated with consuming heavy metals in 17 spirit-based alcoholic beverages in Acoli, Uganda. Thirteen of the sampled beverages were packaged in sachets. Copper had the highest levels of concentration in any spirit brand, followed by barium and manganese, which were found in higher concentrations than the combined levels of selenium, arsenic, nickel, vanadium, chromium, tin, and antimony in all brands (Otim et al., 2019a). In Nigeria, Okafor et al. (2022) assessed the levels of heavy metals in a sample of 9 alcoholic beverages (whisky, beer, imported red wine, palm wine, herbal gin, local, and imported dry gin). Copper and zinc were commonly found across all alcoholic beverages sampled. Cadmium exceeded the MPL in some beverages, while local dry gin (0.936 mg/L) and imported red wine (0.075 mg/L) had higher concentrations of copper and iron, respectively. Local dry gin (0.078 mg/L) imported red wine (0.048 mg/L), Heineken (0.009 mg/L), and Guinness stout (0.33 mg/L) also had the highest levels of lead, manganese, nickel, and zinc, respectively (Okafor et al., 2022). Ubuoh et al. (2013) reported that the concentrations of Cr, Fe, Ni, Cd, and Pb exceeded MPL while Zn, Al, and Cu were below MPL in 10 samples of canned beers consumed in Owerri, Nigeria. Udata and Umoudofia (2011), analysed metal concentration in 6 different bottled beer brands, 6 samples of 'utofop', a locally distilled gin, and 2 commercial gins consumed in Uyo, Nigeria. They found Fe, Pb, Cu, and Al above MPL in 'utofop'.

Iwegbue et al. (2014) conducted one of the few studies estimating associated risks and the concentration of trace metals in distilled alcoholic beverages and liquors consumed in Nigeria. Samples comprised of eighty-two imported and indigenous brands consumed across the various social and income strata in Nigeria. The mean concentrations of 12 heavy metals in the alcoholic beverages varied significantly within the same category of distilled beverages and the 13 different classes. Cream liquor contained higher concentrations of zinc, magnesium, calcium, and potassium compared to other categories of alcoholic beverages, suggesting greater exposure to the metal in individuals who regularly consume it. Heavy metal concentrations in the 13 classes of alcoholic beverages were reported to be below the WHO and International Statutory Limits for alcoholic beverages, MPL. The estimated daily intake of the metals was less than 3% of the tolerable daily intake of each metal, and less than 1 for individual and combined target hazard quotients, suggesting no long-term health concerns from consuming the alcoholic beverages based on their metal content alone (Iwegbue et al., 2014). The study did not consider brand variation in metal concentration; the actual variation reported by the authors may have been above MPL.

Despite the growing research assessing levels of heavy metals in alcoholic beverages in Nigeria, samples mostly comprise alcoholic beverages packaged in bottles and cans, and not sachets. In Nigeria, spirit-based drinks (gin, herbal mixtures, vodka, whiskey, rum, and brandy) are commonly packaged in 30 ml, 50 ml, and 100 ml plastic sachets containing between 40% and 43% alcohol by volume (ABV). The production method often lacks quality control, and products are not

reported to authorities, increasing the likelihood of heavy metal contamination. Although the legal drinking age in Nigeria is 18 years, this is poorly regulated and barely enforced (Odeigah & Patton, 2023). The packaging, affordability, and accessibility of sachet alcohol contribute to underage drinking among children and adolescents in Nigeria (Arasi & Ajuwon, 2020a; NAFDAC, 2024), leading to adverse consequences like substance abuse, risky behaviors, long-term health issues, and poor academic performance (Arasi & Ajuwon, 2020a; Emoekpere, 2024).

In 2018, the National Agency for Food and Drug Administration and Control revised the spirit drinks regulation, and set MPL of heavy metals such as Cu, Pb, Cd, Zn, Fe as 5 mg/kg, 0.2 mg/kg, 0.1 mg/kg, 5 mg/kg, 15 mg/kg, respectively (NAFDAC, 2019). It also prohibited the production, packaging, distribution, and sale of spirit drinks in sachets, PET bottles, and foils below 200ml, effective December 2023, and commenced enforcing the ban in January 2024 (Idowu, 2024; NAFDAC, 2024; Opanuga, 2024). Shortly after commencing enforcement, the House of Representatives directed NAFDAC to suspend the ban (Abuh & Onyenucheya, 2024; ChapiOdekina, 2024b; Vanguard News, 2024) following several protests and lobbying by the alcohol industry (Ogunnaike, 2024; Omogbolagun, 2024; Umoru, 2024).

The increased prevalence of harmful alcohol consumption in Nigeria has been linked to uncontrolled distribution, sale, and consumption of sachets and other low-volume alcohol (NAFDAC, 2024). The presence of heavy metals in alcoholic beverages raises safety concerns and highlights the need for ongoing monitoring to protect consumer health. Sachet alcohol in Nigeria contains 30–45% alcohol by volume (ABV), roughly the same amount of pure alcohol (10 grams) as a standard drink (World Health Organization., 2025). Despite the small volume, the high ABV translates to a significant amount of alcohol per serving, potentially leading to faster intoxication and increased health risks. Unlike regulated bottled drinks, sachet alcohol often lacks accurate information about ingredients, precise alcohol content, and health risks (Ogoko et al., 2024). Inaccurate labeling of alcohol content on product labels further compounds concern about heavy metal concentrations, as consumers may unknowingly consume higher levels of alcohol than intended. Inadvertently exposing themselves to heightened health risks and putting pressure on the already weak health care system in the country.

Despite these potential risks, there is limited research assessing the levels of micro-elements and heavy metal contamination in sachet alcohol in Nigeria. Moreover, studies are yet to compare the actual level of alcohol in sachet-based spirit drinks compared to the values displayed on product labels. This study begins to fill this gap by assessing the presence of heavy metals and micro-elements in sachet alcohol and verifying the accuracy of declared alcohol content on the product label compared to actual alcohol content. By analyzing the presence of heavy metal contamination and discrepancies in alcohol content on product labels, this research highlights potential health hazards and advocates for improved regulatory oversight in the production and labeling of sachet alcohol.

2.0 Method

2.1 Study Design: This study was a laboratory-based quantitative cross-sectional study.

2.2 Study Area: The samples for the research were obtained from three major and large markets (Kuto, Lafenwa, and Itoku markets) in Abeokuta, Ogun State, Nigeria. The markets are strategically located and easily accessible to residents within the city and neighbouring areas. They serve as central hubs for wholesale and retail distribution of food, beverages and household items. The markets are known for the availability of various brands of sachet packaged alcoholic beverages and high patronage makes the markets the ideal locations for sampling products widely consumed by the local population. Its diverse customer base provides a representative sample for evaluating the safety and quality of these beverages.

2.3 Estimation of Sample Size:

The number of samples used for the study was estimated using Cochran's formula (Uakarn et al., 2021):

$$n_o = \frac{Z^2 * P * (1 - P)}{e^2}$$

Where:

n_o

Sample size for initial population

Z – values (Z): Corresponds to the confidence level. For 95% confidence level, Z = 1.96

Estimated proportion of presence (p): Proportion of alcoholic beverages suspected of heavy metal contamination

- Margin of error (e): Desired level of precision
- Population size (n): Number of samples.

Initial sample size (Cochran's formula):

$$n_o = \frac{1.96^2 * 0.5 * (1 - 0.5)}{0.05^2} = 384.16$$

Adjusted sample size for finite population :

The number of sachet-packaged alcoholic beverages in existence was not up to 385, so a pilot survey was conducted among local vendors to determine the number of brands sold in the selected markets and to ensure that the selected brands were representative of consumers' preferences. The following information was obtained from vendors: brands with the highest patronage, customer preferences and feedback on these brands, and emerging trends in sachet alcohol consumption.

Adjusting the sample size, this formula was deployed

$$n_f = \frac{n_o}{1 + \frac{n_o - 1}{N}}$$

Where;

- n_o : Sample size for initial population
- n_f : sample size for finite population
- N: population size.

$$n_f = \frac{385}{1 + \frac{385 - 1}{15}} = \frac{385}{39.4} = 14.5$$

This approximately equalled fifteen brands. Based on responses from the pilot survey, a simple random sampling technique was employed to select 15 sachet alcohol from popular brands identified, sold and consumed in Abeokuta. These brands were labelled Brands A to Brand O and included in the final sample (Table 1).

2.4 Inclusion criteria

The inclusion criteria specified that the alcohol sampled in the study must be in sachet form.

2.5 Exclusion criteria

The study excludes alcoholic beverages in bottles.

2.6 Reagents

Analytical grade reagents were used throughout the experiments. Ultrapure water (resistivity 18 M Ω .cm) was obtained from a Milli-Q purification system (Millipore, USA), nitric acid (65% w/w) and hydrogen peroxide (30% w/w) were manufactured by Merck. Trifluoroacetic acid (99%), acetonitrile (HPLC grade), n-propanol, n-Hexane, benzene, and tetrahydrofuran were all obtained from Sigma Aldrich (USA). Stock solutions (1000 mg/L) of the metals studied were obtained from Sigma-Aldrich (USA).

2.7 Water bath assisted acid digestion of samples

10 mL aliquot of each sample of alcoholic beverages was emptied into a digestion flask after which, 5 mL of concentrated nitric acid was slowly added to the sample in the digestion flask. The digestion flask and its content were thereafter transferred to a water bath and heated at 80⁰C for 1 hour. To ensure complete oxidation of all the organic matter, 2 mL of hydrogen peroxide was added to the cooled mixture in the digestion flask. The digested solution was filtered and diluted with ultrapure water to a final volume of 50 mL. Blank samples were also analysed for trace and heavy metals following the same procedure. However, the solutions were prepared without the alcoholic beverages.

2.7 Inductively Coupled Plasma- Optical Emission Spectroscopy (ICP-OES):

Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) was used for measuring the levels of micro-elements and heavy metals in the sachet packaged alcohol samples. Digested samples of each of the alcoholic beverages were transferred into polyethylene vials, and aspirated through a peristaltic pump and nebulizer system into the ICP-OES (Perkin Elmer) for quantitative determination of trace and heavy metals. The instrument was operated under the manufacturer's specifications. The operating conditions used are: nebulizer argon flow rate of 0.8 L min⁻¹, auxiliary argon flow rate of 1.0 Lmin⁻¹, plasma argon flow rate of 12 L min⁻¹, radio frequency power of 1.2 kW, sample flow rate of 1.0 mL min⁻¹ and sample flush time of 20 s between measurements. The instrument was calibrated using standard solutions prepared in 1% (v/v) nitric acid. The calibration curve obtained using a series of standard solutions with appropriate concentrations had correlation coefficients (R²) $\geq$ 0.9999. Each metal was analysed at the appropriate wavelength. Also, each sample of alcoholic beverage was analysed in triplicate, and the results were presented as the mean.

2.8 Sample preparation- Liquid Chromatography (SPLC)

Sample Preparation and Liquid Chromatography (SPLC) was used to measure the alcohol by volume (ABV) in each sample of the sachet packaged alcohol.

2.8.1. Preparation of extraction solvent: The extraction solvent was prepared by transferring 25mL benzene, 20 mL hexane, and 20 mL tetrahydrofuran into a beaker. The mixture of benzene, hexane, and tetrahydrofuran was carefully transferred into a volumetric flask, and the mixture was made up to the 1.0 dm³ mark with ultrapure water.

2.8.2 Preparation of sample: A 5 mL sample of the alcoholic beverage was transferred into a centrifuge tube, and 20 mL of the extraction solvent was added to the sample in the centrifuge. The content of the centrifuge tube was tightly stoppered and shaken for 10 minutes to ensure complete extraction and a homogeneous mixture. The mixture was thereafter centrifuged at 5000 rpm for 5 minutes. To improve instrument sensitivity, the resulting supernatant was treated with phthalic anhydride and afterwards transferred to a set of 15 mL HPLC vials for chromatographic analysis.

2.8.3 HPLC: Chromatographic analysis was done on a Water 616/626 HPLC system equipped with a UV detector. The alcoholic components were separated on the basis of their interaction with the mobile and stationary phases, and the eluted compounds were detected by the UV detector. Operation parameters used are: 250 mm $\times$ 4.6 mm octadecylsilyl column as the stationary phase, mobile phase A: acetonitrile + 0.1% (v/v) trifluoroacetic acid, Mobile phase B: acetonitrile + 0.1% (v/v) trifluoroacetic acid, UV detection at 254 nm, flow rate of 1.0 mL min⁻¹, column temperature of 30 ⁰C. injection

volume of 20 μ L, elution time of 20 minutes. The calibration curve was prepared using ethanol as the reference standard and the levels of ethanol were determined from the calibration equation. The concentration obtained from the calibration equation was corrected for dilution, and the results were expressed as ABV (% v/v). To correct variations in sample preparation and instrumental response. n-Propanol was used as the internal standard and was added to each of the samples before the extraction process. The internal standard was also added to the reference solution to ensure consistency in sample preparation. Each sample was analysed in triplicate and the results presented as mean values.

2.9 Quality control and assurance

All samples were blinded during the laboratory analytical phase of the study, and then unblinded during the reporting stage. This was performed to eliminate any form of bias and improve quality assurance. Glassware, digestion vessels, and sample bottles were soaked in nitric acid for 12 hours and thereafter rinsed with deionized water to avoid contamination. Ultrapure deionized water was used for all the analyses. All analytical measurements were performed by strictly following standard operating procedures (SOP). Analyses were made in duplicate and mean values were used for the final calculation.

2. 10 Data analysis

Quantitative data were subjected to test for Normality, and the Wilcoxon signed-rank test using SPSS vs 23. The results for the micro-elements and heavy metals were compared with the WHO permissible limits from the guidelines for drinking water, and samples that exceeded the limits were recorded. Information declared on product labels was compared with NAFDAC regulations for labelling spirit-based drinks(Federal Government of Nigeria, 2021; NAFDAC, 2019b) and alcoholic beverages (NAFDAC, 2019b).

3.0 Results

A total of 15 sachet alcoholic beverage brands were sampled in the study (Table 1). The sample included a variety of commonly consumed spirit-based alcoholic beverages such as gins, schnapps, bitters, liqueurs, rum-based, and energy spirit drinks (See Supplementary File for brand photos).

Table 1
Characteristics of sampled sachet-alcohol brands

Full Brand Name	Type of Alcohol	Code Name	Volume	Declared ABV	Measured ABV
Chealsea London dry Gin	Gin	CLG	30 ml	43%	21.8%
Eagle Aromatic Schnapps	Schnapp	EAS	30 ml	43%	29.7%
Night Charger Spirit Drink	Flavored spirit	NCS	50 ml	40%	20.4%
Long Jack Bitters	Bitters	LJB	50 ml	25%	20.8%
Gbefun Super Bitters	Bitters	GSB	50 ml	40%	12.2%
Seamans Schnapps	Schnapps	SSP	30 ml	40%	40.6%
Black wood Alcoholic Bitters	Bitters	BAB	50 ml	40%	6.0%
Action bitters	Bitters	ABS	50 ml	40%	9.0%
Striker bitters Alcoholic Drink	Bitters	SBS	50 ml	35%	0.1%
DeRok Cafe Liquor	Liqueur	DQL	50 ml	40%	6.1%
Confam Bitters	Bitters	CBS	50 ml	30%	0.1%
Regal Deluxe London Dry Gin	Gin	RDG	30 ml	36.8%	12.7%
Captain jack Blended Cafe Rum	Rum	CJR	30 ml	37.5%	4.4%
Krush Alcoholic Liqueur	Liqueur	KAL	50 ml	30%	9%
D-Riders Bitters	Bitters	DRB	5 cl	40%	7.4%

Measured percentage of alcohol by volume vs declared value

Table 1 contains values of measured ABV (%) and declared ABV (%) on product labels of the sampled brands. The analysis showed a wide gap between measured and declared ABV values, with measured ABV ranging from as low as 0.1% to 40.6%, while declared values ranged from 25% to 43%. The average measured ABV was 13.35%, far below the mean declared ABV of 37.35%, with an average discrepancy of 24.00%.

A closer look at the individual brands reveals two major trends:

1. Under-declared ABV (actual ABV higher than value on product label): Only one sampled brand (Seamans Schnapps) contained a measured ABV of 40.6%, slightly above the declared 40%, suggesting minor under-declaration.
2. Over-declared ABV (value on product label higher than actual content): The vast majority of sampled brands (14 out of 15) showed significant over-declaration. Notable examples include: Chelsea London Dry Gin (measured – 21.8%, declared – 43%), Eagle Aromatic Schnapps (measured – 29.7%, declared – 43%), Night Charger Spirit Drink (measured – 20.4%, declared 40%), Gbefun Super Bitters (measured – 12.2%, declared – 40%), Confam Bitters and Striker Bitters (both declared between 30–35% ABV), but only measured 0.1%, indicating near absence of ethanol.

This over-declaration trend was statistically significant ($Z = -3.351$, $p = 0.001$), suggesting that the difference between measured and declared ABV is not due to chance, but systemic misrepresentation.

Micro-Elements and Heavy Metals concentration in sampled sachet alcohol brands

The presence of 6 micro-elements, namely manganese (Mn), iron (Fe), zinc (Zn), copper (Cu), selenium (Se), and Boron (B) were assessed in the sampled brands (Table 2). Levels of Mn ranged from 1 to 298 µg/L across sampled products, which

were below the WHO guideline of 4000 µg/L. However, 2 of the sampled brands (Chelsea London Dry Gin (298 µg/L) and Seamans Schnapps (220 µg/L) had relatively higher values. Iron (Fe) presented values ranging from 3 to 519 µg/L. Thirteen out of 15 sampled brands contained Fe values below the WHO MPL (300 µg/L), while 3 brands, namely Chelsea London Dry Gin (519 µg/L), Night Charger Spirit Drink (343 µg/L), and Seamans Schnapps (395 µg/L) exceeded the guideline, indicating potential health risks. Zinc (Zn), copper (Cu), and selenium (Se) levels were generally low across all samples, and all fell below their respective WHO guideline values of 5000 µg/L, 2000 µg/L, and 40 µg/L, respectively. Boron (B) showed the most variations among the heavy metals analysed, with concentrations ranging from 0 to 49 µg/L. While still far below the WHO permissible limit of 2400 µg/L.

Table 2
Micro-Elements concentration in sampled sachet alcohol

Micro Elements							
SN	CODE	Mn (µg/L)	Fe (µg/L)	Zn (µg/L)	Cu (µg/L)	B (µg/L)	Se (µg/L)
1.	CLG	298	519	37	5	13	7
2.	EAS	97	174	12	2	8	2
3.	NCS	191	343	25	3	12	5
4.	LJB	35	63	5	1	9	1
5.	GSB	74	134	1	1	7	2
6.	SSP	220	395	28	4	9	5
7.	BAB	34	61	4	1	4	1
8.	ABS	137	245	17	3	49	3
9.	SBS	25	44	3	0	0	1
10.	DQL	85	152	11	2	4	2
11.	CBS	12	21	1	0	0	0
12.	RDG	95	170	12	2	4	2
13.	CJR	33	59	4	1	3	1
14.	KAL	1	3	0	0	6	0
15.	DRB	68	123	9	1	5	2
WHO MPL		4000	300	5000	2000	2400	40

The wide range suggests differing water sources or ingredient profiles across manufacturers.

The presence of toxic metals (lead (Pb), Arsenic (As), mercury (Hg), cadmium (Cd), barium (Ba), Nickel (Ni), Cobalt (Co), and Antimony (Sb)) was also assessed in the sampled brands (Table 3).

Table 3
Heavy Metal concentration in sampled sachet alcohol

Heavy Metals									
SN	CODE	Pb (µg/L)	Ni (µg/L)	Co (µg/L)	As (µg/L)	Cd (µg/L)	Ba (µg/L)	Sb (µg/L)	Hg (µg/L)
1.	CLG	0	4	19	0	0	0	1	0
2.	EAS	0	1	6	0	0	0	3	0
3.	NCS	0	3	12	0	0	0	5	0
4.	LJB	0	1	2	0	0	0	4	0
5.	GSB	0	1	5	0	0	0	3	0
6.	SSP	0	3	14	0	0	0	4	0
7.	BAB	0	0	2	0	0	0	2	0
8.	ABS	0	2	9	0	0	0	2	0
9.	SBS	0	0	1	0	0	0	0	0
10.	DQL	0	1	6	0	0	0	2	0
11.	CBS	0	0	1	0	0	0	0	0
12.	RDG	0	1	6	0	0	0	1	0
13.	CJR	0	0	2	0	0	0	1	0
14.	KAL	0	0	0	0	0	0	2	0
15.	DRB	0	1	4	0	0	0	2	0
WHO MPL		10	70	50	10	3	1300	20	6

The following heavy metals were not detected in any of the sampled brands: lead (Pb), Arsenic (As), mercury (Hg), cadmium (Cd), and barium (Ba). The level of Nickel (Ni) was low in most of the samples (10 out of 15 brands) with values ranging from 0 to 4 µg/L, which was significantly below the WHO MPL of 70 µg/L. Cobalt (Co), an essential trace element required for vitamin B12 synthesis, was more widely distributed across the samples (14 out of 15 brands), with concentrations ranging from 0 to 19 µg/L, well below the WHO limit of 50 µg/L. Some brands, namely Chelsea London Dry Gin (19 µg/L) and Seamans Schnapps (14 µg/L), contained relatively high values of Co. Antimony (Sb) was detected in trace amounts across most samples, with values ranging from 0 to 5 µg/L, which is well below the WHO guideline of 20 µg/.

Brand compliance with NAFDAC required labelling regulations

Table 4
Brand Compliance with NAFDAC Labeling Regulation

NAFDAC Label information	Compliant Brands	Non-Compliant Brands
Mandatory	n (%)	n (%)
Percentage Alcohol by Volume	15 (100)	0 (0)
Volume Declared	15 (100)	0 (0)
List of ingredients	13 (86.7)	2 (13.3)
Health Claims shall not be made	11 (73.3)	4 (26.7)
NAFDAC Registration Number	15 (100)	0 (0)
NAFDAC Registration Number (valid and active)	6 (40)	9 (60)
Age Restriction (18+)	14 (93.3)	1 (6.7)
Non-mandatory		
Caution for pregnant women	12 (80)	3 (20)
Drink Responsibly Statement	7 (46.7)	8 (53.5)

Table 4 contains information on brand compliance with NAFDAC labelling regulation for spirit drinks on product labels (See supplementary Table S1 for a comprehensive list). All the sampled brands (15) displayed the ABV and volume on product labels in compliance with the NAFDAC labelling regulations. Thirteen brands displayed the full ingredient list on their product labels, while two brands (Eagle Aromatic Schnapps and Long Jack Bitters) did not disclose the ingredients used. Two brands (Gbefun Super Bitters and Striker Bitters) stated herbal ingredients on their product labels but did not specify the exact herbal ingredients, posing risk of undetected toxicity due to undisclosed plant extracts. Some brands included medicinal claims and potential toxicity risks on product labels. For example, Gbefun Super Bitters, Long Jack Bitters, and D-Rider Bitters advertised unsubstantiated therapeutic benefits, including treating malaria, back pain, and sexual dysfunction.

All the brands displayed their NAFDAC registration number which were verified on NAFDAC Automated Product Administration and Monitoring System (NAPAMS) website. Ten out of the 15 brands were found on the website and verified. However, only six had active NAFDAC registration numbers while the remaining were expired. The NAFDAC registration number of four brands (eagle aromatic schnapps, action bitters, regal deluxe London dry gin, and Sooper Krush) were not found on the website, while one brand (Gbefun Super Bitters) displayed a different product manufactured by the same company. Only 1 brand did not display the required age restriction (18+) for consuming spirit-based drinks on their product labels. Some brands included non-mandatory NAFDAC information on product labels. For example, 12 out of 15 brands displayed don't drink during pregnancy logo, while 7 brands included a drink responsibly statement.

4.0 Discussion

The study is part of a growing body of research that assesses levels of heavy metals in sachet spirit-based alcoholic beverages in Nigeria. Previous studies in Nigeria have mostly assessed levels of heavy metals in alcoholic beverages packaged in bottles and cans (C. M. A. Iwegbue et al., 2014; Okafor et al., 2022; Udotu & Umoudofia, 2011). The current study is among the first to evaluate levels of 6 micro-elements and 8 heavy metals in sachet spirit-based alcoholic beverages, including brand compliance with regulatory labeling guidelines in Nigeria. The findings contribute relevant information to the growing concern on the production, distribution, and consumption of sachet spirit drinks in Nigeria and the African region.

In the current study, we found that the levels of Fe in Chelsea London Dry Gin (519 µg/L) and Seaman Schnapps (395 µg/L) exceeded the WHO MPL. Levels of Fe have also been reported to exceed the WHO MPL in samples of alcoholic beverages commonly consumed in Aba (Ogoko et al., 2024), Owerri (Ubuoh et al., 2013), Akwa (Okafor et al., 2022) and Uyo (Udota & Umoudofia, 2011) in Nigeria. Consumers who regularly ingest Fe in sachet alcoholic beverages, especially in large quantities, may face cumulative exposure risks. High iron intake has been associated with conditions such as hemochromatosis, gastrointestinal irritation, and oxidative stress, particularly when intake exceeds the body's regulatory capacity (Taiwo et al., 2020). This raises safety concerns and suggests the need for continuous monitoring. Ude et al. [38] assessed serum trace elements among alcohol consumers in Nigeria and found altered levels of micronutrients, suggesting that habitual alcohol intake might disrupt normal micronutrient metabolism (Ogoko et al., 2024; Taiwo et al., 2020). This is particularly concerning for essential elements like Se and Z, whose deficiency can impair immune function, reproduction, and antioxidant defence.

Overall, none of the 8 heavy metals sampled in the current study exceeded the WHO guideline values for drinking water, and most were either not detected or presented at very low levels. The non-detection of Arsenic (As), mercury (Hg), cadmium (Cd), and barium (Ba) across the sample is a highly favourable outcome, given that each of these elements is classified as toxic and carcinogenic at certain concentrations. These findings are consistent with the findings from other researchers (Opanuga, 2024; Otim et al., 2019).

The WHO guidelines for these metals are stringent (10 µg/L for arsenic, 6 µg/L for mercury, 3 µg/L for cadmium, and 1300 µg/L for barium) due to their well-established links with kidney damage, cancer, and neurological effects (World Health Organization, 2022). The absence of these metals in sampled products indicates minimal environmental or industrial contamination and suggests good raw material sources and quality assurance.

Nonetheless, some brands showed relatively higher levels of cobalt, boron, and antimony, which highlights potential inconsistencies in ingredient sources or production processes. We found elevated values of Cobalt in Chelsea London Dry Gin (19 µg/L) and Seamans Schnapps (14 µg/L). Exposure to high cobalt levels, especially in individuals with compromised renal function, may pose health risks. Essential trace metals could accumulate to undesirable levels in habitual alcohol consumers who consume large amounts of the brands (Ude et al., 2016). Boron is an essential nutrient in small amounts but has been associated with reproductive and developmental toxicity at high doses (Duydu & Başaran, 2023). Its presence in moderate quantities across many of the samples may not pose a risk, but it underscores the importance of standardizing production inputs. Antimony is not frequently assessed in food safety surveys, but its presence in sampled products could be linked with leaching from PET plastic packaging. Its detection, although at safe levels, highlights the importance of monitoring storage and packaging materials, especially under high temperatures.

One of the most noteworthy findings from the study was the complete absence of lead (Pb) in all 15 sampled products. This result is particularly significant given that lead is a well-documented neurotoxin and environmental pollutant, with cumulative effects especially harmful to children and vulnerable adults (Peña-Bautista et al., 2020). The WHO sets a maximum allowable concentration of 10 µg/L for lead in drinking water. The absence of Pb in all sampled products suggests they were not exposed to lead contamination during processing, packaging, or distribution. Studies have reported low or non-detectable lead levels in similar beverage products in Nigeria (Iweala et al., 2014; Taiwo et al., 2020; Udota & Umoudofia, 2011), indicating effective sourcing and manufacturing practices.

The NAFDAC has regulations guiding the labelling of spirit-based drinks in Nigeria. Some mandatory information required on product labels of spirit drinks includes brand name, manufacturer address, list of ingredients, ABV%, volume, and NAFDAC registration number (NAFDAC, 2019b). Our findings indicate widespread mislabelling of sachet-packaged alcoholic beverages in Abeokuta. Almost all the brands significantly overstated their ABV, and there was a clear disconnect between label information and actual ethanol content, while some omitted the legal age of consumption (18+) on product labels. These findings raise public health and consumer protection concerns. Consumers may be

unintentionally misled into believing they are consuming higher-proof alcohol than they are. This may encourage over-consumption or risky behaviour, especially among habitual drinkers who rely on label information for consumption. The small, portable packaging (30–50ml) and low cost of these products facilitate binge drinking, dependency, and accessibility among youths, contributing to rising cases of alcohol related disorders (Arasi & Ajuwon, 2020a; Zhou et al., 2016).

The unexpectedly low ethanol content in many samples suggests that the intoxicating effects reported by consumers may not be attributable to ethanol alone. This raises the possibility that these products may contain other psychoactive substances, such as synthetic cannabinoids, hallucinogens, stimulants, or high levels of bitters and herbal extracts that might interact with CNS activity. Previous studies have also reported that some locally produced bitters, herbal bitters, and alcoholic beverages in Nigeria might contain unregulated or undeclared substances to enhance their psychoactive effects (Onyedika-Ugoeze & Nzor, 2022). Some sachet alcohols have been reported to contain botanicals like *Khaya ivorensis*, which has been associated with neurotoxicity in high doses (Agbedahunsi et al., 2004). This is especially concerning because consumers, particularly in low-income settings, may consume these products under the assumption that they are safe, regulated, and standardized. The actual composition is unpredictable, and there may be adulterants that pose additional toxicological risks. Furthermore, a significant discrepancy between labelled and measured alcohol content may lead consumers to increase their intake of sachet alcohol beverages when perceived effects do not align with expectations, thereby predisposing them to intoxication and other associated medical consequences

Although NAFDAC prohibits making health claims on the product labels of spirit drinks (NAFDAC, 2019b); 40% of sampled brands contained health claims and potential toxicity risks on product labels. Brands advertised unsubstantiated therapeutic benefits, including treating malaria, back pain, and sexual dysfunction. Umarudeen et al., [1] found similar health claims such as sex-related vitality and physical enhancement, and alleviation of low back ache, pile, or menstrual disorders in 16 out of 64 alcoholic beverages in Nigeria. Consumption of sachet-based spirit drinks has been linked to engagement in risky sexual behaviours among adolescents in Nigeria (Akinsorotan, 2015; Arasi & Ajuwon, 2020b). Alcohol brands use health claims and the inclusion of herbal ingredients to market their products, given that medicinal properties are attributed to herbs in the country. Health claims on alcoholic beverages potentially lack scientific validation and may encourage consumers to self-medicate with alcohol instead of seeking proper medical care. Brands often failed to disclose the exact herbal ingredients associated with their claim, posing a risk of undetected toxicity due to undisclosed plant extracts.

The presence of expired NAFDAC registration numbers on product labels of some sampled brands can be attributed to NAFDAC's refusal to renew the registration of alcoholic beverage brands in sachets and bottles less than 200ml (Ogadinma, 2024). In 2018, NAFDAC the Federal Ministry of Health, the Federal Competition and Consumer Protection Commission (FCCPC), and alcohol industry groups including the Distillers and Blenders Association of Nigeria (DIBAN) and Association of Food, Beverages and Tobacco Employers (AFBTE) signed a five-year memorandum of understanding to end the production and distribution of sachet or bottle alcohol less than 200 ml by 31 January 2024 (NAFDAC, 2024). In January 2022, NAFDAC stopped registering alcoholic beverage brands in sachet and small volume PET and Glass bottles below 200ml (Ogadinma, 2024) and began enforcing the ban on January 2024 (NAFDAC, 2024). Four out of the 15 brands sampled in the study were not found on the NAFDAC registration website suggesting that the manufacturers might have commenced production and distribution of the brands after NAFDAC stopped registering new brands in January 2022.

Despite the importance of the ban for public health and consumer safety, NAFDAC's initial enforcement of the ban was met with protests and extensive pressure from the alcohol industry and trade unions (Ogunnaike, 2024; Omogbolagun, 2024; Umoru, 2024). Alcohol industry interference has also been reported to interfere with implementing the sachet alcohol ban in Uganda and Malawi (Uny et al., 2025). Following an investigation of the ban, the Nigerian House of Representatives (lower chamber) ordered NAFDAC to suspend the ban in April 2024 (ChapiOdekina, 2024a, 2024b;

Dumbili, 2024). Defending their position, the lawmakers argued that the ban's enforcement was ill-timed and could lead to unemployment and poverty, given the severe economic strain in the country (Vanguard News, 2024).

Sachet alcohols are affordable and readily available in Nigeria, known for its high alcohol outlet density even around schools (Odeigah et al., 2023). Being presented in a small package makes it attractive to young people and convenient for low-income earners. Arasi and Ajuwon, (2020) found that 39.5% of adolescents in Ibadan, Nigeria, were current users of sachet alcohol, and 33.6% consumed sachet alcohol before engaging in sexual activities. Approximately 55% of adolescents in Nigeria aged 15–19 years reported engaging in heavy episodic drinking (World Health Organization, 2024). Alcohol consumption can disrupt brain development in young consumers and lead to alcohol use disorders (Tapert & Eberson-Shumate, 2022; Tetteh-Quarshie & Risher, 2023). Commercial drivers have also been reported to consume sachet alcohol excessively (Akinsorotan, 2015; Idowu, 2024). (Osu & Ishola, 2024) study among commercial drivers in Lagos revealed that 44% consumed above 5 bottles/sachets of alcohol daily, while 85.5% drank before driving. Our study found high levels of ABV in Chelsea London Dry Gin (21.8%), Eagle Aromatic Schnapps (29.7%), and Seamans Schnapps (40.6%) packed in 30ml sachets and are commonly consumed among commercial drivers. Drinking and driving is associated with impaired judgment and the risk of fatal motor accidents (Garrisson et al., 2021). The presence of high concentrations of micro-elements and heavy metals further exacerbates their impact on consumers.

Our findings support the growing health concern surrounding the production, marketing, and consumption of sachet-based spirit drinks in the country (Idowu, 2024; Rogers et al., 2024; Umarudeen et al., 2023). We therefore recommend that the federal government approve NAFDAC's enforcement of the ban on alcohol packed in sachets and bottles above 200ml. The agency should conduct a routine assessment of the presence of heavy metals in sachet-based alcoholic beverages and sanction defaulters who fail to adhere to regulatory guidelines. Manufacturers should be mandated to use corrosion-resistant equipment to reduce Fe leaching and adopt transparent labeling aligned with NAFDAC Spirit drink labeling regulations.

5.0 Limitation

The study had some limitations. Only fifteen sachet-based alcoholic beverages were sampled. Although care was taken to select a representative sample of commonly consumed brands, this might have excluded other brands. The study only assessed the presence of micro-elements and heavy metals, but did not conduct a health impact assessment of these elements. We found high levels of Iron, but the source of contamination (e.g., raw materials, equipment) was not traced. Further studies should expand the sample selection to include a larger sample from the rural areas, investigate sources of Fe contamination (e.g., water and raw materials), and conduct a health risk assessment.

6.0 Conclusion

This study exposes critical safety gaps in sachet spirit-based alcoholic beverages commonly sold and consumed in Abeokuta. Iron levels exceeded WHO limits in 20% of samples, widespread misinformation on product labels, with most brands containing significantly less alcohol than declared. These findings, combined with frequent regulatory non-compliance in labeling practices, underscore the urgent need for stricter enforcement of production standards, transparent labeling, and consumer education.

Declarations

Ethical Approval

Not applicable

Consent for Publication

Not applicable.

Author Contributions

S.A: Investigation, study design, data collection, literature search, interpretation of results, and conceptual support

O.O: Conceptual support, manuscript drafting, literature review, manuscript editing, interpretation of results, and manuscript revision

R. A: Study design, manuscript drafting, manuscript revision, manuscript editing

A.A: Study design, supervision, correspondence, manuscript drafting, literature review, conceptual support, manuscript revision, interpretation of results, manuscript editing

All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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Conflict of Interest

Nil

Data Availability

The data generated for this study are available from the corresponding author:

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Conflict of interest:

Nil

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