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Phytochemical Properties and Heavy Metal Contents of Commonly Consumed Alcoholic Beverages Flavoured with Herbal Extract in Nigeria

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Abstract: There is proliferation of alcoholic beverages flavoured with herbal-extracts that are perceived to have medicinal values. Information on the phytochemical and heavy metal contents of these products is scarce. This study assessed the phytochemical properties and heavy metal contents of herbal-extract flavoured alcoholic beverages in major motor parks in Ibadan, Nigeria. The phytochemical properties of the beverages were determined in triplicate using standard methods, while the heavy metal contents were assessed while using atomic absorption spectrophotometry. Data were analyzed using descriptive statistics, and means were compared using ANOVA at $p < 0.05$. The pH range of the beverages was 3.28–6.57 and the alcohol content was 34.0–51.5%. Detected major phytochemicals and concentration ranges were phytic acid (0.72–2.37 mg/g), alkaloids (0.42–4.11 mg/g), flavonoids (0.22–3.64 mg rutin equivalents/g), total phenols (1.13–3.66 mg gallic acid equivalents/g), anthraquinones (0.74–1.93 mg/g), and triterpenoids (0.74–1.93 mg/g). The heavy metal contents were Pb (2.13–4.70 mg/L), Cd (0.06–0.07 mg/L), Co (0.12–0.23 mg/L), Zn (0.14–0.40 mg/L), and Fe (0.72–4.22 mg/L); only Pb and Cd were above the World Health Organization (WHO) limits of 0.01 mg/L and 0.03 mg/L in water, respectively. The herbal-extract flavoured alcoholic beverages contain beneficial phytochemicals and traces of heavy metals. Safety awareness of these products for improved consumers' health would be of public health importance.

Keywords: phytochemical; heavy metals; flavoured alcoholic beverages; herbal extract

1. Introduction

Beverages play important role in the diets of people and some beverages are flavoured with herbal products, which are based on the perceived health benefits of the herbs. Many consumers are increasingly engaged in this practice as initiative to obtain certain health benefits or preventing an illness rather than waiting to cure diseases [1]. Beverages can be alcoholic, such as wine, spirits, and beers and non-alcoholic such as soft drink, candies, chocolates, and milks. Energy drink constitutes an increasingly popular beverage in Nigeria following perceived stimulating properties that are caused by its caffeine, guarana extract, taurine, ginseng, and other beneficial components [2]. Beverages are consumed in Nigeria irrespective of age, sex, and socioeconomic status. Beverages may be alcoholic (wine, spirits, and beers) or non-alcoholic (soft drink, energy drinks, candies, chocolates, and milks). Notwithstanding, most beverages are packed in cans, bottles, and plastics.

Though the product was introduced in Europe and Asia in 1960 primarily to satisfy consumers demand for a dietary supplement that would result in increased energy, it is now a regular consumption

in many countries, including Nigeria. Producers have initiated many innovative approaches to promote sales and the increased consumption of energy drinks in Nigeria with shifting emphasis on increased energy to herbal extracts. This is particularly interesting following the resurgence in the use of herbal medicines in sub-Saharan Africa, perceived affordability, safety of herbal products as compared to modern medicines [3], and its ready mix with the socio-cultural life of the people. Studies have shown that large number of the people in developing countries relies on herbal medicines for their primary health care [4,5]. As at 2008, 80% of the world's population was using herbal medicine for one form of primary health care or another and its health risk posed a major concern [6]. Many medicinal herbs are rich in a multitude of chemical compounds, like alkaloids, tannins, saponins, flavonoids, resins, and triterpenoids [7,8].

In addition to herbal extracts, reports have shown the presence of heavy metals in many beverages. Maduabuchi et al. [9] reported that among 21 canned and 30 non-canned beverages, 95.25% and 75.86%, respectively (iron), 42.86% and 51.72%, respectively (manganese), 80.95% and 72.41%, respectively (nickel) have high concentration, while Magomya et al. [10] reported that out of 24 soft drinks, 53.33%, 7.14%, 20.83%, 29.17%, and 16.67% exceeded the set safe limits for iron, copper, chromium, lead, and cadmium, respectively. Though some heavy metals could be beneficial, these metals possess deleterious effect when present or their levels in food and drinks exceed the tolerable limit [11]. Interestingly, both beverages and herbal extracts separately are noted as source of heavy metals and the additive effects of heavy metals from these sources could be particularly harmful to health. Studies have reported the presence of lead, cadmium, mercury, and arsenic in beverages, which lead to progressing physical, muscular, and neurologically-degenerating disease conditions [12,13].

Phytochemical assessment is essential to evaluate the chemical components that may be responsible for the observed/perceived health benefits that are associated with the herbal beverages. Phytochemicals are naturally occurring compounds that contribute to the color, flavor, and smell of plants and form part of a plant's natural defense mechanism against diseases. The therapeutic values of phytochemicals in human health and disease prevention have been reported [7,14]. Phytochemical screening is a tool by which the presence of these chemical compounds can be investigated in herbal products consumption of these beverages. Therefore, there is the need to identify the presence and the potentials of the phytochemical constituents of the beverages that are spiced with herbal medicines. This is particularly necessary to ensure safety following controversies with regulation and standardization in spite of the increasing use of herbal extracts in foods and drinks, especially alcoholic beverages. Though, there are information on the chemical constituents of the beverages and the herbal mixtures separately, but information is scarce on the ready to consume form of the preparations. Therefore, the evaluation of heavy metals and phytochemical properties of commonly consumed beverages is essential to promote food safety and consumers' health. In addition, it will be useful in providing information that could lead to necessary intervention and policy formulation. This study is; therefore, designed to assess the phytochemical properties and heavy metal contents of commonly consumed alcoholic beverages that are flavoured with herbal extract in Nigeria.

2. Materials and Methods

2.1. Collection of Samples for Laboratory Analysis

A consumption survey of alcohol beverages that are flavoured with herbal extracts was conducted among young adults within selected motor parks in Ibadan, Nigeria to identify five most frequently consumed brands. The brands were designated as Samples 1–5. Samples of these five beverages were randomly purchased from the sale points in the major motor parks (Ojoo motor park, Sango Motor Park, Iwo road motor park, Gate motor park, and Dugbe Motor park) in Ibadan, Nigeria and maintained in the prescribed storage condition prior to analysis. The manufacturer, brand name, expiry date, regulatory agency registration number, and percentage alcohol content were recorded.

2.2. Quantitative Phytochemical Analysis

Quantitative estimation of alkaloids content was conducted by the alkaline precipitation gravimetric method [15] and expressed as mg alkaloid per mL of the sample. Alkaloid in the extract was precipitated by a drop wise addition of concentrated NH_4OH at full turbidity. Precipitate was recovered by filtration, washed with 1% NH_4OH solution, dried in the oven at $100\text{ }^\circ\text{C}$ for an hour, cooled in a desiccator, and reweighed. By difference, the weight of alkaloid was determined and expressed as mg alkaloid per mL of the sample. The aluminum chloride method was used for the determination of the total flavonoid content and absorbance at 415 nm after 30 min of incubation [10]. A volume of 0.1 mL Na-K tartarate and 2.8 mL distilled water were added sequentially to 20 mL of the sample of extract solutions and made up with methanol. The test solution was vigorously shaken and absorbance at 415 nm was recorded after 30 min of incubation. A standard calibration plot was generated at 415 nm using known concentrations of quercetin. The concentrations of flavonoid in the test samples were calculated from the calibration plot and then expressed as mg quercetin equivalent/mL of sample. Total Phenolic concentration in sample extract was measured by Folin-Ciocalteu assay. A 5 mL of distilled water, 5 mL of sample, and 1.0 mL of Folin-Ciocalteu reagent was added to a 25 mL flask. The content was mixed and allowed to stand for 5–8 min at room temperature. Thereafter, 10 mL of 7% sodium carbonate solution was added, followed by distilled water to mark. Solution was mixed and allowed to stand at room temperature for 15 min, and then absorbance was recorded at 750 nm [16].

Total Phenol content was standardized against gallic acid and expressed as milligram per mL of gallic acid equivalents (GAE). The linearity range for this assay was determined as 0.5–5.0 mg/L GAE. Saponin content was obtained while using procedures of Edeoga [8]. A total of 100 mL of sample extract was transferred into 250 mL separating funnel and 20 mL of diethyl ether was added. The aqueous layer was recovered while the ether layer was discarded. The purification process was repeated and 60 mL of n-butanol was added. The combined n-butanol extract was washed twice with 10 mL of 5% aqueous sodium chloride. The remaining solution was heated in a water bath. After evaporation, the samples were dried in the oven to constant weight and the saponin content was calculated. Oxalate composition was determined at 590 nm absorbance while using UV/VIS spectrophotometer [17] and expressed in milligrams per mL. A total of 20 mL of sample extract was transferred into a 50 mL standard flask and the pH was corrected between 5 and 7. 1 mL oxalate reagent A [DMAB (3-dimethylamino) benzoic acid 1 MBTH (3-methyl-2-benzothiazolinonehydrazone)] was then added followed by addition of 0.5 mL of oxalate reagent B (oxalate oxidase and peroxidase). The flask was mixed by gentle inversion and incubated at $40\text{ }^\circ\text{C}$ for 5 min and the absorbance taken at 590 nm using a UV/VIS spectrophotometer. Blanks and oxalate standards were subjected to equal treatment. The concentration of oxalate was determined in milligrams per mL. Tannin content was determined using Butanol-HCl reagent and expressed in mg per mL [18]. Sample extract of 0.5 mL was placed into glass test tube diluted with 70% acetone and 3.0 mL of the butanol-HCl reagent and 0.1 mL of the ferric reagent were added. The mouth of each tube was covered with a glass marble and tubes was put in a heating block and adjusted at 97 to $100\text{ }^\circ\text{C}$ (or in a boiling water bath) for 60 min. Tubes were cooled and absorbance was recorded at 550 nm. Phytic acid concentration was determined using FeCl_3 as precipitant [19]. 20 mL of the sample was extracted with 0.5N HCl. Thereafter, FeCl_3 was used to precipitate the phytic acid as ferric phytate and NaOH solution was used to convert the precipitate into sodium phytate, and then digested with acid mix containing equal portions of concentrated H_2SO_4 and HClO_4 . The liberated phosphorus was quantitated colorimetrically at 620 nm after colour development with molybdate ascorbic acid reagent solution.

2.3. Determination of Heavy Metals

The samples were digested in Teflon lab ware that had been cleaned in a high-efficiency particulate air—(HEPA) filtered. This involved sequential cleaning of the lab ware in a series of baths in solutions and rinses in a three-step order. Glassware was soaked in 10% Nitric acid for 24 h, rinsed with distilled

water then with demineralized water, and oven dried at 100 °C for 10 min before use to avoid any form of heavy metal contamination.

Standard Association of Official Analytical Chemists (AOAC) methods for the determination of Pb, Cd, Cr, Co, Fe, and Zn in food and beverages were used [20]. Concentrated acids (HNO₃ and HClO₄) of BDH analar grade and demineralized water were used for analysis. Stock standard solutions of Pb, Cd, Cr, Co, Fe, and Zn containing 1000ppm of each metal were also used, while calibration standards of each metal were obtained by appropriate dilution of the stock solutions.

Sample extract (50 mL) was concentrated to 25 mL using 2 mL concentrated HNO₃. The solutions were allowed to cool and then filtered. Lead, cadmium, chromium, cobalt, iron, and zinc contents of the alcoholic beverages flavoured with herbal extract were determined spectrophotometrically by using Buck 200 atomic absorption spectrophotometer Buck Scientific, Norwalk United Kingdom [20] and compared with absorption of standards of these minerals. All samples were determined in triplicate.

Codex food standard, which is a joint Food and Agricultural Organization (FAO)/World Health Organization (WHO) Codex Alimentarius Commission (CAC), was used for the comparison of the heavy metals [21,22]. To confirm the precision and the accuracy for the heavy metals analysis, a standard reference material (SRM) was obtained from NIST and Standard Organization of Nigeria (SON).

2.4. Statistical Analysis

Data were processed using the Statistical Package for Social Sciences (SPSS) for Windows 20.0 (SPSS, Chicago, IL, USA) software. The results obtained were analysed using one way analysis of variance (ANOVA), and level of significance was set at $p < 0.05$.

3. Results

3.1. Physical Properties of the Alcoholic Beverages

The physical properties of the samples are presented in Table 1. The pH range of the alcoholic beverages was 3.28–6.57 and the alcohol content (%) ranged from 34.0 to 51.5. For the samples, the alcoholic contents were higher than was indicated on the beverages labels.

Table 1. pH and the alcohol contents of the alcoholic beverages.

Samples	NAFDAC Reg. No.	pH	Alcohol Label Claim (%)	^a Alcohol (%) Determined in the Laboratory	<i>t</i> -Test Value (<i>p</i> Value)
Sample 1	B1-4103L	3.28 ± 0.04	42	41.1 ± 0.02	−7.794 (0.01)
Sample 2 *	-	4.57 ± 0.3	NA	34.0 ± 5	Nil
Sample 3	B1-7529	6.57 ± 0.07	40	42.0 ± 0.55	6.709 (0.003)
Sample 4	08-0630	4.34 ± 0.2	30	40.6 ± 0.35	52.114 (0.000)
Sample 5	A1-8029	5.77 ± 0.1	42	51.5 ± 0.03	53.116 (0.000)

^a An alcoholic beverage flavoured with herbal extract that is not packaged and branded; * NA—Not Available. Respective means in Samples 1 and 3–5 (in the same column with superscript “a” are significantly ($p > 0.05$) different from the mean of the unbranded Sample 2.

Statistical analysis using *t*-test at p value < 0.05 showed that there is a significant difference between the labelled and the experimental alcoholic content of Samples 1 and 3–5. Sample 2 was omitted because it does not have the alcoholic content label claim on it.

3.2. Phytochemical Quantitative Analysis of Alcoholic Beverages Flavoured with Herbal Extracts

Phytochemical compositions of the beverages in mg/ml are presented in Table 2. Phytic acid was present in Samples: 1, 2, and 4 and concentrations in order of abundance were 2.43 ± 0.1 mg/g, 2.37 ± 0.30 mg/g, and 0.72 ± 0.1 mg/g for Samples 1, 2, and 4, respectively. Oxalates were not detected

in all of the samples. Alkaloids and flavonoids were present in all of the samples. The concentration of alkaloids ranged from 0.42 to 4.11 (mg/g). 'Sample 1' had the highest concentration of alkaloids with mean concentration of 4.11 ± 0.2 mg/g. Alkaloids concentration in Sample 2–5 were 1.93 ± 0.3 mg/g, 0.42 ± 0.1 mg/g, 0.37 ± 0.2 mg/g, and 0.27 ± 0.1 mg/g, respectively, in decreasing order of abundance.

Table 2. Phytochemical quantitative analysis of alcoholic beverages flavoured with herbal extracts.

No.	Parameters	Sample 1	Sample 2 *	Sample 3	Sample 4	Sample 5
1	Phytic acid (mg/g)	2.37 ± 0.30	2.43 ± 0.1	0.00	0.72 ± 0.1	0.00
2	Oxalate (mg/g)	0.00	0.00	0.00	0.00	0.00
3	Alkaloids (mg/g)	4.11 ± 0.2	1.93 ± 0.3	0.27 ± 0.1	0.37 ± 0.2	0.42 ± 0.1
4	Flavonoids (mg rutin equivalents/g)	3.64 ± 0.05	0.77 ± 0.1	0.68 ± 0.1	0.22 ± 1	0.52 ± 0.2
5	Tannins (mg/g)	0.00	0.00	0.00	0.12 ± 0.4	1.43 ± 0.4
6	Saponins (mg diosgenin equivalents/g)	0.17 ± 0.02	0.00	0.00	0.00	0.22 ± 0.1
7	Total Phenolic (mg gallic acid equivalents/g)	3.66 ± 0.05	1.13 ± 0.1	1.58 ± 0.2	0.00	1.55 ± 0.3
8	Anthraquinones (mg/g)	1.93 ± 0.30	0.00	0.74 ± 0.1	0.00	0.00
9	Triterpenoids	0.11 ± 0.01	0.24 ± 0.1	0.93 ± 0.5	0.00	0.00

*An alcoholic beverage flavoured with herbal extract that is not branded. Means of the samples were not compared because of the non-detectable values. The table represents the mean concentrations of the parameters only, where order of abundances were generated.

Phenolic compounds were found in all of the samples, except for Sample 4. Saponins were found in Samples 1 and 5. Tanins were found in Samples 4 and 5. Anthraquinones were found in Samples 1 and 3 while triterpenoids were found in Samples 1–3. The mean concentration of flavonoids ranged from 0.22 to 3.64. Sample 1 had the highest level of flavonoids with mean concentration of 3.64 ± 0.05 mg rutin equivalents/g and Sample 4 had the lowest level (0.22 ± 0.01 mg rutin equivalents/g). Tannins content was 1.43 ± 0.4 mg/g in Sample 5, 0.12 ± 0.4 mg/g in Sample 4, and was not detected in other samples.

The mean concentrations of saponins (mg diosgenin equivalents/g) were 0.22 ± 0.01 and 0.17 ± 0.02 for Sample 1 and 5, respectively. Total phenols were present in all of the samples, except Sample 4 with a mean concentration of 3.66 ± 0.05 mg gallic acid equivalents/g and 1.13 ± 0.1 mg gallic acid equivalents/g for Samples 1 and 2, respectively. Anthraquinones (mg/g) was found only in Sample 1 (1.93 ± 0.30) and Sample 3 (0.74 ± 0.01). Triterpenoids contents were 0.93 ± 0.05 , 0.24 ± 0.1 and 0.11 ± 0.01 for Samples 1–3, respectively.

3.3. Heavy Metals Content of the Alcoholic Beverages Flavoured with Herbal Extracts

Heavy metals content of the alcoholic beverages that were flavoured with herbal extracts samples are presented in Table 3. The Pb concentration ranged from 2.13–4.70 mg/L; Sample 5 had the highest concentration (4.70 ± 0.5 mg/L); and, Sample 1 had the lowest (2.13 ± 0.01 mg/L). The Cd content was similar in all of the samples and ranged from 0.06–0.07 mg/L. The Cr concentration (mg/L) was highest in Sample 3 (0.35 ± 0.02 mg/L) and undetected in Sample 1. The Co content was highest in Sample 3 (0.2 ± 0.5 mg/L) and least in Sample 2 (0.12 ± 0.03 mg/L). Zinc and iron were present in all samples. Sample 1 had the highest Zn (0.40 ± 0.02 mg/L) and Fe (4.22 ± 0.02 mg/L) contents.

Statistical analysis using one-way ANOVA showed significant difference between Lead, Chromium, Cobalt, Zinc, and Iron content of the unbranded and the branded alcoholic beverages flavoured with herbal extract {(F(4,10) = 6345.3, $p = 0.000$), (F(4,10) = 223.038, $p = 0.000$), (F(4,10) = 33.545, $p = 0.000$), (F(4,10) = 128.78, $p = 0.000$), and (F(4,10) = 2.044, $p = 0.000$)}, respectively. There was no significant difference in the Cd content of the unbranded and the branded alcoholic beverages that were flavoured with herbal extract (F(4,10) = 563, $p = 0.695$). A post hoc Turkey test further showed the significant differences of each of the branded sample of the alcoholic beverages flavoured with herbal extract and the unbranded sample (Sample 2).

Table 3. Heavy metal content of the alcoholic beverages flavoured with herbal extracts (mg/L).

Samples	Pb	Cd	Cr	Co	Zn	Fe	Reference
1	2.13 ± 0.01 ^a	0.07 ± 0.02	0.00	0.13 ± 0.1	0.40 ± 0.02 ^a	4.22 ± 0.02 ^a	
2*	2.39 ± 0.01	0.06 ± 0.03	0.15 ± 0.02	0.12 ± 0.03	0.19 ± 0.04	0.83 ± 0.01	
3	3.91 ± 0.01 ^a	0.06 ± 0.03	0.35 ± 0.02 ^a	0.23 ± 0.01	0.14 ± 0.03	1.01 ± 0.01 ^a	
4	2.51 ± 0.04 ^a	0.06 ± 0.01	0.22 ± 0.04 ^a	0.13 ± 0.02	0.17 ± 0.01	0.72 ± 0.05	
5	4.70 ± 0.50 ^a	0.07 ± 0.01	0.31 ± 0.01 ^a	0.20 ± 0.50 ^a	0.22 ± 0.01	1.10 ± 0.10 ^a	
WHO	0.01	0.03	0.05	-	60	100	[23]
SON	0.01	0.03	0.05	-	3.0	0.3	[24]
RDA	0.3 mg/week		10–60	-	100	10–60	
F(p value)	6345.3 (0.000)	0.56 (0.695)	223.038 (0.000)	33.545 (0.000)	128.78 (0.000)	2044 (0.000)	

Metals in mg/L. * An alcoholic beverage flavoured with herbal extract that was not branded. Means in the same column with superscript “a” are significantly ($p > 0.05$) different from the mean of the unbranded Sample 2.

4. Discussion

This study presents the phytochemical properties and the heavy metals content of five commonly consumed herbal-flavoured beverages in Ibadan. The phytochemical contents of these beverages differ and alkaloids, flavonoid, and total phenol constituted the common and abundant phytochemicals in these products. Phytochemicals are noted to be abundant in herbs, fruits, and vegetables and their health benefits include reduced risk of oxidative stress-related diseases and chronic diseases, antioxidant properties, cell maintenance, DNA repair, and promote longevity [25,26]. The presence of these phytochemicals indicates that these beverages could be potential sources of beneficial antioxidants and confers health benefits that are associated with these phytochemicals. The intake should however be with caution as a study in Nigeria has linked intake of these phytochemicals to infertility [27]. Likewise, phenolic compounds have high inhibitory effect on iron absorption and reduced protein and carbohydrate digestibility [28]. The beverages contain tannin in varying quantity, all within the recommended intake level in Europe. Tannins could reduce the bioavailability of protein by reducing its nutritional quality through hydrogen binding and hydrophobic interactions [29]. Saponins act as chelators of transition metals (Cu^{2+} or Fe^{2+}) and it results in diminished cellular sensitivity to oxidant damage [30]. Two of these beverages (Samples 1 and 3) contain Anthraquinones, which possess a variety of antimicrobial, antioxidant, anti-inflammatory, antiviral, or antitumor promoting biological activities [31,32]. The presence of triterpenoids in three beverages precisely Samples 1–3 suggests the potential of the beverages exhibiting protective effects against cardiovascular disease and inflammation that are associated with this compound [33]. The intake level of the phytochemicals in the present study is low when compared with intake level of polyphenols of about 1 g in Europe [34].

Phytic acid was found in three samples at levels that were below the antinutritional limit of 500 mg/100 g. Phytic acid could play antinutritional role by forming a complex with calcium, iron, zinc, and other minerals, thereby reducing their bioavailability [35]. Hurrell et al. [36] reported that a mole of phytic acid binds 6 moles ferric iron, which is the major form of iron in plant foods. With phytic acid average content of about 2 mg/g in some herbal-flavoured beverages, heavy consumers may be at risk of iron deficiency.

Heavy metals constitute health risks in human when intakes are higher than the permissible levels. In the present study, all of the tested heavy metals were found in the herbal-flavoured beverages in varying proportions. The presence of these heavy metals conforms to earlier findings that reported the presence of impurities, such as heavy metals, including cadmium, copper, iron, nickel, selenium, zinc, lead, and mercury in soft drinks, beverages, and herbal products in Nigeria [37,38]. The lead concentration in the samples is above the WHO permissible level of 0.01 mg/L in water and this is unacceptable and raises public health concern. The presence of lead in the entire samples suggests the need for stricter regulations on the production and marketing of herbal-flavoured drinks in Nigeria. Earlier studies have reported similar levels of lead in Nigerian drinks and herbal products [37–41]. Lead toxicity can lead to kidney dysfunction, inhibition in haemoglobin synthesis, and damage to cardiovascular and the central nervous system [13,40].

Cadmium level in this study is also above the SON and WHO permissible limit and United States Environmental Protection agency recommended level of 0.03 mg/L [23,24]. This result showed that consumers' health, especially young children, adolescents, and pregnant women may be at risk following consumption of the herbal-flavoured beverages.

The level found in this study is higher than reported by Onianwa et al. [39] and similar to the findings of some other authors that reported an unsafe level of cadmium in Nigerian drinks [37,38]. Chromium contamination in this study agrees with earlier report showing the presence of chromium in Nigerian drinks [42,43]. This finding suggests a risk of lead, cadmium, and chromium intoxication when considering the frequency of consumption of these drinks.

Calcium and zinc constitute heavy metals with known biological importance in human nutrition and health, and with known recommended intake levels. Yet, intakes of these metals are expected to be within the recommended limits; otherwise, toxicity may occur with serious health implications [40,41]. Zinc is a micronutrient of public health importance. Its presence in these beverages suggests the reduced likelihood of the consumers' susceptibility to zinc deficiency. Zinc deficiency is known to lead to anaemia and growth retardation and toxicity can result in vomiting, diarrhea, bloody urine, liver failure, kidney failure and anemia [43].

5. Conclusions

The major phytochemicals in the herbal-extract flavoured alcoholic beverages in Nigeria were phytic acid (0.72–2.37 mg/g), alkaloids (0.42–4.11 mg/g), flavonoids (0.22–3.64 mg rutin equivalents/g), total phenols (1.13–3.66 mg gallic acid equivalents/g), anthraquinones (0.74–1.93 mg/g), and triterpenoids (0.74–1.93 mg/g). The heavy metals content was Pb (2.13–4.70 mg/L), Cd (0.06–0.07 mg/L), Co (0.12–0.23 mg/L), Zn (0.14–0.40 mg/L), and Fe (0.72–4.22 mg/L); only Pb and Cd were above the WHO limits of 0.01 mg/L and 0.03 mg/L in water, respectively. Public education to sensitize the consumers of herbal-extract flavoured alcoholic beverages on the health risk that is associated with these drinks is hereby suggested. Also, strict measures should be put in place to enhance the quality of production of these products.

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