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RESEARCH ARTICLE

Toxic Metal Profiles, Carcinogenic and Non-Carcinogenic Human Health Risk Assessment of Some Locally Produced Beverages in Nigeria

Odangowei I Ogidi[1*], Uchechi E Enenebeaku[2], Ebifanimi Okara[3] and Stephanie A Elumelu[1]

[1]*Department of Biochemistry, Federal Polytechnic, Ekowe, Bayelsa State, Nigeria*

[2]*Department of Biological Sciences, Hezekiah University, Umudi, Imo State, Nigeria*

[3]*Research Laboratory, Federal Medical Center, Yenagoa, Bayelsa State, Nigeria*

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***Corresponding author:** *Odangowei I Ogidi, Department of Biochemistry, Federal Polytechnic, Ekowe, Bayelsa State, Nigeria, Tel: +2347030081566*

Abstract

Background: Toxic metal contamination is a major problem of our environment and they are also one of the major contaminating agents of our food supply. The knowledge of metals in foods is essential for calculating the dietary intakes of essential metals and evaluation of human exposure to toxic elements. The aim of this study was to assess the toxic metal profiles, carcinogenic and non-carcinogenic human health risk of some locally produced beverages in Nigeria.

Methods: Seven (7) samples of locally produced beverages (Mokite, Palm wine, Agbo, Ogogoro, Kunu, Pigweed and Zobo) were purchased at Yenagoa, Bayelsa State, Nigeria and were taken to the laboratory for analysis. Standard wet digestion procedure was adopted for sample preparation while Atomic Absorption Spectrophotometer (AAS) technique was adopted for metal analysis.

Results: The results show that the mean toxic metal concentrations of Cr, [Mokite (0.35 mg/kg), palm wine (0.075 mg/kg), Kunu (0.66 mg/kg), Pigweed (0.141 mg/kg) and Zobo (0.06 mg/kg)] Ni [Palm wine (0.097 mg/kg), Kunu (0.16 mg/kg), pigweed (0.076 mg/kg) and Zobo (0.138 mg/kg)] and Mn [Mokite (0.156 mg/kg), Agbo (1.055 mg/kg), Kunu (0.278 mg/kg), Pigweed (0.11 mg/kg) and Zobo (1.03 mg/kg) in the beverage samples were above World Health Organization (WHO) permissible limits of 0.05 mg/kg, 0.02 mg/kg and 0.10 mg/kg respectively. Fe concentrations [Mokite (1.83 mg/kg), palm wine (0.953 mg/kg), Agbo (1.26 mg/kg), Ogogoro (1.115 mg/kg), Kunu (2.89 mg/kg), Pigweed (1.21 mg/kg) and Zobo (1.31 mg/kg)] of samples were also above WHO tolerable limits of 0.3 mg/kg. Cu and Zn in all the beverage samples were below the permissible limits of 2.0 mg/kg and 3.00 mg/kg respectively. The non-carcinogenic risk assessments indicate that the Estimated Daily Intake of metal concentrations in the beverage samples were all below the permissible tolerable daily intake limits as recommended by European Food and Safety Agency. The Target hazard quotient and Hazard index values on the metals were less than (<) 1 which indicates that there are no potential non-carcinogenic risks. In carcinogenic risk assessments, the carcinogenic risk (CR) values of the metals under study were observed to be greater than the mean incremental lifetime cancer risk of 1×10^{-4} which indicates that there is a significant cancer risk to people who consume these beverages in Nigeria.

Conclusion: Therefore, regular monitoring of toxic metals in locally produced beverages in Nigeria is highly recommended to avert a major public health problem.

Keywords

Toxic metals, Carcinogenic risk, Non-carcinogenic risk, Human health, Nigeria, Beverages

Introduction

Heavy metals are metallic elements of relatively high density, some of which are poisonous or toxic even at low concentrations, and characterized by their bio-accumulative and non-biodegradable potentials [1]. Certain heavy metals are required by living organisms in

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minute levels for physiochemical processes but they become toxic and perilous at higher concentrations in the cell. Heavy metals contamination is a major problem of our environment and they are also one of the major contaminating agents of our food supply [2,3]. The knowledge of metals in foods is essential for calculating the dietary intakes of essential metals and evaluation of human exposure to toxic elements [4]. This problem is receiving more and more attention globally and developing countries in particular.

In human health, toxic metals have been reported to affect cellular organelles and components such as cell membrane, mitochondrial and some enzymes involved in metabolism, detoxification, and damage repair [5,6]. Several studies from the laboratory have demonstrated that reactive oxygen species (ROS) production and oxidative stress play important roles in the toxicity and carcinogenicity of metals such as As, Cd, Cr, Pb and Hg [7]. Due to their high degree of toxicity, these elements are included in significant metals of great importance to public health. These metals are all systemic toxicants which are known to induce multiple organ damage, even at low levels of exposure; each of them is known to have unique features and physicochemical properties that confer on it specific toxicological mechanisms of action [7]. Therefore it is important to monitor the level of such pollutants in the environments especially the foods and drinks consumed in the rural areas of developing countries such as Nigeria [8].

Beverages consumed in Nigeria are either produced locally or imported. Some local beverages widely consumed in Nigeria include Palm wine (also known as 'Tumbo'), a whitish sap collected in vessels attached to the base of the tree from where some leaves have been removed. Fresh wine from these sources is sweet and contains little alcohol but, with fermentation, the alcohol content increases with time [9]. Generally, palm wine, which has an alcohol content of 3-6%, is also widely consumed in the southern part of Nigeria [10]. 'Ogogoro' (also known as kaikai) is a drink distilled locally from fermented Raphia palm tree (*Raphia hookeri* or *vinifera*) juice. In Nigeria, distillation of ogogoro takes place in small sheds dotted along the coastal areas and in villages across the South. The end product is a clear liquid with alcohol content often higher than 40% [11].

'Mokite' is a new Marijuana-infused beer and the legend of the monkey tail. The beverage is made to taste like normal beer but actually has zero alcohol. It is made instead with tetrahydocannabinol (THC), the main psychoactive ingredient in marijuana. 'Agbo' (a Yoruba name for herbal medicines), is a concoction prepared from a variety of herbs. It is one of the most popular herbal preparations taken for various ailments, especially by the natives.

'Zobo' is a Nigerian drink obtained from dried red calyces and sepals of the Roselle plant (*Hibiscus sabdariffa*) known as Zobo leaves in Nigeria. Zobo is usually served as a chilled refreshing drink but can also be enjoyed as a relaxing hot tea and leaves used in production of jam/jelly, food colouring, syrups and soup/sauces. According to several scientific investigations, whether as tea, jams or sauces, this drink helps to reduce high blood pressure, aid digestion, promote the health of the urinary tract and the overall health [8]. 'Kunu' is a popular drink consumed throughout Nigeria, mostly in the Northern part of Nigeria. It is usually made from grains such as millet or sorghum, although it can also be made from maize. A variety of the drinks made from sorghum have a milky light-brown colour, while Kunu made from millet and maize is whitish in colour [12].

The massive consumption of these beverages could be due to the poor economic situation of the country, traditional practices and nutritive as well as their medicinal values. This study was aimed at assessing the toxic metal profiles, carcinogenic and non-carcinogenic human health risk of some locally produced beverages in Nigeria.

Materials and Methods

Study area

The study area (Yenagoa), is the State Capital Territory of Bayelsa State. It is a wet land located on the southernmost part of Nigeria. It has a deltaic landmass, and characterized by shallow aquifer with several networks of creek and creeklets. Residents of this homogenous Ijaw city are lovers of commerce. Every day, including Sunday, is a market day in some communities in the metropolis. It has a well-organized and mapped out market called Swali market and other smaller community markets.

Sample collection

Seven (7) samples of locally prepared beverages namely: Mokite, Palmwine, Agbo, Ogogoro, Kunu, Pigweed and Zobo were randomly purchased at Swali, Tombia and Kpansia markets in Yenagoa, Bayelsa State, Nigeria. All the samples were collected in clean plastic bottles and were taken to the Niger Delta University Central Research Equipment Laboratory, Wilberforce Island, Bayelsa State and were kept in deep freezer prior to analysis.

Samples preparation and procedure

Wet digestion method was used in the preparation of the drinks for heavy metal analysis. 5 ml of analytical unit (sample) was weighed into digestive tube and 20 ml of digestion acid at ratio 1:3:1:1: (HNO_3 + H_2SO_4 + HCl + $HClO_4$) was added. This was latter digested using FOSS TECATOR Digester Model 210 at 250 °C for 1 hour at the first instance and continued until a clear solution was obtained in a fume cupboard. The clear solution was filtered into a 100 ml volumetric flask and completed to the mark with de-ionised water.

Determination of toxic metals

All digested samples were analyzed in triplicate using Atomic Absorption Spectrophotometer (Buck 210). Standard for each element under investigation was prepared in mgl/100 g and the limit standard concentration for each element was adhered to according to the BUCK Scientific instruction and the results obtained were compared with World Health Organization standards for the metal limits for human consumption.

Quality assurance protocol and statistical analysis

Appropriate quality assurance procedure and precautions were carried out to ensure reliability of the results. Samples were carefully handled to avoid contamination. Glassware and sample containers were soaked in 1 mol/L HNO_3 for 48 h and rinsed with ultrapure water and the reagents were of analytical grade. Precision and accuracy of the analytical procedure was also investigated by carrying out recovery experiments. Accuracy of the digestion procedures was verified by examination of the recovery data, spiking analyzed samples with aliquots of metal standards and then reanalyzing the samples. The percentage recovery was greater than 95% with the percent relative standard deviations less than eleven, indicating good accuracy and precision. The results were expressed as mean ± standard (SD) using SPSS Statistic 17.0.

Human health risk assessment

To assess the human health risks associated with the ingestion of toxic metals from the beverages, the Estimated Daily Intake (EDI) of toxic metals, Target Hazard Quotient (THQ), Hazard Index (HI) and Carcinogenic Risk (CR) were calculated using equation 1.

Estimated Daily Intake (EDI)

$$EDI = \frac{CMetal\ x\ DFood\ Intake}{BWaverage} \quad (1)$$

Where:

Cmetal is the metal concentration in the beverages in mg/kg,

Dfood intake is the daily intake of food in kg person^{-1} and

BWaverage is average body weight in kg person^{-1}

An average daily intake of beverages of 3.6 L/kg was used in this study. This value was adopted based on the WHO GENACIS Study on regional survey of adult daily consumption of drinks. An average adult body weight was considered to be 60 kg in this study [13].

Non-carcinogenic health effect

Target hazard quotient (THQ): Non-carcinogenic risk estimation of toxic metals consumption was determined using THQ values. THQ is a ratio of the determined dose of a toxicant to a reference dose considered harmful. If the ratio is equal to or greater than 1, an exposed population is at risk. THQ values were calculated using equation 2 [14].

$$THQ = \frac{Efr\ x\ ED\ x\ FIR\ x\ C}{RfDo\ x\ BWaverage\ x\ ATn}\ x\ 10^{-3} \quad (2)$$

Where:

Efr is exposure frequency in 190 days year^{-1},

ED is exposure duration in 56 years equivalent to an average lifetime,

FIR is average daily Intake in Kg/person/day,

C is concentration of metal in food sample in mg/kg

Rf Do is reference dose in mg/Kg day^{-1} and

ATn is average exposure time for non-carcinogens in days (190 × 56).

The following reference doses were used (Cu = 0.040 mg/kg, Ni = 0.020 mg/kg, Cr = 0.5 mg/kg, Mn = 0.014 mg/kg, Zn = 0.300 mg/kg and Fe = 0.700 mg/kg) [15,16].

Calculation of hazard index: Hazard index is used to evaluate the potential risk to human health when more than one toxic metal is involved. Hazard index was calculated as the sum of target hazard quotients (THQs) [17]. Since different pollutants can cause similar adverse health effects, it is often appropriate to combine THQs associated with different substances [18] as seen in equation 3.

$$HI = \sum THQ\left(THQ1 + THQ2 + THQ3.....THQn\right) \quad (3)$$

Carcinogenic health effect

Incremental lifetime cancer risk is the lifetime probability of an individual developing any type of cancer due to carcinogenic daily exposure to a contaminant over a life time. The ILCR is obtained using the Cancer Slope Factor (CSF) which evaluates the probability of an individual developing cancer from oral exposure to contaminant levels over a period of a lifetime as described by ATSDR in 2010 and it is contaminant specific [19]. Ingestion cancer slope factors are expressed in units of (mg/kg/day). The cancer risk was calculated using the equation 4:

$$Carcinogenic\ Risk\ = EDI\ x\ CSFing \quad (4)$$

Where:

EDI is the estimated daily intake of each heavy metal (mg/kg/day)

CSFing is ingestion cancer slope factor (mg/kg/day)$^{-1}$

USEPA, [16] states that 10^{-6} (1 in 1,000,000) to 10^{-4} (1 in 10,000) represent a range of permissible predicted lifetime risks for carcinogens. Chemical for which the risk factor falls below 10^{-6} may be eliminated from further consideration as a chemical of concern.

Table 1: Toxic Metal Profiles of Some Locally Produced Beverages in Nigeria.

Sample Code	Toxic metals (mg/kg)					
	Cr	Cu	Zn	Ni	Mn	Fe
Mokite	0.35 ± 0.001	0.66 ± 0.001	0.08 ± 0.001	0.033 ± 0.001	0.156 ± 0.001	1.83 ± 0.001
Palm wine	0.075 ± 0.001	0.14 ± 0.002	0.059 ± 0.001	0.097 ± 0.001	0.092 ± 0.001	0.953 ± 0.001
Agbo	0.019 ± 0.001	BDL	0.12 ± 0.001	BDL	1.055 ± 0.002	1.26 ± 0.001
Ogogoro	0.014 ± 0.001	0.006 ± 0.001	0.055 ± 0.001	BDL	0.059 ± 0.001	1.115 ± 0.001
Kunu	0.66 ± 0.001	0.055 ± 0.001	0.19 ± 0.001	0.16 ± 0.001	0.278 ± 0.001	2.89 ± 0.001
Pigweed	0.141 ± 0.002	BDL	0.04 ± 0.001	0.076 ± 0.001	0.109 ± 0.001	1.21 ± 0.001
Zobo	0.057 ± 0.002	BDL	0.122 ± 0.001	0.138 ± 0.001	1.03 ± 0.001	1.31 ± 0.001
WHO	0.05	2.0	3.00	0.02	0.10	0.3

Note: Data are mean ± SD of triplicate determination

BDL: Below Detectable Limit; WHO: World Health Organization

Table 2: Estimated Daily Intake (EDI) of toxic metals (mg/kg) for adult (60 kg) from consumption of some Nigerian locally produced beverages.

Samples	Toxic metals					
	Cr	Cu	Zn	Ni	Mn	Fe
Mokite	0.021	0.040	0.005	0.002	0.009	0.110
Palmwine	0.005	0.008	0.004	0.006	0.006	0.057
Agbo	0.001		0.007		0.063	0.076
Ogogoro	8.4 E-4	3.6 E-4	0.003		0.004	0.067
Kunu	0.040	0.003	0.011	0.010	0.017	0.173
Pigweed	0.008		0.002	0.005	0.007	0.072
Zobo	0.003		0.007	0.008	0.062	0.078

Table 3: Target hazard quotient (THQ) and Hazard index (HI) for adult exposed to some locally produced beverages contaminated with toxic metals.

Samples	Toxic metals (mg/kg)						
	Cr	Cu	Zn	Ni	Mn	Fe	HI
Mokite	4.2 E-5	0.010	0.017	9.9 E-5	3.94 E-4	8.17 E-5	0.0276
Palmwine	9 E-6	2.1 E-4	1.18 E-5	2.91 E-4	3.94 E-4	8.17 E-5	0.00099
Agbo	2.28 E-6		2.4 E-5		0.0045	1.08 E-4	0.00463
Ogogoro	1.68 E-6	9 E-6	1.1 E-5		2.53 E-4	9.56 E-5	0.00037
Kunu	7.92 E-5	8.4 E-5	3.8 E-5	4.8 E-4	0.0012	2.47 E-4	0.00209
Pigweed	1.69 E-5		8 E-6	2.28 E-4	4.67 E-4	1.03 E-4	0.00082
Zobo	6.84 E-6		2.44 E-5	4.14 E-4	0.0044	1.12 E-4	0.00496

Results

Toxic metal profiles

Toxic metal profiles in the beverage samples are shown in Table 1. The highest mean value of Cr was Kunu (0.66 ± 0.001 mg/kg) and lowest was Ogogoro (0.014 ± 0.001 mg/kg). Highest copper mean value was 0.66 ± 0.001 mg/kg (Mokite) while Agbo, Pigweed and Zobo were below detectable limits. Kunu recorded highest Zn levels (0.19 ± 0.001 mg/kg) while Pigweed recorded lowest levels (0.04 ± 0.001 mg/kg). Highest value of Nickel was 0.16 ± 0.001 mg/kg recorded for Kunu while it was not detected in Agbo and Ogogoro. For Mn, 1.055 ± 0.002 mg/kg was recorded for Agbo and 1.03 ± 0.001 mg/kg for Zobo was the highest whereas 0.059 ± 0.001 mg/kg observed for Ogogoro was the lowest. Highest Fe contents was observed for Kunu (2.89 ± 0.001 mg/kg) and Mokite (1.83 ± 0.001 mg/kg) while Palm wine was lowest (0.953 ± 0.001 mg/kg).

Health risks to consumers from toxic metal consumption of locally produced beverages

The EDI values of heavy metals from the beverage samples were below the permissible tolerable daily intake limits as shown in Table 2. Target hazard quotient (THQ) and hazard index (HI) values were less than 1 (Table 3). The carcinogenic risk (CR) values of Fe, Zn and Cr in all the beverage samples were greater than 1×10^{-4} while for Mokite, palm wine and Kunu, Cu values were greater than $1 \times 10^{-4.}$ For Mokite, Agbo, Kunu and Zobo

Table 4: Carcinogenic Risk for adult exposed to toxic metals in some locally produced beverages in Nigeria.

Samples	Toxic metals (mg/kg)					
	Cr	Cu	Zn	Ni	Mn	Fe
Mokite	0.011	0.002	0.002	3.96 E-5	1.31 E-4	0.077
Palm wine	0.0023	3.4 E-4	0.0012	1.16 E-4	7.73 E-5	0.040
Agbo	5.7 E-4		0.0022		8.86 E-4	0.053
Ogogoro	4.2 E-4	1.44 E-5	9.9 E-4		4.96 E-5	0.0468
Kunu	0.0198	1.3 E-4	0.0034	1.92 E-4	2.34 E-4	0.1212
Pigweed	0.0042		7.2 E-4	9.12 E-6	9.16 E-5	0.0510
Zobo	0.0017		0.0022	1.66 E-4	8.65 E-4	0.0548

Mn values were greater than 1×10^{-4} For Palm wine, Kunu and Zobo, Ni values were greater as shown in Table 4.

Discussion

Toxic metal profiles

The intake of foods contaminated with chemicals may result to intoxication which can be described as acute or when the disease appears after a latent period of time and long term or chronic intoxications. Ingestion of contaminated food is the main source of human exposure to toxic compounds accounting for more than 90% compared to other routes. The present study has highlighted the toxic metal profiles, carcinogenic and non-carcinogenic effects of locally produced beverages in Nigeria.

Chromium toxicity is very dependent on the species and oxidation states present. It is normally found in the considerably less toxic trivalent state in foods and is poorly absorbed in the gastrointestinal tract, the hexavalent form is carcinogenic [20]. Chromium concentrations in the samples (Mokite, Kunu, Pigweed and Zobo) under study were above 0.05 mg/kg value as recommended by World Health Organization. Among all the samples analyzed for Cr, palm wine and Ogogoro were below the WHO permissible limit. The findings are in agreement with the reports of reference [8].

The physiologic roles of Cu include amine oxidases, caeruloplasmin, dopamine hydrolase, and collagen synthesis [21]. Copper was below detectable limit in Agbo, Pigweed and Zobo but the mean concentration of Cu in Kunu, Mokite, Palm wine and Ogogoro were below WHO recommended range of 2.0 mg/kg for local beverages without adverse effect. This result is in agreement with the findings of reference [22].

Zinc is an essential component of several enzymes participating in the synthesis and degradation of carbohydrates, lipids, proteins and nucleic acid as well as in the metabolism of other nutrients. Furthermore, zinc has an essential role in polynucleotide transcription and thus in the process of genetic expression. Its involvement in such fundamental activities probably accounts for all life forms [23]. Nevertheless, low levels or excess of zinc in the body are associated with the incidence of development of prostate enlargement and human cancer [24]. The mean concentration of Zn was found to be below the WHO limit for local drinks standard of 3.00 mg/kg in all the locally produced beverage samples in this study. The result is in concordance with the works of reference [8].

The major use of Nickel is in the preparation of alloys because of its strength, ductility and resistance to corrosion and heat. Nickel can accumulate in the kidneys, bones, and thyroid glands and cause toxicity. In small quantities nickel is essential, but when uptake is too high it can be a danger to human health. An uptake of two large quantities of nickel causes lung embolism, lung cancer, sickness and dizziness after exposure to nickel gas, asthma and chronic bronchitis, heart disorders, and allergic reactions [25]. Nickel allergy can also cause systematic reactions. Nickel concentrations was not detected in Agbo and Ogogoro drinks while the Ni concentrations in Mokite, Kunu, Zobo, Pigweed and Palm wine beverages were above WHO permissible limit of 0.02 mg/kg. These findings were accord with references [8,22].

Manganese serves as an active constituent of several enzymes including antioxidants such as mitochondrial superoxide dismutase among others. The concentrations of Mn in these alcoholic beverages varied from 0.092 to 1.055 mg/kg. Higher concentration range of Mn was recorded in the Agbo and Zobo samples which varied over very small range as compared with other local beverages studied. The WHO permissible limit for Mn is 0.10 mg/kg and the concentrations of beverage samples were higher than the permissible level of Mn in drinks except for Ogogoro and palm wine samples. These results are in concordance with the findings of references [8,22,26].

Iron is a component of haemoglobin, the oxygen carrying component of the blood; it is also a component of myoglobin, which helps muscle cells store oxygen. Without iron, ATP cannot be properly synthesized. Although iron is a component of the antioxidant enzyme, catalase, it is not generally considered an antioxidant because too much iron causes oxidative damage [27]. Drinkers of native beers are at risk of iron accumulation although that would be dependent on absorption of iron from the gastrointestinal tract, gastric emptying, and level of fibre in both the native beers drank and the foods consumed (bioavailability). Excess intracellular iron results in formation and deposition of haemosiderin which can lead to cellular dysfunction and damage [28]. Iron solubility gradually increases during beer making process of germination and fermentation [29]. Iron toxicity can be classified as corrosive or cellular. Ingested iron can have an extremely corrosive effect on the gastrointestinal (GI) mucosa which can manifest as nausea, vomiting, abdominal pain, hematemesis, and diarrhea; patients maybecome hypovolemic because of significant fluid and blood loss. Haemochromatosis, a disorder of iron metabolism is characterized by excessive iron absorption, saturation of iron-binding proteins and deposition of haemosiderin in the tissues is of the numerous problems associated with iron metabolism; the primary tissues affected are liver, skin and pancreas. Iron deposition in liver leads to cirrhosis, incapacitating liver's numerous biochemical functions, and in the pancreas causes diabetes [30].

The concentrations of Fe in the present study was above the WHO recommended limit of 0.3 mg/kg in drinks. The high metal content of Fe in Kunu, Mokite and Zobo could be from cooking utensil where high temperature was applied during the production process. This is not acceptable to the consumers, as it could give rise to iron dependent bacteria which in turn cause further deterioration in the quality of local drinks by prohibition of slimes, or objectionable colour [31]. The metallic impurities detected may be traced to the raw materials, water used in the production, equipment, ingredients added, and containers, packaging materials and environmental pollutants during the preparation process. The findings are in agreement with [26,32].

Human health risk assessment

Today, risk assessment is one of the best approaches for investigating the potential risks of heavy metal exposure on human health, offering important information to public health decision makers for protecting consumer health [33]. Therefore, the potential health risks associated with heavy metal exposure to locally produced beverages in Nigeria was assessed using the data obtained in this study.

Non-carcinogenic effects

Human health risk assessment comprises the determination of the nature and magnitude of adverse health effects in humans who may be exposed to toxic substances in a contaminated environment. In the present work, exposure and risk assessments were carried out based on the USEPA methodology. Human exposure to toxic metals principally occurs via pathways of drinking water, food, inhaled aerosol particles and dust. The degree of toxicity of heavy metals to human health is directly related to their daily intake. However, ingestion via drinks was considered in this study. The first step in the non-carcinogenic effects is the calculation of estimated daily intake of metals values.

Estimated daily intake (EDI) of metals is used to calculate the amount of metal taken by an adult or children per day. From the results in this study, the concentrations of Cr, Cu, Zn, Ni, Mn and Fe in the beverage samples were all below the permissible tolerable daily intake (PTDI) limit as recommended by EFSA (European Food and Safety Agency) thereby attracting no health risk (see Table 2).

Target hazard quotient (THQ) and Hazard index (HI): The THQ value is a dimensionless index of risk associated with long term exposure to chemicals. From the results obtained in the present study, the concentrations of Cr, Cu, Zn, Ni, Mn and Fe of the locally produced beverage samples were all less than 1 which indicates no obvious individual non-carcinogenic effects. Meanwhile, Hazard Index (HI) is the calculation which shows when a population is at risk. From the results in the present study, it was observed that the combined HI values for all the samples under study were less than (<) 1 which indicates that there are no potential health (non-carcinogenic) risk to those consuming these locally produced beverages in Nigeria as shown in Table 3.

Carcinogenic effects

EPA defined carcinogenic or cancer risks (CR) as "the incremental probability of an individual to develop cancer, over a lifetime, as a result of exposure to a potential carcinogen" [34]. A meta-analysis of studies published in 2009 found that consumption of only 2 standard drinks per day increased the cancer risk by 20% [35]. Heavy metals (Cr, Cu, Zn, Ni, Mn and Fe) can potentially enhance the risk of cancer in humans. Long term exposure to low amounts of toxic metals could, therefore, result in many types of cancers. The total exposure of these toxic metals was assessed based on the mean EDI values given in Table 2. The carcinogenic risk assessment for adults is given in Table 4. According to the USEPA, for one heavy metal, an incremental lifetime cancer risk (ILCR) of 1×10^{-6} to 1×10^{-4} was considered as acceptable or inconsequential risk and the cancer risk can be neglected; while an ILCR above 1×10^{-4} was considered as harmful and the cancer risk as troublesome [36]. Among all the studied locally produced beverage samples, Kunu was observed to have the highest toxic metal CR value higher than the mean ILCR value (1×10^{-4}) and lowest was Ogogoro. The metal CR values of the samples were in this order Kunu > Mokite > Zobo > Palm wine > Pigweed > Agbo > Ogogoro. Based on the results obtained, all the locally produced beverage samples in Nigeria has the potential carcinogenic risk, because most of the toxic metals CR values were greater than 1×10^{-4} (see Table 4). The results suggest that there is a significant cancer risk to people who consume these beverages in Nigeria.

Conclusion

The results from the present study showed that the Cr, Ni and Mn concentrations of the locally produced beverage samples were above WHO permissible limits. For Fe, all the beverage samples were above WHO tolerable limits (0.3 mg/kg) while Cu and Zn were below the permissible limits. The non-carcinogenic risk assessments indicate that the Estimated Daily Intake of metal concentrations in the beverage samples were all below the permissible tolerable daily intake limits as recommended by EFSA. The Target hazard quotient and Hazard index values for all samples were less than 1 which indicates that there are no potential non-carcinogenic risks to those consuming the beverages. For carcinogenic risk assessment, all the beverage samples understudied were observed to have toxic metal CR values greater than the mean incremental lifetime cancer risk of 1×10^{-4} which indicates that there is a significant cancer risk to people who consume these locally produced beverages in Nigeria. Therefore, regulatory agencies such as the Standards Organization of Nigeria (SON) and National Agency for Food and Drug Administration and Control (NAFDAC), as a matter of public health emergency, monitor and regulate the quality of products produced and sold to consumers.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author Contributions

Odangowei I Ogidi: Conceptualization, methodology, project administration, supervision and formal analysis.

Uchechi E Enenebeaku: Visualization, writing-review and editing and validation.

Ebifanimi Okara: Writing- original draft, data curation and investigation.

Stephanie A Elumelu: Funding acquisition, resources and investigation.

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