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CHARACTERIZATION AND HEALTH RISK ASSESSMENT OF CONSUMED HERBAL AND ENERGY DRINKS IN SOME SOUTH-WEST STATES, NIGERIA.

Temitope, M. Osobamiro[1]*, Mayowa, S. Adebisi[1] and Peter K. Mensah[1]
[1]Department of Chemical Science, Faculty of Science, Olabisi Onabanjo University, Ogun State, Nigeria

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ABSTRACT

This study determines the physicochemical properties and concentrations of heavy metals in eighteen energy drinks (ED) and twelve herbal mixtures (HM) purchased from two markets in South-West, Nigeria. Physiochemical properties and metal contents were determined using standard methods and Inductive Coupled Plasma-Optical Emission Spectrophotometer (ICP-OES) respectively. The health risk was estimated by calculating the Hazard Quotient (HQ), Hazard Index (HI) and Carcinogenic Risk (CR). The result of physiochemical properties are as follows: pH ≤ (5.53, 6.09), TDS ≤ (95.2, 846) and EC ≤ (194, 787). The concentrations of As and heavy metals (mg/L) in ED and HM were ≤; As (0.006, 0.001), Cd (0.008, 0.007), Co (0.007, 0.004), Cr (0.008, 0.052), Cu (0.061, 0.007), Fe (15.0, 7.28), Mn (2.03, 2.29), Ni (0.010, 0.004), Pb (0.016, 0.005) and Zn (8.86, 4.02). Levels in ED were higher than HM except for Cr and Mn and all were within the permissible levels except Co, Fe, Mn and Zn in some ED and HM samples. The HQ and total HQ for all the metals in ED and HM are less than 1.00 except Mn and Zn while, total HI was 5.21. Carcinogenic risk of Cd and Pb in most of the HM were above the acceptable limit so, long term consumption should be discouraged.

Keywords: Arsenic, Energy drink, Health risk, Heavy Metals, Herbal mixture

INTRODUCTION

Energy drinks are commonly consumed indiscriminately for different purposes including; increase energy level, improve physical performance, endurance and serve as a mood elevator when mixed with alcohol (Bedi et. al. 2014). Nowadays, energy drinks spiked with herbs have gain popularity; added herbs are purported to enhance their medicinal properties in serving as preventive measures against some diseases (Falodun 2010, Okareh et. al. 2018). Herbs rich in alkaloids, tannins, saponins, flavonoids, resins, and triterpenoids which have been used for the treatment and prevention of several ailments such as cough, diarrhea, fever, sexually transmitted diseases, sexual impotency, hypertension, cancer, and diabetes are now been added to energy drinks (Edeoga et. al. 2005, Dghaim et. al. 2015, Meseret et. al. 2020)

However, the safety and quality of these drinks is now a major concern to health practitioners, pharmaceutical industries, regulatory bodies and the general public (Okareh et. al. 2018; Meseret et. al. 2020). Toxic substances including heavy metals contaminants above the recommended levels have been found in most energy and herbal drinks (Szymczycha-Madeja et. al. 2013, Meseret et. al. 2020). Higher levels of nickel, arsenic, mercury, lead, and cadmium have been reported in some alcoholic and non-alcoholic drinks consumed in Nigeria (Salako et. al. 2016, Izah et. al. 2017, Thompson et. al. 2019, Luo et. al. 2021). The exposure to high levels of some of the heavy metals found in these drinks has been documented to be carcinogenic, lung damage, hypercholesterolemia, increased low density lipoproteins and even death (Balali-Mood et. al. 2021, Luo et. al. 2021).

Physicochemical properties of energy drinks can serve as indicator of their toxicity and overall quality (Tchounwou et. al. 2012, Cretescu et. al. 2016). The consumption of energy drinks of low pH has been linked with tooth decay by wearing off the enamel which serves as protective sheath after long term consumption (Gimba et. al. 2014, Cretescu et. al. 2016). The additive effects of energy drinks combined with herbal extracts both of which have been reported as sources of heavy metals need to be investigated. Also, prevalence of diagnosis of cancerous diseases nowadays necessitates the assessment of the health risk associated with the long term consumption of these drinks. Therefore, this study assessed the health risk associated with the consumption of ED flavoured with herbs in term of heavy metals content, these involves determination of physiochemical properties (TDS, pH, Conductivity), concentrations of and heavy metals in commonly consumed herbal and energy drinks and assessment of the health risk associated with their consumption.

MATERIALS AND METHODS

Sample Collection

A total of six liquid samples of commonly consumed energy drinks flavored with herbal extracts (A, B, C, F, G, H) and four liquid local herbal mixtures (D, E, I, J) in triplicates were randomly purchased from drink vendors and local herb hawkers in two popular cities (Lagos and Ibadan) in selected South-west States in Nigeria. The energy drinks were sold in plastic bottles while the herbal drink samples were collected in labeled pretreated glass bottles. The collected samples were stored in ice-bag and transported immediately to the laboratory for analysis. The description of the physical appearance, content, use, and alcoholic percentage of the collected samples as indicated on the label is presented in Table 1.

Table 1: Description of the collected samples of energy and herbal drinks

Sample	Colour /Type	Content	Uses	Alcohol (%)
A & F	Black (ED)	Treated water, Ethanol, Sativum, *Zinigiber, officinaills* Eugenia	It lowers blood pressure and heart attack risk	25
B & G	Black (ED)	Water, Ethyl alcohol, caramel, sugar, herb and fruit extract of myrrh, cinnamon and orange	It improves protein digestion and mineral absorption	20
C & H	Black (ED)	Water, Ethanol, Caramel, Herbal Flavour Extracts, Senna leaf.	Sexual enhancement	42
D & I	Black (HM)	Bale, honey and water	Sexual enhancement	Non-alcoholic
E & J	Brown (HM)	Local herbs(oganwo), water	Use to regulate sugar content in the body	Non-alcoholic

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Physicochemical Analysis

Physicochemical characteristics (pH, Total Dissolved Solid (TDS) and electrical conductivity (EC) of the collected samples were determined using official methods of analysis of the Association of Official Analytical Chemists (AOAC 2004). pH and electrical conductivity (EC) of each sample was determined using the pH meter Consort C3010 after standardization with buffer solutions of pH 4 and 7 at 25^{0} C.

Heavy Metal Determination

Acid Digestion

Each sample bottle of energy drink was left open under a laminar hood for 2 hours to release CO_2 gas before taking the test sample for analysis. 10 mL of each of the energy and herbal drink samples was measured into clean 50ml Pyrex conical flask and digested with 10ml conc. HNO_3 at a temperature of 105°C for about 45 minutes giving a clear solution, filtered and made up to 25ml volumetric flask with deionized water.

Instrumentation and Quality Control

The concentrations of As and heavy metals in the digested drinks were determined using Inductive Coupled Plasma- ICP-OES adopting the method reported by Martins *et al.,* (2019). Agilent 710-ES with megapixel CCD detector (Agilent Technologies, USA) was used for simultaneous metal quantification while the Agilent SPS3 auto sampler was used for sample introduction. Agilent Expert II Software was used to regulate the instrument and acquire data. Appropriate calibration standard solutions were prepared from Accustandard QCSTD-27 multi-element (1000 µg mL^{-1}) ICP standard (Merck), ultrapure Merck Lichrosolv water was used for standard dilution and these were also stabilized in high purity 2% v/v concentrated nitric acid (HNO_3).The instrument operating parameters were as follows: 1.0 kW RF power, 15 L min^{-1} plasma flow rate, 1.5 L min−1 auxiliary gas flow rate, 30 s sample flush time, 3.0 mL min^{-1} sample uptake rate, 15 rpm normal pump speed, 30 s replicate reading time, 30 s instrument stabilization delay, and three replicates (n = 3). Metallic content in the blanks were also determined using ICP-OES to ascertain that the rinse solution and the reagents were free from metal contamination.

Health Risk Assessment of Heavy Metals

The non-carcinogenic and carcinogenic risk of the long-term consumption of the energy and herbal drinks by adult was estimated by calculating Hazard Quotient (HQ), Hazard Index (HI) and carcinogenic risk (CR) respectively. This was computed based on the EPA guidelines for health risk assessment and it depends on the mean daily dietary intake of the drink (Adusei-Mensah et. al. 2019). HQ was calculated using equation 1.

$$HQ = \frac{Cx\ IR\ x\ EF\ x\ ED}{AT\ x\ BW\ x\ RfD}$$ ----------Equation 1

C is metal concentration in the sampled drinks, IR is Ingestion Rate (0.5 L/day), EF (Exposure Frequency (365 days/year), ED is Exposure Duration (70 years), AT is Average Time 25550 days), BW is Average Body Weight (70 kg), RfD is Oral Reference Dose is the estimated daily tolerable exposure of a person without any significant health risk throughout a lifetime. RfD for As: 0.03, Cd: 0.1, Co: 0.03, Cr: 0.003, Cu: 0.0371, Fe: 0.7, Mn: 0.024, Ni: 0.02, Pb: 0.0014 and Zn: 0.3 mg/kg/d (Masok et. al. 2017). HQ<1means no potential health risk is expected from exposure, while HQ> 1 means there is potential health risks (Meseret et. al. 2020).

Hazard Index (HI)

This is the evaluation of the additive non-carcinogenic risk of human exposure to the mixture of heavy metals in drinks. So, HI is the sum of the HQ of all the heavy metals as described in equation 2 (Mohammadi et. al. 2019, Meseret et. al. 2020, and Luo et. al. 2021).

HI = Σ HQAs + HQCd + HQCo + HQCr+ HQCu + HQFe + HQMn + HQNi + HQPb + HQZn ---Equation. 2

Carcinogenic Risk (CR) of Intake of the Sampled Energy and Herbal Drinks

Environmental Protection Agency (EPA) defined carcinogenic or cancer risk (CR) as “the incremental probability of an individual to develop cancer, over a lifetime, as a result of exposure to a potential carcinogen” (EPA, 2016). The CR of Pb, Cr, Cd and Ni which have been found to be carcinogenic were calculated using equation 3.

$$CR = \frac{Cx\ IR\ x\ EF\ x\ ED\ x\ CSF}{AT\ x\ BW}$$ ----------Equation 3

The Cancer Slope Factor (CSF) is defined as the risk generated by a lifetime average amount of one mg/kg/day of carcinogen chemical and this is contaminant specific (Tepanosyan et. al. 2017). CSF for Pb, Cr, Cd and Ni is 8.5, 41, 6.1, and 0.84 respectively.

Statistical Analysis of Data

Descriptive statistic and Pearson correlation were used for the statistical analysis of the obtained result. All analyses were performed using IBM SPSS Statistics version 23 (StatSoft, Inc., Tulsa, OK, USA). The significance level obtained for the statistical analysis of data was $p < 0.05$.

RESULTS AND DISCUSSION

Physicochemical Properties

The result of the physicochemical properties of the sampled energy drinks (pH, conductivity and total dissolved solids) is presented in table 2. The pH of all the sampled energy and herbal drinks are below the recommended permissible level set by WHO except for sample A and J. All the sampled drinks are generally acidic similar to literature report for pH of energy and herbal drinks by Cretescu et. al. (2016), Adepoju and Ojo, (2014) and Oyekunle et. al. (2019). ED samples have lower pH compared to HD samples and sample H for ED and D for HD have d lowest pH values, being the most acidic.

Table 2: Physicochemical Properties of the studied drinks

	SAMPLE	pH	TDS (mg/L)	Conductivity (µS)
Energy Drinks	A	5.53	34.6	69.0
	B	4.55	95.2	194
	C	4.86	60.4	124
	F	4.89	36.1	73.6
	G	5.09	89.6	183
	H	3.42	52.8	108
Mean± S.D		4.72±0.72	61.5±25.9	125±53.2
	D	4.13	300	614
	E	4.81	339	693
Herbal Drink	I	4.27	387	787
	J	6.09	846	721
Mean± S.D		4.83±0.89	468±254.	704±72.0
WHO, 2004		5.50 - 8.50	500	200 – 2000

S.D= Standard Deviation

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The optimal ideal pH for the saliva in oral cavity is 6.5 to 7.5. Consumption of low pH drinks have been linked with demineralization of tooth enamel causing dental decay. The result of this study is higher than the pH of energy drink samples reported by Cretescu et. al. (2016) and Adepoju and Ojo, (2014) and soft drinks results reported by Oyekunle et. al. (2019). Though low pH will not permit the growth of micro-organisms in ED, caution needs to be taken in the regular consumption of large quantity of these drinks.

The TDS and conductivity of herbal drinks are significantly higher than those of energy drinks. This is an indication that herbal drinks are richer in mineral or inorganic content. The TDS and conductivity of all the samples are within the permissible range with samples J and I (HD) having the highest values for both parameters respectively. Conductivity depends on the number of mobile ions or electrolytes in energy drink. Conductivity of HD samples is higher than ED so, they are richer in inorganic substances and will replenish lost electrolytes compare to ED samples. The palatability of drink is related to the level of its TDS, the palatability of all the drinks falls within the good range according to W.H.O rating (W.H.O. 2004) except sample J which is fairly poor (Ansari et. al. 2021). Result of this study is similar to the result of Gimba et. al. (2014).

Result of Heavy Metals Analysis

Arsenic and heavy metals were detected in almost all the ED and HD samples with Fe having the highest value followed by Zn as presented in Table 3 (A and B). Fe, Mn, Zn and Cd recorded levels in some of the samples of ED and HD were above the WHO permissible limit.

Table 3A: Concentration of metals in the sampled energy drinks (µg/100ml)

Element	A	B	C	F	G	H	WHO STD
As	0.564±0.01	0.320±0.001	BDL	0.211±0.001	0.402±0.0111	BDL	1.00
Cd	BDL	0.420±0.020	0.023±0.001	BDL	BDL	0.765±0.001	0.30
Co	0.23±0.01	0.393±0.003	0.212±0.001	0.678±0.001	0.0634±0.001	0.476±0.001	5.00
Cr	0.12±0.02	0.210±0.007	0.823±0.001	0.478±0.001	0.577±0.001	0.239±0.001	5.00
Cu	1.23±0.04	2.94±0.009	0.789±0.001	6.09±0.55	0.880±0.001	0.355±0.001	200
Fe	1260±2.45	403±5.60	590±6.75	1490±7.85	516±5.65	496±3.65	30.0
Mn	1.23±0.01	5.88±0.150	187±7.15	4.18±0.25	0.464±0.001	202±6.45	40.0
Ni	0.0493±0.002	0.330±0.001	BDL	0.979±0.001	0.229±0.001	BDL	2.00
Pb	BDL	0.220±0.001	BDL	BDL	1.56±0.02	BDL	1.00
Zn	575±3.55	143±8.55	382±5.55	886±5.75	461±4.85	505±6.50	300

BDL-Below Detection Limit

Table 3B: Concentration of metals present in the sampled herbal drinks (µg/100ml)

Element	D	E	I	J	WHO STD
As	0.0182±0.0010	0.0258±0.0010	0.0128±0.0010	0.122±0.0010	1.00
Cd	0.678±0.004	BDL	0.838±0.050	BDL	0.30
Co	0.433±0.005	0.540±0.015	BDL	0.246±0.024	5.00
Cr	4.49±0.04	0.586±0.010	5.19±0.22	0.204±0.001	5.00
Cu	0.272±0.003	0.677±0.025	0.477±0.031	0.384±0.003	200
Fe	491±13	728±15	387±18	648±16	30.0
Mn	0.880±0.025	229±16	0.455±0.07	138±09	40.0

Ni	0.0835±0.0030	0.444±0.021	BDL	0.195±0.004	2.00
Pb	0.151±0.003	0.153±0.002	0.465±0.023	0.392±0.002	1.00
Zn	402±11	117±14	373±15	148±11	300

BDL-Below Detection Limit

As were detected in all the ED and HD samples except samples C and H (ED) all fall below WHO permissible level. Higher levels of Arsenic above the recommended levels have been detected in beverages consumed in Nigeria by Salako et. al. (2016), 0.71 μg/100 ml by Adepoju and Ojo, (2014) and 0.76–6.73 μg L^{-1} by Kilic et. al. (2018). Acute arsenic poisoning can lead to the destruction of blood vessels, gastrointestinal tissue and can affect the heart and brain. Chronic arsenic toxicity which is termed arsenicosis usually focus on skin manifestations such as pigmentation and keratosis (Martin et. al. 2014).

Cd was only detected in samples B, C and H (ED) and D and I (HD), all were above WHO permissible limit (0.30 μg/100ml) except sample C. Though low levels of Cd have been reported in non-alcoholic beverages by Salako et. al. (2016), Meseret et. al. (2020), however, instances of cadmium exceeding maximum limits have been reported in herbal drinks (Iweala et. al. 2014, Kilic et. al. 2018). High doses of cadmium could lead to liver, kidney, and bone disease conditions (Izah, et. al. 2016, Muhammad et. al. 2014) gastro- intestinal irritation, and pulmonary effects (Tchounwou et. al. 2012), vomiting, lung damage, and even death (Garba et. al. 2015).

Co was detected in all ED and HD samples except sample I (HD) and all fall below the WHO recommended level. Higher levels of Co (0.12–0.23 mg/L) have been reported by Okareh et. al. (2018). High levels of Cr were detected in HD samples compare to ED and all falls below the permissible limit except sample E. Higher levels of Cr (5.35–10.7 mg/kg) was reported by Meseret (2020), 13.3–100.9 μg L^{-1} by Kilic et. al. (2018) and 60.89 μg/100ml by Adepoju and Ojo, (2014) in energy drinks.

Cu- was detected in both ED and HD samples; all were below the permissible limit. This is similar to the report of Ogunlana et. al. (2015), and Adegbola et. al. (2015) for some beverage drinks consumed in Nigeria. However, high levels of copper have been reported in herbal drinks by Iweala et. al. (2014), for herbal drink from Etiophia (Meseret et. al. 2020) and Kilic et. al. (2018).

Levels of Fe in all the ED and HD samples were above the permissible level. Concentrations of Fe above the set limits have been reported in alcoholic drinks in Nigeria (Ogunlana et. al. (2015), Salako et. al. (2016), 334.7-937.1 μg/L (Kilic et. al. 2018), 0.138-1.38 mg/L (Leśniewicz et. al. (2016) from Poland, 0.72-4.22 mg/L (Okareh et. al. 2018). Excessive intake of iron can cause health-related problems, including liver damage (Salako et. al. 2016), lung disease and siderosis (Izah et. al. 2016, Muhammad *et al.,* 2015) and colorectal cancer (Senesse et. al. 2004).

Mn- was detected in all the samples, with sample E (HD) and H (ED) having the highest concentration. Levels in samples C, H, E and J are above the maximum limit for Mn set by WHO. Higher concentrations of **Mn (**0.25 - 0.66 mg/L and 5.45–489.93 μg L^{-1}) above permissible limits have been reported in non-alcoholic canned drinks consumed in Nigeria by Oyekunle et. al. (2019) and Kilic et. al. (2018). Levels of Ni recorded in samples B, F, G (ED) and D, E and J (HD) were all below the permissible limit. However, high levels above the permissible limits have been reported in beverages consumed in Nigeria by

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Salako et. al. (2016), Iweala et. al. (2014) and Kilic et. al. (2018).

Lead was only detected in two ED samples (B and G) but was detected in all the HD samples. All were below the permissible limit except for samples G. This is similar to the result of Iweala et. al. (2014) and Adepoju and Ojo, (2014). Higher levels above the set limits have been reported in beverages, by Kilic et. al. (2018), Okareh et. al. (2018) and Meseret et. al. (2020) for herbal drink from Etiophia, in soft drinks samples from Nigeria by Oyekunle et. al. 2019.

Zn- was detected in all the samples in the range of 143-886 (ED) and 117-402 (HD). The concentration of Zn in all the ED samples are above the permissible limit except sample B but, only sample D contains concentration above the limit for HD samples. The concentration of **zinc** in beverages is usually within the reference range of 3 mg/L in drinking water as reported by Salako et. al. (2016), Iweala et. al. (2014). Zinc plays several functions in the human body, such as wound healing, blood clotting, proper thyroid function, maintenance of good vision (Salako et. al. 2016).

The difference between the mean concentrations of As and heavy metals in energy and herbal drinks was compared using independent T-test at $p<0.05$ and the result is presented in Table 4. The difference between the mean concentrations of As, Cd, Mn and Zn in energy and herbal drinks is not significant at $p< 0.05$ while that of Co, Cr, Cu, Fe, Ni and Pb is significant. The concentration of As, Cu and Fe in ED is significantly higher than HD while the concentration of Cr in HD is significantly higher than in ED at $p<0.05$. Though, the concentrations of As, Co, Ni, and Zn in ED are higher than levels in HD, though the difference is not statistically significant (Table 4). Heavy metal accumulation can predispose people to non-communicable diseases such as cardiovascular diseases and cancers of various types.

Table 4: Comparison of mean levels of As and heavy metals in sampled drinks

Metals	drinks	Mean	Sig.	
As	Energy_drink	0.250±0.225	0.039	SIG
	Herbal_drink	0.045±0.052		
Cd	Energy_drink	0.201±0.322	0.179	NS
	Herbal_drink	0.379±0.443		
Co	Energy_drink	0.342±0.220	0.913	NS
	Herbal_drink	0.305±0.237		
Cr	Energy_drink	0.408±0.267	0.000	SIG
	Herbal_drink	2.62±1.59		
Cu	Energy_drink	2.05±1.17	0.040	SIG
	Herbal_drink	0.452±0.172		
Fe	Energy_drink	793±113	0.023	SIG
	Herbal_drink	563±103		
Mn	Energy_drink	66.9±19.2	0.798	NS
	Herbal_drink	91.9±19.8		
Ni	Energy_drink	0.265±0.035	0.384	NS
	Herbal_drink	0.181±0.103		

Pb	Energy_drink	0.296±0.125	0.226	NS
	Herbal_drink	0.290±0.162		
Zn	Energy_drink	492±106	0.684	NS
	Herbal_drink	260±101		

Pearson Correlation Matrix

The degree of association between As and heavy metals in the sampled ED and HD was evaluated in order to predict whether they have similar source. This was done using Pearson linear correlation and the result is presented on Table 5and 6which contains the Pearson coefficient (r) value for ED and HD samples respectively.

There exist strong, positive and significant correlations between Cr and Cd, Ni and Co is positive, strong and significant at 0.01 and 0.05 levels respectively while, the correlation between Zn and Ni is negative, strong and significant at 0.05 level (Table 5). There is also positive and strong correlations though, not significant between Cu and As, Fe and As, Zn and Fe, Ni and Mn.

The correlation between Zn and Cu, Fe and Ni, Zn and Fe, Ni and Zn is positive, strong and significant at 0.05 level. The correlation between Fe and Cu, Ni and Cu is positive, strong and significant at 0.01 level for HD samples (Table 6). The correlation between Mn and As is negative, strong and significant at 0.05 level. Positive and strong correlations though, not significant exist between Pb and As, Mn and Cd, also between Co and Cu, Fe, Ni and Zn (Table 6). Strong and positive correlations between metals, especially for HD samples may indicate same origin, probably in the raw material (Froes et al. 2009, Oyekunle et. al. 2019).

Table 5: Pearson correlation matrix for ED

	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
As										
Cd	-0.440									
Co	-0.089	-0.378								
Cr	-0.602	0.893**	-0.397							
Cu	0.578	-0.058	0.187	-0.487						
Fe	0.706	-0.710	0.037	-0.529	-0.067					
Mn	-0.377	-0.636	0.486	-0.435	-0.297	0.099				
Ni	-0.129	-0.489	0.765*	-0.599	0.377	-0.116	0.724			
Pb	-0.596	0.430	-0.571	0.406	-0.246	-0.692	0.051	-0.162		
Zn	0.444	0.222	-0.439	0.352	-0.215	0.517	-0.668	-0.824*	-0.396	

**. Correlation is significant at the 0.01 level (1-tailed).

*. Correlation is significant at the 0.05 level (1-tailed).

Table 6: Pearson correlation matrix for ED

	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
As	1									
Cd	-0.550	1								
Co	-0.317	0.281	1							
Cr	0.059	-0.783	-0.543	1						

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Cu	0.252	-0.424	0.727	-0.072	1					
Fe	0.174	-0.396	0.760	-0.066	0.997**	1				
Mn	-0.919*	0.643	-0.022	-0.048	-0.611	-0.546	1			
Ni	0.423	-0.451	0.647	-0.117	0.981**	0.963*	-0.742	1		
Pb	0.857	-0.347	-0.716	0.132	-0.282	-0.357	-0.588	-0.104	1	
Zn	0.231	-0.176	0.831	-0.356	0.958*	0.952*	-0.569	0.956*	-0.289	1

*. Correlation is significant at the 0.05 level (1-tailed).
**. Correlation is significant at the 0.01 level (1-tailed).

Health Risk Assessment

The result of non-carcinogenic (Hazard Quotient (HQ) and Hazard Index (HI) presented on Table 7 for As and heavy metals in the studied drinks is less than 1 and falls below the acceptable limit of 1.00. Only the cumulative HQ of Mn in ED (1.3947) and HD (1.2773) and cumulative HI of As and all the heavy metals in ED (3.0005) and HD (2.2067) are above the acceptable limits. Overall effect of consuming multiple ED and HD may lead to non-carcinogenic diseases, as opined by Balali-Mood et. al. (2021). This is similar to the result of Mohammadi et. al. 2019 for Fe, Mn, Zn, Cu and Ni for all samples, but less than the result reported by Luo et. al. (2021) for medicinal herbs.

Table 7: Hazard Quotient (HQ) and Hazard Index (HI) of Energy and herbal Drinks

	Sample ID	Hazard Quotient (HQ)										
		As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn	HI
Energy Drink	A	0.0016	0.0000	0.0006	0.0033	0.0028	0.1496	0.0043	0.0002	0.0000	0.1597	0.3221
	B	0.0009	0.0003	0.0011	0.0058	0.0066	0.0480	0.0204	0.0014	0.0131	0.0397	0.1374
	C	0.0000	0.0000	0.0006	0.0229	0.0018	0.0702	0.6509	0.0000	0.0000	0.1061	0.8525
	F	0.0006	0.0000	0.0019	0.0133	0.0137	0.1783	0.0145	0.0041	0.0000	0.2461	0.4725
	G	0.0011	0.0000	0.0002	0.0160	0.0020	0.0615	0.0016	0.0010	0.0928	0.1282	0.3043
	H	0.0000	0.0006	0.0013	0.0066	0.0008	0.0591	0.7030	0.0000	0.0000	0.1404	0.9118
		0.0042	0.0010	0.0057	0.0680	0.0276	0.5667	1.3947	0.0066	0.1059	0.8202	3.0005
Herbal Drink	D	0.0001	0.0006	0.0012	0.1246	0.0006	0.0585	0.0031	0.0003	0.0090	0.1118	0.3097
	E	0.0001	0.0000	0.0015	0.0163	0.0015	0.0867	0.7942	0.0018	0.0091	0.0325	0.9436
	I	0.0000	0.0007	0.0000	0.1441	0.0011	0.0460	0.0016	0.0000	0.0277	0.1036	0.3248
	J	0.0003	0.0000	0.0007	0.0057	0.0009	0.0772	0.4785	0.0008	0.0233	0.0412	0.6286
		0.0005	0.0013	0.0034	0.2906	0.0041	0.2684	1.2773	0.0030	0.0691	0.2891	2.2067

Table 8: Carcinogenic Risk assessment of toxic metals in Energy and herbal Drinks

Drink	Sample	Cd	Cr	Ni	Pb
Energy Drink	A	0.0000	2.20E-05	1.52E-05	0.0000
	B	0.0010	0.000038	1.02E-04	0.0007
	C	0.0001	0.000151	0.00E+00	0.0000
	F	0.0000	8.76E-05	3.01E-04	0.0000
	G	0.0000	1.06E-04	7.06E-05	0.0049
	H	0.0018	4.38E-05	0.00E+00	0.0000
Herbal Drink	D	0.0016	8.22E-04	2.57E-05	0.0005
	E	0.0000	1.07E-04	1.37E-04	0.0005
	I	0.0019	9.51E-04	0.00E+00	0.0014
	J	0.0000	3.73E-05	6.02E-05	0.0012

The carcinogenic risk assessment of Cd, Cr, Ni and Pb for adults is presented in Table 8. All the drinks contain heavy metals with significant Carcinogenic risk above the acceptable range (1.0E-06 to 1.0E-04) except sample A (Table 8).CR of Pb in all HD samples is higher than the acceptable limit. The highest Carcinogenic risk for Cd, Cr, Ni and Pb was found in samples J (HD), I (HD), F (ED) and G (ED) respectively. Though, both ED and HD samples contains heavy metals with high Carcinogenic risk, the CR of HD samples is greater than that of ED. The result of this study is similar to that of (Mohammadi et. al. 2019). Herbal drinks have been reported to contain heavy metals with high Carcinogenic risk (Luo et. al. 2021)

CONCLUSION

The study reveals that pH of all the sampled drinks is acidic; consumption of large volume should be discouraged to avoid tooth decay. High levels above WHO limits of Fe, Zn and Cd were detected in both energy drink flavoured with herbs and herbal drinks. Moderate consumption of single ED and HD may not lead to non-carcinogenic diseases but, long term intake of either ED flavoured with herbs or HD should be avoided because of their high carcinogenic risk.

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