

Evaluation of Chemical, Minerals, and Heavy Metals in Selected Energy Drinks in Benin City, Edo State, Nigeria

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Abstract

Energy drinks are consumed on a daily basis, due to their ability to enhance energy levels, improve concentration, and boost physical and mental performance. However, the high demand may compromise the quality of production with possible contamination of heavy metals which have been shown to cause intoxication and death in humans. This study evaluated some constituents of five energy drinks commonly consumed in Nigeria and investigated the presence of some chemical, mineral and heavy metal. Five (5) different energy drinks with 3 samples per group was used for the study. The energy drinks were screened for the presence of sugars, carbon dioxide, phosphate and alcohol as well as the pH was determined using standard protocols. Heavy metals (Cadmium, Mercury, Arsenic, Chromium and Lead) and minerals were determined using an Atomic Absorption Spectrophotometer. The results showed the presence of carbon dioxide, high levels (+++) of sugar and alcohol, and a trace of phosphate in the energy drinks. The energy drinks were acidic in nature with pH ranging from 2 to 4. Lead and cadmium were non-detectable, while arsenic and mercury were present in all 5 samples ranging from 0.004 to 1.00 mg/L. The levels of the heavy metal were above the tolerated limits for good quality drinking water in most samples when compared to EPA, WHO and NIS standards. The overall findings of this study suggest that though the energy drinks in Benin may contain some crucial minerals, However, the presence of some heavy metals in the energy drinks may not be safe for consumption.

Keywords: Contamination, Energy drinks, Heavy metals, Minerals, Nigeria

1.0 Introduction

In recent times the consumption of energy drink has been on the increase by Nigerians. Energy drinks appears to be the new drink consumed by males and females for the purpose of enhancing energy levels, improve concentration, and boost physical and mental performance [1]. However, due to the high level of consumption and demand of energy drink, quality control within the process of production may be compromised and the quality of energy drinks may be challenging resulting in potential hazards and metabolic diseases. Aside from the intended benefits in the use of energy drinks dates back to the early 1900s, when products such as Lucozade were marketed as health drinks intended to aid recovery from illness [2]. Over the past few

decades, energy drinks have gained significant popularity, particularly among adolescents, young adults, and athletes seeking improved endurance and alertness [3]. These energy drinks are beverages that typically contain caffeine, and are fortified with other ingredients such as taurine, guarana, vitamin B, and sugars. [4]. However, concerns regarding their chemical composition, mineral content, and potential health effects have led to increased scrutiny by researchers and health professionals [5].

Energy drinks contain various minerals and trace elements, some of which are essential for physiological functions, while others pose potential health risks. Essential minerals such as calcium, magnesium, and potassium play roles in muscle function, bone health, and electrolyte balance,

whereas trace elements like zinc and iron contribute to enzyme activity and immune function [6]. In addition, some energy drinks may contain heavy metals, either as contaminants or due to ingredient sources. Heavy metals such as cadmium, lead, manganese, and copper can enter energy drinks through environmental contamination, manufacturing processes, or packaging materials [7]. Unlike organic toxins, heavy metals cannot be broken down or eliminated easily, making their accumulation a serious health concern [8]. In addition to minerals, the chemical properties of energy drinks such as pH, buffering capacity, and ionic strength affect their physiological impact. Many energy drinks have high acidity, which has been linked to dental erosion, gastrointestinal irritation, and metabolic imbalances [9]. High sugar content is another concern, as it contributes to spikes in blood glucose levels, insulin resistance, and increased risk of type 2 diabetes [10]. Furthermore, caffeine, a primary component in energy drinks, interacts with mineral absorption and kidney function, potentially exacerbating mineral imbalances and toxicity risks [1].

The increasing consumption of energy drinks, particularly among young adults and adolescents, has raised concerns about their long-term health effects. High caffeine intake can lead to cardiovascular complications, including elevated heart rate and hypertension, while excessive sugar consumption is associated with obesity, metabolic disorders, and insulin resistance [12]. Furthermore, the presence of trace metals and heavy metals in energy drinks may pose additional health risks, including oxidative stress and neurotoxicity [13]. Because some heavy metals operate as catalysts in oxidative reactions involving biological macromolecules, their intoxication may cause oxidative tissue damage or even cancer.[14]. Some keynote heavy metals of health importance include Cadmium, Lead, Mercury whose longtime accumulation may lead to cancer since they are carcinogenic elements [4]. Also, intake of cadmium over a long time, may accumulate in the kidney and liver because of its long biological half-life and may lead to kidney damage [4]. Lead is highly poisonous and can affect most organs in the body of humans and animals of all ages but most severe in young children [4]. The most common presentation of lead poisoning is central neurotoxicity. Other symptoms may include anemia, peripheral motor

neuropathy, gastrointestinal complaints such as anorexia, vomiting, and abdominal pain, and growth delay in children [4]. Mercury poisoning in infants and adults may interfere with numerous cellular processes including protein and nucleic acid synthesis, oxidative stress, calcium homeostasis, and protein phosphorylation [4]. Currently, concerns have been raised due to the increase in health challenges especially kidney disease in youths and young adults. Thus, this study was aimed to evaluate some chemical, and heavy metal presence in selected energy drinks in Nigeria.

2.0 Materials and Method

2.1 Materials

Energy drinks (Supa kommando, Monster, Blue bullet, Predator and Fearless) were purchased from a local grocery stores in Benin city, Edo State, Nigeria

2.2 Methods

Supa kommando, Monster, Blue bullet, Predator and Fearless were qualitatively analyzed for the presence of sugar, carbon dioxide, alcohol and phosphate while the pH, minerals and heavy metals concentration were quantified. The presence of sugar, carbon dioxide, phosphates and pH were determined according to the procedures of AOAC [14].

2.2.1 Test for Carbon dioxide (CO₂)

Upon opening the samples, 3 mL of each sample was added to 2 mL of lime water (calcium hydroxide) according to its respectively labelled test tubes. The change of lime water from colorless to milky confirmed the presence of dissolved carbon dioxide in the energy drink [4].

2.2.2 Test for Sugar

Benedicts test and Fehlings solution was carried out according to standard procedures[4]

2.2.3 Test for Alcohol

Using a micropipette, 3mL of each sample was measured into a test tube. 1 mL of iodine was added, followed by 1 mL of potassium iodide and 1

mL of sodium hydroxide (NaOH) solution. The tubes were placed in a boiling water bath for 5 minutes. Appearance of yellow colored precipitate confirmed the presence of alcohol in energy drinks [4].

2.2.4 Test for Phosphates

Three millilitres (3 mL) of each sample were transferred into separate test tubes using a micropipette. Thereafter, 2 mL of ammonium molybdate was added, followed by the addition of 2 mL of strong nitric acid. The tubes were placed in a boiling water bath for 10 minutes. The presence of phosphate ions in energy drinks was verified by the formation of a canary-yellow precipitate [4].

2.2.5 Determination of pH

After rinsing the pH meter's (Techmel and Techmel, USA) glass electrode with distilled water, 75 cl of the sample was measured into a beaker, then the electrode was inserted into the sample to ensure it was sufficiently submerged, and the steady reading was recorded.

2.2.6 Quantification of Alkali metals and heavy metals

Digestion of samples was carried out according to the method described by Victor Dmitrievich [15].

2.2.6.1 Preparation of sample

Ten millilitres (10 mL) of each sample was placed in a Kjeldahl flask. Thereafter, 10mL of mixed acid (Nitric acid and perchloric acid mixture, ratio 3 to 1) was added to each flask. The flask was mildly heated for 20 minutes at a temperature of 40°C and then increased to about 100°C for another 40 minutes. The samples were heated until the volume remained about one-third the initial volume. Red fumes were observed, indicating the release of nitric acid. The samples were allowed to cool, about 20 mL distilled water added and filtered into a standard flask. It was made up to the 100 mL mark with distilled water. The samples were left to settle and ready for atomic absorption spectrophotometer (AAS) using the PG-990 model.

2.2.6.2 Preparation of metal ion and ASS analysis

Preparation of metal ion and ASS analysis. The calibration plot method described in the British Pharmacopoeia [16] was adopted for the preparation of metal ion and AAS analysis. A stock standard solution, 1000 ppm, of the metal ion was prepared by dividing the molar mass of the compound containing the element by the molar mass of the element. The weight obtained was equivalent to 1.0 g of the metal ion. This weight (which is equivalent to 1.0 g of the metal) was dissolved in 1000 ml to give 1000 ppm. A working solution of 100 ppm was prepared from the stock solution and serial dilutions were made from the working solution. The absorbance of these solutions was obtained using AAS at 228.8, 283.3, 253.7 and 193.7 nm for cadmium, lead, mercury and arsenic respectively. A digital concentration read-out (meter) gives the direct concentration of the metals. The calibration graph was plotted and the regression equation was used to determine the heavy metal concentration. Deionised water was used as control.

2.2.6.3 Analysis for Heavy Metal Contamination in Energy Drink

The maximum contaminant level goal (MCLG) and maximum contaminant level (MCL) are the two units of measurement that the US Environmental Protection Agency defines as the standard for determining heavy metal contamination in soft drinks [17].

MCLG is the level of a contaminant in drinking water below which there is no known or expected risk to health and hence allow for a margin of safety and are non-enforceable public health goals. On the other hand, MCL is the highest level of a contaminant that is allowed in drinking water. The MCLG and MCL are measured in milligrams per litre (mg/L) which is equivalent to parts per million [17].

2.3 Data Analysis

The data obtained from three replicated measurements were used to calculate the mean and then the standard error of the mean. Furthermore, a one-way Analysis of Variance (ANOVA) was performed on the data using GraphPad Prism version 8.0 software (GraphPad Software, Inc., San Diego, California, United States).

3.0 Results

3.1 Chemical Properties

The results for the chemical properties screening of the energy drinks revealed that sugar was abundantly present in all the 5 samples except for reducing sugar which was absent in all the samples. Phosphate was present in the energy drink fearless, but trace was observed in the other 4 samples. Carbon dioxide was present in all the samples. All the energy drinks were acidic with low pH ranging from 2 to 4. (Table 1).

3.2 Heavy Metals

Heavy metal analysis showed the presence of Chromium, Arsenic and Mercury in all the samples while, Cadmium and lead were not detected in all the samples as seen in Table 2.

3.3 Mineral contents

Supa kommando, Monster, Blue bullet, Predator and Fearless energy drinks revealed the presence of zinc, calcium, potassium, manganese, magnesium iron, copper. However, minerals such as manganese, copper and phosphorus were not detected in monster, blue bullet, predator and supa kommando respectively (Table 3).

Table 1: Chemical properties of the energy drinks

Samples	CO ₂	Benedict test	Fehlings test	Alcohol	Phosphate	pH
Supa	+	+++	-	+++	Trace	3.24
Kommando						
Monster	++	+++	-	+++	Trace	3.65
Blue Bullet	+	+++	-	+++	Trace	3.55
Predator	++	+++	-	+++	Trace	3.15
Fearless	++	+++	-	+++	+	2.65

+ low; ++ moderately present; +++ abundantly present; - absent.

Table 2: Heavy metals concentration in some energy drinks in Nigeria

Samples	Pd(mg/L)	Cd(mg/L)	Cr (mg/L)	As (mg/L)	Hg (mg/L)
Supa Kommando	ND	ND	0.030 ± 0.006	0.476 ± 0.001	0.035 ± 0.001
Monster	ND	ND	0.060 ± 0.006	0.239 ± 0.004	0.018 ± 0.001
Blue Bullet	ND	ND	0.047 ± 0.003	0.955 ± 0.004	0.070 ± 0.001
Predator	ND	ND	0.067 ± 0.007	0.059 ± 0.001	0.004 ± 0.000
Fearless	ND	ND	0.020 ± 0.000	0.119 ± 0.005	0.009 ± 0.000
Acceptable Limit (NIS/WHO [18])	0.00-0.015	0.003-0.005		0.010-0.130	0.001-0.002

Values were presented in mean ± SEM (n=3), Pd= Lead; Cd=Cadmium; Cr=Chromium; As= Arsenic; Hg= Mercury

Table 3: Levels of minerals in the energy drinks

parameter	Sample SK	Sample M	Sample BB	Sample P	Sample F
Manganese	0.08±0.00	ND	0.05±0.01	0.05±0.01	ND
Zinc	0.08±0.00	0.58±0.10	0.28±0.12	0.08±0.04	0.08±0.00
Calcium	16.73±0.23	0.20±0.00	24.47±0.15	20.87±0.87	20.57±0.03
Iron	1.13±0.06	0.33±0.03	0.93±0.03	1.10±0.00	0.50±0.00
Potassium	0.57±0.03	0.27±0.03	0.30±0.00	4.27±0.03	3.80±0.06
Copper	0.34±0.33	ND	ND	ND	0.01±0.00
Phosphorus	ND	1.47±0.00	1.67±0.00	1.67±0.00	1.47±0.00
Magnesium	0.28±0.00	0.12±0.01	1.17±0.03	1.02±0.01	0.80±0.01

SK =Supa kommando, M=Monster; BB=Blue Bullet, P=Predator; F=Fearless; ND= not detected. Values are mean ± SEM of 3 replicates

4.0 Discussion

The main reasons for the consumption of energy drinks are their ability to foster alertness and endurance. This study examined the chemical, mineral and heavy metal contents of five energy drinks. These results provide insight into the chemicals, minerals, and heavy metal composition of the drinks.

From this study, the five energy drinks exhibited a high sugar content responsible for caloric intake, which is a major characteristic of energy drinks. The high sugar content observed in this study is in agreement with the report of Alsunni et al. [19] that high sugar in energy drinks contributes to excessive caloric intake. Usually, energy drinks contain large amounts of sugar, ranging from 21 g to 34 g per oz, which is mainly in the form of sucrose, glucose or high fructose corn syrup. According to Alsunni, [19] the high sugar content in energy drinks may raise the risk of obesity and type 2 diabetes. The pH and carbonation levels varied, with certain energy drinks exhibiting high levels of acidity and carbonation, which adds to their sensory appeal but may also have consequences for metabolic health problems, gastrointestinal distress, and dental erosion [4]. The level of alcohol was quantified, and the result showed a high alcohol level which could lead to problems like drunkenness and alcohol intoxication. Additionally, the presence of alcohol may assist maintain high energy levels [20].

Additionally, the presence of heavy metals has been demonstrated to be toxic and detrimental to human health [21][22] and is a significant public health issue. The trace levels of certain heavy metals (Chromium, Arsenic, and Mercury) in the energy drinks may indicate that regular energy drink intake may provide safety risks that could result in toxicity of any kind for consumers. Even at low concentrations, heavy metals can build up in the human body over time and cause major health problems like neurotoxicity, organ damage, and metabolic disorders. The levels of arsenic in predator and fearless were found to be within the permissible limits, indicating minimal risk. The ingredients and production technique may be responsible for the observed results. These findings

are consistent with [23][4]. Furthermore Chromium, Arsenic, and Mercury were detected in BlueBullet, Supa kommando and Monster Energy Drink in varying concentrations, above permissible limits, raising concerns about possible contamination sources, indicating potential exposure risks from prolonged consumption. This finding again proved that energy drinks can induce toxicity. This result is in agreement with the report of Yahaya [21]; Izah et al. [24]; Udoata and Umuodofia [25] who reported the presence of heavy metals above permissible limits in some energy drinks in Nigeria. Since mercury and arsenic were found in the majority of samples and the levels were significantly higher than the recommended acceptable Maximum Contaminant Level limit of NIS (0.001 mg/L) and EPA (0.002 mg/L) as well as their Maximum Contaminant level goal limit of 0.002 mg/L, these findings highlight the necessity of stringent regulatory oversight and ongoing monitoring of heavy metal levels in commercially available beverages.

Energy drinks contain a variety of minerals in trace amount. The presence of some minerals such as iron, zinc, calcium, potassium, and magnesium suggest that the energy drinks may have the potential benefit in supporting enzyme function, preventing anemia, bone development, immune function, support oxygen transport and metabolism in the body [26]. Furthermore, micronutrients including iron (Fe), zinc (Zn), copper (Cu), and magnesium (Mg) are essential for human metabolism, and an imbalance in them might have negative health implications [27]. The results of this study do not support the WHO's acceptable limit for copper (2.0 mg/L), iron (0.3 mg/L), manganese (0.4 mg/L), and zinc (3.0 mg/L) [18]. The discrepancy in the outcome could indicate variations in ingredient composition, sourcing, and fortification techniques. Overall, even while energy drinks provide short-term energy increases, their nutritional advantages are minimal in comparison to the risks they pose, which emphasizes the need for cautious use and regulatory monitoring.

5.0 Conclusion

The findings from this study showed that Supa Kommando, Monster, Blue Bullet, Predator and Fearless energy drinks studied in Benin contain sugar, carbon dioxide, phosphate, low pH, alcohol, some heavy metals and minerals. The chemical composition of this drink justifies the frequent consumption of energy drink due to their ability to improve energy levels, concentration, and boost physical and mental performance. However, due to presence of some heavy metals above permissible limit frequent consumption may pose a risk and a major public health concern. This therefore suggest that the energy drinks sold and consumed in Benin City may not be suitable for consumption. Therefore, quality of raw materials should be put into consideration and also regulatory bodies should monitor and control the quality of energy drinks to minimize toxicity.

6.0 Recommendations

Based on the report of this study, consumers should be sensitized on the occurrence and risk of heavy metals in energy drinks, also agencies responsible for monitoring the safety of food and drinks, should enforce quality control measures on producers of energy drinks.

7.0 Conflict of Interest

The authors have no conflict of interest.

References

1. Seifert SM, Schaechter JL, Hershoin ER, Lipshultz SE. Health effects of energy drinks on children, adolescents, and young adults. *Pediatric*. 2021;127(3), 511-528.
2. Hani MM, Yamashita T, Sakamoto Y. The Japanese energy drink market: Growth, regulation, and consumer perception. *Asian Journal of Food Sciences*. 2022; 8(2), 178-192.
3. Ahmad S. The evolution of energy drinks: History, formulation, and market impact. *International Journal of Nutrition and Metabolism*. 2011; 5(4), 210-219.
4. Engwa AG, Ihekwoaba CJ, Ilo US, Unaegbu M, Ayuk LE, Osuji AG. Determination of some soft drink constituents and contamination by some heavy metals in Nigeria. *Elsevier, Toxicology Reports* 2. 2015; 384–390
5. Reissig CJ, Strain EC, Griffiths RR. Caffeinated energy drinks—A growing problem. *Drug and Alcohol Dependence*. 2009;99(1-3), 1-10.
6. Heckman MA, Sherry K, Gonzalez de Mejia E. Energy drinks: An assessment of their market size, ingredients, regulations, and potential health effects. *Comprehensive Reviews in Food Science and Food Safety*. (2010); 9(3), 303-317.
7. Abubakar AI, Bello AA, Yusuf A. Heavy metal contamination in beverages: Sources, health risks, and regulatory perspectives. *Journal of Food Safety and Toxicology*. 2022;12(3), 134-148.
8. Hamad MA, Khalid A, Yusuf H. Heavy metal toxicity in food and beverages: Implications for human health. *Toxicology Reports*. 2023; 7(1), 56-73.
9. Tahmassebi JF, Duggal MS, Malik-Kotru G, Curzon ME. Soft drinks and dental health: A review of current literature. *Journal of Dentistry*. 2006;34(1), 2-11.
10. Malik VS, Popkin BM, Bray GA, Després JP, Hu FB. Sugar-sweetened beverages and risk of metabolic disorders. *The American Journal of Clinical Nutrition*. 2020; 111(1), 179-188.
11. Mclellan TM, Lieberman HR. Caffeine and cognitive function: Implications for performance enhancement and health risks. *Neuroscience & Biobehavioral Reviews*. 2022;134(4), 456-472.
12. Higgins JP, Tuttle TD, Higgins CL. Energy beverages: Content and safety. *Mayo Clinic Proceedings*. 2018; 93(6), 875-892.
13. Yehuda S. The role of trace elements in cognitive function and brain health. *Nutritional Neuroscience* 2021;24(3), 187-200.
14. AOAC, Official Methods of Analysis of AOAC International, 18th ed.,AOAC International, Gaithersburg, MD, USA, 2005
15. Victor Dmitrievich S. Methods for heavy metal detection in beverages: A comprehensive review. *Analytical Chemistry*. 2013;85(5), 230-245.
16. British Pharmacopoeia, Atomic Spectrophotometry: Emission and Absorption, Appendix IID, CD, 2005.
17. EPA (United States Environmental Protection Agency), 2011 Edition of the Drinking Water Standards and Health Advisories, Office of Water U.S. Environmental Protection Agency,

- Washington, DC, 2011, pp. 8, 719–726, 731–732.
18. World Health Organization (WHO). Guidelines for drinking water quality, 4th Edition. World Health Organization, Geneva, 2011, pp. 564
 19. Alsunni AA. Energy Drink Consumption: Beneficial and Adverse Health Effects. *International Journal of Health Sciences*, 9(4), 468. 2015
 20. Tarragon E. Alcohol and energy drinks: individual contribution of common ingredients on ethanol-induced behaviour. *Frontiers in Behavioral Neuroscience*. 2023; 17:1057262
 21. Yahaya TO, Gulumbe BH, Umar AK, Yusuf A, Mohammed AZ, Izuafa A, et al. Heavy metal content and associated health risks in selected energy drinks sold in birninkebbi, Nigeria. *African Journal of Health, Safety and Environment*. 2022; Vol: 3 (1): 26-34
 22. Wallace HA. Principles and Methods of Toxicology, 4th ed., Taylor and Francis Publishing Inc., Philadelphia, pp. 50–55. 2001.
 23. Yusuf ZM, Aliyu IA, Yusuf YS, Abubakar MM, Muhammad II, Maimunatu HY. Et al. Ismail. Safety Assessment of the Hydroethanolic Extract of Citrullus lanatus Seeds in Female Wistar Rats. 2024; Vol. 1(3): 61-68; Dec.
 24. Izah CS, Inyang IR, Angaye TCN, Okowa IP. A Review of Heavy Metal Concentration and Potential Health Implications of Beverages Consumed in Nigeria. *Toxics*. 2017; 5(1): 1-15.
 25. Udotu HIJ, Umoudofia SJ. Heavy metal contamination of some selected Nigerian and imported alcoholic drinks. *Journal of Industrial Pollution Control*. 2011;27: 1–4.
 26. Hamza AA, Bajoga AD, Auwal YM, Seydou H. Determination of Some Physicochemical Properties, Heavy Metals and Micronutrients of Some Energy Drinks Available in Nigeria. *Communication in Physical Sciences*. 2025;12(3), 933–950
 27. Czarnek K, Tatarczak-Michalewska M, Wójcik G, Szopa A, Majerek D, Fila K, Hamitoglu M, Gogacz M. Nutritional risks of heavy metals in the human diet — multi-elemental analysis of energy drinks. *Nutrients*. 2024; 16(24), 4306.



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