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Determination of Caffeine and Some Heavy Metals in Energy Drinks

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Abstract

The increasing popularity of energy drinks has raised concerns about their potential health risks, particularly among young adults. Energy drinks are widely consumed globally, with a significant market share in Nigeria. The high caffeine and sugar content of energy drinks has been linked to various health problems, including cardiovascular disease, type 2 diabetes, and dental caries. This study aimed to determine the caffeine content of selected energy drinks available in the Nigerian market, determine the levels of heavy metals (lead, cadmium, mercury, and iron) in selected energy drinks, and compare the levels of caffeine and heavy metals in energy drinks from different manufacturers. Fourteen brands of energy drinks, including liquid and powdered forms, were randomly purchased from Katsina central market, Nigeria. The samples were analyzed for caffeine and heavy metal content using Aqua regia digestion and vortex mixer/sonnicator extraction methods, respectively. The caffeine and heavy metal concentrations were determined using high-performance liquid chromatography (HPLC) and atomic absorption spectroscopy (AAS), respectively. The results showed that caffeine concentrations ranged from 1.11 mg/L to 2487.13 mg/L, with one sample exceeding the recommended daily intake. Heavy metal concentrations were generally within acceptable limits, although some samples contained elevated levels of lead (up to 0.209 mg/L) and cadmium (up to 0.012 mg/L). The study found significant variations in caffeine and heavy metal concentrations across different energy drink brands. The study highlights the need for stricter regulation and monitoring of energy drink ingredients in Nigeria, as well as consumer awareness and education on potential health risks associated with energy drink consumption. The findings of this study contribute to the existing literature on the safety of energy drinks and inform policy decisions on their regulation.

Keywords: Caffeine, Energy drinks, Heavy metals, Lead, Nigeria, Public health.

Introduction

The consumption of energy drinks has become increasingly popular worldwide, particularly among young adults, due to their perceived benefits of enhancing physical and mental performance [1]. This trend has been driven by the growing demand for products that can provide a quick energy boost and improve mental alertness. In today's fast-paced world, individuals are constantly seeking ways to optimize their productivity, stay focused, and maintain their energy levels throughout the day. Energy drinks have emerged as a convenient and appealing solution, offering a promise of enhanced physical and mental performance. However,

concerns have been raised about the potential health risks associated with the consumption of energy drinks, particularly regarding their high caffeine and sugar content, as well as the presence of other stimulants and ingredients [2).

In Nigeria, the growing demand for energy drinks has led to an influx of various brands in the market, yet there is limited information on the safety and quality of these products. The Nigerian energy drink market is characterized by a proliferation of local and international brands, each offering a unique blend of ingredients and flavors. This has created a challenge for consumers, who are often left to navigate the complex and unregulated market without adequate guidance or protection. Furthermore, the lack of effective regulation and monitoring has raised concerns about the potential health risks associated with the consumption of energy drinks in Nigeria.

Energy drinks typically contain a combination of ingredients such as caffeine, taurine, guarana, and B vitamins, which are claimed to provide an energy boost and enhance physical performance [3]. Caffeine, in particular, is a key ingredient in energy drinks, and its high levels have raised concerns about its potential impact on cardiovascular health, anxiety, and sleep patterns [4]. Additionally, the interaction between caffeine and other ingredients in energy drinks, such as taurine and guarana, is not well understood, and this has raised concerns about the potential for adverse effects [5]. The long-term consequences of consuming energy drinks are also not well understood, and this has created a need for further research and investigation.

Furthermore, the presence of heavy metals in energy drinks is a significant concern, as these elements can have toxic effects on human health even at low concentrations [6]. The World Health Organization (WHO) has established guidelines for the maximum permissible levels of heavy metals in food and beverages, but the levels of these metals in energy drinks available in Nigeria are largely unknown [7]. This knowledge gap is a significant concern, as heavy metal contamination can have serious health implications, including kidney damage, neurological problems, and cancer [8]. The potential health risks associated with heavy metal contamination in energy drinks are particularly concerning in Nigeria, where access to healthcare is limited and the population is already vulnerable to a range of health challenges.

This study aims to investigate the levels of caffeine and heavy metals in selected energy drinks available in the Nigerian market, with a view to assessing their safety and quality. The findings of this study will contribute to the existing body of knowledge on the safety of energy drinks and provide valuable information for policymakers, regulatory agencies, and consumers.

Materials and Methods

Materials

The materials used in this study are listed in Table 1.

Table 1: Materials used in this study

Material	Grade	Supplier
Energy drinks	Various brands	Local market
Caffeine standard	Reagent grade	Sigma-Aldrich
Lead standard	Reagent grade	Merck
Cadmium standard	Reagent grade	Fluka
Mercury standard	Reagent grade	Alfa Aesar
Iron standard	Reagent grade	BDH
Methanol	HPLC grade	J.T. Baker
Acetonitrile	HPLC grade	Fisher Scientific
Buffer tablets (pH 4.00 and pH 7.00)	Reagent grade	Merck
6 M HCl	Reagent grade	BDH
2.5 M NaOH	Reagent grade	Fisher Scientific
Aqua regia	Reagent grade	Merck
Distilled water	-	Laboratory source

Sample Collection and Preparation

Fourteen (14) brands of energy drinks were randomly purchased from the Nigerian market. The samples were refrigerated prior to analysis to prevent degradation of the analytes [9]. Liquid samples (30 ml) and powdered samples (1.0 g) were measured into a clean 250 ml dry Pyrex digestion flask.

Sample Preparation for Heavy Metal Analysis

The samples were digested using concentrated aqua regia (25 ml) according to the method described by the United States Environmental Protection Agency (USEPA) [10]. Briefly, the digestion flask was heated gently until frothing subsided. The samples were then heated to dryness, dissolved in 30 ml distilled water, and filtered with filter paper.

Sample Preparation for Caffeine Analysis

Caffeine was extracted from the energy drink samples using deionised water according to the method described by the Association of Official Analytical Chemists (AOAC) [11]. Briefly, liquid samples (2 ml) and powdered samples (2.0 g) were measured into 10 ml volumetric flasks. Deionised

water (5 ml) was added, and the mixture was shaken for 5 minutes using a vortex mixer.

Statistical Analysis

All results were analyzed statistically using one--way analysis of variance (ANOVA) with Duncan post hoc test. Differences were considered significant for $p < 0.05$ [12].

Results and Discussion

Heavy Metal Concentrations

Table 2 shows the concentrations of heavy metals (lead, cadmium, mercury, and iron) in the sampled energy drinks.

Table 2: Concentrations of heavy metals in energy drinks

Sample	**Sample type**	**Pb (mg/L)**	**Cd (mg/L)**	**Hg (mg/L)**	**Fe (mg/L)**
EJ	Powder	0.209±0.0009	0.012±0.0005	ND	0.544±0.0008
PA	Powder	0.122±0.0001	ND	ND	0.392±0.0006
PH	Liquid	ND	ND	ND	0.480±0.0008
RB	Liquid	0.045±0.0005	ND	ND	0.326±0.0005
AL	Powder	0.083±0.0003	ND	ND	0.799±0.0005
XL	Liquid	0.054±0.0010	ND	ND	0.418±0.0002
EV	Liquid	0.028±0.0006	ND	ND	0.539±0.0005
BU	Liquid	0.068±0.0002	ND	ND	0.294±0.0005
JW	Liquid	ND	ND	ND	0.412±0.0003
HC	Liquid	0.050±0.0000	ND	ND	0.326±0.0006
WD	Liquid	0.078±0.0005	ND	ND	0.386±0.0002
LB	Liquid	ND	ND	ND	0.586±0.0010
KM	Liquid	0.043±0.0003	ND	ND	0.353±0.0007
SO	Liquid	0.139±0.0004	ND	ND	1.961±0.0003

The concentrations of lead ranged from 0.028 mg/L (EV) to 0.209 mg/L (EJ), with most samples below the recommended limit of 0.15 mg/L set by the World Health Organization (WHO) [13]. These

findings are consistent with those reported in a previous study, which detected lead levels ranging from 0.01 mg/L to 0.20 mg/L in energy drinks [19]. However, another study reported higher lead levels, ranging from 0.10 mg/L to 0.50 mg/L, in energy drinks [20]. The discrepancies in lead levels reported in these studies may be attributed to differences in the manufacturing processes, ingredients, or contamination sources.

A study conducted by the European Food Safety Authority (EFSA) reported that the average lead intake from energy drinks was 0.12 mg/L, which is below the recommended limit [21]. However, the EFSA study noted that some energy drinks contained lead levels exceeding the recommended limit, highlighting the need for stricter quality control measures.

Cadmium was detected in only two samples (EJ and PA), with concentrations below the recommended limit of 0.003 mg/L set by the WHO [13]. These findings are consistent with those reported in a previous study, which detected cadmium levels ranging from 0.001 mg/L to 0.005 mg/L in energy drinks [22]. The low levels of cadmium detected in this study suggest that energy drinks may not be a significant source of cadmium exposure.

Mercury was not detected in any sample, indicating compliance with regulatory standards. This finding is consistent with those reported in previous studies, which also detected no mercury in energy drinks [23].

Iron concentrations ranged from 0.294 mg/L (BU) to 1.961 mg/L (SO), with most samples within recommended limits. These findings are consistent with those reported in a previous study, which detected iron levels ranging from 0.10 mg/L to 2.00 mg/L in energy drinks [24]. Excessive iron intake may lead to hemochromatosis, a condition characterized by iron overload [15]. The high levels of iron detected in some samples may be attributed to the use of iron-containing ingredients or contamination during the manufacturing process.

Caffeine Concentrations

Table 3 shows the concentrations of caffeine in the sampled energy drinks.

Table 3: Concentrations of caffeine in energy drinks

Sample	Sample type	Caffeine (mg/L)
SO	Liquid	67.08c
BU	Liquid	30.94b
HC	Liquid	200.10h
LB	Liquid	190.22g
EV	Liquid	1.11a
PH	Liquid	237.95i
XL	Liquid	62.84c
JW	Liquid	130.58f
WD	Liquid	103.97d
KM	Liquid	118.63e
RB	Liquid	234.84i
PA	Powder	361.1c
EJ	Powder	14.25a
AL	Powder	2487.13j

Caffeine concentrations ranged from 1.11 mg/L (EV) to 2487.13 mg/L (AL), with most samples below the recommended daily intake of 400 mg/day set by Health Canada [16]. However, sample AL exceeded this limit, posing potential health risks. Caffeine is a stimulant that can cause jitteriness, anxiety, and insomnia in high doses [19]. The high levels of caffeine detected in some samples may be attributed to the use of caffeine-containing ingredients or contamination during the manufacturing process.

A study conducted by the American Academy of Sleep Medicine reported that consuming high levels of caffeine can lead to sleep disturbances and daytime fatigue [25]. Another study published in the Journal of Clinical Psychopharmacology found that caffeine can exacerbate anxiety symptoms in individuals with anxiety disorders [26]. These

findings highlight the importance of regulating caffeine levels in energy drinks to ensure consumer safety.

The findings of this study are consistent with those reported in previous studies, which also detected heavy metals and caffeine in energy drinks [19, 20, 22, 24]. However, the levels of heavy metals and caffeine detected in this study were generally lower than those reported in previous studies. This may be attributed to differences in the manufacturing processes, ingredients, or contamination sources.

Conclusion

This study provides a comprehensive analysis of the caffeine and heavy metal concentrations in energy drinks available in the Nigerian market. The results reveal varying levels of caffeine (1.11-2487.13 mg/L) and heavy metals (lead, cadmium, and iron), which raises concerns about the potential health risks associated with the consumption of these products. While most samples were within acceptable limits, sample AL exceeded the recommended daily caffeine intake, posing a significant risk to consumers. Furthermore, samples EJ and others exceeded the maximum contaminant levels for cadmium and lead, respectively, highlighting the need for stricter quality control measures.

The detection of essential elements like iron, calcium, zinc, and potassium in the energy drinks is notable. However, excessive intake of these substances can have adverse health effects. Therefore, it is crucial to monitor consumption patterns and ensure that consumers are aware of the potential health risks associated with excessive intake.

The study recommends that manufacturers should implement stricter quality control measures to ensure that their products comply with regulatory standards and guidelines and energy drink manufacturers should be required to label their products with accurate information about the levels of caffeine and heavy metals present. However, regulatory agencies and healthcare professionals should educate consumers about the potential health risks associated with energy drink consumption and provide guidance on safe consumption practices.

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