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Comparative Assessment of Concentration of Cyanocobalamin (Vitamin-B12) in Energy Drinks Manufactured in Africa and Foreign-Based Energy Drinks Consumed in Nigeria

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Abstract

As certain sicknesses previously linked to old age, especially kidney dialysis, cardiovascular and nervous system disorders, are becoming more prevalent among the young male and female adults in recent times, medical and science researchers have been saddled with the urgency to unravel the common diets and lifestyles possibly responsible for such soaring. However, the recent accusations have been partly on excessive consumption of energy drinks containing cyanocobalamin. Thus, comparative assessment of the concentration of cyanocobalamin (Vitamin-B12) in energy drinks manufactured in Africa and Foreign-based energy drinks consumed in Nigeria has been studied using High-Performance Liquid Chromatography (HPLC) methodology. The results of the study reveal that the concentrations of cyanocobalamin in the energy drinks manufactured in Africa and the foreign-based counterparts were approximately the same. Both the foreign-based energy drinks and those produced in African continent have pH values ranging from (4..75-6.22), and the cyanocobalamin concentrations were found on the range of (0.0015-0.0180±0.001) within the recommended limits of 10 µg (or 0.01mg/250ml) recommended by National Agency for Food and Drug Administration and Control (NAFDAC) in Nigeria, and within the daily permissible allowance of 2.4 µg/day (or 0.0024mg/L) recommended by US FDA. The results further showed that the energy drinks from the UK and USA have higher electrical conductivity of $1.28x10^{-3}$-$4.57x10^{-3}$ and $1.26x10^{-3}$-$4.59x10^{-3}$ µS/cm. Additionally, the findings show that both African and Foreign producers of energy drinks have complied with the National and International recommended permissible limits of cyanocobalamin in energy drinks, thereby making the investigated energy drinks safe for human consumption.

Keywords: Concentration; Producers; Consumption; Vitamin-B12; Drinks

1 Introduction

Cyanocobalamin, also known as α(-(5,6-Dimethylbenzimidazol-2-yl)cobamide cyanide, is the artificial or synthetic form of vitamin B12 [1, 2], and it seems to attract more attention, and it has continued to raise a global concern about its general usage by manufacturers as an energy-boasting ingredient in energy food drinks and vitamin-B12 supplements [2, 3]. One of the major health concerns about the utilization of cyanocobalamin in energy drinks is that the cyanide ion of the vitamin is believed to interact with sensitive human body organs like mitochondria and possibly cause a disorder or malfunctioning of the mitochondria process by obstructing oxygen circulation and usage in the tiny cell factories of the delicate organelles [2, 4]. According to the subsequent development, mitochondria cannot produce adenosine triphosphate (ATP), the body's main energy source, without an adequate oxygen supply to the organelle. Fundamentally, this might result in mitochondrial damage and possible health problems such as fatigue and muscle

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weakness [5]. Based on the foregoing analysis, cyanocobalamin has caused fear and anxiety in the minds of the people in the general public [2]. In that regard, researchers and the scientific community as a whole have suspected that the chemical's use as an ingredient in energy drinks may pose a health risk to consumers, especially when the drinks are consumed in excess. Most likely due to the chemical's ability to combine with bodily fluids and interact with other chemicals, either creating a more toxic chemical compound or interfering with biochemical processes, which may further alter biochemical mechanisms and have harmful effects on human health [2].

Meanwhile, there is substantial further evidence that excessive energy drink intake or acute or chronic abuse of energy drinks has detrimental effects on human health, which is a relatively improbable but plausible possibility. For instance, in a recent report, Costantino *et al*. [6] reviewed the reported effects of acute or chronic abuse of energy drinks on human health, and their analysis revealed a significant prevalence of adverse effects, particularly on the cardiovascular and neurovegetative human systems. These implications may include cardiovascular problems, nervous system disorders, and the potential for addiction. As reported by Idongesit et al. [2], it seems more accurate to establish further that energy drinks, which are widely consumed by people of all ages and sexes, especially young people, are consumed for a variety of motives. There is some evidence that consumers consume excessive amounts of these drinks to achieve their goals, and that such consumption may be harmful to human health [2]. Nevertheless, it is crucial to note that energy drinks were initially designed to instantly, easily, and quickly increase human energy levels, improve alertness, and boost academic or athletic performance. The ingredients used to make all types of energy drinks are the same and act as stimulants and aid humans' performance [2, 6].

Besides, it is instructive to note that the caffeine and other legal stimulants in energy drinks can increase alertness, attention, and boost energy, as well as increase blood pressure, the rate of heartbeat, and breathing, which justifies the purpose of energy drink brands being marketed as enhancers of mental acuity and physical performance [7, 8]. In this context, it has been frequently asserted that consuming substantial doses of vitamin B_{12} from energy drinks improves a person's mood and promotes mental alertness and focus. According to different reports, particularly those of Idongesit *et al*. [2] and Campbell *et al*. [9], energy drinks are frequently marketed to consumers with claims of increased energy and alertness, which results in decreased feelings of fatigue, improved physical performance, increased metabolic activity, and a host of other physiological, metabolic, cognitive, and performance benefits. Based on this, people reflectively understand that energy drinks have stimulating inherent properties that can purportedly boost the rate of heartbeat and blood pressure, affect dehydration in the body, exacerbate the effects of other stimulants, and cause insomnia [2]. Emphatically, the common reason why energy drinks are often consumed in excess is that people who are aware that energy drinks have inherently stimulating qualities that can allegedly increase blood pressure and heart rate, cause dehydration in the body, worsen the effects of other stimulants, and make it difficult to fall asleep may frequently use this knowledge to make decisions about the brands of energy drinks they choose [2].

Nonetheless, concerns about the immediate and long-term safety of ingesting these products have been raised, especially with relation to cyanocobalamin [2, 10]. More often than not, these worries have sparked research in that field, and scientists have persistently employed various techniques to evaluate the effects of cyanocobalamin in energy drinks. In light of the aforementioned, it seems appropriate to state that, unfortunately, an increasing number of case reports and clinical trials have revealed a variety of negative effects after excessive energy drink consumption, including acute hemodynamic perturbations, disruptions in vascular function, and other cardiovascular abnormalities, particularly when consumed in excess [2,10,11,12, 13]. Similar to this, a different team of researchers has drawn attention to a report that highlights the detrimental effects of energy drinks on a wide range of bodily organs, including more serious consequences like rhabdomyolysis, acute kidney injury (AKI), ventricular fibrillation, seizures, acute mania, and stroke [14,15,16]. Not only that, but regular energy drink consumption has also been linked to anxiety, substance abuse problems, and sleep disturbances [2,10,17,18,19], as well as well-documented cases in more severe cases.

Owing to the identified health problems linked to energy drinks and panic of cyanide in cyanocobalamin, there is an unceasing argument as to whether the presence of cyanide in cyanocobalamin used in energy drinks has made energy drinks unsafe for human consumption. In addition, there is equally a growing concern about the quantity of cyanocobalamin in energy drinks from manufacturers, as high concentrations of the chemical in energy drinks are allegedly believed to cause or trigger health challenges. Therefore, to determine the quantity or concentration of cyanocobalamin (synthetic vitmin-B_{12}) and compare its concentrations in different brands of energy drinks manufactured in Nigeria and other African countries like South Africa, and Ghana as well as to compare with the concentrations in imported energy drinks from countries like Canada, USA and United Kingdom consumed in Nigeria and with the ultimate aim of comparing each concentration with the National (NAFDAC) and International (US FDA) permissible limits of the chemical in energy drinks, to ascertain whether manufacturers comply is the primary objective of this investigation.

2 Materials and Methods

2.1 Sample Collection

A total of ten (10) different brands of energy drinks manufactured in Nigeria were purchased at different supermarkets from each state capital and FCT Abuja making a total (370 cans of energy drinks) and five (5) different brands of energy drinks manufactured in South Africa (EDMSA), Ghana (EDMGH), USA (EDMUSA), Canada (EDMCA) and United Kingdom (EDMUK) respectively from each state capital and FCT Abuja, giving a total 185 cans for each. In all, a total of 1, 295 different brands of energy drinks were analyzed for cyanocobalamin concentration.

2.2 Sample Preparation and Analysis

Each energy drink sample was prepared for analysis using the procedure reported by Idongesit *et al*. (2024). The HPLC analysis was performed on each sample to determine the concentration of cyanocobalamin, and statistical analysis of data was done following the procedures described in Idongesit *et al*. [2].

2.3 Cyanocobalamin Determination in Energy Drinks

High-performance liquid Chromatography (HPLC) equipment was used to determine the cyanocobalamin contents of the samples. The HPLC analysis was carried out on a 250 x 4.6 mm reverse-phase column (Supelco). The mobile phase was 0.25 % dehydrogenated phosphate and 0.0025 M [2]. The concentration of cyanocobalamin in milligrams per liter (mg/L) was determined using this relationship:

Concentration of Cyanocobalamin (Vit. B_{12}) in (mg) = $\left(\frac{C\ x\ V1\ x\ V3}{W\ x\ V2}\right)\ \boldsymbol{X\ 1000}$; - - - - - - - - (1)

Where, C = Instrument concentration (mg); V1 = Volume make-up (mL); V2 = Volume loaded of Filtrate on Cartridge (mL); V3 = Volume of diluent added to the Vitamin B_{12} from Cartridge (mL);

W = Sample Weight (g) [2].

2.4 Analysis of Statistics Data

All information is displayed as means ± SD. To create a common energy drink cyanocobalamin ingredient profile that makes it simple to identify values that are above the recommended percentage daily value (% DV) or tolerable upper intake limit, the means and standard deviations for each sample brand were calculated, the relative uncertainty for each sample result was extrapolated, and the mean of each result was compared and inferred accordingly for the cyanocobalamin ingredient across each product as described in Idongesit *et al*. [2].

Deviation from the Mean (SD) =$\sqrt{\Sigma(xi-\dot{x})^2/N-1}$; ---------- (2)

Where xi = Individual value; x = Mean value, and N = Number of measurements/observations.

3 Results and Discussion

Table 1 Results of Conductivity and Concentration of Cyanocobalamin of Investigated Energy Drinks

Energy Drink	Total	Colour	Conductivity Range (µS/cm)
EDMN	370	Colourless/Amber	1.14 x 10^{-3} - 4.52 x 10^{-3}
EDMSA	185	Colourless/Amber	1.22 x 10^{-3} - 4.53 x 10^{-3}
EDMGH	185	Colourless/Amber	1.23 x 10^{-3} - 4.50 x 10^{-3}
EDMUSA	185	Colourless	1.26 x 10^{-3} - 4.59 x 10^{-3}
ENDMCA	185	Colourless	1.24 x 10^{-3} - 4.55 x 10^{-3}
ENDMUK	185	Colourless	1.28 x 10^{-3} - 4.57 x 10^{-3}

The investigated energy drinks were either colourless or amber in colour. Another physicochemical property of the energy drinks investigated was the electrical conductivity. According to Maurice [20] and Idongesit *et al*. [2], the conductivity of a liquid substance is the property or ability of the substance to allow an electric current to pass through the water in the substance, using the substance as an impurity and electrical conductors contained in the water. In that regard, the results of the conductivity of the energy drinks reveal that energy drinks manufactured in the USA (EDMUSA) have the highest conductivity, ranging from $1.26x10^{-3}$ to $4.59x10^{-3}$ µS/cm, followed by energy drinks manufactured in the United Kingdom (EDMUK), $1.28x10^{-3}$ to $4.57x10^{-3}$ µS/cm, then the energy drinks manufactured in Canada (EDMCA) with $1.24x10^{-3}$ to $4.55x10^{-3}$ µS/cm range. The results of the conductivity of all the investigated energy drinks in this order: EDMUSA > EDMUK > EDMCA > EDMSA > EDMGH > EDMN. Meanwhile, although the results of conductivity values obtained in the current study are somewhat higher than those reported by Idongesit and co-workers in [2], the results of the conductivity of the investigated African-based and foreign-based energy drinks are within the range reported by Idongesit *et al*. [2].

In addition, the results of the present study are consistent with the results of the previous studies, reported by Chukwuelesie [21], who reported 497±1.155 -2210 ± 0.006 µs/cm, Abbas *et al*. [22], reported 497 ± 0.006 – 1935 ±1.555 S/µcm, Byrd *et al*. [23], who reported 2000-2500 µS/cm, and Millam *et al*. [24], reported 166.95±1.44 to 1024±2.828 µS/cm. Notably, although the conductivity values of the investigated energy drinks reported in the current study are higher than some reported results elsewhere, the results obtained in this study are equally lower than some of those reported elsewhere. In this consideration, the low conductivity values obtained in this study may be attributed to the water used for the preparation of the energy drinks. Furthermore, it could be attributed to the low concentrations of cyanocobalamin and mobile ions from other ingredients in the studied energy drinks. As a common scientific fact, when water contains a lot of impurities, it is more conductive; however, if water is pure, it is less conductive unless the water is polarized [2, 20]. Hence, energy drinks' ability to conduct electricity may be due to the presence of mobile ions, derived partly from water and partly from the dissolved chemical substances they contain. Conspicuously, therefore, the conductivity of energy drinks may depend largely on the state of purity of water used in mixing the components of energy drinks during their production, the types, and the amount of dissolvable solute chemical ingredients contained in them [2].

Table 2 Results of Cyanocobalamin in the Investigated Energy Drinks

Results of A Total of 1, 295 Energy Drinks Were Investigated					
Energy Drink	Total	Colour	Conductivity Range ($\boldsymbol{\mu S/cm}$)	Range of Conc. of Cyanocobal. (mg/L)	% of Rel. Uncert.
EDMN	370	Colourless/Amber	$1.14x10^{-3}$ - $4.52x10^{-3}$	0.0180 -0.0085±0.001	5.6-11.8
EDMSA	185	Colourless/Amber	$1.22x10^{-3}$ - $4.53x10^{-3}$	0.0020-0.0096±0.001	10.42-50
EDMGH	185	Colourless/Amber	$1.23x10^{-3}$ - $4.50x10^{-3}$	0.0026-0.0070±0.001	14.29-38.46
EDMUSA	185	Colourless	$1.26x10^{-3}$ - $4.59x10^{-3}$	0.0015-0.0060±0.001	16.7-66.7
ENDMCA	185	Colourless	$1.24x10^{-3}$ - $4.55x10^{-3}$	0.0022-0.0065±0.001	15.38-45.45
ENDMUK	185	Colourless	$1.28x10^{-3}$ - $4.57x10^{-3}$	0.0018-0.0056±0.001	17.86-55.6

The results obtained in this study show that the concentrations of cyanocobalamin in the different brands of the investigated energy drinks were low and are within the recommended daily amount of 2.4 micrograms (or 0.0024 mg/L) of vitamin-B12 for adults recommended by the US FDA and (10 µg (or 0.01 mg/250 ml) recommended by the Nigerian National Agency for Food and Drug Administration and Control [2, 25]. Although the results obtained in the current study are in agreement with those reported by Idongesit *et al*. [2], the relative uncertainty percentage reported here is somewhat lower than in other studies. In general, our results obtained in the present work point to a low prevalence of cyanocobalamin (synthetic vitamin-B12) in all the brands of energy drink products examined. Many of the brands' formulations contained well below and within the recommended daily value of 2.4 µg/day of vitamin-B12 reported by Jagim et al. [10], 50–150 micrograms daily of cyanocobalamin tablets reported in [2], and 120 % daily allowance (RDA) of B12 in a typical 250 mL can of energy drink reported by Yunusa and Ahmad [26].

More importantly, it is interesting to note that the National Agency for Food and Drug Administration and Control recommends adding no more than 10 µg of cyanocobalamin (vitamin B12) to formulated caffeinated beverages [25], and all the results obtained in the current study fall within that range. Although at the moment there is no internationally

agreed and specified quantity of cyanocobalamin to be added to a specific quantity or volume of energy drink, and in addition, the United States Department of Agriculture (USDA) or other chemical regulatory agencies have not disclosed the precise concentration of cyanocobalamin (vitamins B12) to be used or added to a specific quantity (250 or 500 mL) of energy drinks, as such data of cyanocobalamin, specifically for energy drinks, are not widely available to critically compare our results with, except the daily amount or allowance of vitamin-B12 levels of previous studies in the literature, hence that is the only available information that this investigation results are being compared.

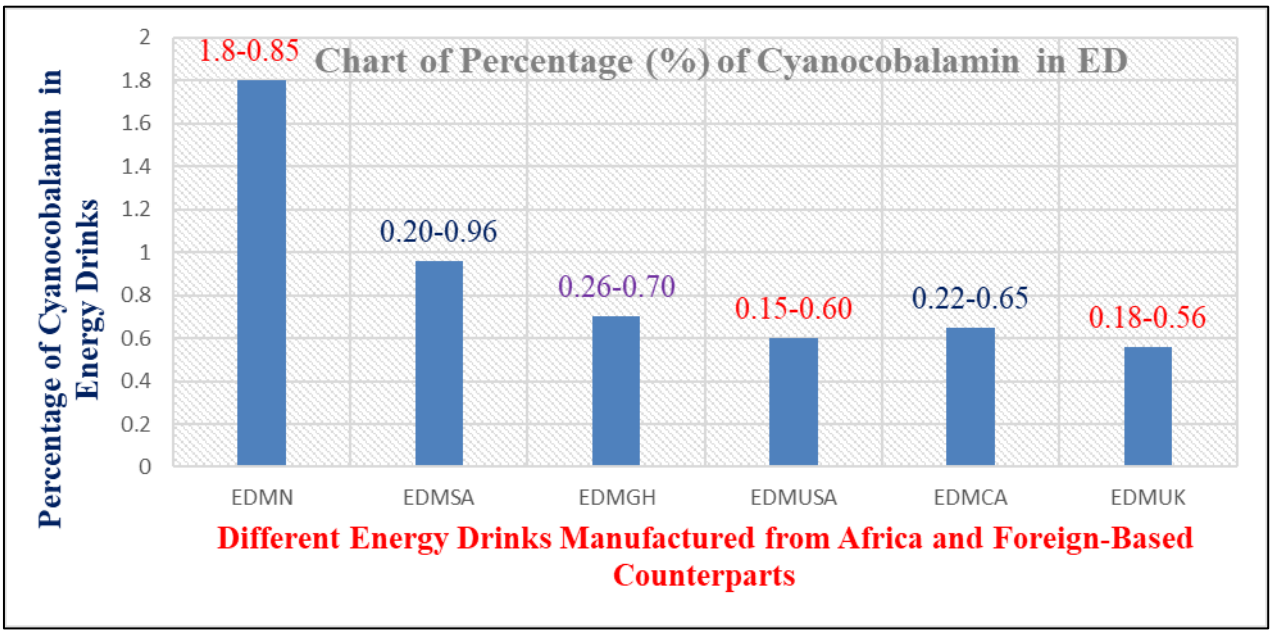

Figure 1 Chart of the Range of Percentage of Cyanocobalamin in Each Energy Drink

Table 3 Results of pH of Energy Drinks and Percentage Concentration of Cyanocobalamin

Energy Drink	pH Range	% Cyanocobalamin in ED
EDMN	4.95-6.22	1.8-0.85
EDMSA	4.92-6.40	0.20-0.96
EDMGH	5.0-6.35	0.26-0.70
EDMUSA	4.80-6.34	0.15-0.60
EDMCA	4.81-6.30	0.22-0.65
EDMUK	4.75-6.25	0.18-0.56

The results of the pH of the studied energy drinks show that the pH of all the energy drinks fall within the acidic pH, ranging from 4.95-6.22 for those manufactured in Nigeria (EDMN), 4.92-6.40 for those

Manufactured in South Africa (EDMSA), 5.0-6.35 for those manufactured in Ghana (EDMGH), 4.80-6.34 for the energy drinks manufactured in the United States of America (EDMUSA), (4.81-6.30) for those manufactured in Canada (EDMCA), and (4.75-6.25) for energy drinks manufactured in the United Kingdom (EDMUK). Meanwhile, the pH results obtained for the energy drinks investigated in this study are higher than (3.43 ± 0.01) for Red Bull, (2.82 ± 0.00) for the 5-Hour Energy drink, (3.35 ± 0.00) for Monster Energy Drink, and (2.74 ± 0.01) for Rockstar Energy Drink, as reported by Reddy *et al.* [27]. Also, the results of pH obtained in the present study are higher than those of (3.3 -3.5), for Red Bull energy drinks, (2.7-3.1) for Monster Energy Drinks, and 2.9 for Rockstar energy drinks reported by MōD Energy [28]. Furthermore, the pH results of this are higher than (3.81 ± 0.21) for Red Bull, achieved by Pinto *et al.* [29], (2.81), for 5-Hour Energy drink acquired by Yildirim [30], (3.35 ± 0.00), and (3.5 - 4.5), Monster Energy Drinks reported by Sugarmaroon [31].

Fundamentally, the high pH values obtained in the present study may be attributed to the batch of production, raw materials utilized, storage conditions, and, equally, the current efforts by manufacturers of energy drinks to reduce the acidity of manufactured products, which has been reported to cause dental erosion or erosion of the dentine surface [2, 27, 29]. Essentially, one of the most important aspects of these results is that all the pH values of the energy drinks obtained in the current work fall within the minimally erosive pH (pH ≥ 4.0), considering the values reported by [2, 27, 29]. Importantly, it is necessary to assert that the pH range of (4.80 to 6.20) is what is infrequently recommended as the best pH for energy drinks that could prevent tooth and enamel erosions, and the obtained results in this study are within that recommended pH range [2].

3.1 Results of FITIR Analysis of Energy Drink Samples

The FTIR spectra of the two energy drinks shown in Figures 2.0 and 3.0 have somewhat revealed the presence of cyanide in the energy drinks with the C≡N stretching bands centered at 2124 cm^{-1} in Figure 2.0 and at 2098 cm^{-1} in Figure 3.0, respectively. The stretching bands within the region of 2200 to 2100 cm^{-1} are usually associated with the occurrence of cyanide bond (C≡N). Meanwhile, since the peaks on each of the FTIR spectra of the energy drinks occurred around 2124 cm^{-1} and 2098 $cm^{-1,}$ respectively, it may indicate the presence of cyanide ions ($C\equiv N^-$) in the drinks, as cyanide groups exhibit strong and sharp absorption bands in the vibrational spectra between 2200 and 2100 cm^{-1} [2].

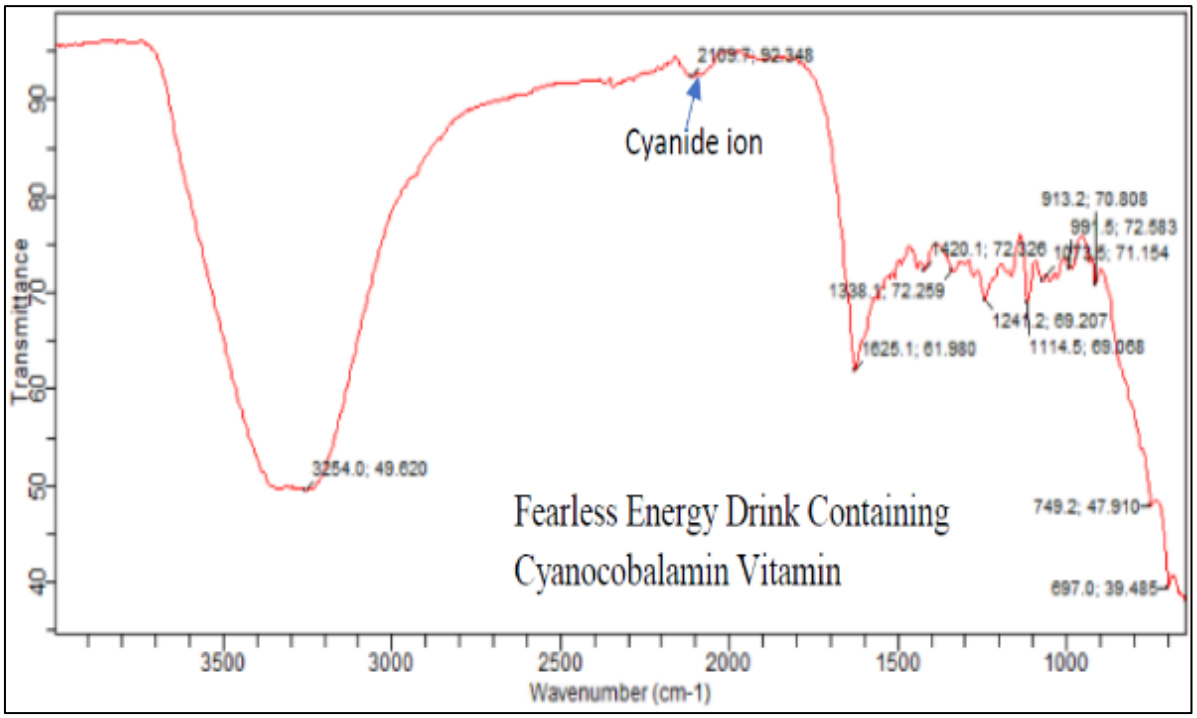

Figure 2 FTIR Spectrum of Fearless Energy Drink (FEARLESS_12-3-2024T2-41-49PM.a2r) Showing the Presence of Cyanide Ion (Idongesit *et al*., 2024)

Interestingly, in all the investigated energy drinks, the peak is observed to occur within the sharp absorption bands in the vibrational spectrum range of 2098 and 2124 cm^{-1}. This may probably suggest that all the investigated energy drinks contain the cyanocobalamin chemical component. Furthermore, while significant absorption bands at 3268.9 cm^{-1}, 2981.9 cm^{-1}, 2124.6 cm^{-1}, 1628.8 cm^{-1}, and 1420.1 cm^{-1} in Figure 3 may indicate the stretches for these function groups -OH, C-H, CN-, C=O, and $-NH_2$ respectively, the absorption bands at 1319.5 cm^{-1}, 1080.9 cm^{-1}, and 1043.7 cm^{-1} may indicate C-H bending, C-O stretching, and C-O-C stretch, respectively [2]. Similar to this, the Fearless FTIR spectrum in Figure 4 reveals other notable absorption bands at 3254 cm^{-1}, 2109.7 cm^{-1}, 1625.1 cm^{-1}, 1420.1 cm^{-1}, 1338.1 cm^{-1}, 1241.2 cm^{-1}, 1114.5 cm^{-1}, 1073.5 cm^{-1}, 913.2 cm^{-1}, 749.2 cm^{-1}, and 697 cm^{-1}. The simple explanation for these absorption bands is that the stretches at 3254 cm^{-1}, 2109.7 cm^{-1}, 1625.1 cm^{-1}, 1420.1 cm^{-1}, and 1338.1 cm^{-1} might represent the presence of CO-NH, C≡N, C=O, C-F, and C-O bonds, respectively, in the energy drink [2].

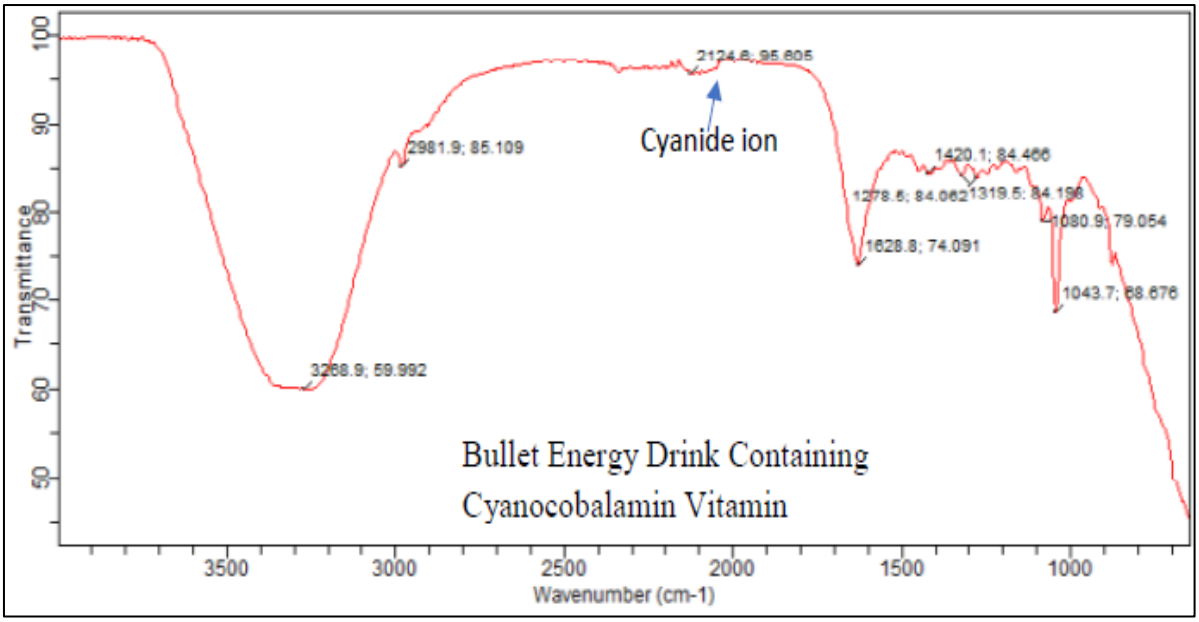

Figure 3 FTIR Result of Bullet Energy Drink (BULLET_12-3-2024T2-46-57 PM.a2r) Showing the Presence of Cyanide Ion (Idongesit *et al*., 2024)

4 Conclusion

The results of this study have shown that all the energy drinks manufactured in Africa and those produced outside the shores of the African continent undoubtedly contained cyanocobalamin, but in reasonably low concentrations in the range of (0.0015-0.0180±0.001), with some of the brands containing far below the US FDA and NAFDAC recommended permissible limits. Furthermore, although the foreign-based brands of the energy drinks seem to have better physical qualities, in terms of conductivity and pH, in general, all the African-based and the foreign brands of the energy drinks have good physicochemical properties in line with the standard recommended limits. Meanwhile, even with the low concentration of cyanocobalamin in the investigated energy drinks, excessive doses or concentrations of the chemical taken either as supplements or through daily consumption of high quantities of energy drinks could cause a build-up of the chemical with an increase of cyanide ions in the human body, which may result in certain health challenges. Nevertheless, if energy drinks are consumed with caution, the extent of the harmful effects of the chemicals on human health can be reduced owing to the low concentration of the chemicals in the energy drinks [2].

However, unfortunately, as reported by a group of researchers, it is clear that from 2003 to 2016, the prevalence of energy drink consumption among young adults increased significantly from 0.5 % to 5.5 % [2, 10], and it was unquestionably anticipated that this alarming consumption rate pattern had risen to 12.5 % by the end of the year 2025. Therefore, videos, lectures, and posts strongly denouncing cyanocobalamin as a chemical that causes mortality and criticizing energy drink producers for adding the chemical used in nuclear stations to their products have likely been posted on social media due to the high rate of energy drink consumption. Nonetheless, it has been reported that only 6 micrograms of vitamin B12 (cyanocobalamin) may be absorbed by the human body, accounting for only 0.12 mg of cyanide, whereas 100–200 mg is a deadly dose of cyanide [32,33]. In that, taking into account the highest cyanocobalamin value found in this study (0.0096±0.001 mg/L), a significant correlation is that 250 mL of energy may contain roughly 0.00237 mg of cyanocobalamin and only contribute a negligible amount of 0.0000475 mg of cyanide to the body. This indicates that "consumers should not be concerned about cyanide in vitamin-B12 used to make energy drinks and supplements [34,35], as our results and the above analysis indicate that the amount of cyanide that the human body can absorb is quite negligible. Therefore, there is no reason for people to worry about cyanide in cyanocobalamin (vitamin-B12) used to manufacture energy drinks and supplements [34], as reports have expounded in addition that the safety of cyanocobalamin has been established for most people and is supported by evidence from various trusted medical research sources.

Compliance with Ethical Standards

Disclosure of Conflict of Interest

The authors declare no conflicts of interest during and after the execution of this research work.

Statement of Ethical Approval

Since the names of the investigated energy drink products and their manufacturing companies are concealed, no consent or ethical approval was obtained for the brands of energy drinks used in this work.

Data Availability

All data generated and used in this study will be made readily available to any individual researcher, manufacturer, or organization upon reasonable and proper demand.

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Authors' Contribution

- Idongesit, Nnammonso Akpan designed the research topic, drafted, typeset, edited, and developed the research paper, and further played the role of the supervisory researcher of the team.
- Lawn, Yilkura, coordinated the laboratory analysis work, data analysis, and interpretations of the established results. Also, Lawn, Yilkura further read-proofed the final copy of the manuscript.
- Umar, Lawan Mai also actively took part in the laboratory analysis work, data analysis, and interpretations of the presented results. He further computed the data of analyses results.
- Onwoke, Ebibi Elijah coordinated the purchase of energy drink samples from different states and geopolitical zones of the country, took an active part in the laboratory analysis work, and also provided the statistical tools used for data analysis.

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