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# MICROBIOLOGICAL, CHEMICAL, AND ELECTRO-PHYSICAL PROFILING OF A LOCALLY PRODUCED ENERGY DRINK "SOKUDAYE"

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**ABSTRACT**
This study aimed to evaluate the safety of the locally produced energy drink "Sokudaye." The objectives were to investigate microbial contamination, heavy metal and mineral content, and the physicochemical properties of the drink. Laboratory analyses were conducted to assess bacterial presence, concentrations of lead, mercury, copper, sodium, phosphorus, and nitrogen, as well as physicochemical properties and electrical resistivity. The drink was found to be acidic and contaminated with pathogenic bacteria and heavy metals, particularly lead and mercury above permissible limits, alongside abnormal mineral content and electrical resistivity variations. The results indicate that "Sokudaye" poses significant health risks due to microbial and chemical contamination, emphasizing the need for improved production oversight and public health interventions.

**Keywords:** Assessment, Bacteria, Electrical Resistivity, Energy Drink, Mineral Element.

## INTRODUCTION

Energy-boosting drinks have gained significant popularity in recent years, leading to an alarming rate of use among people. Energy drinks are still frequently consumed by people even though a number of reports have shown that they have negative health impacts (Costantino et al., 2023; Mahmood *et al*., 2024). Consumers of energy drinks claimed to enjoy the refreshing supply of alertness and a quick boost in physical and cognitive performance (Alsunni, 2015). Many energy drinks include natural ingredients like guarana, ginseng, and taurine, in addition to significant amounts of caffeine and sugar (Alsunni, 2015; Bigot *et al*., 2019). Aonso-Diego *et al.* (2024) reported global consumption of energy drinks to be high, particularly among adolescents and young adults. The consumption of energy drinks has increased significantly in past years, with a growing market that is estimated to reach $61 billion by 2021 worldwide (Piccioni *et al.*, 2021).

Energy drinks are in high demand in the market, hence the production of various types of branded energy drinks. Products marketed as energy drinks are adulterated due to their strong demand. Given the well-known effects of caffeine as a stimulant of the central nervous system, some manufacturers counterfeit goods marketed as energy drinks and sell them to consumers. One such beverage is "Sokudaye," a traditional energy drink valued in several African nations, including Benin, Niger, Nigeria, and Cameroon, for its energizing properties. This drink is characterized as a nonpolar, pungent, and volatile liquid. According to the producers, "Sokudaye" is formulated using a blend of petroleum-derived solvents, along with various substances such as tramadol and caffeine, and is sweetened with a variety of sugars. This drink has been reported to contain heavy chemicals of known toxicity effects (Bigot *et al.*, 2019). "Sokudaye" chemical constituents are not declared on labels, and the safety regulations for this product are not properly enforced. Less-educated consumers purchase the energy drink due to the lowest prices and easily accessible outlets. In Nigeria, this drink is popularly known as "sokudaye" or "sokudalaye" among the Southerners and "Yangaria" or "Gangaria" among the Northerners. The sale of this regionally manufactured energy drink is common at motor parks and garages. The consumption of "sokudaye" continues to rise among primary and secondary school students, despite public warnings regarding its detrimental effects. This trend is believed to contribute to an increase in criminal activities and other vices among children and adolescents. Research has shown that the impact of "sokudaye" on young individuals is rapidly becoming a significant threat, not only to their well-being but also to the broader society (Vanguard, 2019). To the best of our understanding, multidisciplinary safety assessment of this locally produced energy drink has been less reported. This research focuses on evaluating the safety of the "Sokudaye" drink by isolating and identifying microorganisms, analyzing its mineral content, and measuring its electrical resistivity.

## MATERIALS AND METHODS

### Sample collection

Eight samples of the locally produced energy drink "Sokudaye" were obtained from different vendors within the Abeokuta metropolis, Abeokuta, Ogun State, and kept in 20 mL sterile glass containers. The pH levels and temperatures of the samples were measured at the time of purchase using a HANNA pH/mV/Temperature Meter (Model HI 8424). The samples were labeled as S1-S8 and were brought to the laboratory.

### Isolation and Identification of Bacteria

Each sample underwent serial dilution with sterile distilled water serving as the diluent. One milliliter of the sample was transferred into a test tube containing ten milliliters of distilled water. Subsequently, utilizing a separate sterile pipette, one milliliter from this test tube was transferred into another test tube that already contained nine milliliters of distilled water, thereby creating dilutions of $10^{-2}$ and $10^{-3}$. A 0.1 mL of the diluted sample was then inoculated into nutrient and MacConkey media separately, employing the spread plate technique as described by Sarika *et al.* (2012). The media were incubated at 37 °C for a duration of 48 h.

**Identification and characterization of bacterial isolates**

Bacterial isolates were examined based on their morphological and biochemical characteristics, and identification was conducted in accordance with Bergey's Manual of Systematic Bacteriology (Holt, 1994). The microbiological identification process encompassed the Gram staining technique, motility assessment, observation of color or pigmentation on culture plates, and smell. Biochemical analyses included tests for oxidase, citrate utilization, catalase, indole, the methyl red test (MR), and Voges-Proskauer (VP).

**Assessment of Mineral Components**

The determination of mineral elements in the sample was conducted utilizing standard analytical techniques as outlined by A.O.A.C (2005). Each sample's ash was subjected to digestion by the addition of five mL of 2M HCl, followed by heating until dry on a heating mantle. An additional five mL of 2M HCl was then added, heated, and the mixture was filtered through Whatman No. 1 filter paper into a 100 mL volumetric flask. The resulting filtrate was subsequently diluted to the required volume with distilled water, sealed, and prepared for analysis using the flame photometer (JENWAY Model PFP7, Germany).

The concentration of each element was determined utilizing the following formula:

$$\%\text{Mineral element} = \frac{\text{Meter Reading(MR) x Slope x Dilution factor}}{1000} \quad (1)$$

**Phosphorus Determination**

The ash from each sample was treated with a 2M HCl solution, following the procedure outlined for mineral determination. A volume of 10 mL of the resulting filtrate was transferred into a 50 mL standard flask, to which 10 mL of vanadate-molybdate solution was added. The flask was then filled to the mark with distilled water, sealed, and allowed to stand for ten minutes to ensure complete development of the yellow color. The phosphorus concentration was determined by measuring the absorbance of the solution using a UV spectrophotometer (MODEL 752G, China) at a wavelength of 470 nm (A.O.A.C, 2005).

The percentage of phosphorus was calculated from using the formula:

$$\%\ \text{Phosphorus} = \frac{\text{Absorbance x Slope x Dilution factor}}{1000} \quad (2)$$

**Determination of Pb, Cu, Hg**

The ash digest from each sample, utilized for mineral content analysis, was transferred into a 100 mL volumetric flask and diluted to the mark with deionized water. This solution was then aspirated into the Buck 200 Atomic Absorption Spectrophotometer (AAS) via the suction tube. Each trace mineral element was examined at its specific wavelength, employing the appropriate hollow cathode lamps and the correct combination of fuel and oxidant, as outlined by A.O.A.C (2005). The readings obtained for each element were subsequently used for calculations, using the formula:

$$\%\ of\ mineral = \frac{ppm\ or\ mg/kg}{1000} \quad (3)$$

**Resistivity Measurement**

Samples were labeled D1–D8. Each of the samples was placed in the resistance box and then connected to the resistance meter via current and potential cables. The ambient temperature was kept at 20 °C to prevent fluctuations in temperature from influencing the electrical resistivity during the experiment (Barroso-Bogeat *et al.,* 2015). Electric current was injected into the drink samples through the current cables while the potential drop across the drink samples was measured with the aid of the potential cables. The resistance meter displays the value of the sample resistance R. The electrode system was chosen for the test because of its low polarization effects (Campanella & Davies, 1997), with slight modification. The resistance meter therefore displays the value of the resistance:

$$\rho = \mathrm{R}\,.\frac{\mathrm{A}}{\mathrm{L}} \quad (4)$$

**Statistical analysis**

Statistical analysis was conducted using IBM SPSS Statistics Version 25. Analysis of Variance (ANOVA) was applied to evaluate differences in electrical resistivity, microbial content, and elemental composition of the sample drinks. Where significant differences occurred, Tukey's Honestly Significant Difference (HSD) test was employed for post hoc comparison of means. Furthermore, correlation, regression, and curve fitting analyses were carried out to model and interpret the relationship between electrical resistivity and mercury (Hg) content, providing insights into the strength and nature of the association between these variables.

**RESULTS**

Table 1 presents the physicochemical properties of the energy drink samples, focusing on pH values and temperature measurements. These factors are critical for assessing the acidity and thermal stability of the drinks, both of which can affect flavour, shelf life, and potential health impacts. The pH values ranged from $3.98{\pm}0.07^{a}$ to $4.23{\pm}0.07^{a}$, confirming that all energy drink samples are acidic. Sample S3, with the highest pH of 4.23, is the least acidic, while S8, with the lowest pH of 3.98, is the most acidic. Temperature readings ranged from $25{\pm}0.47^{a}$ °C to $27.17{\pm}0.27^{e}$ °C. These variations may result from differing storage conditions or environmental factors at the time of testing.

**Table 1**: Physicochemical properties of the samples

| Sample Code | pH Value | Temp. (°C) |
|---|---|---|
| S1 | $4.08{\pm}0.04^{b}$ | $26.33{\pm}0.54^{c}$ |
| S2 | $4.07{\pm}0.07^{b}$ | $25.17{\pm}0.27^{ab}$ |
| S3 | $4.23{\pm}0.07^{a}$ | $27.0{\pm}0.47^{b}$ |
| S4 | $4.10{+}0.05^{d}$ | $26.33{\pm}0.27^{d}$ |
| S5 | $4.02{\pm}0.07^{a}$ | $25.00{\pm}0.47^{a}$ |
| S6 | $4.13{\pm}0.09^{c}$ | $26.67{\pm}0.27^{c}$ |
| S7 | $4.11{\pm}0.07^{d}$ | $26.38{\pm}0.27^{c}$ |
| S8 | $3.98{\pm}0.07^{a}$ | $27.17{\pm}0.27^{e}$ |

Table 2 presents the bacterial load of the energy drink samples, expressed as colony-forming units per milliliter (CFU/mL). Average bacterial counts from triplicate samples ranged from $1.1 \pm 0.07^{a} \times 10^{2}$ to $3.3 \pm 0.01^{d} \times 10^{2}$, and $0.7 \pm 0.11^{a} \times 10^{3}$ to $2.5 \pm 0.09^{a} \times 10^{3}$. Sample S8 recorded the highest bacterial load, with $3.3 \pm 0.01^{d} \times 10^{2}$ and $2.5 \pm 0.09^{a} \times 10^{3}$ CFU/mL, followed closely by Sample S6

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with 3.2 ± 0.51ᵃ x $10^2$ and 2.4 ± 0.36ᶜ x $10^3$ CFU/mL. The lowest bacterial count was observed in Sample S2, which showed 1.1 ± 0.07ᵃ x $10^2$ and 0.7 ± 0.11ᵃ x $10^3$ CFU/mL.

**Table 2**: Range (n=3) of colonies of bacteria isolated from the samples (CFU/mL)

| Sample Code | No of cell (CFU/mL) $10^2$ | $10^2$ |
|---|---|---|
| **S1** | 1.5 ± 0.03ᶜ | 0.9 ± 0.33ᵇ |
| **S2** | 1.1 ± 0.07ᵃ | 0.7 ± 0.11ᵃ |
| **S3** | 2.4 ± 0.01ᵃ | 1.6 ± 0.21ᶜ |
| **S4** | 1.8 ± 0.09ᵈ | 1.2 ± 0.14ᵃ |
| **S5** | 1.6 ± 0.21ᵇ | 1.1 ± 0.13ᵃ |
| **S6** | 3.2 ± 0.51ᵃ | 2.4 ± 0.36ᶜ |
| **S7** | 1.7 ± 0.22ᶜ | 1.3 ± 0.17ᵇ |
| **S8** | 3.3 ± 0.01ᵈ | 2.5 ± 0.09ᵃ |

The result in Fig. 1 below shows the percentage occurrence of different bacteria in the drink samples. *Staphylococcus aureus* had the highest percentage occurrence of 9 (50 %), followed by *Proteus mirabilis* 5 (28%) and *Pseudomonas aeruginosa* having the least occurrence 4 (22 %).

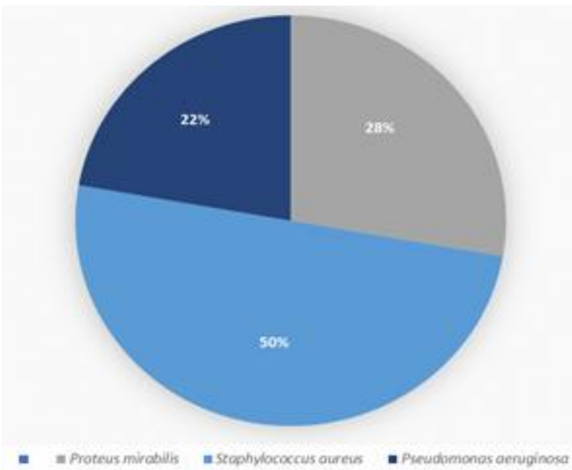


**Figure 1**: Percentage of occurrence of bacteria in the samples

The bacterial isolates were identified based on their morphological, Gram staining, and biochemical characteristics (Table 3). The first isolate, identified as *Staphylococcus aureus*, exhibited yellow, smooth, undulate, circular colonies and was Gram-positive cocci. It fermented glucose, sucrose, lactose, galactose, and fructose, and tested positive for catalase, methyl red, Voges-Proskauer, and citrate, while being non-motile, indole-negative, and oxidase-negative. The second isolate, *Proteus mirabilis*, appeared as white, translucent, smooth, irregular colonies and was a Gram-negative rod. It fermented glucose, xylose, and galactose, and showed positive results for urease, catalase, methyl red, motility, and citrate, but was negative for sucrose, lactose, fructose, indole, oxidase, and Voges-Proskauer. The third isolate, identified as *Pseudomonas aeruginosa*, formed white, smooth, circular, raised colonies and was also a Gram-negative rod. It fermented only glucose and fructose, and tested positive for catalase, oxidase, motility, and citrate, but was negative for most other sugar fermentations and biochemical tests including methyl red, indole, urease, and Voges-Proskauer. These results collectively support the identification of the isolates as *Staphylococcus aureus, Proteus mirabilis,* and *Pseudomonas aeruginosa*.

**Table 3:** Morphological and Biochemical Characteristics of Bacterial Isolates

| **Colonial morphology** | **Yellow, smooth undulate, circular** | **White, translucent, Smooth, irregular** | **White, smooth circular, raised** |
|---|---|---|---|
| **Gram reaction** | Gram positive cocci | Gram negative rod | Gram negative rod |
| **Glucose** | + | + | + |
| **Sucrose** | + | - | - |
| **Lactose** | + | - | - |
| **Xylose** | - | + | - |
| **Galactose** | + | + | - |
| **Catalase** | + | + | + |
| **Methyl red** | + | + | - |
| **Indole** | - | - | - |
| **Urease** | + | + | - |
| **Motility** | - | + | + |
| **Oxidase** | - | - | + |
| **Arabinose** | - | - | - |
| **Fructose** | + | NA | + |
| **Voges Proskauer** | + | - | - |
| **Spore** | - | - | _ |
| **Citrate** | + | + | + |
| **Probable organism** | *Staphylococcus aureus* | *Proteus mirabilis* | *Pseudomonas aeruginosa* |

NA: Not Applicable, +: Positive, -: Negative

As stated in the result in table 4 below, the samples analyzed exhibited varying concentrations of elements. Specifically, the lead concentration was found to range between 0.13 and 0.35 mg/L, while copper concentrations fluctuated from 0.03 to 0.19 mg/L. Mercury levels were observed to range from 0.01 to 0.05 mg/L. Sodium concentrations varied from 0.65 to 1.13 mg/L, phosphorus levels ranged from 0.93 to 1.27 mg/L, and nitrogen content was found to vary between 0.52 and 0.94 mg/L

**Table 4**: Heavy Metal and Mineral Concentration (mg/L).

| Sample | Pb | Cu | Hg | Na | P | N |
|---|---|---|---|---|---|---|
| **S1** | 0.18 | 0.08 | 0.005 | 0.89 | 1.13 | 0.61 |
| **S2** | 0.29 | 0.14 | 0.009 | 0.96 | 1.19 | 0.82 |
| **S3** | 0.21 | 0.06 | 0.003 | 0.82 | 1.05 | 0.56 |
| **S4** | 0.35 | 0.19 | 0.012 | 1.13 | 1.27 | 0.94 |
| **S5** | 0.19 | 0.16 | 0.006 | 0.92 | 1.08 | 0.63 |
| **S6** | 0.15 | 0.05 | 0.007 | 0.94 | 1.11 | 0.58 |
| **S7** | 0.21 | 0.11 | 0.005 | 0.73 | 1.09 | 0.77 |
| **S8** | 0.13 | 0.03 | 0.001 | 0.65 | 0.93 | 0.52 |

The resistivity values of the drink samples, as presented in Table 5, varied between 6.85 x $10^{-8}$ and 8.11 x $10^{-8}$ Ω.m. The findings reveal that the drink sample exhibiting the lowest resistivity value of 6.85 x $10^{-8}$ Ω.m corresponds to the least concentration of the analyzed elements (Pb = 0.13, Cu = 0.03, Hg = 0.001, Na = 0.65,

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P = 0.93, N = 0.52). Conversely, the sample with the highest resistivity value of 8.11 x $10^{-8}$ Ω.m contains the greatest concentration of the examined elements (Pb = 0.35, Cu = 0.19, Hg = 0.012, Na = 1.13, P = 1.27, N = 0.94). Additionally, drink samples with resistivity values ranging from 7.04 x $10^{-8}$ to 7.61 x $10^{-8}$ Ω.m displayed nearly uniform concentrations of the analyzed elements. Overall, the results suggest a trend of increasing element concentrations in conjunction with rising resistivity values of the drink samples.

**Table 5**: Resistivity (**Ω.m**) of sample "sokudaye" drink with some selected metallic and non-metallic elements (**mg/L**)

| Drink Sample | Electrical Resistivity | Pb | Cu | Hg | Na | P | N |
|---|---|---|---|---|---|---|---|
| **S1** | 7.56 x $10^{-8}$ | 0.18 | 0.08 | 0.005 | 0.89 | 1.13 | 0.61 |
| **S2** | 7.42 x $10^{-8}$ | 0.29 | 0.14 | 0.009 | 0.96 | 1.19 | 0.82 |
| **S3** | 7.10 x $10^{-8}$ | 0.21 | 0.06 | 0.003 | 0.82 | 1.05 | 0.56 |
| **S4** | 8.11 x $10^{-8}$ | 0.35 | 0.19 | 0.012 | 1.13 | 1.27 | 0.94 |
| **S5** | 7.40 x $10^{-8}$ | 0.19 | 0.16 | 0.006 | 0.92 | 1.08 | 0.63 |
| **S6** | 7.61 x $10^{-8}$ | 0.15 | 0.05 | 0.007 | 0.94 | 1.11 | 0.58 |
| **S7** | 7.04 x $10^{-8}$ | 0.21 | 0.11 | 0.005 | 0.73 | 1.09 | 0.77 |
| **S8** | 6.85 x $10^{-8}$ | 0.13 | 0.03 | 0.001 | 0.65 | 0.93 | 0.52 |

The results in table 6 below show the descriptive statistics of the sample drinks' resistivity and examined element content. The samples have minimum, maximum and mean resistivity values of 6.85 x $10^{-8}$ Ω.m, 8.11 x $10^{-8}$ Ω.m and 7.39 x $10^{-8}$ Ω.m with a standard deviation of 0.396. Similarly, for all the elements examined, the standard deviation ranged from 0.003 to 0.148. This indicates a small variation in the values observed, indicating consistent components making up the sample drinks.

**Table 6**: Descriptive statistics of resistivity (ρ) of sample drinks with content element.

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| **Resistivity(Ω.m)** | 8 | 6.85 x $10^{-8}$ | 8.11 x $10^{-8}$ | 7.39 x $10^{-8}$ | 0.396 |
| **Pb (mg/L)** | 8 | 0.130 | 0.350 | 0.214 | 0.073 |
| **Cu (mg/L)** | 8 | 0.030 | 0.190 | 0.103 | 0.057 |
| **Hg (mg/L)** | 8 | 0.001 | 0.007 | 0.006 | 0.003 |
| **Na(mg/L)** | 8 | 0.650 | 1.130 | 0.880 | 0.148 |
| **P (mg/L)** | 8 | 0.930 | 1.270 | 1.106 | 0.100 |
| **N (mg/L)** | 8 | 0.520 | 0.940 | 0.679 | 0.148 |

The analysis demonstrating the correlation between the element contents of the sample drinks and their resistivity ($\rho_{sd}$) is presented in Table 7. The sample drinks' resistivity ($\rho_{sd}$) correlated significantly with all element content examined at varying levels (85% - 99% confidence limits). As indicated in the result, the sample drinks' resistivity ($\rho_{sd}$) correlated positively and significantly with mercury, sodium, and phosphorus with correlation coefficients of r = 0.884**, 0.957**, and 0.877**, respectively, at the 0.01 level. This implies that the mercury, sodium, and phosphorus contents of the drinks significantly accounted for the drinks' resistivity ($\rho_{sd}$). This correlation results further indicate that as the mercury, sodium, and phosphorus contents of drinks increase, the drinks' resistivity also increases.

**Table 7**: Correlation of Resistivity (ρ) of local sample energy drinks with content element

| | | **Electrical Resistivity (ρ)** | | |
|---|---|---|---|---|
| **S/N** | **Element** | **Correlation Coeff., r** | **Sig. (2-tailed)** | **Remarks** |
| **1.** | Pb | 0.634 | 0.091 | significant correlation 0.15 level (90% confidence limit) |
| **2.** | Cu | 0.622 | 0.100 | significant correlation 0.15 level (85% confidence limit) |
| **3.** | Hg | 0.884** | 0.004 | significant correlation 0.01 level (99% confidence limit) |
| **4.** | Na | 0.957** | 0.000 | significant correlation 0.01 level (99% confidence limit) |
| **5.** | P | 0.877** | 0.004 | significant correlation 0.01 level (99% confidence limit) |
| **6.** | N | 0.603 | 0.113 | significant correlation 0.15 level (85% confidence limit) |

**:correlation is significant at 0.01 level

The result presented in Table 8 shows the summary of curve estimation analysis to determine the empirical relationship between the resistivity of the local energy drink and mercury (Hg) content. The results indicate that linear, logarithm, inverse, quadratic and cubic functions had better regression coefficients ($R^2$ = 0.782, 0.782, 0.780, 0.782, 0.782) compared to other functions.

**Table 8**: Summary of curve analysis of electrical resistivity and mercury (Hg) content

| | Model Summary | | | Parameter Estimates | | | |
|---|---|---|---|---|---|---|---|
| Equation | R² | F | Sig. | Const | b1 | b2 | b3 |
| Linear | 0.782 | 21.554 | .004 | -.051 | .008 | | |
| Logarithmic | 0.782 | 21.488 | .004 | -.108 | .057 | | |
| Inverse | 0.780 | 21.296 | .004 | .063 | - .423 | | |
| Quadratic | 0.782 | 8.981 | .022 | -.047 | .007 | 6.004 E-5 | |
| Cubic | 0.782 | 8.983 | .022 | -.046 | .007 | .000 | 5.002 E-6 |
| Power | 0.689 | 13.268 | .011 | 1.996 E-13 | 11.973 | | |
| Exponential | 0.674 | 12.390 | .013 | 3.905 E-8 | 1.590 | | |

Dependent Variable: Hg, Independent variable: Resistivity

The summary of curve estimation analysis to determine the empirical relationship between the resistivity of the local energy drink and sodium (Na) content indicates that linear, logarithm, inverse, quadratic and cubic functions had better regression coefficients ($R^2$ = 0.915, 0.920, 0.924, 0.925, 0.925) compared to other functions, as presented in Table 9.

**Table 9**: Summary of curve analysis of Electrical Resistivity and Sodium (Na) content

| | Model Summary | | | Parameter Estimates | | | |
|---|---|---|---|---|---|---|---|
| Equation | R² | F | Sig. | Const | b1 | b2 | b3 |
| Linear | 0.915 | 64.797 | 0.000 | -1.763 | .358 | | |
| Logarithm | .920 | 69.247 | .000 | - 4.462 | 2.673 | | |
| Inverse | .924 | 72.896 | .000 | 3.581 | -19.898 | | |
| Quadratic | .925 | 31.033 | .002 | - 6.637 | 1.667 | - 0.088 | |
| Cubic | .925 | 31.033 | .002 | - 6.637 | 1.667 | - 0.088 | 0.000 |
| Power | .898 | 52.897 | .000 | .002 | 3.069 | | |
| Exponential | .888 | 47.726 | .000 | .042 | .410 | | |

Dependent Variable: Na, Independent variable: Resistivity

The result presented in Table 10 below shows the summary of curve estimation analysis to determine the empirical relationship between the resistivity of the local energy drink and Phosphorus (P) content. The results indicate that linear, logarithm, inverse, quadratic and cubic functions had better regression coefficients ($R^2$ = 0.770, 0.774, 0.777, 0.776, 0.776) compared to other functions.

**Table 10**: Summary of curve analysis of electrical resistivity and phosphorus (P)

| | Model Summary | | | Parameter Estimates | | | |
|---|---|---|---|---|---|---|---|
| Equation | R² | F | Sig. | Const | b1 | b2 | b3 |
| Linear | .770 | 20.077 | .004 | -.528 | .221 | | |
| Logarithm | .774 | 20.513 | .004 | -2.195 | 1.652 | | |
| Inverse | .777 | 20.855 | .004 | 2.775 | -12.294 | | |
| Quadratic | .776 | 8.675 | .024 | -3.126 | .919 | -.047 | |
| Cubic | .776 | 8.675 | .024 | -3.126 | .919 | -.047 | .000 |
| Power | .761 | 19.100 | .005 | .055 | 1.501 | | |
| Exponential | .755 | 18.456 | .005 | .250 | .201 | | |

Dependent Variable: P, Independent variable: Resistivity

**DISCUSSION**

The outcome of the physicochemical analysis of the samples revealed that the pH of the samples was acidic, which decreased as the temperature increased. The "Sokudaye" drink is sold in thick glass bottles, exposed to sunlight, and absorbs energy from the sun, particularly infrared radiation. This absorption increases the kinetic energy of the alcohol molecules, raising the temperature of the liquid. The heat accelerates the oxidation of alcohol, leading to the formation of unpleasant compounds (Grant-Preece *et al.*, 2017; Králik *et al.*, 2024). These substances can lead to effects that vary from mild discomfort to significant health complications, contingent upon the degree of exposure and intake. According to Li *et al.* (2011) and Cederbaum (2012), the consumption of ethanol can result in negative effects that range from unpleasant sensations to severe illnesses. Additionally, the metabolic processes associated with ethanol produce harmful byproducts, such as free radicals and acetaldehyde, which contribute to oxidative stress and cellular damage (Moreno *et al.,* 2008; Boye, 2016). Akter *et al.* (2023) discovered that the pH level of alcoholic beverages is below the critical threshold of 5.5, which is necessary for the demineralization of tooth enamel. Studies by Reddy *et al.* (2016) further indicated that the regular consumption of acidic beverages can be detrimental to dental health. A total of eighteen bacterial strains were isolated from the samples, and the presence of bacteria from

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the genus *Proteus* in the sample renders it unsuitable for consumption due to the potential health risks and spoilage issues associated with these bacteria. *Proteus species* are known to cause food poisoning and are increasingly recognized for their antibiotic resistance, which poses significant public health concerns (Ma *et al*., 2022; El-Saeed *et al.,* 2024).

The origin of the water utilized in the production of this locally manufactured energy drink remains unidentified, posing a significant risk to consumer health. Two out of five well waters in Nigeria that were treated as drinking water had *Proteus* spp. found in them (Aboh *et al*., 2015). Detection of *Pseudomonas aeruginosa* in the drink is also of public concern. *P. aeruginosa* are able to endure and multiply in water, it can easily cause secondary contamination (Li *et al*., 2023). The presence of *Staphylococcus aureus* in the sample indicates contaminants primarily through human contact, such as poor hygiene by food handlers, contact with infected wounds, or respiratory secretions from carriers (Castro *et al.,* 2016). The presence of aciduric bacteria in the drink samples likely results from poor processing and handling practices, which can be attributed to a lack of compliance with, or enforcement of, public health regulations. These microorganisms are of particular concern in soft drinks, as they are well-adapted to survive and grow in acidic environments even in the presence of preservatives and carbon dioxide (Azeredo *et al*., 2016), highlighting the critical role of regulatory oversight in ensuring safety.

The World Health Organization (WHO, 2008) has established a maximum contaminant level for lead in drinking water at 0.015 mg/L. All analyzed samples, ranging from 0.13 to 0.35 mg/L, surpass this threshold, indicating a potential health hazard. The Environmental Protection Agency (EPA, 1985) has determined a maximum contaminant level for copper in drinking water to be 1.3 mg/L. The copper levels in the samples, which range from 0.03 to 0.19 mg/L, remain comfortably below this limit, suggesting no immediate health concerns. Additionally, both the WHO and the EPA have set the mercury limit in drinking water at 0.006 mg/L. However, the majority of the samples, with concentrations between 0.01 and 0.05 mg/L, exceed this limit, thereby presenting a significant health risk associated with mercury exposure. Lead and mercury levels are significantly above safe consumption limits, indicating serious contamination concerns.

For national comparison, the concentrations of heavy metals and sodium in the analyzed drink samples were evaluated against the Nigerian Industrial Standard (NIS 554:2015), established by the Standards Organization of Nigeria (SON, 2015). The lead content in the samples ranged from 0.13 mg/L to 0.35 mg/L, which significantly exceeds the permissible limit of 0.01 mg/L. Copper concentrations ranged from 0.03 mg/L to 0.19 mg/L, remaining within the acceptable limit of 1.0 mg/L for drinking water. However, the mercury content, ranging from 0.001 mg/L to 0.012 mg/L, exceeded the SON permissible limit of 0.001 mg/L. In contrast, sodium levels in all samples were relatively low, ranging from 0.65 mg/L to 1.13 mg/L, well below the maximum allowable limit of 200 mg/L. These findings highlight potential safety concerns, particularly with respect to lead and mercury contamination.
Meanwhile, the presence of sodium, phosphorus, and nitrogen in the alcoholic drink suggests health-compromising ingredients used in the production of the drink. These results imply that the energy drink tested may not be safe for consumption, particularly due to high lead and mercury levels, which can have severe health implications (Casimir *et al.,* 2014; Erdmann *et al*., 2021).

Electrical resistivity is a critical parameter in the analysis of alcoholic samples, it is a sign of their composition and purity. The unique electrical properties of solvents and solutes, such as ethanol and various impurities, affect how they interact with electrical currents (Barroso-Bogeat, 2021). The outcome sample that was tested suggests that the resistivity of the drink is very low; therefore, it could allow the conduction of electricity. The significant positive correlations between electrical resistivity and concentrations of Hg, Na, and P suggest that as the concentrations of these elements increase, the electrical resistivity of the samples also increases. The lower resistivity observed in correlation with lead and copper concentrations may be attributed to their levels exceeding the permissible limits, as electrical conductivity increases in the presence of free ions in solution (Gimba, 2014).
Few studies have examined the correlation between electrical resistivity and heavy metal concentrations in "Sokudaye", particularly the observed reduction in resistivity associated with the presence of lead and copper at levels exceeding permissible limits. This gap in the literature limits direct comparison with previous findings. However, the widespread and increasing consumption of this drink underscores the urgent need for this research to understand the potential public health risks associated with its consumption.

**Conclusion**
This present study investigates the safety of "sokudaye," a locally made energy drink, revealing high consumption rates despite known health risks. Findings indicate that the drink is acidic, contains harmful bacteria, and exceeds safe limits for lead and mercury, posing serious health risks to consumers. Additionally, low electrical resistivity suggests the potential for conductivity, further emphasizing contamination concerns.

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