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# Heavy Metal Analysis of Fruit Juice and Soft Drinks Bought From Retail Market in Accra, Ghana

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***Authors' contributions***

*This work was done in collaboration between all authors. Literature search and the first drafted manuscript were carried out by author HO. Authors MO and GA read the first draft of the manuscript. All authors read and approved the final manuscript.*

***Research Article***

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## ABSTRACT

**Aims:** To determine the levels of Cu, Fe, Pb, and Zn in fruit juice and soft drinks bought from retail markets in Accra as heavy metals contamination has become a matter of public health concern but this has not received much research attention in Ghana especially fruit juice and soft drinks contamination through heavy metals.
**Study Design:** The results obtained from the analysis were compared with WHO specifications of heavy metals in drinking water.
**Place and Duration of Study:** Food Chemistry Division of CSIR- Food Research Institute in Accra, Ghana between June and December 2012
**Methodology:** Twenty bottles comprising of fruit juice and soft drinks bought from retail markets in Accra, were analysed using the dry ashing method. Acid digestion was carried out during the sample preparation and Flame Atomic Absorption Spectrophotometer used to read the absorbance values at appropriate wavelength of the interested metal in the sample solution. The metal content of the samples were derived from calibration curves made up of minimum of three standards.
**Results:** The mean concentrations of heavy metals were in the order Fe>Zn>Pb>Cu for fruit juice and soft drinks. In the fruit juice samples analysed, the mean concentrations of heavy metals determined were 0.83±0.48 mg.L$^{-1}$, 9.07±3.62 mg.L$^{-1}$, 1.59±0.90 mg.L$^{-1}$,

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3.33±1.29 $mg.L^{-1}$ for Cu, Fe, Pb and Zn respectively whiles in the soft drink samples, the mean concentrations of heavy metals determined were 0.34±0.05 $mg.L^{-1}$, 7.72±3.12 $mg.L^{1}$, 0.72±0.99 $mg.L^{1-}$, 1.07±0.66 $mg.L^{-1}$ for Cu, Fe, Pb and Zn respectively.
**Conclusion:** The concentration of some of the heavy metals found in both fruit juice and soft drinks were above the safe limit recommended by WHO.

*Keywords: Heavy metals; fruit juice; soft drinks; public health; WHO.*

## 1. INTRODUCTION

Fruit juice and soft drinks are the usual beverages used in most festivities and celebrations in Ghana. These celebrations include Marriages, Weddings, Naming of babies and Funerals. In most offices and homes, fruit juice and soft drink is served as lunch with addition of pastries or biscuit and sometimes bread. Fruit juices that found themselves in the retail markets are mostly derived from citrus fruits. After expression in a reamer the juice is strained, flash pasteurized, filled into bottles and sealed [6]. Soft drinks, also called ready-to-drink beverages are sweetened water-based non-alcoholic beverages, mostly with balanced acidity [3].The soft drinks are mostly carbonated usually prepared from a concentrated syrup containing sugar, fruit juice or flavouring essence, citric acid and preservative (sodium benzoate). Benzoic acid is commonly used as preservative [6].

As a result of the soil, atmosphere, underground and surface water pollution, our foods and beverages are contaminated with heavy metals [5]. Some essential metals are involved in numerous biochemical processes and adequate intake of certain essential metals relates to the prevention of deficiency diseases. Iron (Fe) deficiency anemia for instance affects one third of the world population. On the other hand, excessive iron intake has been associated with an overall increase risk of colorectal cancer [8]. Copper (Cu) and zinc (Zn) are essential metals which perform important biochemical functions and are necessary for maintaining health throughout life. Zn constitutes about 33 ppm of adult body weight and is essential as constituent of many enzymes involved in number of physiological functions, such as protein synthesis and energy metabolism. Zn deficiency, resulting from poor diet, alcoholism and malabsorption, causes dwarfism, hypogonadism and dermatitis, while toxicity of Zn due to excessive intake may lead to electrolyte imbalance, nausea, anemia and lethargy [7]. Adult human body contains about 1.5-2.0 ppm of Cu which is essential as a constituent of some metalloenzymes and is required in haemoglobin synthesis and in the catalysis of metabolic oxidation. Symptoms of Cu deficiency in humans include bone demineralization, depressed growth, depigmentation and gastro-intestinal disturbances, among others, while toxicity due to excessive intake has been reported to cause liver cirrhosis, dermatitis and neurological disorders [9]. Lead and cadmium are two potentially harmful metals that have aroused considerable concern [2]. Impairment related to lead toxicity in humans includes abnormal size and haemoglobin content of the erythrocytes, hyperstimulation of erythropoiesis and inhibition of haeme synthesis [10].

Heavy metals contamination has become a matter of public health concern but this has not received much research attention in Ghana especially fruit juice and soft drinks contamination through heavy metals. In the present study, levels of Cu, Fe, Pb, and Zn of fruit juice and soft drinks bought from retail markets in Accra, Ghana between June and December 2012 were determined using Buck Scientific Flame Atomic Absorption Spectrophotometer (FAAS).

## 2. MATERIAL AND METHODS

Twenty bottles comprising of ten fruit juice and ten soft drinks were bought from retail markets in Accra between the month of June and December 2012. Accra occupies an area of 200 $km^2$ and lies between latitudes 5º-32$^{l}$ and latitude 0º-14$^{1}$ with total population of about 3.9 million.

For acidity analysis, 20 mL of juice and soft drink samples was allowed to rest for 24 hours to allow its gases evaporated.10 mL of juice or soft drink was titrated with 0.1 Molar NaOH, using phenolphthalein indicator [1].

$$\text{Calculation: X\% acidity} = \frac{\text{Titre x factor (0.007 gm citric acid) x 100}}{\text{Volume}}$$

The citric acid (monohydrate) content was calculated as % $w.v^{-1}$. 1 mL of 0.1 Molar NaOH = 0.007003 gm citric acid (monohydrate).

The dry ashing method was used in the present study for AAS analysis [1]. All glassware's were washed with 1% nitric acid followed by demineralised water. 20 mL of soft drink was allowed to rest for 24 hours to allow its gases evaporated whiles the fruit juice was homogenously mixed before samples were taken for analysis. 5 mL of sample was measured into platinum crucibles. The samples were evaporated on hot plate till dryness. The crucible and the test portion were placed in the Muffle furnace at a temperature 550ºC for 8 hours. The crucible with ash was put in desiccator to cool. 5 mL of nitric acid of mass fraction not less than 65 %, having a density of approximately ρ ($HNO_3$) = 1 400 $mg.mL^{-1}$ was added, ensuring that all the ash came into contact with the acid and the resultant solution heated on hot plate until the ash dissolved. 10 mL of 0.1 $mol.L^{-1}$ nitric acid was added and filtered into 50 ml volumetric flask. The resultant solution was top up to the mark with 0.1 $mol.L^{-1}$ nitric acid. Blank solution was treated the same way as the sample. Buck Scientific 210VGP Flame Atomic Absorption Spectrophotometer (Buck Scientific, Inc. East Norwalk, USA) was used to read the absorbance values at appropriate wavelength of the interested metal in the sample solution. Cathode lamps used were Cu (wavelength 324.8 nm, lamp current 1.5 mA), Fe (wavelength 248.3 nm, lamp current 7.0 mA), Pb (wavelength 217.0 nm, lamp current 3.0 mA), and Zn (wavelength 213.9 nm, lamp current 2.0 mA). Air/Acetylene gas was used for all the analysis. The metal content of the samples were derived from calibration curves made up of minimum of three standards with a minimal values of determination coefficient ($R^2$ ) of Cu, Fe, Pb, and Zn standard curves being 1.00, 0.99, 0.98 and 0.99 respectively. Standard solutions were prepared using spectrochemical grade metal solution from BDH.

## 3. QUALITY CONTROL

As part of quality control measure to ensure reliability of results, samples were handled carefully to avoid contamination. The recovery test of the total analytical procedures was also carried out for the metals analysed in the selected samples by spiking analysed samples with aliquots of metal standards and then reanalyzed the samples. Acceptable recoveries of 97±1%, 95±1%, 94±1%, 94±1% were obtained for Cu, Pb, Fe and Zn respectively.

## 4. RESULTS AND DISCUSSION

The mean acidity and mean concentrations of some heavy metals, copper, iron, lead and zinc in fruit juice and soft drinks are presented in Table 1.

Each result represents the mean for 10 samples each of fruit juice and soft drinks analyzed. The data obtained indicated that concentrations of heavy metals are depended on the type of drink analyzed. One way ANOVA test conducted, revealed that there were no statistical differences in acidity between the fruit juice and the soft drinks analysed ($P \le 0.05$).

However mean concentrations of copper and zinc between fruit juice and soft drinks analysed was significantly different whiles the difference in mean concentrations of iron and lead between fruit juice and soft drink analyzed was insignificant at $P \le 0.05$. In the fruit juice samples analysed, the mean concentrations of heavy metals determined were 0.83±0.48 $mg.L^{-1}$, 9.07±3.62 $mg.L^{-1}$, 1.59±0.90 $mg.L^{-1}$, 3.33±1.29 $mg.L^{-1}$ for Cu, Fe, Pb and Zn respectively whiles in the soft drink samples, the mean concentrations of heavy metals determined were 0.34±0.05 $mg.L^{-1}$, 7.72±3.12 $mg.L^{1}$, 0.72±0.99 $mg.L^{1-}$, 1.07±0.66 $mg.L^{-1}$ for Cu, Fe, Pb and Zn respectively. The order of heavy metals concentrations in terms of magnitude was Fe>Zn>Pb>Cu for fruit juice and soft drinks. In general, the mean concentration of Fe was the highest with Cu having the least mean concentration in both fruit juice and soft drink samples analysed.

The maximum concentration of lead detected in fruit juice and soft drink were 1.75 $mg.L^{-1}$ and 2.78 $mg.L^{-1}$ respectively which are far above the safe limit of 0.01 $mg.L^{-1}$ recommended by WHO; According to Venugopal and Luckey [10], lead toxicity is associated with abnormal size and haemoglobin content of the erythrocytes, hyperstimulation of erythropoiesis and inhibition of haeme synthesis. The high concentrations of lead in the samples analysed could be coming from the metallic containers used in preparation of fruit juice and soft drinks and also from the soil where the plants bearing the fruits are grown due to dumping of domestic and industrial waste. WHO has recommended a safe limit of 0.3 $mg.L^{-1}$ for iron in drinking water and 10-50 mg per day of iron as daily requirement for humans depending on age, sex, physiological status and iron bioavailability [4]. The maximum iron concentration determined in both fruit juice and soft drink was 11.62 $mg.L^{-1}$ and 13.41 $mg.L^{-1}$ respectively which are highly above the safe limit recommended by WHO ie 0.3 $mg.L^{-1}$ [11] but these concentrations fall within the 10-50 mg per day as iron requirement for human body depending on age, sex, and iron bioavailability. Copper and zinc are essential trace metals according to Ma et al. [7], and the maximum concentration of copper determined was 1.61 $mg.L^{-1}$ for fruit juice and 0.77 $mg.L^{-1}$ for soft drink samples which are within the safe limit set by WHO ie 3 $mg.L^{-1}$ [11]. The copper level in both fruit juice and soft drink samples do not pose a threat to public health. The maximum concentration of zinc determined was 6.03 $mg.L^{-1}$ and 2.06 $mg.L^{-1}$ in fruit juice and soft drinks respectively which fall in the 10 – 75 $mg.L^{-1}$ limit set by WHO which is also not a threat to public health.

**Table 1. Mean concentrations of heavy metals and acidity during the study period**

| | | Concentration of heavy metals in mg.L$^{-1*}$ | | | |
|---|---|---|---|---|---|
| **Type of drink** | **% Acidity** | **Cu** | **Fe** | **Pb** | **Zn** |
| Fruit juice | 0.61±0.27* | 0.83±0.48* | 9.07±3.62* | 1.59±0 .90* | 3.33±1.29* |
| Soft drink | 0.43±0.06* | 0.34±0.05** | 7.72±3.12* | 0.72±0 .99* | 1.07±0.66** |

*Results are presented as mean ± standard deviation for 10 determinations of fruit juice and 10 determinations soft drink over the study period.*
**Superscripts to figures in the same column represent significant or insignificant differences at P≤0.05 (ANOVA, Duncan test P≤ 0.05).*

Table 2 shows the variations in the concentration of heavy metals determined from fruit juice and soft drink samples bought from the retail market in Accra from June to December 2012. The concentration of Cu, Fe, Pb and Zn were in the range 0.41-1.61, 3.09-11.62, 0.25-1.75 and 1.82-6.03 mg.L$^{-1}$ respectively for fruit juice samples whiles the concentration of Cu, Fe, Pb and Zn were in the range 0.33-0.77, 5.68-13.41, 0.00-2.78 and 0.42-2.06 mg.L$^{-1}$ respectively for soft drink samples.

**Table 2. Variations in the concentration of heavy metals in mg.L$^{-1}$ of fruit juice and soft drinks from retail markets in Accra, Ghana**

| | | Concentration of heavy metals in mg.L$^{-1*}$ | | | |
|---|---|---|---|---|---|
| **Type of drink** | **% Acidity** | **Cu** | **Fe** | **Pb** | **Zn** |
| Fruit juice | 0.78±0.08$^{ab}$ | 0.49±0.06$^{b}$ | 8.05±0.18$^{a}$ | 1.75±0.64$^{c}$ | 1.82±0.52$^{b}$ |
| Fruit juice | 0.82±0.03$^{b}$ | 1.61±0.06$^{d}$ | 11.62±0.62$^{b}$ | 1.57 ±0.51$^{d}$ | 4.56±0.05$^{d}$ |
| Fruit juice | 0.74±0.05$^{a}$ | 1.00±0.20$^{c}$ | 10.24±1.58$^{c}$ | 1.72±0.12$^{c}$ | 4.86±0.38$^{cd}$ |
| Fruit juice | 0.57±0.11$^{c}$ | 0.88 ±0.04$^{a}$ | 4.86±0.21$^{df}$ | 1.47±0.12$^{b}$ | 6.03±1.27$^{c}$ |
| Fruit juice | 0.13±0.03$^{d}$ | 0.41±0.01$^{b}$ | 3.09±0.21$^{d}$ | 0.25±0.13$^{a}$ | 2.92±0.21$^{b}$ |
| Soft drink | 0.44±0.01$^{e}$ | 0.42±0.06$^{b}$ | 6.09±0.98$^{e}$ | ND$^{a}$ | 0.73 ±0.33$^{a}$ |
| Soft drink | 0.46±0.12$^{e}$ | 0.35±0.08$^{b}$ | 5.88±0.69$^{ef}$ | ND$^{a}$ | 0.49±0.01$^{a}$ |
| Soft drink | 0.33±0.01$^{e}$ | 0.77±0.18$^{a}$ | 13.41±0.01$^{g}$ | ND$^{a}$ | 0.42±O.03$^{a}$ |
| Soft drink | 0.49±0.01$^{e}$ | 0.33±0.01$^{b}$ | 5.68±0.40$^{ef}$ | 1.4 9±0.13$^{b}$ | 1.77±0.45$^{b}$ |
| Soft drink | 0.06±0.02$^{f}$ | 0.77±0.18$^{a}$ | 8.74±0.72$^{a}$ | 2.78±0.03$^{e}$ | 2.06±0.01$^{b}$ |

*Results presented as mean concentrations ± standard deviations. Superscripts to figures in the same column represent significant or insignificant differences at P≤0.05 (ANOVA, Duncan test, P≤ 0.05). #ND means not detected. Limit of detection for Cu, 0.02 mg/L; Fe, 0.03 mg/L; Pb, 0.1 mg/L; and Zn, 0.005 mg/L.*

## 5. CONCLUSION

Fruit juice and soft drinks bought from the retail market in Accra posed a health risk based on the concentration of trace metals analysed in the present work. Lead posed the greatest risk as its level far exceeded WHO safe limit. Copper, Iron and Zinc levels were within the limit set by WHO and therefore pose no threat to public health. There were variations in the level of trace metals analysed.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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