Determination of Heavy Metals and Ascorbic Acids in Some Soft Drinks Sold Within Bauchi Metropolis, Nigeria

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Abstract. Soft drinks are consumed in Nigeria due to their easy availability, distinct taste and ability to quench thirst. However, the high demand can reduce production quality due to possible heavy metal contamination, leading to human poisoning and death. This study evaluated some components of 100 soft drinks in Nigeria and investigated the presence of heavy metal contaminants and ascorbic acid concentrations. The presence of Arsenic, Cadmium, Lead, Manganese, Nickel and Chromium in soft drinks was determined using an atomic absorption spectrophotometer; the Ascorbic acid was determined using the titrimetric method. The analysis of the soft drink revealed that Arsenic was present in all the samples in a concentration ranging from 0.017 to 0.33 mg/l; Cadmium - 0.027 to 0.160 mg/l; Lead - 0.046 to 0.109 mg/l; Manganese - 0.036 to 0.116 mg/l; Nickel - 0.002 to 0.110 mg/l; Chromium - 0.057 to 0.122 mg/l. The attention of ascorbic acid ranged between 4.03 to 7.2 mg/100 ml. Compared to WHO standards, the levels of the heavy metal contaminants were above the tolerated limits for good quality drinking water in most samples.

Moreover, the ascorbic acid values in this analysis were lower than those the manufacturers reported. Therefore, the National Health Surveillance agency should monitor ascorbic acid. These results suggest that soft drinks in Nigeria may be contaminated with heavy metals, which constitute a significant public health problem. Quality control is recommended during production, especially during sterilization and purification steps.

Keywords: WHO; Soft Drinks; Ascorbic Acid; Heavy Metals.

INTRODUCTION

Soft drinks are one of the most consumed beverages in Nigeria today. Soft drink consumption in Nigeria in 2007 was estimated at 159.85 g/day per capita [1]. Soft drinks come in various forms and brands and are sold by several breweries in the country [2, 3]. In Nigeria, the young and old consume soft drinks daily in large quantities due to their low price, unique taste and thirst-quenching potential. These drinks are easy to consume daily, especially during hard work or strenuous activities such as sports (EFSA). Due to its relatively low price, it is widely consumed during holidays and celebrations and is traditionally used for naming ceremonies, weddings and funerals. It is presented to the public during festivals [4]. The hot weather conditions in the country also contribute to the high consumption of soft drinks. The increasing demand for food safety stimulates research regarding the benefits and risks of consuming foodstuffs and beverages. Metals composition of foods is of interest because of their essential and/or toxic nature to man. Atmospheric contamination, the excessive use of fertilizers and pesticides, and sewage sludge or irrigation with residual waters are among the causes of contamination of raw foodstuffs [5] as a result of the soil, atmosphere, and underground and surface water pollution, foods and beverages are getting contaminated with heavy metals [6]. Because of their high toxicity, arsenic, lead, and cadmium must be quantified in food and drink [7].

Heavy metals are harmful and toxic to the human body and cause significant health problems [9, 10]. These metals can cause acute and chronic toxicity in children and adults through a variety of mechanisms of action [11, 12]. Because some heavy metals catalyze the oxidation reactions of biological macromolecules, their poisoning can lead to oxidative tissue damage [13]. Others have genotoxic/carcinogenic potential that can cause chromosomal abnormalities and mutations, and cancer [14]. One of the primary mechanisms of the toxic effects of heavy metals is the inhibition of various mitochondrial enzymes and the disruption of cellular respiration by interfering with oxidative phosphorylation [15, 16]. Some heavy metals of health importance include cadmium, lead, mercury, etc. Cadmium is a heavy metal whose long-term accumulation may lead to cancer since it is a carcinogenic element [14]. Also, over a long intake period, cadmium may accumulate in the kidney and liver because of its long biological half-life and may lead to kidney damage [17].

Although lead is known to affect humans and animals of all ages, lead exposure is most severe in young children [18]. Central neurotoxicity is children's most common form of lead poisoning [19]. Other symptoms of lead poisoning in children include gastrointestinal disturbances such as anaemia, peripheral motor neuropathy, anorexia, vomiting, abdominal pain, and growth retardation [20]. Mercury is also dangerous to health. Intoxication can occur in infants and adults and has been shown to disrupt many cellular processes, including protein and nucleic acid synthesis, oxidative stress, calcium homeostasis, and protein phosphorylation [21].

Ascorbic acid (vitamin C) is a water-soluble vitamin found in many biological systems and foodstuffs (fresh vegetables and fruits, namely, citrus). Ascorbic acid plays a vital role in collagen biosynthesis, iron absorption, and immune response activation and is involved in wound healing and osteogenesis. It also acts as a powerful antioxidant which fights against free-radical-induced diseases [22, 23]. Nevertheless, an ascorbic acid excess can lead to gastric irritation, and the metabolic product of vitamin C (oxalic acid) can cause renal problems [24]. In some cases, excessive quantities of ascorbic acid may inhibit natural processes occurring in food and can contribute to taste deterioration; added to apple pulp (250 mg/kg), vitamin C inhibits oxidation processes responsible for apple juice aroma [25]. Ascorbic acid is a labile substance, as enzymes and atmospheric oxygen quickly degrade it. Its oxidation can be accelerated by excessive heat and light and heavy metal cations [22]. That is why the ascorbic acid content of foodstuffs and beverages represents a relevant indicator of quality which has to be carefully monitored regarding its variation during manufacturing and storage. This study aimed to determine the concentration of As, Cd, Pb, Mn, Cr and Ni in soft drinks available in Bauchi, Bauchi State, Nigeria, and to determine the concentration of Ascorbic Acid in soft drinks to compare them with reference levels established for drinking water standard by the WHO.

MATERIALS AND METHOD

Beakers (250 ml), conical flask (250 ml), samples bottle (100 ml), funnel, filter paper, distilled water, analytical weighing balance (JA303P), measuring cylinder (100 ml), burette and pipette, specimen bottles, retort stand, volumetric flask (250 ml), atomic absorption spectroscopy (AA320) and heating mantle (KDM 1000 PEC MEDICAL USA).

Hydro chloric acid (HCL) JHD-AR analytical reagent, Nitric Acid (HNO_3), 1 % Sodium thiosulphate dot five water ($Na_2S_2O_3 . 5H_2O$), 5% Potassium iodide solution (KI), Potassium iodate solution 0.1 M (KIO), Sulphuric acid 0.5 M (H_2SO_4) and Starch indicator.

A hundred samples were collected from Bauchi Local Government Area, Bauchi State, and were transported to the Chemistry Laboratory of Science Laboratory Technology Department of ATAP Bauchi.

The samples for analysis were digested by adding 50 ml of the sample 2 ml of concentrated nitric acid, and 6 ml of hydrochloric acid were added and heating till the total volume was reduced to break the complex bonds and release the sample into solution. The solution was filtered into another cup, made up to 100 ml with distilled water and mixed thoroughly. The samples were taken to the AAS machine for analysis.

The acidity of the soft drinks was done by the acid titration method. 25 ml of the potassium iodate solution was measured in a conical flask.

20 ml of 5% potassium iodide was added. The mixture was acidified with 10 ml of 0.5 H_2SO_4. 50 ml of the sample will be added to the acidified solution, and add few drops of starch solution will shake the flask carefully, titrate the liberated iodide with the sodium thiosulphate solution from the burette to its end point; either colour less or back to the original colour of your sample.

RESULTS AND DISCUSSION

The concentration of the metals: Arsenic, Manganese, Chromium, Cadmium and Nickel in the soft drinks analyzed are presented in Table 1.

Table 1 – Shows the concentration of heavy metals in analyzed soft drinks

Sample	Concentration of heavy metals, mg/l					
	As	Cd	Pb	Mn	Ni	Cr
001	0.64±0.004	0.072±0.022	0.061±0.012	0.135±0.027	0.002±0.001	0.125±0.025
002	0.056±0.003	0.059±0.018	0.081±0.016	0.068±0.014	0.072±0.022	0.059±0.018
003	0.33±0.04	0.077±0.023	0.092±0.018	0.055±0.011	0.066±0.020	0.057±0.011
004	0.13±0.035	0.042±0.008	0.073±0.015	0.116±0.023	0.034±0.010	0.074±0.015
005	0.125±0.05	0.033±0.007	0.066±0.013	0.133±0.027	0.041±0.012	0.064±0.013
006	0.04±0.001	0.027±0.008	0.073±0.015	0.085±0.017	0.063±0.019	0.118±0.024
007	0.065±0.014	0.040±0.008	0.054±0.011	0.100±0.020	0.007±0.002	0.059±0.018
008	0.067±0.031	0.160±0.048	0.046±0.009	0.036±0.007	0.037±0.011	0.005±0.002
009	0.017±0.004	0.026±0.005	0.087±0.017	0.087±0.017	0.110±0.003	0.122±0.024
010	0.024±0.016	0.149±0.045	0.109±0.022	0.044±0.009	0.063±0.019	0.085±0.017

Each result represents the mean for ten samples of each soft drink analyzed. The data obtained indicated that heavy metal concentrations depend on the type of Soft drinks analyzed. Due to confidentiality reasons, detailed information about the exact brand names of the analyzed soft drinks is not disclosed in this study.

Table 2 represents the recommended maximum permissible limits (MPL) for the investigated metals in drinking water as given by WHO.

Table 2 – The maximum permissible limits of drinking water as given by WHO

Metals	Maximum Permissible limits, mg/l
Cr	0.05
Pb	0.01
Cd	0.005
As	0.010
Ni	0.02
Mn	0.05

Table 3 describes the concentration of Ascorbic Acid in the soft drinks analyzed.

Table 3 – The concentration of Ascorbic Acid in soft drinks analyzed

Sample	Concentration of Ascorbic, mg/ 100 ml
001	6.35±1.01
002	5.67±0.68
003	5.45±0.44
004	5.58±0.91
005	6.83±1.01
006	4.03±0.81
007	6.18±1.01
008	7.92±1.20
009	5.33±0.96
010	6.02±1.00

Arsenic was detected in most of the studied samples. The lowest concentration of (As) caught was 0.017 mg/l, and the highest was 0.33 mg/l. The maximum permissible limit for (As) in drinking water is 0.010 mg/l, established by WHO. Because the levels in the examined was higher than this sample's limit. Short-term exposure to levels above the MCL causes nausea, vomiting, diarrhoea, muscle cramps, salivation, sensory disturbances, liver damage, seizures, shock, and kidney failure. As noted above, the long-term effects of MCL Exposure can cause kidney, liver and bone damage. It is also a known carcinogen [14].

Corrosion, discharge from metal refineries, and runoff from industrial waste effluent are all sources of as in water [26] from where it may have been introduced into the soft drinks. The presence of (As) above safe limits in soft drinks is an issue of significant risk to consumers due to the highly detrimental effects of the metals on human health.

Cadmium was detectable in most samples with a concentration range between (0.027 to 0.160 mg/l). This value was far above the value given by WHO (0.005 mg/l). Previous studies in Nigeria have also confirmed the presence of cadmium in soft drinks and have shown the level to be above the tolerated limit [27]. Cadmium is primarily toxic to the kidney, especially the proximal tubular cell, the leading site of accumulation. Once cadmium is absorbed into the body, it is efficiently retained in the human body and accumulates throughout life. Cadmium can also cause bone demineralization either through direct bone damage or indirectly as a result of renal dysfunction.

Another heavy metal investigated in this study is lead. The detection and concentrations of information in all soft drinks were outside the accepted MCLG (0.00) and MCL (0.01) limits. In Nigeria, lead contamination has been found in soft drinks, sediments, and fish. This was observed in a study conducted in Bayelsa State, where lead and other heavy metals were detected in tilapia fish and sediment [28]. However, a study in Nigeria [27] found that lead levels were lower than in MCL. The maximum concentration of lead detected in soft drinks was between 0.046 to 0.109 mg/l, respectively, which are far above the safe limit of 0.01 mg/l recommended by WHO.

According to [29], lead toxicity is associated with an abnormal size and haemoglobin content of the erythrocytes, hyperstimulation of erythropoiesis and inhibition of heme synthesis. The high concentrations of lead in the samples analyzed could be coming from the metallic containers used in the preparation of fruit juice and soft drinks and also from the soil where the plants bearing the fruits are grown due to the dumping of domestic and industrial waste.

Manganese concentrations in the Soft drinks samples ranged below detectable limits to 0.116 mg/l (Table 2). The samples' mean lowest concentration of Manganese was 0.036 mg/l. The highest concentration of Manganese recorded for the pieces was 0.116 mg/l. Manganese levels determined in the samples were above detectable limits by 90 %. Manganese is beneficial for humans because it is a vital part of vitamin, which is essential for human health. The uptake by plants growing on contaminated soils accumulates microscopic particles, especially in the edible portions of the plant, such as the fruits and the seeds. Uptake by humans through eating such dirty plants results in health effects such as vomiting and nausea, vision problems, heart problems, and thyroid damage.

Nickel is toxic to humans and other living things. Toxicity depends on the bioaccumulation potential of the biological tissue. It also affects our brains and the intellectual development of young children. Long-term exposure in both children and adults can cause kidney, reproductive and immune system damage and adverse effects on the nervous system. Recorded nickel levels in soft drink samples ranged from 0.002 to 0.110 mg/l.

In contrast, corresponding nickel concentrations in various fruits (e.g. pineapple, apple and orange) were higher than corresponding levels recorded in a study similar in Nigeria, as shown in Table 2 [30]. This indicates that heavy metal was detected during the examination.

Chromium is a metallic element that was once considered toxic and has now been shown to be essential for health. It is known to play an important role in glucose and fat metabolism. [31]. Chromium exists mainly in the divalent state of the environment: trivalent chromium (Cr III) and hexavalent chromium (Cr VI). Chromium (III) is considered essential. It is necessary to ensure the normal metabolism of glucose, lipids and proteins [32]. It is, however, also toxic when it exceeds the tolerance limit. Cr (VI) is poisonous and has no beneficial role in the human body. The maximum concentration of Cr detected in the soft drinks was 0.122 mg/l, while the lowest detected concentration was 0.057 mg/l. Cr was detected in most of the samples analyzed. The maximum allowed limit for Cr in drinking water is 0.05 mg/l and 0.1 mg, respectively, as given by WHO and EPA. Most soft drink samples analyzed had Cr content above the WHO limit. Overall, the studied samples had Cr content above the permissible limit. Ingestion of high amounts of chromium may result in potentially fatal effects in the respiratory, cardiovascular, gastrointestinal, hepatic, renal, and neurological systems (epa.gov/safewater; IPCS).

According to Table 3, the highest vitamin C concentration of the soft drinks was found in sample 008, with a concentration of 7.92 mg/100 ml, while sample 006 had the lowest vitamin content. 40 % of vitamin C was written on the product, according to the bulletin. When those results were compared, it was clear that there were differences in concentration percentages between companies, industrial soft drinks and improper storage practices. Food processing and preparation significantly negatively impact the vitamin C content of soft drinks. Because it is sensitive to heat, oxygen and acids, it thrives in alkaline environments.

With regards to the manufacturer of the soft drinks, the keepers' airtight containers made of plastics or glass do not cause the loss of what remains of vitamin C as a result of manufacturing processes only about 10 % while keeping containers, they lead to the loss of around 75 %, even if keeping it in the fridge because these containers do not prevent the access of oxygen to soft drinks and oxidize it.

According to the study done in 2000 by [33], the ascorbic content of various fruit juices sold in Greece ranged from 2.4 to 43 mg/100 ml. Ascorbic losses were from 29 % to 41 % when the product was kept in closed containers at room temperature for four months. When stored in open containers in the refrigerator for 31 days, commercial orange juice lost 60 % to 67% of its ascorbic acid content, while fresh orange juice lost between 7 % and 13 % of its AA content. Open containers of commercial fruit juice, when stored outside the refrigerator for ten days, lost 12.5 % of their ascorbic acid content, while the refrigerated juice, for the same period, lost up to 9% of Ascorbic acid.

CONCLUSIONS

The study found that some soft drinks sold in Nigeria contain certain metals that exceed safe limits. Long-term and/or excessive consumption of foods containing metals above the permitted amounts can have dangerous effects on human health. Since soft drinks are widely consumed in Nigeria, they are known to be a significant contributor to the metal consumption of the population. Water is probably the primary source of metals in soft drinks. For this reason, soft drink manufacturers must use reasonable water treatment procedures and quality control measures to ensure the safety of their products. The manufacturers should also take extra care to avoid introducing metals from the industrial processes, the equipment used, packing/storage materials and industrial emissions. Regulatory bodies in the country should regularly monitor metal levels in foods and drinks to safeguard public health.

However, the food industry has not paid enough attention or even accurately measured the amount of ascorbic acid added to products, so government agencies must take the concentration of ascorbic acid seriously. Before and after, a single operation is used in developing this material in these products. Another hypothesis to consider is that the soft drink and food industry may have added an unstable chemical form of ascorbic acid to their products, which can oxidize during shipping and storage

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Competing of Interest

The authors have declared that no competing interests exist.

REFERENCES

1. FAO. (2011). FAOSTAT data. Retrieved from https://www.fao.org/faostat/en/#data

2. Asiegbu, I. F., Awa, H. O., Akpotu, Ch., & Ogbonna, U. B. (2011). Salesforce Competence Development and Marketing Performance of Industrial and Domestic Products Firms in Nigeria. *East Journal of Psychology and Business, 2*(4), 43–59

3. Ambler, T., & Styles, C. (1996). Brand development versus new product development: towards a process model of extension decisions. *Marketing Intelligence & Planning, 14*(7), 10–19. doi: 10.1108/02634509610152664

4. Dharmasena, K. A. (2010). *The Non-Alcoholic Beverage Market in the United States: Demand Interrelationships, Dynamics, Nutrition Issues and Probability Forecast Evaluation* (PhD thesis). Retrieved from http://oaktrust.library.tamu.edu/handle/1969.1/ETD-TAMU-2010-05-7911?show=full

5. Demirozu, B., & Saldamli, I. (2002). Metallic contamination problem in a pasta production plant. *Turkish Journal of Engineering and Environmental Sciences, 26*, 361-365.

6. Krejpcio, Z., Sionkowski, S., & Bartela, J. (2005). Safety of Fresh Fruits and Juices Available on the Polish Market as Determined by Heavy Metal Residues. *Polish Journal of Environmental Studies, 14*(6), 877-881.

7. Barbaste, M., Medina, B., & Perez-Trujillo, J. P. (2003). Analysis of arsenic, lead and cadmium in wines from the Canary Islands, Spain, by ICP/MS. *Food Additives & Contaminants, 20*(2), 141–148. doi: 10.1080/0265203021000031546

8. Duffus, J. H. (2002). Heavy metals" - a meaningless term? *Pure and Applied Chemistry, 74*(5), 793-807.

9. Bingol, M., Yentur, G., ER, B., & Oktem, A. B. (2010). Determination of some heavy metal levels in soft drinks from Turkey using ICP-OES method. *Czech Journal of Food Sciences, 28*(3), 213–216.

10. Cabrera, C., Lorenzo, M. L., & Lopez, M. C. (1995). Lead and Cadmium Contamination in Dairy Products and Its Repercussion on Total Dietary Intake. *Journal of Agricultural and Food Chemistry, 43*(6), 1605–1609. doi: 10.1021/jf00054a035

11. Ibrahim, D., Froberg, B., Wolf, A., & Rusyniak, D. E. (2006). Heavy Metal Poisoning: Clinical Presentations and Pathophysiology. *Clinics in Laboratory Medicine, 26*(1), 67–97. doi: 10.1016/j.cll.2006.02.003

12. Berry, W. L., & Wallace, A. (1981). Toxicity: The concept and relationship to the dose response curve. *Journal of Plant Nutrition, 3*(1–4), 13–19. doi: 10.1080/01904168109362814

13. Shaw, B. P., Sahu, S. K., & Mishra, R. K. (2004). Heavy Metal Induced Oxidative Damage in Terrestrial Plants. *Heavy Metal Stress in Plants*, 84–126. doi: 10.1007/978-3-662-07743-6_4

14. Rubio, C., Hardisson, A., Reguera, J. I., Revert, C., Lafuente, M. A., & González-Iglesias, T. (2006). Cadmium dietary intake in the Canary Islands, Spain. *Environmental Research, 100*(1), 123–129. doi: 10.1016/j.envres.2005.01.008

15. Sharma, R. K., & Agrawal, M. (2005). Biological effects of heavy metals: an overview. *Journal of environmental biology*, *26*, 301–313.

16. Assche, F., & Clijsters, H. (1990). Effects of metals on enzyme activity in plants. *Plant, Cell and Environment, 13*(3), 195–206. doi: 10.1111/j.1365-3040.1990.tb01304.x

17. Godt, J., Scheidig, F., Grosse-Siestrup, C., Esche, V., Brandenburg, P., Reich, A., & Groneberg, D. A. (2006). The toxicity of cadmium and resulting hazards for human health. *Journal of Occupational Medicine and Toxicology, 1*(1). doi: 10.1186/1745-6673-1-22

18. Staudinger, K. C., & Roth, V. S. (1998). Occupational lead poisoning. *American family physician*, *57*(4), 719–732.

19. Lidsky, T. I., & Schneider, J. S. (2003). Lead neurotoxicity in children: basic mechanisms and clinical correlates. *Brain, 126*(1), 5–19. doi: 10.1093/brain/awg014

20 Lockitch, G. (1993). Perspectives on lead toxicity. *Clinical Biochemistry, 26*(5), 371–381. doi: 10.1016/0009-9120(93)90113-k

21. Chang, L. W., & Dyer, R. S. (1995). *Handbook of Neurotoxicology*. New York: M. Dekker

22. Bhagavan, N. V. (2001). *Medical Biochemistry* (4th ed.). Amsterdam: Elsevier.

23. Fox, B. A., Cameron, A. G., & Lean, M. E. (2004). *Fox and Cameron's Food Science, Nutrition and Health* (7th ed.). London: Arnold.

24. Hodgkinson, A. (1978). Oxalic Acid in Biology and Medicine. *Annals of Internal Medicine, 89*, 730. doi: 10.7326/0003-4819-89-5-730_1

25. Wawrzyniak, J., Ryniecki, A., Zembrzuski, W. (2005). Application of voltammetry to determine vitamin C in apple juices. *Acta Scientiarum Polonorum-Technologia Alimentaria, 42*(2), pp. 5–16.

26. EPA. (2022). *Ground Water and Drinking Water*. Retrieved from https://www.epa.gov/ground-water-and-drinking-water

27. Adepoju-Bello, A. A., Oguntibeju, O. O., Adebisi, R. A., Okpala, N., & Coker, H. (2012). Evaluation of the concentration of toxic metals in cosmetic products in Nigeria. *African journal of biotechnology, 11*(97), 16360-16364.

28. Ebenezer, A., & Eremasi, Y. (2012). Determination of heavy metals in water sediments and Tilapia zilli from Kolo-Creek, Ogbia Local Government Area, Bayelsa State, Nigeria. *Scientia Africana, 11*(1), 44–52.

29. Luckey, T. D., & Venugopal, B. (1977). Introduction to Heavy Metal Toxicity in Mammals. *Physiologic and Chemical Basis for Metal Toxicity*, 1–37. doi: 10.1007/978-1-4684-2952-7_1

30. Akan. (2009). Heavy Metals and Anion Levels in Some Samples of Vegetable Grown Within the Vicinity of Challawa Industrial Area, Kano State, Nigeria. *American Journal of Applied Sciences, 6*(3), 534–542. doi: 10.3844/ajassp.2009.534.542

31. Anderson, R. A. (1997). Chromium as an Essential Nutrient for Humans. *Regulatory Toxicology and Pharmacology, 26*(1), 35–41. doi: 10.1006/rtph.1997.1136

32. Expert Group on Vitamins and Minerals. (2003). *Safe Upper Levels for Vitamins and Minerals*. Retrieved from https://cot.food.gov.uk/sites/default/files/vitmin2003.pdf

33. Kabasakalis, V. (2000). Ascorbic acid content of commercial fruit juices and its rate of loss upon storage. *Food Chemistry, 70*(3), 325–328. doi: 10.1016/s0308-8146(00)00093-5