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Determination of Aluminium and Other Metal Contaminants in Milk Consumed in Nairobi County

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Abstract: *Milk is one of the many products obtained from cows and is considered a whole food as it has many nutrients necessary for the human body. It is consumed by both children and adults. However, as a result of human activities and the use of modern drugs to treat ailments in cows, metal contaminants can end up in the body of the cow and as such be deposited in the mammary glands and find their way into the milk. These metals or contaminants can lead to serious health problems in humans, as a result of acute or chronic exposure to them. The study analyzed four milk samples obtained from Naivas supermarket in Nairobi County. The concentrations of Aluminium and Mercury were below detectable levels (BDL) in the samples. The concentrations of Mn were well below the permissible levels of 0.2 mg/L - 0.4 mg/L according to WHO, while one sample had Pb concentrations of 0.49± 0.45 mg/L, which were above the permissible limit of 0.25 mg/L by WHO. The average concentration of Cu in the milk was Cu (0.27± 0.39 mg/L), which was within the allowed range of 0.2 mg/L - 0.8 mg/L as stipulated by WHO.*

Keywords: *Milk, detected, concentrations, permissible levels, Aluminium, contaminants, presence, WHO.*

1. Introduction

Milk is considered an important component of the human diet as it is a whole food that contains a variety of important nutrients like proteins, carbohydrates, fats, vitamins and minerals that are crucial to the growth and development of children and adults [1]. In Nairobi County, it is consumed by a majority of the populace and thus can be a passage route for heavy metals and metal contaminants into the body. Milk is considered to be a good source of calcium [2]. Some of these heavy metals such as Cu and Mn are considered essential, that is, they play important physiological functions in the body, while others such as Pb and Hg are non-essential as they have no biological role [3]. Essential elements can also become toxic at high concentrations [4] making them contaminants. A majority of livestock products have been seen to act as a source of a variety of antibiotics and heavy metals [5]. Several studies have also indicated the presence of heavy metals such as Cu, Zn, Pb, Cd, Cr, Co, Mo and As in milk [6]

A contaminant is defined as any biological, chemical, or physical agent, foreign matter, or other substance that is not intentionally added to food but can compromise its safety or suitability, according to the Kenya Bureau of Standards (KEBS). These metals are considered contaminants as they compromise the safety of the milk. The sources of these metals are both natural and anthropogenic [7]. Some of these metals, like Aluminum, exist naturally in the environment as they form part of the earth’s crust and become available to livestock as a result of weathering or even mining activities. Others, like copper, are mined and during the refining process, might be released into the environment together with the waste materials. Mn, for example, exists naturally in the environment but can also come from industries using manganese-based products releasing their effluents into water resources. Pb and Hg are used in different industries and Hg exists in the earth’s crust. The feed or fodder and the water that cows take come from the environment in which these metals are present. These metals bioaccumulate in the cow’s body and even get deposited in the mammary glands and as a result, end up in the milk. It can therefore be an indicator of environmental contamination [8].

When these contaminants are present in milk, they can be toxic and pose serious health problems to consumers. Depending on the levels of exposure, they can cause acute or chronic health problems. Studies have associated exposure to aluminium with Alzheimer's, breast cancer, and neurotoxicity.

Manganese toxicity can cause a permanent neurological disorder known as manganism, which has symptoms like tremors. Lead and mercury toxicity can be fatal, and lead exposure can also cause retardation. [9].

2. Statement of the Problem

Presence of contaminants in food is a major concern both nationally and globally. This is because they pose serious health risks to the consumer. One such food that can have these contaminants is milk. Its contamination, especially by heavy metals, is a matter of serious concern as it is consumed by a majority of the population, from infants to elderly people. These contaminants accumulate in the body and can lead to disruption of functions of vital organs and glands such as the liver. Some are able to supplant the vital nutritional elements from their original place hence interfering with important biological functions. In infants and the young children, this can lead to serious health complications and developmental problems while in adults the bioaccumulation in the tissues can lead to chronic health problems.

Recent research studies have shown that there is the possibility of aluminium ions leaching into foods, particularly acidic foods such as milk. This Aluminium can be from the milk cans the milk is transported in or the use of aluminium utensils or storage tanks made from aluminium. There has also been research work done that showed the presence of heavy metals in the milk from cows. The contamination of milk by these metals has been attributed to the grazing of the cattle on fields that have been contaminated, the use of feed or fodder grown on contaminated lands, watering the cattle with contaminated water, use of drugs among other factors. There is also little research done in Kenya to establish the presence and levels of contamination in milk by heavy metals. Generally, in Nairobi County, and Kenya as a whole, there is little awareness of the contamination of milk by these metals.

3. General Objective

The General Objective of this study is to investigate and quantify the levels of aluminium and other metal contaminants in milk consumed in Nairobi County.

3.1: specific objectives

The specific objectives of the current study are to:

- Establish the presence of aluminium in milk consumed in Nairobi County.
- Determine the concentrations of aluminium in milk in Nairobi County.
- Analyze and quantify other contaminants in the milk in Nairobi County.
- Compare the levels of aluminium and other contaminants with the acceptable limit set by WHO.

4. Justification of the Study

The study is of utmost importance as it will create awareness to the milk consumers of Nairobi County and the nation at large of the metal contaminants present in the milk they consume. It is expected that the findings of this study will assist the government regulatory bodies tasked with overseeing the quality of processed milk produced to develop quality standards and monitoring strategies to ensure the product that goes to the market is safe for consumption.

5. Materials and Methods

5.1: The study area

Nairobi is the largest and the capital city of Kenya. The city and its surrounding area are the ones that constitute Nairobi County. The county has a total of seventeen constituencies and eighty-five wards. The study area is in westlands constituency where the milk samples were obtained from Naivas supermarket. Figure 1 represents a map of westlands constituency in Nairobi county.

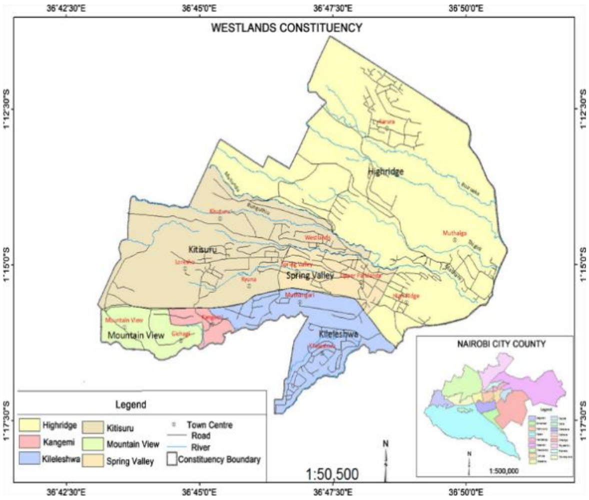

Figure1. *A map of westlands constituency*

Three samples of 500 ml of three popular brands of milk and one litre of milk from the Anytime Milk Machine (ATM) were procured from Naivas supermarket as shown in Figure 2. The samples were placed in a cooler box, labeled and then transported to the laboratory in the Department of Chemistry, University of Nairobi. On the arrival in the laboratory, the samples were then stored in a fridge awaiting the digestion and analysis.

Figure2. *Milk aisle in Naivas supermarket.*

5.2 Reagents and apparatus

The following reagents were used: perchloric acid (72%), nitric acid (70%), distilled water, and standard solutions of Pb, Mn, Cu, Dithizone, and Aluminon.

The apparatus used were: A block digestor, 9 digestor tubes, 50 ml containers (9), a measuring cylinder, and a 500 ml beaker.

5.3 Sample preparation

10 ml of each milk sample was measured using a measuring cylinder and put in a digestor tube. It was done in duplicate.10 ml of the sample was digested using nitric acid and perchloric acid mixture (HNO3:HClO3 = 4:1 v/v) until a transparent solution was obtained. The di-acid was prepared using 160 ml of nitric acid and 40 ml of perchloric acid. 10 ml of the sample was added to each digestor tube including a blank. The tubes were then placed in a digestor tube and the temperature was set to 220 degrees Celsius. They were left to digest for three hours in a fume hood after which they were left to cool as depicted in Figure 3.

Figure3. *Digestion of the milk samples in a block digestor.*

Distilled water was added gradually to wash the sample from the digestor tube and emptied into a 50 ml container. The containers were labeled accordingly. The samples were analyzed for the presence and concentrations using an AAS for Pb, Mn, and Cu and the results were recorded.

Aluminon is a chromogenic compound that forms a colored complex with Aluminum ions. In the case of the study, the samples were treated with Aluminon reagent, and the chromogenic reaction was allowed to proceed for a specific period. In the presence of Aluminium (Al^{3+}), aluminon forms a complex that results in a change in colour to red.

Similarly, the Dithizone method involves a reaction between Mercury ions and a Dithizone solution resulting in a pink to red color compound. The intensity of the color produced is proportional to the concentration of Mercury ions present in the sample. In the study, Dithizone was used to treat the milk samples to detect the presence of Mercury.

6. Results and Discussion

The results obtained from the analysis of Aluminium and other contaminants in the milk consumed in Nairobi County are presented and discussed in this chapter. The data obtained in this study is presented in the form of mean ± SD. The concentration levels of Aluminium and other contaminants that were analyzed in this study in the milk samples can be observed in Table 1

Table1. *Concentrations of Aluminium and other metal contaminants being analyzed.*

Brand	Al	Hg	Pb (mg/L)	Mn (mg/L)	Cu (mg/L)
1	BDL	BDL	0.10	0.04	0.15
2	BDL	BDL	BDL	BDL	0.42
3	BDL	BDL	BDL	BDL	0.79
4	BDL	BDL	BDL	BDL	0.09
SA_{Blank}	BDL	BDL	0.00	0.00	0.00

6.1 Copper (Cu)

Copper was detected in all milk samples. Brand 3 had the highest concentration at 0.56 mg/L ± 0.30 and Brand 1 had the lowest concentration at 0.10 mg/L ± 0.07. Brand 2 and Brand 4 had mean concentrations of 0.52 mg/L ± 0.14 and 0.35 mg/L ± 0.36 respectively. These levels were found to be within range of 0.30 mg/L to 0.80 mg/L the maximum permissible levels as stipulated by WHO. Figure 4 illustrates Cu concentration in the milk samples.

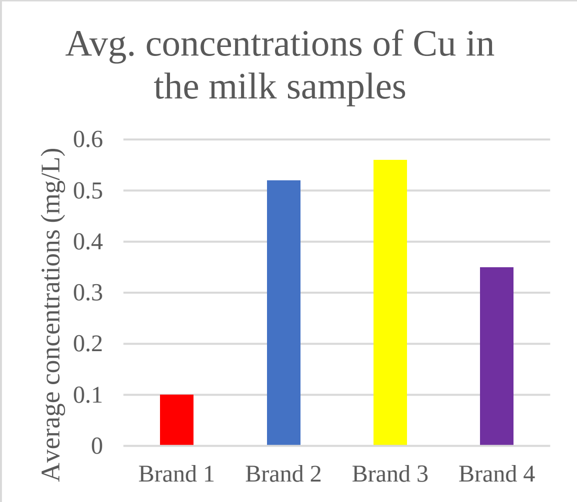

Figure4. *Cu concentration in the milk samples.*

6.2 Manganese (Mn)

Manganese was only detected in the milk sample labeled Brand 1. The levels of Mn in the other samples were below detectable levels (BDL). The average concentration of Mn in Brand 1 was 0.03 mg/L ± 0.02. The WHO standard/ maximum permissible levels for Mn were 0.2 mg/L – 0.4 mg/L. The concentration of Mn in Brand 1 was found to be within range. Figure 5 depicts Mn concentration in milk samples

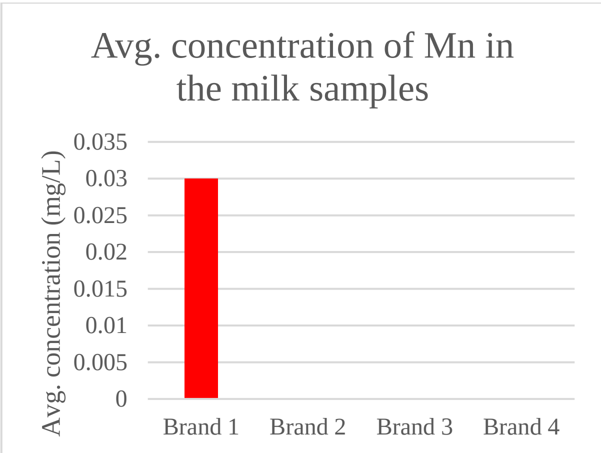

Figure5. *Mn concentration in milk samples.*

6.3: Lead (Pb)

Pb was only detected in the sample labeled Brand 1 and was BDL in all other milk samples as seen in Figure 6. The average concentration of Pb in Brand 1 was 0.45 mg/L ± 0.49 which was above the maximum permissible levels of 0.02 mg/L as stipulated by WHO.

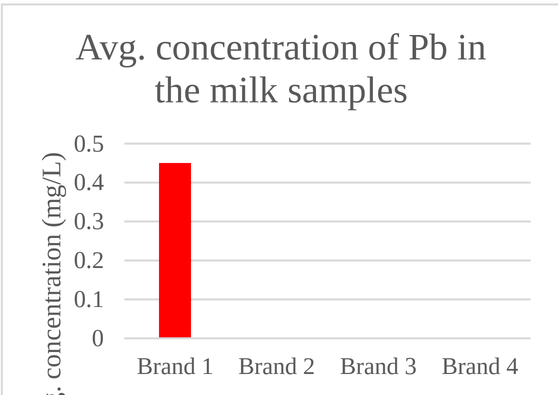

Figure6. *Pb concentration in the milk samples.*

6.4 Aluminum and Mercury

Due to the limited resources and time constraints, Aluminium and Mercury were analyzed using different indicators. Aluminium was analyzed using aluminon and mercury was analyzed using dithizone as the indicator. The indicator was not able to quantify the amount of aluminium or mercury, rather it was only able to detect the presence or absence. As shown in Table 2 all samples were below the detection limits.

Table2. *Results of Aluminium and Mercury using aluminon and dithizone respectively.*

	Aluminium (Al)	Mercury (Hg)
Brand 1	BDL	BDL
Brand 2	BDL	BDL
Brand 3	BDL	BDL
Brand 4	BDL	BDL

The absence or the low levels of mercury below detectable limits may be attributed to how the cow's body acts as a biological filter [11] thus very low levels of mercury end up in the milk. Copper and Manganese are essential trace elements required by humans for biological functions and hence their presence in milk does not normally raise any alarms. Additionally, their presence in milk may be attributed to the use of supplements given to lactating cows and during calving to improve their health. Grazing the cows or feeding the cows fodder grown on contaminated fields can also be a contributor to the contamination of the milk with these metals. The soils can be contaminated by industrial waste, weathering or sewage irrigation. In some of the counties, such as Kiambu County, where milk is sourced from, the dairy cows are fed fish meal [12]. This fish meal can be contaminated by heavy metals and as result end up in the milk. In a research study done, these contaminants are likely to have come from the feed, packaging materials or the polluted environment surrounding the farm [13].

7. Conclusion

From the analysis of Cu, Mn and Pb that was done using the AAS, Cu had the highest average concentration and Mn had the lowest average concentration. The levels of Cu in all milk samples were within range of the maximum permissible levels stated by WHO. The levels of Mn in three milk samples were BDL except for Brand 1, which was within the maximum permissible levels. Pb was detected in only Brand 1 and was BDL in all other milk samples. The average concentration of Pb in Brand 1 was well above the maximum permissible levels of 0.02 mg/L as set forth by KEBS and WHO. Aluminium and Mercury were BDL in all milk samples.

In conclusion, it is evident that contaminants are present in the milk consumed in Nairobi County. There concentrations vary depending on the milk brand, with most of them being within the maximum permissible levels except for Pb. Which was well above the maximum permissible levels set out by the regulatory bodies in one milk sample. Aluminium and Mercury were below detectable limits in all the milk samples analyzed. Mn and Pb were absent in all the milk brands sampled except Brand 1.

8. Recommendations

There is a need to carry out a more detailed investigation of milk being sold for consumption in Nairobi County and other parts of the country for the presence and concentrations of metal contaminants using more sensitive machines. The investigation should be broadened to include more heavy metals and more milk samples from different milk processing facilities. The findings of the broadened investigation would help the government quality regulatory bodies like KEBS to develop guidelines and standards to be adopted by milk processing facilities in the country to ensure food safety and public health. The milk should be analyzed before and after processing and the results compared to determine the source of this metal contaminants.

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