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An Approach to Trace Metals in Milk

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Abstract

The consumption of cow's milk is very popular worldwide because of its medicinal and nutritional properties. Consumption of cow's milk in particular is associated with beneficial health effects in addition to its nutritional value. However, some essential metals can become "toxic" when their concentration is increased in the body, especially at levels 40 to 200 times higher. If intake via the food chain exceeds allowable levels, toxicity can become a serious problem. Cattle have the potential to be used as indicators of environmental contamination. Because they are poorly selective animals, cattle may become contaminated by chewing on objects containing these chemical elements or by ingesting contaminated water or food. Children are especially susceptible to the toxic effects of metal because they are highly absorbed and intoxicated with an element concentration of 50% lower than adults. Milk is known as an excellent source of Ca and provides less Zn and lower Fe and Cu contents. In recent years, milk contamination is considered as one of the most dangerous aspects. Despite increased concern and programs against pollution, very little is known about the distribution, behavior and effects of trace metals in cow's milk. This work aims to report on the presence of trace metals in milk.

Introduction

The maximum permissible levels of metals recommended by the International Milk Federation standard are 0.037 µg/g for Fe, 0.328 µg/g for Zn, 0.02 µg/g for Pb, 0.01 µg/g for Cu and 0.0026 µg/g for Cd. According to the Codex Alimentarius Commission, the maximum residue limit for Pb in milk is 0.02 µg/g [1]. The residues of various antibiotics and antimicrobial drugs can pass into milk through medicated foods and the improper use of drugs intramuscularly. Essential metals as Ca, Fe, Zn, Cu, and If they are necessary for the complete life cycle of an organism, and the lack or insufficiency, also in the human diet, can induce metabolic changes and some diseases.

However, some essential metals can become "toxic" when their concentration is increased, especially at levels higher than 40 to 200 times [2]. If ingestion via the food chain exceeds allowable levels, toxicity can be a problem [3]. The severity of the toxic effect depends on the nature and concentration of the elements, the resistance of the body, and antagonistic effects of other chemical contaminants [4]. For example, iron deficiency increases the absorption of cadmium which affects the use of zinc [5]. The toxic effects of metals can be mediated or increased by interaction or deficiency of essential metals [6].

Heavy metals (or trace elements or trace metals) is a term applied to the group of metals and metalloids with a density greater than 6 g/cm.This term is generally applied to elements such as Cd, Cu, Fe, Pb and Zn which are commonly associated with pollution and toxicity problems [7]. Although these metals are present on the planet as natural constituents of soils and rocks, there are several sources of these elements that can contaminate soil, water and plants and, therefore, animals and man himself, among which atmospheric deposition, agricultural residues, fertilizers and corrective agents, agrochemicals, sewage sludge, irrigation water, compoundsurban waste and urban, industrial and mining waste [8-10].

Although the topic related to heavy metal contamination in several animals is widely addressed in the scientific literature, in cattle, this study is still limited. The proximity of coexistence and the similarity in physiological terms with the human being, in addition to the coincidence of life habitats, make animals like cattle have the potential to be used as indicators of environmental contamination [11]. Because they are not very selective animals, cattle can become contaminated by chewing objects containing these chemical elements or by eating contaminated water or food. Samples of milk for heavy metals analysis are performed on animals with body score 3, in a good state of hydration, and with normal colored mucous. In some studies, samples of powdered infant and adult milk, and milk in liquid form, were analyzed. In both cases, the sample digestion procedures take into account the dryness of the samples in hot plates and a muffle furnace to obtain the ashes, dissolve in acids and further analysis in atomic absorption spectrophotometry equipment. In general, the elements analyzed are Cu, Zn, Ni, Fe, Mn, Cd, Pb.

Oskarsson et al. studied the transfer of lead to milk in cows exposed to heavy metal and found a correlation in the level of lead in blood and milk. According to the authors, this observation compromises the production chain, and man can become intoxicated through the consumption of products of animal origin [12].

Regarding the toxicological aspect, cadmium causes severe pathological changes such as renal dysfunction, tumor testicular, arteriosclerosis, lesions in the central nervous system and growth inhibition in humans and animals. Cadmium still accumulates in milk, eggs and meat, and its concentration in the tissues is proportional to its intake. Church and Pond highlighted that cadmium is dangerous to public health because it causes sterility problems, kidney and testicular injuries, and anemia.

Lead manifests its toxic effects in three ways encephalopathy, gastroenteritis, and peripheral nerve degeneration. Another important aspect is mineral antagonism, where lead and cadmium present in mineral supplements induce the deficiency of essential elements in the

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mineral diet of cattle, mainly calcium [13-15]. It should be noted that lead and cadmium antagonize the actions of zinc which is an essential mineral in the metabolism of some enzymes being a specific constituent of carbonic anhydrase, also acting as a catalyst for aldolases, enolases, phosphatases, catalases, and peptidases, therefore involved with protein synthesis and carbohydrate metabolism [16].

The ingestion of inorganic elements in large quantities, caused by the high contamination rate of the supplements, leads the cattle to defecate large amounts of feces daily. This may mean, in the short term, itinerant contamination of soil, vegetation and sources of drinking water, as different authors have already verified. Cd and Pb are two most toxic contaminants in the food chain. Cd damages the lungs.Pb affects the blood, various organs, and the nervous system. Children are especially susceptible to toxic metal effects because they produce high absorption and become intoxicated with a 50% lower element concentration than adults [17]. Milk samples collected by Kuno and collaborators in animals kept in contaminated areas reached levels of Pb from 1.6 μg/mL to 1.9 μg/mL. Unlike what was mentioned by Swarup and collaborators, blood Pb values above 0.20 μg/mL did not cause metal excretion in milk.

Milk is known as an excellent source of Ca, and it provides less Zn and small levels of Fe and Cu [18]. In recent years, milk contamination is considered to be one of the most dangerous aspects [19]. The consumption of cow's milk is very popular worldwide because of its medicinal and nutritional properties. The consumption of cow's milk, in particular, is associated with beneficial health effects, in addition to its nutritional value. Despite greater concern and programs against pollution, very little is known about the distribution, behavior and effects of trace metals in cow's milk.

According to Farag and collaborators, the concentration of Fe in milk samples ranged from 10.95 to 16.38 μg/mL. Fe can be a problem in dairy products because of its catalytic effect on the oxidation of lipids with the development of an unpleasant smell, precipitating proteins and lipoproteins [20]. The average Zn concentrations ranged from 4.770 μg/mL to 10.75 μg/mL. In the metabolism of some enzymes, being a specific constituent of carbonic anhydrase, also acting as a catalyst for aldolases, enolases, phosphatases, catalases and peptidases, being, therefore, involved with protein synthesis and carbohydrate metabolism.

The average Cu concentrations in milk samples evaluated, regardless of the breeding area and the sampling time, are within the range considered as reference for healthy animals, which is 0.05 μg/mL to 0.2 μg/mL.

Concentrations of Ni in the milk samples, analyzed by Souza were very low (0.002 μg/mL-0.017 μg/mL), however, significant interactions between the breeding area and the time of sampling were diagnosed, similarly to what was verified for biological blood and hair matrices. In the control area, there is no differences between the collections made in the two seasons, while in the industrialized area, higher levels were obtained in the winter. Considering the times of the year, in the summer, higher concentrations were determined in the area without steel mills and, in the winter, in the industrialized area. The presence of industries in a given region does not necessarily imply increases in the concentrations of heavy metals in bovine biological matrices. However, there may be an influence of seasonality on heavy metals concentrations obtained in bovine matrixes.

Commercial powdered milk and infant formulas are deliberately enriched with essential elements, such as iron, zinc, copper to ensure adequate nutrient supply [21]. The assessment of loss and exposure to metal in the diet of infants is very important, in order to have a clear picture of the intake, use and retention of essential nutrients, as well as toxic metals. In work performed with samples of powdered and liquid milk available on the market, Cd was not significantly correlated with other metals, Ni was shown to be correlated with Zn and Cr. And the Cr evaluated, both in powdered and liquid milk, showed a concentration ranging from 0.0001 mg/g-0.0003 mg/g.

The results of the study by Goncalves et al. provide valuable data on heavy and essential metals in various samples of liquid and powdered milk available on the market. It was observed that the determined values were within the acceptable limits for manganese and cadmium in different types of milk. Milk samples contained considerable amounts of calcium, while the magnesium levels were well above the required limits. Copper levels were slightly lower than allowed. The zinc concentrations in powdered milk samples were higher than those of liquid types. And infant milk formulas had better iron levels compared to other milk samples. Still, the results showed that many metals were significantly correlated with each other.

Total mercury levels in human milk have been reported by several authors, with average concentrations between 0.3 ng/mL and 4 ng/mL [22-25]. In Brazil, studies carried out in the Amazon and the Midwest region indicate concentrations of mercury around 5.7 ng/mL, it is above the world average [26,27]. Between 38 and 50% of Hg in human milk is found in the form of methyl mercury, which is the bioavailable form to the body.

Despite the occurrence of mercury in human milk, the World Health Organization (WHO) recommends that all babies be exclusively breastfed until 06 months of age, as the benefits of breastfeeding outweigh the risks related to the presence of mercury [28]. Lactation provides the baby with natural protection against various diseases and the essential nutrients for its development [29,30]. Determining the levels of mercury in human milk, the factors that determine these levels and assessing the risks of exposure to this toxic metal is important for measuring the impact on the child's health and assessing the need for measures to minimize this risk in a given population.

Strontium-89 (radioactive, Sr-89) is often determined by radiometry to determine the separation efficiency of calcium and strontium in milk.In a study carried out by Castro et al., the ^{137}Cs in milk varied from 0.05 to 0.93 Bq/L, but the average values, in the four farms studied, were not statistically different. On one of the farms in the program, occasional peaks in the concentration of ^{137}Cs in milk were observed [31,32]. These seem to be due to livestock management, with temporary permanence in areas where the ^{137}Cs content in soil and pasture are higher than in other areas of the same farm, and in the region in general, due to the influence of micro-climate and topsoil erosion.

Conclusion

The work shows the maximum levels recommended for some metals in milk, as well as, some diseases that can arise in men or animals due to their nutritional deficiencies or excess.Their forms of absorption and or excretion, in addition to the effects on some enzymes necessary for animal metabolismo. The work still suggests that more investigations on the subject need carried out.

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