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Detection of Heavy Metals in Milk Products: A Study

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Abstract
Milk and milk products are the most significant part of our daily dietary requirements. Therefore, this study aims to determine and quantify heavy metals present in different milk product samples. The detection of heavy metals such as Pb, Cd, Cu, Zn and Fe in different samples carried out through Atomic Absorption Spectroscopy (AAS) and assess them under the guidelines of FSSAI. The findings of the study revealed the existence of heavy metals toxicity in milk products. The outcomes of the study are helpful in creating awareness among people about good quality milk and milk products. Additionally, the developed method can be validated through comparison with reference methods, thereby ensuring its reliability for routine analysis of quality of milk products.

Keywords: milk products, heavy metals, heavy metals toxicity, atomic absorption spectroscopy, FSSAI.

INTRODUCTION

Milk is a complete food because of its rich content of protein, fat, carbohydrates, vitamins and various important minerals. Also, Milk is a bio-active substance, an important source of nutrition for newborns, as a source of calcium that is very helpful in the growth and development of children and also helpful to reduce osteoporosis in the elderly. Milk is an essential and nutritious white fluid produced by the mammary glands of mammals, plays a crucial role in offering vital nourishment and immune support for their young ones. Chemically, it is a colloidal solution of fat, proteins and other minerals in water. Casein is a main constituent protein of milk which is fat soluble and other protein is whey protein which is water soluble. It also consists of lactose sugar. Lactic acid bacteria alter lactose to lactic acid through fermentation to produce yogurt. High-fat yogurt is diluted with water; excess fat is separated as butter and the rest is consumed as dough. The nutrients in milk foster growth, development and overall health by providing vital proteins, fats, vitamins and minerals necessary for strong bones, immune support, muscle functions and energy production. With the increase in global population, the demand for milk and its derivatives has risen substantially. Day by day, food adulteration is rapidly increasing due to high demand, lack of safety regulations and monitoring, seasonal variations or to increase profits. Also, excessive exposure to heavy metals has become a serious problem worldwide and a serious threat to food safety and human health[1-5]. The heavy metals can enter to food chains from innumerable anthropogenic sources, but it is affecting human health directly, particularly, several types of diseases have become common among people these

days, the reason behind all this is what food or supplements we are consuming. People consume milk and milk products from the beginning of the day till their bed time meal. Therefore, it is very important to check the quality of the milk we consume daily and also feed to our children.

Some of the metals are naturally present in many foods because they are integrated part of the tissues and fluids of plants and animals. Metals like manganese, copper and zinc etc. as a part of enzymes and proteins are essential for our health because they play vigorous roles in important metabolic processes. When the body doesn't get enough of them, it can lead to metabolic dysfunction causing diseases[6-9]. However, while these metals are necessary in small amounts, the line between what's helpful and what's harmful is very narrow[2-7]. Nowadays, people are more worried about about food safety issues particularly microbial, chemical and physical contaminants. The heavy metal residues such as cadmium (Cd), lead (Pb), arsenic (As) and mercury (Hg) pose a chemical hazard. These heavy metals can be accumulated in the body over time and may cause damage even when exposed to them in a very small amounts[9-11].

Review of Literature

Milk and its products are extremely diverse and contain a extensive range of elements, many of which are essential and basic. These metals play important roles in the body, especially by acting as cofactors for enzymes in important biological processes. In pure and uncontaminated milk, the levels of these metals are typically very precise. However, the production and packaging of milk, their amounts can change significantly. Harmful heavy metals such as lead, cadmium, chromium, nickel and cobalt can enter in to milk through infectious environments, causing serious health problems[5]. According to the 5th China Total Diet Study, vegetables and cereals are prime dietary sources of Cd, As, Cr, and Al, and aquatic products are the main dietary source for Hg and Pb exposure in dietary is from water, beverages, vegetables, cereals and meats[2]. In addition, heavy metal contamination is also found in raw material production such as milk, its processing, storage and transportation[3]. Various research indicates that heavy metals can accumulate in the human body over the time, leading to various health issues. For example, lead exposure has been linked with neurological damage, particularly in children, resulting in cognitive deficits and developmental delays. Studies have shown that even low levels of lead in milk can pose risks, particularly for susceptible populations such as infants and pregnant women[5]. In a recent study, it has been shown that from the contaminated soils, heavy metals can easily enter into the plants through the roots[6-8]. The heavy metal contaminated soil can also pollute the groundwater. Therefore, when the contaminated plant ingested, then the heavy metals easily enter into the body of animals[6]. Due to pollution of heavy metals in soil, water and food through various industrial surroundings, they can simply enter into the food chain and pose a great threat to human and animal health[8-11]. Consequently, heavy metals can build up in the bodies of cattle and end up in products like raw milk, leading to toxic effects[29-31]. How harmful these metals are depending on several things, including how plants absorb them, the amount of contaminated materials used and other factors highlighted in various studies[9, 10].

Methodology

To determine the concentration of heavy metals in the various samples of milk products, the Element AS AAS4141 was used and as the carrier gas, high purity argon gas (99.99%) was also used. In the study, the wet digestion process has employed to ready the milk product samples[17-20]. The following steps have been performed to investigate the samples –

Collection of Samples:

The samples of milk, curd, paneer and khoa were collected from local dairy shops. As we know the milk products are fat- rich substances, their complex compositions cause various challenges in analysing toxic metals in such dairy products. Due to the complex composition of milk and dairy products, in the study we have opted acid digestion method to separate the metals. We have also opted wet digestion method for sample pre-treatment for analysis of different heavy metals by atomic absorption spectroscopy[27].

Sample pre-treatment for detection of heavy metals:

Sample pre-treatment was carried out with the help of conc. nitric acid and hydrochloric acid as digestors. The calibration solutions of respective heavy metals were prepared. All the glass wares were rinsed by acid and distilled water before use. The milk product samples were also homogenized or dehydrated, as per requirements and reduced to usable form before digestion[21-23].

Wet digestion method:

For the samples of Khoa and Paneer, the standard wet digestion method was adopted[12]. The total digestion time was approx. 3 hours. For the samples of curd, suitable standard method was applied for digestion purpose[13]. The total digestion time was approx. 2 hours.

Blank sample: Blank sample has prepared to calibrate the digestors used to check that it doesn't contain any metals residue. It is prepared in the same way for all the samples without containing any sample in it. Blank sample has used as a zero-concentration sample while AAS testing.

Filtration and Dilution :

Filtered all three digested sample solutions using Whatman filter paper. Filtration is necessary to remove the fat content from the sample before AAS testing. Dilute all three filtered solutions up to 25ml using deionised water in a volumetric flask. Dilute the blank sample also up to 25ml using deionised water. Then the samples were tested through AAS.

Result and discussion

As per the results obtained by AAS, it is confirmed that iron and zinc are present in the samples and remaining metals are not present in the samples. Sample of khoa and sample of curd contains 0.681ppm and 0.156ppm amount of iron respectively. According to the WHO, the permissible limit of iron in milk and milk products is generally 0.2 ppm. Another metal which is found in the samples is zinc. Samples of Khoa, Paneer and Curd contains 0.699 ppm, 1.874 ppm and 0.972 ppm amount of zinc respectively.

S.No.	Sample	Pb	Fe	Zn	Cd	Cu
1.	Khoa	0 ppm	0.681ppm	0.699 ppm	0 ppm	0 ppm
2.	Paneer	0 ppm	0.000 ppm	1.874ppm	0 ppm	0 ppm
3.	Curd	0 ppm	0.156 ppm	0.972 ppm	0 ppm	0 ppm

Table: 1 Concentration of heavy metals (in ppm) found in samples tested through AAS

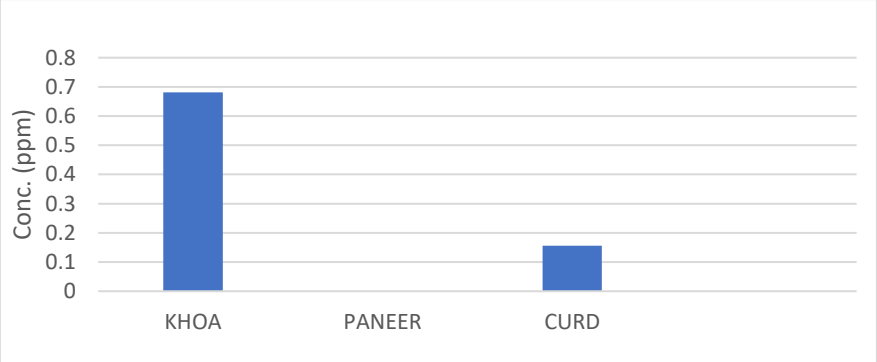

Figure 1: Concentration of Fe in various samples

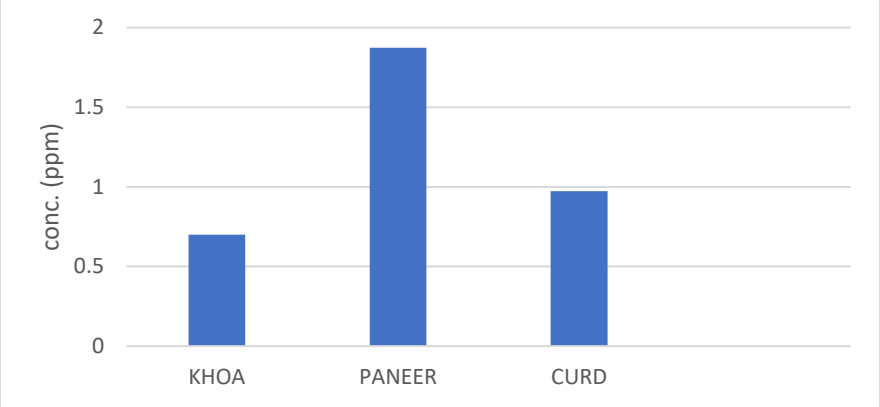

Figure 2: Concentration of Zn in various samples

It is fact that, iron fortification of milk and milk products would be an effective way to increase iron intake and potentially reduce iron deficiency anaemia. FSSAI allowed iron fortification in staple foods including milk and milk products but the excessive iron concentration in milk products can lead to several negative consequences, primarily related to iron overload and potential health issues. Iron from animal sources is prohibited by FSSAI as a source of iron in any food, including milk and milk products. As milk itself is a good source of calcium and protein, its low iron content and the presence of compounds like casein and phosphate can interfere with the absorption of iron from other sources[14,15].

The concentration of zinc found in samples is the usual concentration of zinc present in the milk products. The presence of zinc in milk products can improve zinc absorption from other foods, particularly those high in phytates and can contribute to meeting daily zinc needs, which are vital for various bodily functions like immunity and growth. For infant nutrition, FSSAI has permitted regulation of specific minerals including zinc in milk and milk products for proper growth and development of children. But excessive zinc intake from milk and dairy products can have negative health consequences[28]. High zinc levels can interfere with copper absorption, potentially leading to low copper status and other issues like reduced immune function and lower HDL cholesterol. As zinc is an essential part but its excessive intake can cause nausea, vomiting and stomach cramps as the gastrointestinal symptoms[16,24-26].

Conclusion

Aa milk is an imperative part of our daily diet and it is commonly used as a good source of energy, protein,

vitamins and minerals. Moreover, various milk products are widely consumed across the world on daily basis, occasions and festivals etc. Therefore, the contamination of heavy metals in milk is a serious concern regarding health of people. Since we detected small amounts of Fe and Zn in milk products samples, it is important to know the sources of these metals. Soil and water pollution along with the production of cattle feed can be possible sources of heavy metals contamination in milk and milk products, as they are directly associated to cattle feeding. Apart from pollution and production, the processing, transportation and storage of milk and milk products can also be a reason for the existence of heavy metals in milk and milk products. Such heavy metals, if consumed over a period, can cause a serious health issues in children, adults and elderly. Therefore, it is very important to assess the quality of milk and milk products. Also, the sources of animal feed as well as processing, transportation and storage should be taken care of from time to time.

References

1. Okafor, Sunday Nwankwo, et.al. (2024), Quantitative determination of selected heavy metals and micronutrients in branded dairy products sold in Nigeria using atomic absorption spectroscopy (AAS), African Journal of Pharmaceutical Research and Development 16, no. 1 33-38.
2. Gomaa N. Abdel-Rahman (2022), Heavy metals, definition, sources of food contamination, incidence, impacts and remediation A literature review with recent updates, Egypt. J. Chem. Vol. 65, No. 1, pp. 419 -437.
3. Jia, W., et. al. (2023), Integrative deep learning framework predicts lipidomics-based investigation of preservatives on meat nutritional biomarkers and metabolic pathways. Critical Reviews in Food Science and Nutrition, 1-15.
4. Xia, Changfa, et al. (2022), Cancer statistics in China and United States, 2022: profiles, trends, and determinants, Chinese medical journal 135, no. 05 584-590.
5. Anuradha Sharma et. al. (2024), Progress in analytical methods for monitoring of heavy metals and metalloid in milk and global health risk assessment, Journal of Food Composition and Analysis, Volume 135, November 2024, 106568.
6. Lahiji FA., et al. (2016), Potential of Rice Husk Biosorption in Reduction of Heavy Metals from Oryza sativa Rice, Biosciences Biotechnology Research Asia 13.4 2231-2237.
7. Ziarati, Parisa, et.al. (2018), An overview of the heavy metal contamination in milk and dairy products, Acta scientific pharmaceutical sciences 2, no. 7, 1-14.
8. Gholizadeh E and Ziarati P. (2016), Remediation of Contaminated Rice Farmlands Soil and Oryza sativa Rice Product by Apple Pomace as Adsorbent, Bioscience Biotechnology Research Asia 13.4 2245-2253.
9. Motaghi M and Ziarati P. (2016), Adsorptive Removal of Cadmium and Lead from Oryza sativa Rice by Banana Peel as Bio-sorbent, Biomedical and Pharmacology Journal 9 739-749.
10. A. Yasotha, D. Sylvain Dabadé, Vijay Pal Singh & T. Sivakumar (2021), Risk assessment of heavy metals in milk from cows reared around industrial areas in India, Environmental Geochemistry and Health, Volume 43, pages 1799–1815.
11. Manju Singh, et. al. (2019), Assessment of contamination of milk and milk products with heavy metals, Indian J Dairy Sci 72(6), 608-615.
12. Tripathi, et. al. (1999), Daily intake of heavy metals by infants through milk and milk products, Science of the total environment 227, no. 2-3 229-235.

13. Kaya, Gokce, Ismail Akdeniz, and Mehmet Yaman, (2008), Determination of Cu, Mn, and Pb in yogurt samples by flame atomic absorption spectrometry using dry, wet, and microwave ashing methods, Atomic Spectroscopy 29, no. 3 99-106.
14. Vohra K, et al. (2021), Effect of Iron Fortified Milk and Milk Products on Anemia Status among the Population – A Review, Indian J Nutri., 8(1), 226.
15. Graczykowska, Karolina et al. (2021), The Consequence of Excessive Consumption of Cow's Milk: Protein-Losing Enteropathy with Anasarca in the Course of Iron Deficiency Anaemia-Case Reports and a Literature Review, Nutrients vol. 13, 3 828. doi:10. 3390/nu 3030828
16. Shkembi, Blerina, and Thom Huppertz, (2021), Influence of Dairy Products on Bioavailability of Zinc from Other Food Products: A Review of Complementarity at a Meal Level, Nutrients vol. 13,12 4253. 26 Nov. doi:10.3390/nu13124253.
17. Meshref, Arafa & Moselhy, Walaa & Hassan, Nour, (2014), Heavy metals and trace elements levels in milk and milk products. Journal of Food Measurement and Characterization. 8. 381-388. 10.1007/s11694-014-9203-6.
18. Pilarczyk, Renata et al. (2013), Concentrations of toxic heavy metals and trace elements in raw milk of Simmental and Holstein-Friesian cows from organic farm, Environmental monitoring and assessment vol. 185,10 8383-92. doi:10.1007/s10661-013-3180-9.
19. Aggarwal, Ankur, Tarun Verma, and Sumangal Ghosh, (2022), Heavy Metal Residues in Milk and Milk Products and their Detection Method: Trends and Innovations in Food Science, IntechOpen. doi:10.5772/intechopen.105004.
20. Abidin, et. al. (2021), Evaluation of heavy metals concentration in milk products by using atomic absorption spectroscopy, EKSAKTA: Journal of Sciences and Data Analysis 136-141.
21. Mehrasebi, et. al. (2023), Comparison of three digestion methods for determination of lead and cadmium in milk and dairy products, Environmental Health Engineering and Management Journal 10, no. 2 191-196.
22. Matusiewicz, Henryk, (2003), Wet digestion methods, Sample preparation for trace element analysis 41 193-233.
23. Anzano, J. M., & Ruíz-Gil, M. (2005), Comparison of microwave acid digestion with the wet digestion and ashing methods for the determination of Fe, Mn, and Zn in food samples by flame AAS. Atomic spectroscopy, 26(1), 28-33.
24. Ali Boudebbouz, et. al. (2021), Heavy metals levels in raw cow milk and health risk assessment across the globe: A systematic review, Sci Total Environ. 10, 751, 141830.
25. Kira, Carmen S., et. al. (2004), Comparison of partial digestion procedures for determination of Ca, Cr, Cu, Fe, K, Mg, Mn, Na, P, and Zn in milk by inductively coupled plasma-optical emission spectrometry, Journal of AOAC International 87, no. 1 151-156.
26. Anita Meena and Ravinder Kaur, (2016) Human health risk assessment for heavy metals via intake of contaminated milk and milk products, Journal of Applied and Natural Sciences, Vol 8 No 3.
27. Kaushik, R., and S. Arora (2023), Standardization of Atomic Absorption Spectrometry Protocol for Calcium Analysis in Milk and Milk Products, J Food Chem Nanotechnol 9, no. 1 36-42.
28. Moutaz A.W. Abdul Mounam, (2023), Review: The Health risks caused by heavy metals contamination of milk products, Diyala Journal of Medicine 24(2)141-154.
29. Wong et. al. (2022), Review of regulatory reference values and background levels for heavy metals in the human diet, Regulatory Toxicology and Pharmacology 130, 105122.

30. Altun, Serap Kılıç and Mehmet Emin Aydemir (2021), Determination of some minerals and heavy metal levels in Urfa cheese and cow's milk, Food and Health 7, no. 3 185-193.
31. Damtew, Endale Tesfaye, and Aregay Berhe Gebre (2020), Chemical composition and heavy metals analysis of raw cow's milk, Journal of Environmental & Analytical 10, no. 5 -0-