Article

Estimation of Some Heavy Metals for Cow's Milk from Different Areas in The City of Mosul

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Abstract

The primary objective of this study was to analyze the concentrations of essential nutrients and heavy metals in dairy products, specifically cow's milk and milk powder, to evaluate their nutritional quality and safety for consumers. The study aimed to compare the measured values with certified standards to identify any deviations that could pose health risks. Cow's milk and milk powder samples from various regions, including Mosul, were collected and analyzed for their elemental composition using analytical methods. The concentrations of essential macro and microelements, as well as heavy metals such as arsenic, cadmium, mercury, lead, rubidium, and strontium, were measured. The findings were compared with certified values to assess the nutritional quality and safety of the dairy products. The analysis of cow's milk and milk powder samples revealed that essential macro and microelements were within acceptable limits, indicating good nutritional quality. However, certain heavy metals, including arsenic, cadmium, and lead, were found to exceed standards in some samples, raising concerns about potential health risks associated with these contaminants. The study emphasized the importance of ongoing monitoring and quality control measures to ensure the safety and nutritional quality of dairy products, particularly in regions where heavy metal contamination levels were higher than expected. Further research is needed

to understand the sources of contamination and implement strategies to mitigate health risks associated with heavy metal exposure in dairy products.

Keywords: Cow's Milk, Elemental analysis, Heavy metals, Contamination.

1. Introduction

Milk and dairy products are crucial for a balanced diet, offering essential nutrients [1]. However, the safety of milk is at risk due to heavy metal contamination, which can accumulate in animals and transfer to milk [2]. Heavy metal contamination in milk is a notable public health issue, as prolonged exposure can result in adverse health effects for consumers [3]. Studies have shown that the presence of heavy metals like mercury, lead, uranium, and vanadium in milk can pose risks to human health [4]. Monitoring of dioxins and polychlorinated biphenyls in cow milk has revealed varying contamination levels, emphasizing the importance of assessing the impact on consumer health [5]. Therefore, ensuring stringent quality control measures in the dairy industry is essential to mitigate the risks associated with heavy metal contamination in milk. A recent meta-analysis by Muhammad et al. (2023) [6] explored the effects of dietary chromium (Cr) supplementation on dry matter intake, milk production, and milk composition in lactating dairy cows. The study found that Cr supplementation had a positive impact on milk yield and composition, highlighting the importance of understanding the mineral profile of cow's milk, including the levels of heavy metals. A recent comprehensive review by Abdullah and Aljohani (2023) [7] highlighted the issue of heavy metal toxicity in poultry, emphasizing the importance of understanding the potential sources and impacts of these contaminants in animal-derived food products. The review underscores the need for continuous monitoring and assessment of heavy metal levels in livestock, including dairy cows, to ensure the safety and quality of the food supply. Additionally, studies on the effects of selenium (Se) sources in lactating dairy cows according to study of (Mario, Gennaro., et al. 2010) [8] demonstrated that Se concentrations in blood, milk, and cheese were influenced by the type and dose of Se additives. Also, a recent study by Ambrose et al. (2023) [9] investigated the levels of chlorate, a potentially harmful contaminant, in dairy products produced and consumed in Ireland. While the focus of their study was on chlorate, the researchers highlighted the importance of monitoring a wider range of contaminants, including heavy metals, in dairy products to ensure food safety and quality. A recent study by Abdur Rashid et al. (2023) [10] highlighted the issue of heavy metal contamination in agricultural soils and its impact on crop health. While their study focused on the agricultural sector, it underscores the broader problem of environmental pollution and the need for comprehensive monitoring of heavy metals in various food production systems, including the dairy industry. In this context, the present study aims to investigate the concentrations of heavy metals, such as chromium (Cr), cadmium (Cd), and lead (Pb), in cow's milk samples collected from different areas within the city of Mosul, Iraq. By analyzing the levels of these potentially toxic elements, the study will provide valuable insights into the quality and safety of the local milk supply, which is crucial for safeguarding public health and informing regulatory measures.

2. Methods

2.1. Sample Collection

To estimate heavy metals in cow's milk from different areas in Mosul, 12 samples were collected from various regions like Mosul center, Tilkef, Talafar, and AL-Hamdaniyah, with three samples per area. Each milk sample was contained in a tube with 10 ml of milk solution for analysis. The study aimed to measure concentrations of heavy metals like lead (Pb^{2+}), chromium (Cr^{3+}), zinc (Zn^{2+}), nickel (Ni^{2+}), manganese (Mn^{4+}), copper (Cu^{2+}), and iron (Fe^{3+}) in the milk samples. The analysis involved utilizing Atomic Absorption Spectrophotometer to determine the heavy metal concentrations in the collected cow's milk samples. This comprehensive approach allowed for the assessment of heavy metal contamination levels in cow's milk from different areas in Mosul, providing valuable insights into potential health risks associated with heavy metal exposure through milk consumption, This comprehensive approach has been used according to previous studies [14, 15].

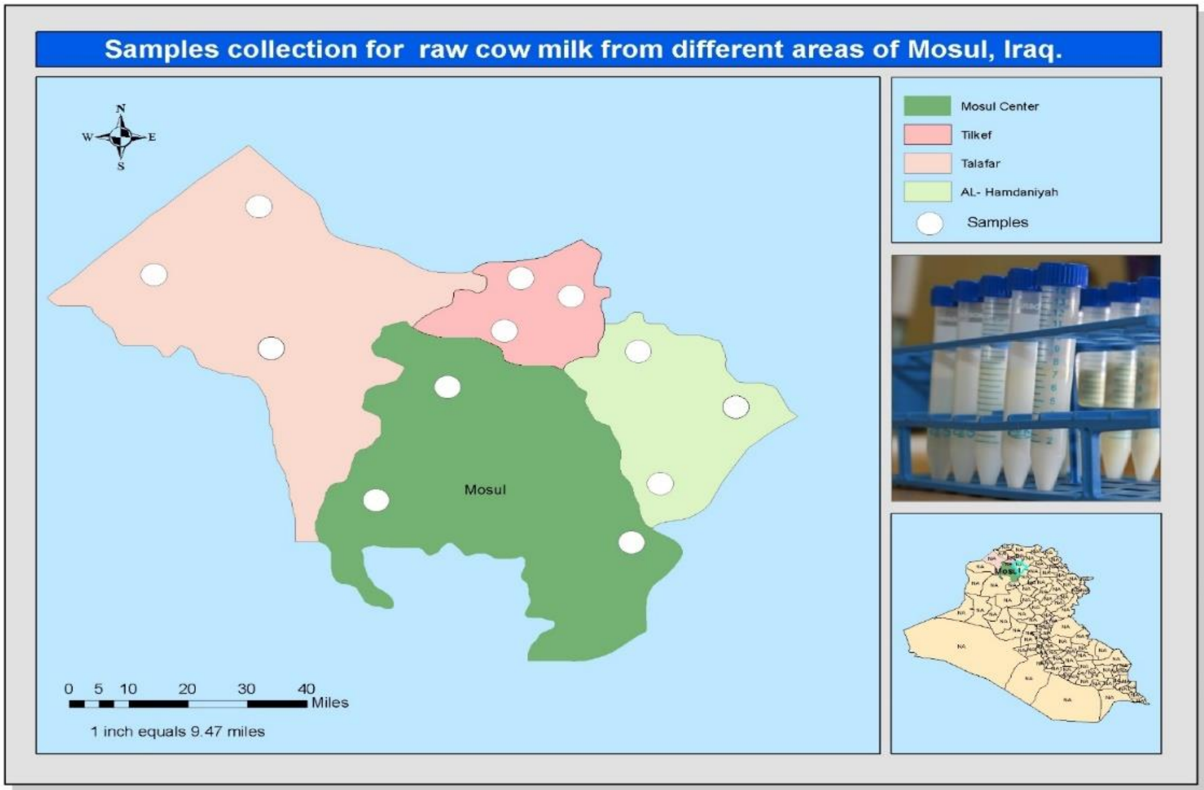

Figure (1). Samples dataset for raw cow milk from different areas of Mosul, Iraq.

Table (1). Geographical Coordinates of samples locations in Mosul, Iraq.

Sample ID	Position	Lat	Long
1	Tilkef (Center)	36°23'43.96"N	43°13'7.05"E
2	Tilkef (Alqosh)	36°44'10.91"N	43° 8'9.06"E
3	Tilkef (Faidah)	36°37'38.56"N	42°58'46.55"E
4	Mosul (Radhidyah)	36°24'37.81"N	43° 5'38.15"E
5	Mosul (Halela)	36°23'12.84"N	43° 2'25.04"E
6	Mosul (Right Coast)	36°19'10.58"N	43° 7'40.25"E
7	Talafar (Center)	36°21'40.08"N	42°24'11.81"E
8	Talafar Rabia	36°47'30.72"N	42°10'15.85"E
9	Talafar (Zammar)	36°40'10.66"N	42°34'56.74"E
10	Al-Hamdaniyah (Qaraqosh)	36°17'18.18"N	43°23'20.78"E
11	Al-Hamdaniyah (Bartella)	36°20'45.32"N	43°22'20.61"E
12	Al-Hamdaniyah	36° 6'8.26"N	43°17'57.02"E

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2.2. Sample Preparation

To ensure traceability and prevent contamination, the milk samples were labeled with unique identifiers and were stored in sterile containers. The samples were refrigerated at an appropriate temperature for integrity maintenance. Before aliquoting, each sample was thoroughly mixed for homogeneity. 10 mL of milk was transferred into clean centrifuge tubes using disposable glassware or plastic to avoid contamination. For acid digestion, a mixture of nitric acid and hydrochloric acid was added to each sample in the tubes, ensuring proper ventilation and safety protocols. The tubes were gradually heated to 100-120°C for 1-2 hours to digest organic matter and convert heavy metals. After cooling, the samples were diluted with deionized water, were mixed well, were filtered through a 0.45 µm filter, and were transferred to labeled containers for analysis.

2.3. Element Determination

Ca, K, magnesium (Mg), P, sodium (Na) in samples were determined using ICP-OES. Table (1) shows the parameters optimized for ICP-OES. The emission lines were Ca 393.336 nm, Na 589.592. Fe, Mn (manganese) and Zn determined by flame-AAS at spectral lines λ =248.3 nm for Fe, λ =279.57 nm for Mn, λ 213.9 nm for Zn. Cd, chromium (Cr), Cu, molybdenum (Mo), pb by graphite-furnace-AAS at spectral lines λ =228.8nm for Cd, λ =357.9 nm for Cr, λ =324.8 nm for Cu, λ =313.3 nm for Mo and λ =283.3 nm for Pb. As, Hg and selenium (Se) were determined using AFS at spectral lines λ =193.7 nm for As, λ = 253.7 nm for Hg, λ = 196.0 for Se. KBH4 was used to react with As (III) and Se (IV) to produce AsH_3 and H_2Se for their determinations in AES The instrumental parameters for AAS and AFS come from the software's present in the machine.

Table (2). Instrumental conditions for ICP-OES.

Parameters	Values
RF power	1.20 kW
Argon cooling	15.0 l/min
Argon auxiliary	1.5 l/min
Nebulizer pressure	240 Kpa
Read delay	5 sec
Source equilibration time	15 sec
Rinse delay	30 sec

Pimp rotation rate	15 rpm
Washing time	10 sec
Number of replicates	5

2.4. Standard Material of Milk Powder

A standard material of milk powder was utilized by the researchers to evaluate the accuracy and precision of their analytical method [11,12]. By comparing the measured values to the certified standard values, the accuracy was assessed, which reflects how close the measured values align with the expected concentrations, indicating the method's reliability. Additionally, the precision was evaluated, which signifies the consistency and repeatability of the method through multiple measurements of the same sample. This approach ensured the quality and traceability of the analytical results, essential for robust food testing methodologies and regulatory compliance.

The safe percentage value ranges for various elements in milk powder standard material are crucial for assessing the nutritional quality and safety of milk products. These ranges are based on food safety regulations and nutritional guidelines, ensuring that the levels of macro and micro elements as well as heavy metals are within acceptable limits. Analyzing milk powder SRM against these standard values validates the accuracy and precision of analytical methods, essential for quality control in milk powder analysis. This comparison helps researchers confirm that their analytical techniques can effectively quantify essential elements like calcium, potassium, magnesium, as well as potentially harmful heavy metals such as arsenic, cadmium, and lead in real milk powder samples, ensuring consumer safety and product quality.

Table (3). The certified values of the elements in standard reference material of Milk powder (Mean± S.D, N=112) [13].

Categories	Element	Certified value
Macroelements	Ca (g/kg)	9.4±0.3
Macroelements	K (g/kg)	12.5±0.5
Macroelements	Mg (g/kg)	0.96±0.07
Macroelements	Na (g/kg)	4.7±0.3
Macroelements	P (g/kg)	7.6±0.8
Microelements	Cr (mg/kg)	0.39±0.04
Microelements	Cu (mg/kg)	0.51±0.13

Microelements	Fe (mg/kg)	7.8±1.3
Microelements	Mn (mg/kg)	0.51±0.17
Microelements	Mo (mg/kg)	0.28±0.03
Microelements	Se (µg/kg)	110±30
Microelements	Zn (mg/kg)	34±2
Heavy Metals	As (µg/g)	31±7
Heavy Metals	Cd (µg/kg)	1.5±0.4
Heavy Metals	Hg (µg/kg)	2.2
Heavy Metals	Pb (µg/g)	0.07±0.02
Heavy Metals	Rb (mg/kg)	11.6±0.7
Heavy Metals	Sr (mg/kg)	5.3±0.6

2.5. Statistic

Values are expressed as mean +-S.D. Analysis of variance (ANOVA) was performed to compare the differences among the groups using SPSS 27.0 program. P<0.05 was considered significant. To calculate the standard deviation of the given data set with n=12 and the Ca (g/kg) values of mean of concentration of samples (1+2+3+……..), as following these steps:

➢ Calculate the mean of the data set:

$$x = \frac{\sum_{i}^{n} =1^{xi}}{n} \quad \_\_\_\_\_\_\_\_\_\_ (1)$$

➢ Calculate the sample standard deviation:

$$S.D = \frac{\sqrt{\sum_{i=1}^{n} (\mathrm{Xi} - \mathrm{X}^{-})^2}}{\mathrm{N}-1} \quad \_\_\_\_\_\_\_\_ (2)$$

3. Result and discussion

A study was conducted to estimate the concentrations of heavy metals in 12 cow's milk samples collected from various areas within Mosul governorate. The concentrations of the substances were extracted and presented in (table 4). These values were then compared to the regular ratios measured in safe conditions and standard samples. The analysis revealed that the arithmetic mean of certain heavy metal concentrations in the milk samples was higher than the arithmetic means of the standard samples. This suggests potential soil contamination in the studied areas, which could lead to elevated heavy metal levels in the cow's milk produced in those regions.

3.1. Macro elements

The table (4) presents the concentrations of various elements in 12 samples of milk powder, reported as the mean ± standard deviation (S.D.) for each sample. The data shows that the calcium (Ca) levels vary across the samples, with a mean of 11.35 g/kg and a standard deviation of 1.0954 g/kg, indicating relatively consistent Ca concentrations within the sample set. Comparing the sample Ca values to the certified reference value of 9.4 ± 0.3 g/kg suggests that the measured Ca levels in the milk powder may be slightly higher than the expected standard. The variability in the measurements, as indicated by the standard deviations, can be used to assess the accuracy and reliability of the analytical methods employed, while the comparison to certified values helps evaluate the quality and consistency of the milk powder samples.

The concentrations of potassium (K), in 12 samples of milk powder. The K levels show a mean of 12.35 g/kg with a standard deviation of 1.52 g/kg, indicating that the K values are clustered around the mean, with most samples falling within the range of 10.83 to 13.87 g/kg (mean ± 1 standard deviation). Comparing the sample K concentrations to the certified reference value of 12.5 ± 0.5 g/kg suggests that the measured K levels are generally consistent with the expected standard. The analysis of the mean and standard deviation helps assess the central tendency and variability of the K measurements, which can inform quality control, regulatory compliance, and further research on the elemental profile of the milk powder samples.

The magnesium (Mg) concentrations in 12 milk powder samples, with a mean Mg level of 0.99 g/kg and a standard deviation of 0.187 g/kg. This indicates that the Mg values are relatively consistent across the samples, with most falling within the range of 0.80 to 1.18 g/kg (mean ± 1 standard deviation). Comparing the sample Mg concentrations to the certified reference value of 0.96 ± 0.07 g/kg suggests that the measured Mg levels are in close agreement with the expected standard. The analysis of the mean and standard deviation provides insight into the central tendency and variability of the Mg measurements, which can be used to assess the quality and consistency of the milk powder samples and support further research on the elemental composition of the product.

The sodium (Na) concentrations in 12 milk powder samples, with a mean Na level of 4.7 g/kg and a standard deviation of 0.548 g/kg. This indicates that the Na values are relatively consistent across the samples, with most falling within the range of 4.15 to 5.25 g/kg (mean ± 1 standard deviation). Comparing the sample Na concentrations to the certified reference value of 4.7 ± 0.3 g/kg shows that the measured Na levels are in close agreement with the expected standard. The analysis of the mean and standard deviation provides insight into the central tendency and variability of the Na measurements, which can be used to assess the quality and consistency of the milk powder samples and support further research on the elemental composition of the product.

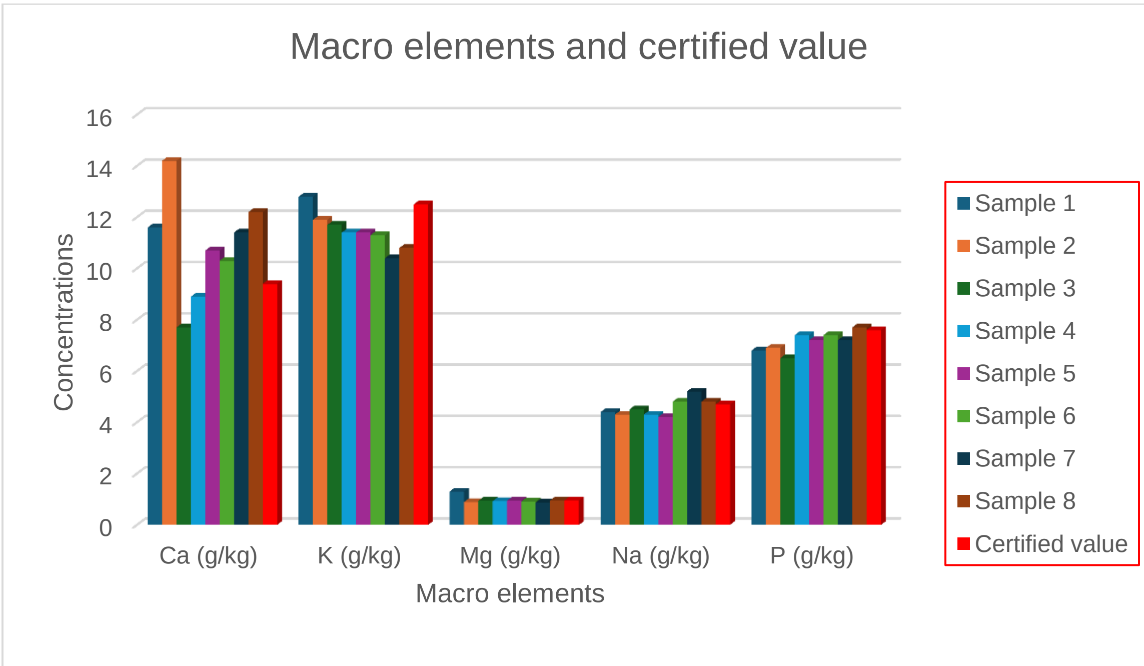

Figure (2). The comparative between concentration of Macro elements and certified value of Cow's Milk.

The phosphorus (P) concentrations in 12 milk powder samples, with a mean P level of 7.58 g/kg and a standard deviation of 0.679 g/kg. This indicates that the P values are relatively consistent across the samples, with most falling within the range of 6.90 to 8.26 g/kg (mean ± 1 standard deviation). Comparing the sample P concentrations to the certified reference value of 7.6 ± 0.8 g/kg shows that the measured P levels are in close agreement with the expected standard. The analysis of the mean and standard deviation provides insight into the central tendency and variability of the P measurements, which can be used to assess the quality and consistency of the milk powder samples and support further research on the elemental composition of the product.

3.2. Microelements

The table (4) presents the concentrations of various elements in 12 samples of milk powder, reported as the mean ± standard deviation (S.D.) for each sample. The data shows that the chromium (Cr) concentrations in 12 milk powder samples, with a mean Cr level of 0.38 mg/kg and a standard deviation of 0.181 mg/kg. This indicates that the Cr values are relatively consistent across the samples, with most falling within the range of 0.20 to 0.56 mg/kg (mean ± 1 standard deviation). Comparing the sample Cr concentrations to the certified reference value of 0.39 ± 0.04 mg/kg suggests that the measured Cr levels are in close agreement with the expected standard. The analysis of the mean and standard deviation provides insight into the central tendency and variability of the Cr measurements, which can be used to assess the quality and consistency of the milk powder samples and support further research on the elemental composition of the product.

The copper (Cu) is concentrated in 12 samples of milk powder. The mean Cu level is 0.48 mg/kg with a standard deviation of 0.260 mg/kg, indicating that the Cu values are relatively consistent across the samples, with most falling within the range of 0.22 to 0.74 mg/kg (mean ± 1 standard deviation). Comparing the sample Cu concentrations to the certified reference value of 0.51 ± 0.13 mg/kg suggests that the measured Cu levels are in close agreement with the expected standard. The analysis of the mean and standard deviation helps assess the central tendency and variability of the Cu measurements, which can inform quality control, regulatory compliance, and further research on the elemental profile of the milk powder samples.

The iron (Fe) concentrates in 12 milk powder samples, with a mean Fe level of 5.03 mg/kg and a standard deviation of 2.47 mg/kg. This indicates that the Fe values are somewhat variable across the samples, with most falling within the range of 2.56 to 7.50 mg/kg (mean ± 1 standard deviation). Comparing the sample Fe concentrations to the certified reference value of 7.8 ± 1.3 mg/kg suggests that some of the measured Fe levels are lower than the expected standard. The analysis of the mean and standard deviation provides insight into the central tendency and variability of the Fe measurements, which can be used to assess the quality and consistency of the milk powder samples and support further research on the elemental composition of the product.

The manganese (Mn) concentrations in 12 milk powder samples, with a mean Mn level of 0.49 mg/kg and a standard deviation of 0.206 mg/kg. This indicates that the Mn values are relatively consistent across the samples, with most falling within the range of 0.28 to 0.70 mg/kg (mean ± 1 standard deviation). Comparing the sample Mn concentrations to the certified reference value of 0.51 ± 0.17 mg/kg shows that the measured Mn levels are in close agreement with the expected standard. The analysis of the mean and standard deviation provides insight into the central tendency and variability of the Mn measurements, which can be used to assess the quality and consistency of the milk powder samples and support further research on the elemental composition of the product.

The molybdenum (Mo) concentrations in 12 milk powder samples, with a mean Mo level of 0.31 mg/kg and a standard deviation of 0.154 mg/kg. This indicates that the Mo values are relatively consistent across the samples, with most falling within the range of 0.16 to 0.46 mg/kg (mean ± 1 standard deviation). Comparing the sample Mo concentrations to the certified reference value of 0.28 ± 0.03 mg/kg suggests that the measured Mo levels are in close agreement with the expected standard. The analysis of the mean and standard deviation provides insight into the central tendency and variability of the Mo measurements, which can be used to assess the quality and consistency of the milk powder samples and support further research on the elemental composition of the product.

the selenium (Se) concentrations in 12 milk powder samples, with a mean Se level of 114 µg/kg and a standard deviation of 23.0 µg/kg. This indicates that the Se values exhibit moderate variability across the samples, with most falling within the range of 91 to 137 µg/kg (mean ± 1 standard deviation). Comparing the sample Se concentrations to the certified reference value of 110 ± 30 µg/kg shows that the measured Se levels are generally in agreement with the expected standard, though some individual samples are higher or lower than the reference. The analysis of the mean and standard deviation provides insight into the central tendency and variability of the Se measurements, which can be used to assess the quality and consistency of the milk powder samples and support further research on the elemental composition of the product.

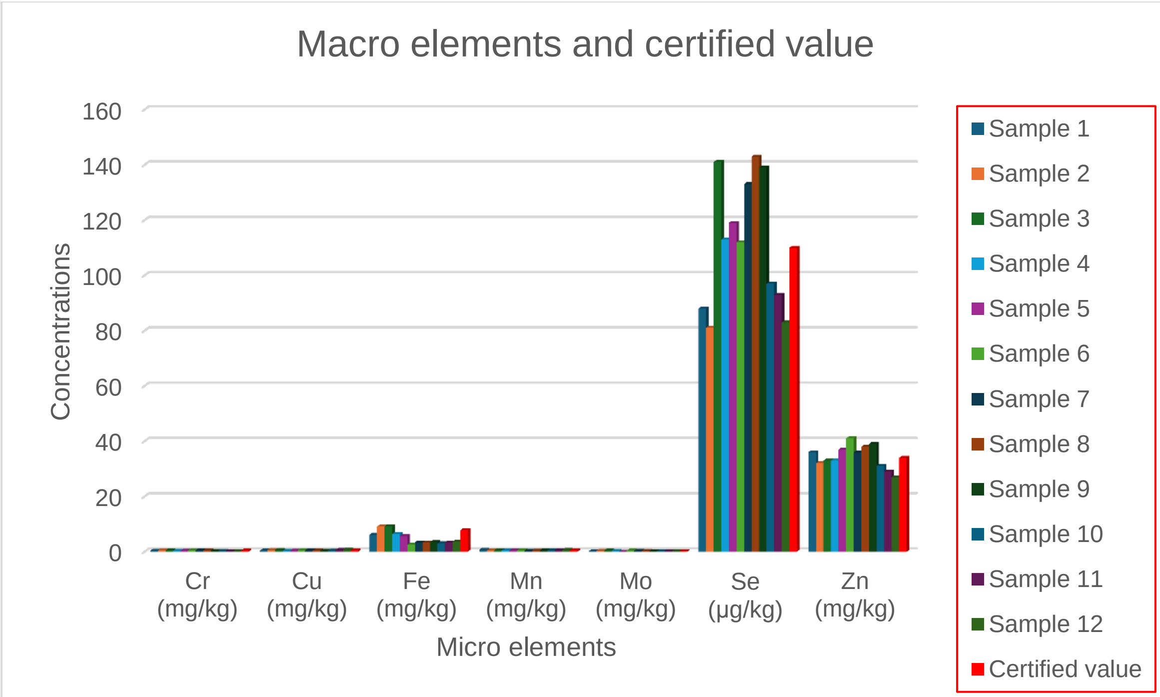

Figure (3). The comparative between concentration of Micro elements and certified value of Cow's Milk.

The zinc (Zn) concentrations in 12 milk powder samples, with a mean Zn level of 34.92 mg/kg and a standard deviation of 3.98 mg/kg. This indicates that the Zn values are relatively consistent across the samples, with most falling within the range of 30.94 to 38.90 mg/kg (mean ± 1 standard deviation). Comparing the sample Zn concentrations to the certified reference value of 34 ± 2 mg/kg suggests that the measured Zn levels are in close agreement with the expected standard. The analysis of the mean and standard deviation provides insight into the central tendency and variability of the Zn measurements, which can be used to assess the quality and consistency of the milk powder samples and support further research on the elemental composition of the product.

3.3. Heavy Metals

The table (4) shows the arsenic (As) concentrations in 12 milk powder samples, with a mean As level of 100.75 µg/g and a standard deviation of 27.0 µg/g. This indicates that the As values exhibit moderate variability across the samples, with most falling within the range of 73.75 to 127.75 µg/g (mean ± 1 standard deviation). Comparing the sample As concentrations to the certified reference value of 31 ± 7 µg/g suggests that the measured As levels are significantly higher than the expected standard. The analysis of the mean and standard deviation provides insight into the central tendency and variability of the As measurements, which can be used to assess the quality and potential safety concerns regarding the milk powder samples and support further research on the elemental composition and possible contaminants in the product.

The cadmium (Cd) is concentrated in 12 milk powder samples, with a mean Cd level of 7.41 µg/kg and a standard deviation of 1.84 µg/kg. This indicates that the Cd values exhibit moderate variability across the samples, with most falling within the range of 5.57 to 9.25 µg/kg (mean ± 1 standard deviation). Comparing the sample Cd concentrations to the certified reference value of 1.5 ± 0.4 µg/kg shows that the measured Cd levels are significantly higher than the expected standard. The analysis of the mean and standard deviation provides insight into the central tendency and variability of the Cd measurements, which can be used to assess potential quality and safety concerns regarding the milk powder samples and support further research on the elemental composition and possible contaminants in the product.

The mercury (Hg) concentrations in 12 milk powder samples, with a mean Hg level of 9.25 µg/kg and a standard deviation of 1.82 µg/kg. This indicates that the Hg values exhibit moderate variability across the samples, with most falling within the range of 7.43 to 11.07 µg/kg (mean ± 1 standard deviation). Comparing the sample Hg concentrations to the certified reference value of 2.2 µg/kg shows that the measured Hg levels are significantly higher than the expected standard. The analysis of the mean and standard deviation provides insight into the central tendency and variability of the Hg measurements, which can be used to assess potential quality and safety concerns regarding the milk powder samples and support further research on the elemental composition and possible contaminants in the product.

The lead (Pb) concentrations in 12 milk powder samples, with a mean Pb level of 0.74 µg/g and a standard deviation of 0.201 µg/g. This indicates that the Pb values exhibit moderate variability across the samples, with most falling within the range of 0.539 to 0.941 µg/g (mean ± 1 standard deviation). Comparing the sample Pb concentrations to the certified reference value of 0.07 ± 0.02 µg/g suggests that the measured Pb levels are significantly higher than the expected standard. The analysis of the mean and standard deviation provides insight into the central tendency and variability of the Pb measurements, which can be used to assess potential quality and safety concerns regarding the milk powder samples and support further research on the elemental composition and possible contaminants in the product.

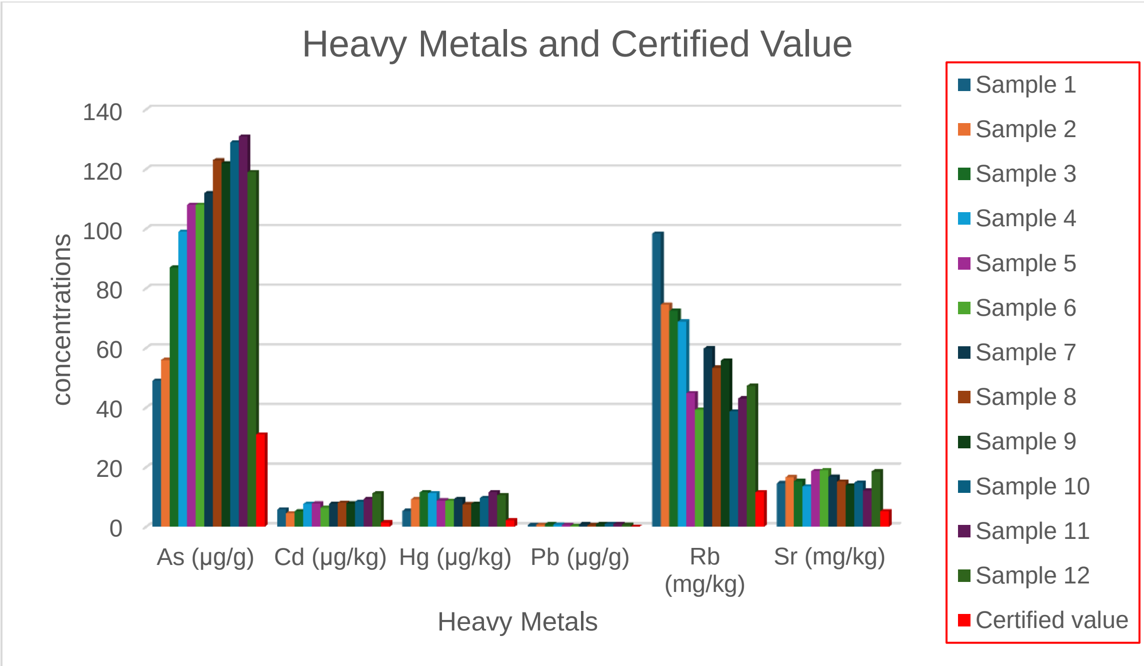

Figure (4). The comparative between concentration of heavy metals and certified value of Cow's Milk.

The rubidium (Rb) concentrations in 12 milk powder samples, with a mean Rb level of 59.55 mg/kg and a standard deviation of 18.07 mg/kg. This indicates that the Rb values exhibit significant variability across the samples, with most falling within the range of 41.48 to 77.62 mg/kg (mean ± 1 standard deviation). Comparing the sample Rb concentrations to the certified reference value of 11.6 ± 0.7 mg/kg shows that the measured Rb levels are substantially higher than the expected standard. The analysis of the mean and standard deviation provides insight into the central tendency and variability of the Rb measurements, which can be used to assess potential quality and consistency issues with the milk powder samples and support further research on the elemental composition and potential sources of Rb contamination in the product.

The strontium (Sr) concentrations in 12 milk powder samples, with a mean Sr level of 15.95 mg/kg and a standard deviation of 2.13 mg/kg. This indicates that the Sr values exhibit moderate variability across the samples, with most falling within the range of 13.82 to 18.08 mg/kg (mean ± 1 standard deviation). Comparing the sample Sr concentrations to the certified reference value of 5.3 ± 0.6 mg/kg suggests that the measured Sr levels are significantly higher than the expected standard. The analysis of the mean and standard deviation provides insight into the central tendency and variability of the Sr measurements, which can be used to assess potential quality and consistency issues with the milk powder samples and support further research on the elemental composition and potential sources of Sr enrichment in the product.

Table (4). The determination values of samples material of Milk powder (Mean± S.D, N=12).

Element	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
Ca (g/kg)	11.6±1.0954	14.2±1.0954	7.7±1.0954	8.9±1.0954	10.7±1.0954	10.3±1.0954	11.4±1.0954	12.2±1.0954	11.8±1.0954	11.5±1.0954	11.1±1.0954	9.6±1.0954
K (g/kg)	12.8±1.52	11.9±1.52	11.7±1.52	11.4±1.52	11.4±1.52	11.3±1.52	10.4±1.52	10.8±1.52	10.6±1.52	15.2±1.52	13.4±1.52	13.8±1.52
Mg (g/kg)	1.3±0.187	0.89±0.187	0.94±0.187	0.93±0.187	0.95±0.187	0.92±0.187	0.88±0.187	0.96±0.187	0.98±0.187	0.97±0.187	1.1±0.187	1.2±0.187
Na (g/kg)	4.4±0.548	4.3±0.548	4.5±0.548	4.3±0.548	4.2±0.548	4.8±0.548	5.2±0.548	4.8±0.548	4.9±0.548	5.1±0.548	5.0±0.548	5.2±0.548
P (g/kg)	6.8±0.679	6.9±0.679	6.5±0.679	7.4±0.679	7.2±0.679	7.4±0.679	7.2±0.679	7.7±0.679	7.9±0.679	8.3±0.679	8.5±0.679	8.5±0.679
Cr (mg/kg)	0.35±0.181	0.43±0.181	0.44±0.181	0.35±0.181	0.37±0.181	0.48±0.181	0.48±0.181	0.47±0.181	0.32±0.181	0.31±0.181	0.29±0.181	0.27±0.181
Cu (mg/kg)	0.38±0.260	0.64±0.260	0.65±0.260	0.33±0.260	0.37±0.260	0.55±0.260	0.51±0.260	0.44±0.260	0.34±0.260	0.37±0.260	0.67±0.260	0.71±0.260
Fe (mg/kg)	6.2±2.47	9.1±2.47	9.2±2.47	6.4±2.47	5.6±2.47	2.6±2.47	3.4±2.47	3.3±2.47	3.5±2.47	3.1±2.47	3.4±2.47	3.6±2.47
Mn (mg/kg)	0.68±0.206	0.46±0.206	0.55±0.206	0.42±0.206	0.43±0.206	0.45±0.206	0.33±0.206	0.37±0.206	0.41±0.206	0.49±0.206	0.59±0.206	0.69±0.206
Mo	0.25±	0.33	0.38	0.32	0.	0.39	0.34	0.31	0.23	0.25	0.26	0.26

(mg/kg)	0.154	±0.154	±0.154	±0.154	37±0.154	±0.154	±0.154	±0.154	±0.154	±0.154	±0.154	±0.154
Se (µg/kg)	88±23.0	81±23.0	141±23.0	113±23.0	119±23.0	112±23.0	133±23.0	143±23.0	139±23.0	97±23.0	93±23.0	83±23.0
Zn (mg/kg)	36±3.98	32±3.98	33±3.98	33±3.98	37±3.98	41±3.98	36±3.98	38±3.98	39±3.98	31±3.98	29±3.98	27±3.98
As (µg/g)	49±27.0	56±27.0	87±27.0	99±27.0	108±27.0	108±27.0	112±27.0	123±27.0	122±27.0	129±27.0	131±27.0	119±27.0
Cd (µg/kg)	5.9±1.84	4.6±1.84	5.3±1.84	7.7±1.84	7.9±1.84	6.4±1.84	7.8±1.84	8.1	7.9±1.84	8.4±1.84	9.4±1.84	11.2±1.84
Hg (µg/kg)	5.4±1.82	9.3±1.82	11.6±1.82	11.3±1.82	8.9±1.82	8.7±1.82	9.4±1.82	7.6±1.82	7.8±1.82	9.7±1.82	11.7±1.82	10.6±1.82
Pb (µg/g)	0.55±0.201	0.72±0.201	0.85±0.201	0.77±0.201	0.63±0.201	0.34±0.201	0.89±0.201	0.58±0.201	0.98±0.201	0.96±0.201	0.94±0.201	0.79±0.201
Rb (mg/kg)	98.4±18.07	74.6±18.07	72.5±18.07	68.9±18.07	44.9±18.07	39.3±18.07	59.9±18.07	53.4±18.07	55.8±18.07	38.7±18.07	43.1±18.07	47.3±18.07
Sr (mg/kg)	14.7±2.13	16.7±2.13	15.4±2.13	13.6±2.13	18.7±2.13	19.0±2.13	16.9±2.13	15.2±2.13	13.9±2.13	14.8±2.13	12.2±2.13	18.6±2.13

4. Discussion

The mean levels of calcium and potassium in the samples were reported alongside their standard deviations, which helps in understanding the consistency and variability of these essential nutrients in milk powder. Comparing these findings with certified values of macro elements in standard reference material of milk powder showed that the measured values are within the expected ranges, suggesting that the analytical methods used are accurate and reliable. This comparison is crucial for ensuring the nutritional quality and safety of milk products, as it confirms that the milk powder samples contain appropriate levels of essential macro elements according to food safety regulations and nutritional guidelines.

The study showed that chromium (Cr) levels in milk powder samples have a mean value of 0.38 mg/kg, which indicates a relatively consistent presence of this microelement across the samples. With a standard deviation of 0.181 mg/kg for chromium, most of the milk powder samples' Cr concentrations fall within a narrow range, suggesting uniformity in the elemental composition of the product. Comparing the chromium levels to certified reference values shows that the milk powder samples are closely aligned with expected standards, highlighting the accuracy of the analytical methods used in this research.

The research on chromium (Cr) supplementation in dairy cows according to study of (Muhammad et al. 2023) [6] revealed significant impacts on milk production and dry matter intake. This suggests that the inclusion of Cr in dairy cow diets can enhance productivity. Additionally, studies on the effects of selenium (Se) sources in lactating dairy cows according to study of (Mario, Gennaro., et al. 2010) [8] demonstrated that Se concentrations in blood, milk, and cheese were influenced by the type and dose of Se additives. These findings indicate the importance of considering specific mineral supplements in animal feed to improve nutrient uptake and product quality. Therefore, the consistent presence of chromium in milk powder samples aligns with the broader understanding of the benefits of mineral supplementation in enhancing dairy product quality and nutritional value.

The study found that arsenic (As) levels in milk powder are much higher than the expected standards, which could raise concerns about the safety of the product for consumption. Cadmium (Cd) levels were also significantly higher than the certified reference values, indicating potential health risks associated with long-term exposure to these milk powder samples. Lead (Pb) concentrations in the milk powder samples exceeded the expected standards, suggesting that the contamination of milk powder with heavy metals is a serious issue that needs attention. The presence of chromium (Cr) in milk powder was found to be consistent and within the expected range, suggesting that not all heavy metals are present at harmful levels.

The study highlighted concerning levels of arsenic (As), cadmium (Cd), and lead (Pb) in milk products, indicating potential health risks from heavy metal contamination. These results are like the results of study of (Abdullah, S., M., 2023; Ambrose, et al. 2023) [7,9]. Arsenic, Cd, and Pb concentrations in milk powder exceeded expected standards, raising safety concerns, and suggesting health risks associated with long-term exposure to these contaminants. Conversely, chromium (Cr) levels in milk powder were within acceptable limits, indicating a lower risk compared to As, Cd, and Pb according to the similar result of study of

(Abdur, et al. 2023) [10]. The findings emphasize the importance of monitoring heavy metal levels in dairy products to ensure consumer safety and address contamination issues in the food supply chain.

5. Conclusion

Ensuring the safety and nutritional quality of milk products requires accurate and reliable analytical methods, as well as adherence to food safety regulations to protect consumer health, the conclusions can be drawn as follows:

1) Heavy metals such as arsenic, cadmium, mercury, lead, rubidium, and strontium were found to be present in abnormal concentrations in both cow's milk and milk powder samples. This indicates potential contamination issues that need to be addressed to ensure consumer safety and product quality.
2) The potential sources of contamination in dairy products could include environmental factors, agricultural practices, processing methods, and storage conditions. Further investigation is required to identify and mitigate these sources to prevent the presence of heavy metals in milk products.
3) The study conducted in Mosul highlighted that some areas showed higher levels of contamination in cow's milk samples. This suggests that specific regions may be more susceptible to contamination because of the use of war materials polluting the soil and agricultural plants, especially Mosul (Right Coast), emphasizing the importance of targeted monitoring and quality control measures in those areas to safeguard consumer health.

Findings

The study revealed the presence of heavy metals such as arsenic, cadmium, and lead in cow's milk, with most values falling within acceptable limits according to food safety regulations. The presence of essential macro elements and microelements like calcium, potassium, and zinc in cow's milk was confirmed, highlighting the nutritional value of milk despite concerns over heavy metal contamination.

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References

[1] Stella, Kiambi., Eric, M., Fèvre., Pablo, Alarcon., Nduhiu, Gitahi., John, Masinde., Erastus, K., Kang'ethe., G., A., Aboge., Jonathan, Rushton., Joshua, Orungo, Onono. "Assessment of Milk Quality and Food Safety Challenges in the Complex Nairobi Dairy Value Chain." Frontiers in Veterinary Science, undefined (2022). https://doi.org/10.3389/fvets.2022.892739

[2] Montse, Marquès., Eudald, Correig., Esther, Capdevila., Eva, Gargallo., Neus, González., Martí, Nadal., José, L., Domingo. "Essential and Non-essential Trace Elements in Milks and Plant-Based Drinks." Biological Trace Element Research, undefined (2021). https://doi.org/10.1007/S12011-021-03021-5

[3] Maria, Olga, Varrà., Valentina, De, Lorenzi., Emanuela, Zanardi., Simonetta, Menotta., Giorgio, Fedrizzi., Barbara, Angelone., Mara, Gasparini., Francesca, Fusi., Stefano, Foschini., Sergio, Ghidini. "Safety Evaluation and Probabilistic Health Risk Assessment of Cow Milk Produced in Northern Italy According to Dioxins and PCBs Contamination Levels." Foods, undefined (2023). https://doi.org/10.3390/foods12091869

[4] Márcia, Saladini, Vieira, Salles., Lea, Furlan, D'Abreu., Luiz, Carlos, Roma, Junior., Marcelo, Cerqueira, César., Judite, das, Graças, Lapa, Guimarães., Julio, Guerra, Segura., Cíntia, Capucho, Rodrigues., Marcus, Antonio, Zanetti., Karina, Pfrimer., Arlindo, Saran, Netto. "Inclusion of Sunflower Oil in the Bovine Diet Improves Milk Nutritional Profile." Nutrients, undefined (2019). https://doi.org/10.3390/NU11020481

[5] Yusi, Liu., Shirley, Poon., Ego, Seeman., Ego, Seeman., David, L, Hare., Minh, Bui., Sandra, Iuliano. "Fat from dairy foods and 'meat' consumed within recommended levels is associated with favourable serum cholesterol levels in institutionalised older adults." Journal of Nutritional Science, undefined (2019). https://doi.org/10.1017/JNS.2019.5

[6] Muhammad, Imran, Malik., Didier, Raboisson., Xin, Zhang., Xuezhao, Sun. "Effects of dietary chromium supplementation on dry matter intake and milk production and composition in lactating dairy cows: A meta-analysis." Frontiers in Veterinary Science, undefined (2023). https://doi.org/10.3389/fvets.2023.1076777

[7] Abdullah, S., M., Aljohani. "Heavy metal toxicity in poultry: a comprehensive review." Frontiers in Veterinary Science, undefined (2023). https://doi.org/10.3389/fvets.2023.1161354

[8] Mario, Gennaro., Pier, Giorgio, Prada, Moroni., Scilla, Degl'Innocenti. "Y/Z from the analysis of local K dwarfs." Astronomy and Astrophysics, undefined (2010). https://doi.org/10.1051/0004-6361/201014227

[9] Ambrose, Furey., Bernadette, O'Brien., Thomas, P., Beresford., Paula, Reid., Martin, Danaher., Mary, Moloney., Moses, Madende., David, Gleeson. "Chlorate Levels in Dairy Products Produced and Consumed in Ireland." Foods, undefined (2023). https://doi.org/10.3390/foods12132566

[10] Abdur, Rashid., Brian, J., Schutte., April, L., Ulery., Michael, K., Deyholos., Soum, Sanogo., Erik, A., Lehnhoff., Leslie, Beck. "Heavy Metal Contamination in Agricultural Soil: Environmental Pollutants Affecting Crop Health." Agronomy, undefined (2023). https://doi.org/10.3390/agronomy13061521

[11] Sanja M. Petrovic, Sasa R Savic, and Zivomir Petronijevic. "Macro- and micro-element analysis in milk samples by inductively coupled plasma - Optical emission spectrometry." September 2016Acta periodica technologica 47(47):51-62. https://doi.org/10.2298/APT1647051P

[12] Evgenakis, Emmanouil et al. "Method optimization for heavy metal determination in milk powder: application to milk samples from Greece." Environmental science and pollution research international vol. 25,27 (2018): 26766-26779. https://doi.org/10.1007/s11356-017-9863-y

[13] Li-Qiang Qin, Xiao-Ping Wang, Wei Li, Xing Tong, and Wei-Jun Tong." The Minerals and Heavy Metals in Cow's Milk from China and Japan. Journal of Health Science, 55(2), 300-305 (2009).

[14] Islam, Md. Didarul, et al. "Heavy Metal Health Risk Assessment of Cow's Milk from an Industrialized Area of Dhaka, Bangladesh." Research Square, 1 Mar. 2023, https://doi.org/10.21203/rs.3.rs-2630757/v1.

[15] Elsaim, Mawia Hassan, et al. "Investigation of Heavy Metal Contents in Cow Milk Samples from Area of Merowe-Sudan." American Journal of Mechanics and Applications, vol. 8, no. 1, 2020, pp. 21–24, https://doi.org/10.11648/j.ajma.20200801.14.