Afyon Kocatepe Üniversitesi Fen ve Mühendislik Bilimleri Dergisi
Afyon Kocatepe University – Journal of Science and Engineering
https://dergipark.org.tr/tr/pub/akufemubid

Araştırma Makalesi / Research Article
DOI: https://doi.org/10.35414/akufemubid.1391478
AKÜ FEMÜBİD 24 (2024) 045401 (839-846)
AKU J. Sci. Eng. 24 (2024) 045401 (839-846)

Determination of Some Minerals and Heavy metals in Raw Cow's Milk

Makale Bilgisi / Article Info
Alındı/Received: 15.11.2023
Kabul/Accepted: 13.06.2024
Yayımlandı/Published: 20.08.2024

Çiğ İnek Sütünde Bazı Minerallerin ve Ağır Metallerin Belirlenmesi

Neslihan YILDIZ KÜÇÜK*, **Ramazan GÖKÇEK**

Muş Alparslan University, Vocational School of Social Sciences, Department of Hotel, Restaurant and Catering Service, Muş, Türkiye

Öz
Süt, sağlıklı ve besleyici bir gıdadır. Tüm yaş gruplarında tüketilebilmesi ve kolay ulaşılabilir olması sütün beslenmemizdeki önemini artırmaktadır. Teknolojik gelişmelerin artmasıyla birlikte çevre kirliliği de artış göstermektedir. Bu kirlilik sonucunda ağır metaller ve metal karışımlı bileşikler, besin zinciri yoluyla hayvanlara ve insanlara geçmektedir. Bu durum ise canlı sağlığını olumsuz bir şekilde etkilemektedir. Ayrıca bazı mineral maddelerin aşırı miktarda vücuda alımı da toksik olabilmektedir. Ağır metallerin gıdalara bulaşması çeşitli yollarla ortaya çıkmaktadır. Süt ve peynir gibi asidik nitelikli gıdaların üretiminde kullanılan kapların bileşimindeki metallerin çözünerek ürüne geçme riski diğer gıdalara göre daha kolay meydana gelmektedir. Bu amaçla araştırmamızda, Muş ilinin farklı bölgelerinden toplanan 10 adet çiğ inek sütü örneğinde, kalsiyum, magnezyum, sodyum, potasyum, çinko, demir, bakır, mangan minerallerinin ve kurşun, kadmiyum ağır metallerinin miktarı Atomik Absorbsiyon Spektrometresi cihazı ile belirlenmiştir. Numunelerin kurşun, kadmiyum, demir, bakır ve mangan içerikleri sırasıyla 0.40±0.01-0.19±0.01, 0.38±0.00-0.20±0.00, 1.96±0.01-0.24±0.01, 0.50±0.00-0.11±0.00 ve 0.20±0.00-0.12±0.00 mg/L olarak belirlenmiştir. En yüksek kalsiyum (433.45±0.00 mg/L) ve potasyum (1146.25±0.02 mg/L) seviyeleri S10 numunesinde tespit edilmiştir. En düşük magnezyum (197.81±0.00 mg/L) ve sodyum (661.17±0.01 mg/L) seviyeleri S3 numunesinde bulunmuştur. Örneklerin çinko içerikleri 8.25±0.00-14.51±0.00 mg/L arasında değişmektedir. Elde edilen sonuçlar, sütte mineral madde miktarını ve ağır metal bulaşmasını etkileyen faktörler göz önünde bulundurularak değerlendirilmiştir.

Anahtar Kelimeler: *Çiğ inek sütü; Ağır metal; Mineral içerik; AAS*

Abstract
Milk is a healthy and nutritious food. Its ability to be consumed by all age groups and its easy accessibility increase the importance of milk in our diet. As technological developments increase, so does environmental pollution. As a result of this pollution, metals and metal mixtures reach animals and humans through the food chain. This situation negatively affects the health of living organisms. In addition, excessive intake of some mineral substances can also be toxic. The contamination of heavy metals in food occurs through various pathways. The risk of metals in the composition of the containers used in the production of acidic foods such as milk and cheese dissolving and passing into the product is more likely to occur than in other foods. For this purpose, in our research, 10 samples of raw cattle milk collected from different regions of Muş province were analyzed for the amounts of calcium, magnesium, sodium, potassium, zinc, iron, copper, manganese, and heavy metals lead and cadmium using Atomic Absorption Spectrometry device. The samples' lead, cadmium, iron, copper, and manganese contents were determined as 0.40±0.01-0.19±0.01, 0.38±0.00-0.20±0.00, 1.96±0.01-0.24±0.01, 0.50±0.00-0.11±0.00 and 0.20±0.00-0.12±0.00 mg/L, respectively. The highest levels of calcium (433.45±0.00 mg/L) and potassium (1146.25±0.02 mg/L) were detected in sample S10. The lowest levels of magnesium (197.81±0.00 mg/L) and sodium (661.17±0.01 mg/L) were found in sample S3. The zinc contents of the samples varied between 8.25±0.00-14.51±0.00 mg/L. The results obtained were evaluated considering the factors affecting the amount of mineral substances and heavy metal contamination in the milk.

Keywords: *Raw's cow milk; Heavy metal; Mineral content; AAS*

1. Introduction

Milk is preferred by consumers due to its high biological value, numerous health benefits, easy accessibility, and affordability. It is considered a complete food due to its composition of proteins, essential fatty acids, lactose, and mineral contents (Meshref *et al.* 2014, Licata *et al.* 2004, Enb *et al.* 2009). Milk is a source of macroelements such as Ca (calcium) and P (phosphorus). Additionally, milk may contain microelements and heavy metals. Microelements such as copper (Cu), iron (Fe), selenium (Se), and zinc (Zn), which are important for growth, are referred to as trace elements. While a certain amount of these elements is necessary for the body, high levels can have adverse effects on human health (Varol and Sünbül 2020, Qin *et al.* 2009, Kazi *et al.* 2009). Metals generally serve as cofactors for many enzymes and play a crucial role in various physiological functions of humans and animals. The deficiency of these essential elements, vital for living organisms, can lead to disruptions in the entire physiological system (Khan *et al.* 2014).

**Sorumlu Yazar/Corresponding Author: Neslihan YILDIZ KÜÇÜK*
e-posta/e-mail: n.yildiz@alparslan.edu.tr

Heavy metals, which are not naturally present in the structure of food, contaminate food from water, soil, and air, as well as from metallic tools and equipment used during production, and packaging materials used during storage and distribution (Türközü *et al.* 2014). However, environmental pollution caused by human activities, industrial pollution, and agricultural practices increases the probability of heavy metals being present in food. Lead (Pb), cadmium (Cd), nickel (Ni), cobalt (Co), and arsenic (As) are among the heavy metals that contaminate food (İstanbulluoğlu *et al.* 2013, Enb *et al.* 2009, Algan *et al.* 2012). Heavy metal toxicity varies according to factors such as age, gender, intake level, exposure route and duration, metal oxidation state, solubility, intake frequency, absorption amount, and excretion mechanisms/efficiency (Khan *et al.* 2014).

The contamination of milk and dairy products with heavy metals can occur due to the tanks, machinery, and equipment used during milking, transportation, production, and storage of dairy products. Additionally, heavy metals from different sources can contaminate the animals that produce milk through the feed they consume, the water they drink, and the air they breathe (Safaei *et al.* 2020, Özturan and Atasever 2018, İstanbulluoğlu *et al.* 2013). Furthermore, metals such as Cu, Zn, Fe, As, Cd, and Sn (tin) can also contaminate milk and dairy products through the processing water used in the production process (Özturan and Atasever 2018). Therefore, determining the concentration of heavy metals in milk and dairy products is not only an indicator of the product's safety but also provides information about the level of pollution in the environment where the animals that provide the milk live and feed (Kılıç and Bozkaya 2017).

Several heavy metal contaminations, including Pb, Cd, Zn, Co, Cu, Fe, Ni, As, Se, aluminum (Al), chromium (Cr), and manganese (Mn), have been identified in milk and dairy products in various research studies (Al Sidawi *et al.* 2021, Sarsembayeva *et al*. 2020, Safonov 2020, Licata *et al.* 2004, Jorhem *et al.* 1991, Coni *et al.* 1996, Chirinos-Peinado and Castro-Bedriñana 2020, Campillo *et al.* 1998). Chary *et al.* (2000) found Zn, Cr, Cu, Ni, Co, and Pb content in soil, plant, and milk samples, demonstrating that contamination in soil and plants also affects milk and other plant products. Chirinos-Peinado and Castro-Bedriñana 2020, Campillo *et al.* 1998). Chary *et al.* (2000) found Zn, Cr, Cu, Ni, Co, and Pb content in soil, plant, and milk samples, demonstrating that contamination in soil and plants also affects milk and other plant products. The studies have generally been conducted in the environments where the researchers are located, providing information about the contaminations in those regions (Temurci *et al.* 2006, Simsek *et al.* 2000, İnci *et al.* 2017, Bıgucu *et al.* 2016, Ayar *et al.* 2007).

Heavy metals, when ingested through food, can lead to various health problems depending on their concentrations and the tissues in which they are stored. These health issues include various types of cancer, cardiovascular diseases, organ failures, and various irregularities in the body (Saei-Dehkordi and Fallah 2011, Özlü *et al.* 2012, Järup 2003, Boudebbouz *et al.* 2021). The toxic effects of heavy metals are particularly observed in the brain and kidneys. The accumulation rate of heavy metals in the body is influenced by the individual's age, nutritional status, and the chemical structure of the metal (Hu 2002). High levels of Cd intake can lead to liver and kidney failure; Pb can cause mental and physical developmental delays in children, kidney failure and high blood pressure in adults; Hg can lead to inflammatory rheumatism, irregularities in the kidneys, nerves, and circulatory system; As can cause circulatory disorders and cardiovascular diseases. High levels of Zn in the body can lead to skin irritations, vomiting, and stomach cramps; and high concentrations of Ni can cause kidney and lung cancer (Türközü and Şanlıer 2012, Azimi *et al.* 2017).

In terms of food safety, it is crucial to regularly analyze milk and dairy products for heavy metals. Therefore, our study was conducted to provide information on the mineral content and the presence of heavy metals in raw milk from the specified region, which is important for human health. Additionally, the mineral and heavy metal content of raw milk was evaluated taking into consideration the animal's diet, the materials used in milking, the equipment used in milk storage, and the industrial and traffic density of the location.

2. Materials and Methods

2.1 Study area and sampling

In this study, 10 samples of raw cow's milk obtained from different regions of Muş province in Türkiye were used (Figure 1). The location of the raw milk samples and their sample codes are given in Table 1. The milk collected from different regions was placed in 100 mL sample containers and stored at -20°C until the day of analysis.

2.2 Preparation of samples and AAS analysis

The samples were prepared by modifying the method used by Kılıç and Bozkaya (2017). 27 mL of raw milk sample was mixed with 23 mL of 20% TCA (trichloroacetic acid) solution and left at room temperature for 10 minutes. The mixture was then transferred to 50 mL centrifuge tubes and centrifuged at 4°C-4100 rpm. After centrifugation, the serum part (40 mL) was transferred to a round-bottom flask and 4 mL of concentrated nitric acid (HNO_3) was added. The mixture was heated at 200°C until the volume was reduced by half. The approximately 20 mL sample was then cooled to room temperature on a heating plate. Subsequently, 2 mL of concentrated HNO_3 was added and the sample was evaporated at 200°C for 15 minutes.

Table 1. Sample code and regions

Sample code	Regions
S1	Muş/ Center/ Güzeltepe Neighborhood
S2	Muş/ Center/ Güzeltepe Neighborhood
S3	Muş/ Center/ Güzeltepe Neighborhood
S4	Muş/ Center/ Güzeltepe Neighborhood
S5	Muş/ Center/ Özdilek Village
S6	Muş/ Center/ Özdilek Village
S7	Muş/ Center/ Özdilek Village
S8	Muş/ Center/ Özdilek Village
S9	Muş/ Center/ Ağaçlık Village
S10	Muş/ Center/ Sungu Town

After cooling to room temperature, 4 mL of 30% Hydrogen Peroxide (H_2O_2) and 2 mL of concentrated sulfuric acid (H_2SO_4) were added. The solution was evaporated at 200°C for 15 minutes until it turned brown. The samples were then cooled to room temperature, and 2 mL of concentrated perchloric acid ($HClO_4$) was added. After the sample became clear and the volume was reduced to 10 mL, it was cooled to room temperature. Distilled water was added to dilute the samples to 20 mL, and they were centrifuged at 4100 rpm for 15 minutes. The serum parts were then transferred to centrifuge tubes and prepared for analysis. The analyses conducted on the Atomic Absorption Spectrometer (AAS) device (Agilent 240FS AA) involved the calibration curves of Pb, Cd, Fe, Cu, Mn, Ca, Mg, Na, K, and Zn elements using 1000 mg/L ICP multi-element standard solution IV stock solution. The wavelengths of the elements are 217.0, 228.8, 248.3, 324.8, 279.5, 422.7, 285.2, 589.0, 766.5, and 213.9 nm, respectively. After the calibration curves were drawn, the amount of each element (mg/L) in the samples was determined.

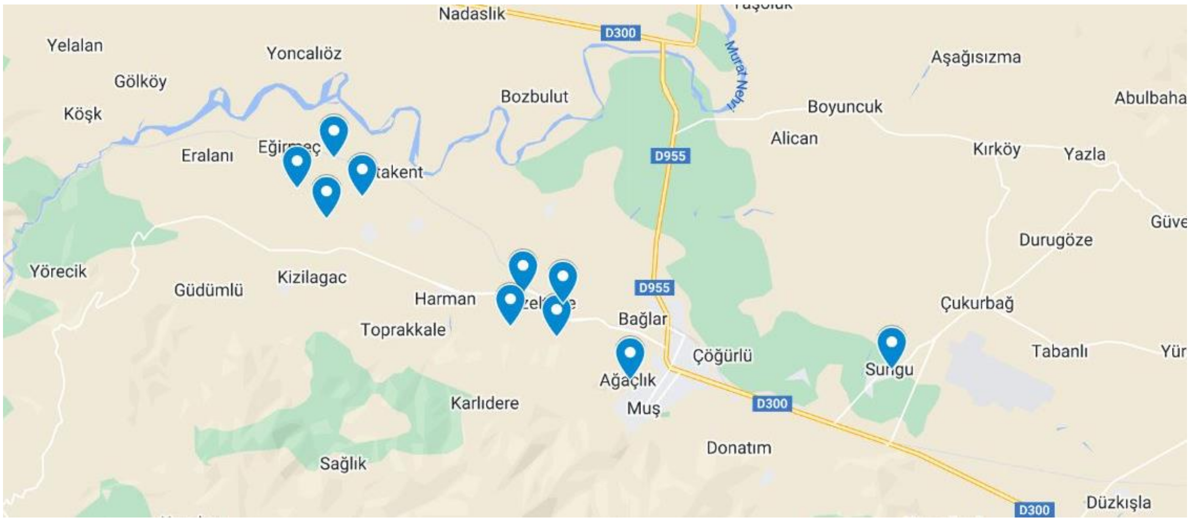

Figure 1. Map of the study area

Table 2. Amounts of heavy metals and minerals in raw cow milk (Mean±S.D.) (mg/L)

Samples	Pb	Cd	Fe	Cu	Mn	Ca	Mg	Na	K	Zn
S1	0.38±0.01	0.20±0.00	0.97±0.02	0.11±0.00	0.12±0.00	118.10±0.00	230.36±0.00	1119.54±0.07	228.80±0.01	9.85±0.01
S2	0.37±0.01	0.30±0.00	1.96±0.01	0.19±0.00	0.18±0.00	217.07±0.02	294.19±0.00	1312.16±0.05	466.43±0.01	10.69±0.00
S3	0.21±0.01	0.26±0.00	0.34±0.02	0.23±0.00	0.14±0.00	215.47±0.00	197.81±0.00	661.17±0.01	463.09±0.01	10.03±0.00
S4	0.27±0.01	0.30±0.00	0.24±0.01	0.50±0.00	0.17±0.00	328.80±0.01	262.02±0.01	770.40±0.01	604.17±0.02	8.25±0.00
S5	0.40±0.01	0.31±0.00	0.52±0.00	0.14±0.00	0.19±0.00	234.29±0.00	211.09±0.01	1494.51±0.02	347.57±0.01	14.51±0.00
S6	0.40±0.01	0.28±0.00	0.72±0.07	0.11±0.00	0.17±0.00	231.47±0.00	252.40±0.01	2498.99±0.01	446.88±0.02	9.84±0.00
S7	0.29±0.01	0.28±0.00	0.56±0.01	0.15±0.00	0.16±0.00	199.59±0.00	256.24±0.00	1247.56±0.02	379.51±0.04	13.55±0.00
S8	0.19±0.01	0.28±0.00	0.92±0.00	0.13±0.00	0.15±0.00	219.73±0.00	254.88±0.00	1241.71±0.02	635.57±0.05	10.08±0.00
S9	0.21±0.00	0.31±0.00	0.95±0.01	0.14±0.00	0.17±0.00	367.73±0.00	249.17±0.00	709.23±0.04	637.44±0.05	12.05±0.00
S10	0.44±0.01	0.38±0.00	0.60±0.01	0.14±0.00	0.20±0.00	433.45±0.00	254.91±0.00	1526.55±0.04	1146.25±0.02	14.18±0.00

3. Results and Discussion

The amounts of Pb, Cd, Fe, Cu, Mn, Ca, Mg, Na, K, and Zn detected in cow's milk obtained from different regions of Muş are shown in Table 2. The contamination of the environment with metals such as lead is a well-known problem worldwide.

The increase in lead concentration in the air, soil, plants, and water generally occurs as a result of the lead in gasoline being emitted into the atmosphere by motor vehicle exhaust gases. Industrial facilities, waste incineration, and coal combustion are other sources that contribute to the increase of lead in the atmosphere. Therefore, it is likely that the levels of lead are high in regions with intense industrialization.

Lead is a highly toxic element for the nervous, blood, stomach, urine, and genital systems (Enb *et al.* 2009). It has been found that the amount of lead in the samples (Table 2) exceeds the limit specified for raw milk in the Turkish Food Codex Contaminants Regulation (0.02 mg/kg) (URL-1). Since there is no residue limit specified for other elements in the regulation, a comparison could not be made. The presence of lead levels exceeding the limit in the milk obtained from different settlements is thought to be due to the animals being fed in areas close to traffic. Animals in areas close to traffic may be exposed to lead through both respiration and food. Indeed, in a similar study conducted by Simsek *et al.* (2000), 75 raw milk samples were examined for heavy metals. The researchers reported that the lead levels detected in the industrial and traffic areas exceeded the value specified in the Turkish Food Codex Raw Milk Regulation, while they were lower in rural areas. In a similar study conducted by Çakır and Yarsan (2021), the average Pb levels in milk samples collected from different regions of Turkey were found to be 0.008±0.009 mg/L. It was reported that the concentrations of Pb in 10 samples exceeded the value specified in the Turkish Food Codex Contaminants Regulation.

Cadmium is one of the most toxic metals. Additionally, cadmium is a substance that can easily evaporate at the operating temperatures of common industrial processes. A large part of the cadmium in the atmosphere is released as a result of burning iron scrap and metallurgical processes. Therefore, the spread of industrial waste into the environment poses a great risk. Cd leads to health problems such as high blood pressure, prostate cancer, mutations, and fetal (embryonic) death (Enb *et al.* 2009). In addition, Cd can cross the placental barrier and can cause neurotoxic problems (Boudebbouz *et al.* 2021). The concentration of Cd in milk samples varied between 0.20±0.00-0.38±0.00 mg/L (Table 2). The detected amounts of Cd were found to be higher than those determined in studies by Qin *et al.* (2009) and Enb *et al.* (2009) (1.13-4.19 µg/kg, 0.070-0.112 mg/kg, respectively), while they were similar to the values detected by Bıgucu *et al.* (2016) in the months of November and December. The tolerable Cd intake has been determined by the Expert Committee on Food Additives (JECFA) as 0.007 mg/kg/week (Serencam vd. 2018). It was determined that the obtained results exceeded the tolerable Cd limit.

Iron is an important mineral found in the structure of hemoglobin, which carries oxygen to the tissues, and myoglobin, which stores oxygen in the muscles. Milk is quite poor in Fe content (0.2 mg/kg) (Tarakçı and Küçüköner 2005). Excess iron taken into the body can cause tissue damage and organ failure and increase the risk of cancer (Eid *et al.* 2017). When the Fe contents of the samples were examined, it was determined that the Fe amount of sample S2 (1.96±0.01 mg/L) was higher than the other samples (Table 2). It has been reported that the amount of Fe in milk varies depending on the species of the animal and the lactation period, and that there is no change due to nutrition sources (Gaucheron 2000). In a similar study conducted by Sucak *et al.* (2020), the average Fe content of raw milk obtained from the Muş region was determined to be 0.83±0.09 mg/L. The intake of Fe mineral above the recommended amount can cause a toxic condition (Boudebbouz *et al.* 2021). Indeed, it was determined that the Fe content in the samples was not higher than the daily Fe intake recommended (10-18 mg/day) (Ilgaz *et al.* 2020). However, the reason for the higher amount of Fe mineral in the samples than naturally found in milk could be the transfer of Fe from the containers used for storage of milk after milking. Cu is essential for normal human growth. However, its excessive intake can lead to negative effects on human health, in particular Wilson's disease, which manifests as ceruloplasmin deficiency. Mn taken in high doses seriously affects human health. It leads to deterioration of neuromuscular and neurological control as well as emotional and mental problems (Sidawi *et al.* 2021). When the concentrations of Cu and Mn in the samples were examined, higher levels of Cu were found in samples S2, S3, and S4 compared to the other samples, while the highest level of Mn was detected in sample S10 (Table 2). In a study conducted by Çakır and Yarsan (2021), the levels of certain elements in milk samples collected from different regions of Turkey were examined. It was found that the amount of Fe was lower in our study's data, while the amount of Cu showed similarity. It was suggested that cadmium was generally not detected in the samples. In another study by İnci *et al.* (2017), the levels of some heavy metals in cow's milk produced in the Aydın province were examined. It was observed that the Fe content in the milk was higher than the values determined in our study, while the Mn content was found to be at lower levels. The daily tolerable intake of Cu determined by JECFA is 0.5 mg/kg (Serencam *et al.* 2018). The trace elements known as Cu and Mn in milk are found to be 190-300 µg/L and 5-87 µg/L, respectively (Metin 2010). Indeed, it was determined that the amount of Cu in sample S4 was higher than the naturally occurring copper in milk, while normal levels of Cu were found in the other samples. The Mn content was found to be higher than the naturally occurring manganese in milk in all samples.

The contamination of milk with iron, copper, and manganese can occur due to factors such as the equipment and containers used for milk transportation and storage, water sources, feed, environmental pollutants, and milk processing stages. The levels of heavy metals vary depending on the geographical region, animal species, feed type, and processing methods. The high content of heavy metals in animal feed increases the likelihood of their presence in milk (Özturan and Atasever 2018). Considering the levels of heavy metals detected in milk in our study, it is thought that the contamination of raw milk with heavy metals increases due to the equipment and containers used for milk transportation and storage, feed, and environmental factors.

The chemical and sensory properties of raw cow's milk vary according to regional conditions, and therefore the mineral content also varies. The mineral content varies according to the breed and type of milk-producing animal, lactation period, animal nutrition, health status, and season (Metin 2010). The trace elements found in milk generally originate from plant sources in the region where the dairy animals are raised. Milk contains 0.75% mineral matter (Özturan and Atasever 2018).

The technological features in the formation of milk and its importance in terms of nutrition are closely associated with calcium, a crucial mineral. Calcium plays a significant role, particularly in the developmental process of children. Approximately 75% of the daily calcium requirement is obtained from milk and dairy products (Metin, 2010). Within the scope of our study, the calcium content of the analyzed milks varied between 118.10±0.00-433.45±0.00 mg/L, as indicated in Table 2. The lower calcium levels are presumed to be attributed to the spring season when the milks were sourced. A similar study identified fluctuations in the calcium content of cow's milk from different regions of Çanakkale, with a decrease observed during the spring months (Bıgucu *et al.* 2016). In another study, the mineral content of 106 samples of cow's milk from the Thrace region was determined, with an average 43Ca value of 168 mg/L and a 44Ca value of 278 mg/L (Öztürk 2022). Various research on mineral content in cow's milk has indicated calcium levels ranging from 900 to 1200 mg/L (Sucak *et al.* 2020, Özturan and Atasever 2018, Efe 2008).

Magnesium is a mineral that supports bone and heart health and regulates nervous system and muscle functions (Fiorentini *et al.* 2021). Magnesium was detected in the milk samples in the range of 197.81±0.00-294.19±0.00 mg/L (Table 2). Generally, the magnesium content of the samples shows similarity to each other. Sodium is an essential mineral used in nutrition. It is important for maintaining appropriate blood volume and blood pressure. Excessive sodium intake is associated with chronic kidney disease, cardiovascular diseases, hypertension, and stroke (Patel and Joseph 2020). The sodium content of the samples ranged from a minimum of 661.17±0.01 mg/L to a maximum of 2498.99±0.01 mg/L. It was observed that the S6 sample had a higher sodium content compared to the other samples (Table 2). A diet rich in potassium has been found to have many health benefits. These benefits include a lower risk of cardiovascular disease, stroke, and blood pressure (Clegg *et al.* 2020). The lowest potassium amount in the samples was found in the S1 sample (228.80±0.01 mg/L), and the highest potassium amount (1146.25±0.02 mg/L) was detected in the S10 sample (Table 2).

Zinc is one of the most important minerals involved in numerous biological functions. Due to its ability to bind enzymes and transcription factors, it is considered a versatile trace element. It is used in protein and collagen synthesis (Chasapis *et al.* 2020). When examining the zinc content of the milk samples, a variation in the range of 8.25±0.00-14.51±0.00 mg/L was determined. Bıgucu *et al.* (2016) reported potassium, sodium, and magnesium levels in cow's milk in the ranges of 19.86±0.387-884.6±8.011 mg/L, 92.95±1.856-532.5±4.970 mg/L, and 12.44±0.371-248.7±1.998 mg/L, respectively. In another study, the average magnesium, potassium, and sodium levels in 100 examined milk samples were observed to be 82.2 mg/L, 1210 mg/L, and 249 mg/L, respectively (Öztürk 2022). The magnesium content in milk analyzed in Diyarbakır was determined to be an average of 135.9±48.9 mg/kg, indicating that the milk in Diyarbakır province and its districts is rich in magnesium (Efe 2008). In a study by Meshref *et al.* (2014), the zinc content of analyzed milks ranged from 2.73 to 18.316 mg/L. The similarity in the mineral content of the examined milks can be explained by the similarity in the plant presence in the feeding areas of the animals. Additionally, the quantity of minerals in the samples highlights the influence of seasonal variations. The high sodium content in the samples can be attributed to the generally sodium-enriched nature of animal feeds and the increase in sodium in the bodies of animals fed with these feeds, leading to its transfer into milk.

4. Conclusion

The findings obtained indicate contamination with heavy metals in milk samples, with the lead content exceeding the limit specified for raw milk in the Turkish Food Codex Contaminants Regulation. Since the regulation does not specify limits for other heavy metals, comparisons could not be made. Evaluation of trace elements in milk was conducted based on their natural occurrence rates in milk. In light of the literature, it is believed that heavy metals and trace elements may contaminate milk through various pathways. The mineral content of the samples generally showed similarities. This is attributed to the similarity in the soil and plant conditions where the dairy animals are fed and the simultaneous collection of milk within the same time frame. It was determined that nutrition and seasonal factors are crucial in the variation of mineral content. The presence of heavy metals in milk poses a serious threat to health. High consumption of these substances can lead to kidney diseases, cancer, neurological disorders, and other health problems. Therefore, regulations or standards regarding the presence of heavy metals in milk need to be more comprehensive.

In conclusion, considering the detected levels of heavy metals in raw milk in our study and those reported in the literature, it is evident that necessary precautions should be taken in this regard. Moreover, implementing measures to reduce heavy metal pollution in agricultural practices and industrial processes can enhance the safety and quality of milk and dairy products. Additionally, by paying attention to the nutrition of animals, the mineral content of raw milk can be enriched, making it more beneficial from a nutritional standpoint.

Declaration of Ethical Standards
The authors declare that they comply with all ethical standards.

Credit Authorship Contribution Statement
Author-1: Investigation, methodology, software, validation, formal analysis, writing/review and editing.
Author-2: Investigation, Software, formal analysis.

Declaration of Competing Interest
The authors have no conflicts of interest to declare regarding the content of this article.

Data Availability Statement
Datasets are available on request. The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Acknowledgements

The authors acknowledge the financial support of The Scientific and Technological Research Council of Türkiye under (TÜBiTAK) 2209-A Research Project Support Programme for Undergraduate Students.

5. References

Algan, G., Tekinşen, O.C. and Gök, V., 2012. Investigation of some heavy metal presence in the milk of cattle. *Eurasian Journal of Veterinary Sciences*, **28**, 159-163.

Al Sidawi, R., Ghambashidze, G., Urushadze, T. and Ploeger, A., 2021. Heavy metal levels in milk and cheese produced in the Kvemo Kartli region, Georgia. *Foods*, **10**, 2234. https://doi.org/10.3390/foods10092234

Ayar, A., Sert, D. and Akın, N., 2007. Konya'da tüketime sunulan süt ve ürünlerinin ağır metal içeriklerinin belirlenmesi. *Selçuk Üniversitesi Ziraat Fakültesi Dergisi*, **21**, 58-64.

Azimi, A., Azari, A., Rezakazemi, M. and Ansarpour, M., 2017. Removal of heavy metals from industrial wastewaters: a review. *ChemBioEng Reviews*, **4**, 37-59. https://doi.org/10.1002/cben.201600010

Bıgucu, E., Kaptan, B., Palabıyık, İ. and Oksuz, O., 2016. The effect of environmental factors on heavy metal and mineral compositions of raw milk and water samples. *Journal of Tekirdag Agricultural Faculty*, **13**, 61-70.

Boudebbouz, A., Boudalia, S., Bousbia, A., Habila, S., Boussadia, M.I. and Gueroui, Y., 2021. Heavy metals levels in raw cow milk and health risk assessment across the globe: a systematic review. *Science of The Total Environment*, 751, 141830. https://doi.org/10.1016/j.scitotenv.2020.141830

Campillo, N., Vinas, P., Lopez-Garcıa, I. and Hernandez-Cordoba, M., 1998. Direct determination of copper and zinc in cow milk, human milk and infant formula samples using electrothermal atomization atomic absorption spectrometry. *Talanta*, **46**, 615-622. https://doi.org/10.1016/S0039-9140(97)00306-8

Chary, N.S., Kamala, C.T. and Raj, D.S.S., 2008. Assessing risk of heavy metals from consuming food grown on sewage irrigated soils and food chain transfer. *Ecotoxicology and Environmental Safety*, **69**, 513-524.

https://doi.org/10.1016/j.ecoenv.2007.04.013

Chasapis, C. T., Ntoupa, P. S. A., Spiliopoulou, C. A. and Stefanidou, M. E., 2020. Recent aspects of the effects of zinc on human health. *Archives of toxicology*, **94**, 1443-1460. https://doi.org/10.1007/s00204-020-02702-9

Chirinos-Peinado, D. M. and Castro-Bedriñana, J. I., 2020. Lead and cadmium blood levels and transfer to milk in cattle reared in a mining area. *Heliyon*, **6**, e03579. https://doi.org/10.1016/j.heliyon.2020.e03579

Clegg, D. J., Headley, S. A. and Germain, M. J., 2020. Impact of dietary potassium restrictions in CKD on clinical outcomes: benefits of a plant-based diet. *Kidney Medicine*, **2**, 476-487. https://doi.org/10.1016/j.xkme.2020.04.007

Coni, E., Bocca, A., Coppoelli, P., Caroli, S., Cavallucci, C. and Trabalza Marinucci, M., 1996. Minor and trace element content in sheep and goat milk and dairy products. *Food Chemistry*, **57**, 253-260. https://doi.org/10.1016/0308-8146(95)00216-2

Çakir, E.O. and Yarsan, E., 2021. Türkiye'nin farklı bölgelerinden toplanan süt örneklerinde bazı metal düzeyleri. *Etlik Veteriner Mikrobiyoloji Dergisi*, **32**, 50-62. https://doi.org/10.35864/evmd.879842

Efe, A., 2008. Diyarbakır il ve ilçelerinden temin edilen sütlerde ağır metal ve mineral madde içeriklerinin incelenmesi. Yüksek Lisans Tezi, Dicle Üniversitesi Fen Bilimleri Enstitüsü, Diyarbakır, 73.

Eid, R., Arab, N. T. and Greenwood, M. T., 2017. Iron mediated toxicity and programmed cell death: A review and a re-examination of existing paradigms. *Biochimica et Biophysica Acta (BBA)-Molecular Cell Research*, **1864**, 399-430. https://doi.org/10.1016/j.bbamcr.2016.12.002

Enb, A., Abou Donia, M.A., Abd-Rabou, N.S., Abou-Arab, A.A.K. and El-Senaity, M.H., 2009. Chemical composition of raw milk and heavy metals behavior during processing of milk products. *Global veterinaria*, **3**, 268-275.

Fiorentini, D., Cappadone, C., Farruggia, G. and Prata, C., 2021. Magnesium: biochemistry, nutrition, detection, and social impact of diseases linked to its deficiency. *Nutrients*, **13**, 1136. https://doi.org/10.3390/nu13041136

Gaucheron, F., 2000. Iron fortification in dairy industry. *Trends in Food Science & Technology*, **11**, 403-409. https://doi.org/10.1016/S0924-2244(01)00032-2

Hu, H., 2002. Human Health and Toxic Metals. McCally, M., MIT Press, 65-81.

Ilgaz, Ş., Yardım, N., Çimen, M.Y.B., Kanbur, N., Özmert, E.N., Satman, İ., Tavil, B., Tayfur, M. and Ulman, C., 2020. Türkiye'de besinlerin D vitamini, folik asit ve demir ile zenginleştirilmesi: sağlık Bakanlığı önerileri. *Turkish Journal of Public Health*, **18**, 226-248.

İnci, A., Aypak, S.Ü. and Güven, G., 2017. Aydın ilinde üretilen inek sütlerinde bazı ağır metal düzeylerinin araştırılması. *Gıda*, **42**, 229-234. https://doi.org/10.15237/gida.GD16079

İstanbulluoğlu, H., Oğur, R., Tekbaş, Ö.F. and Bakır, B., 2013. Süt ve süt ürünlerinde ağır metal kirliliği. *Türkiye Klinikleri Tıp Bilimleri Dergisi*, **33**, 410-419. https://doi.org/10.5336/medsci.2012-29718

Järup, L., 2003. Hazards of heavy metal contamination. *British Medical Bulletin*, **68**, 167-182. https://doi.org/10.1093/bmb/ldg032

Jorhem, L., Slorach, S., Sundström, B. and Ohlin, B., 1991. Lead, cadmium, arsenic and mercury in meat, liver and kidney of Swedish pigs and cattle in 1984–88. *Food Additives & Contaminants*, **8**, 201-211. https://doi.org/10.1080/02652039109373970

Kazi, T.G., Jalbani, N., Baig, J.A., Kandhro, G.A., Afridi, H.I., Arain, M.B., Jamali, M.K. and Shah, A.Q., 2009. Assessment of toxic metals in raw and processed milk samples using electrothermal atomic absorption spectrophotometer. *Food and Chemical Toxicology*, **47**, 2163-2169. https://doi.org/10.1016/j.fct.2009.05.035

Khan, N., Jeong, I.S., Hwang, I.M., Kim, J.S., Choi, S.H., Nho, E.Y., Choi, J.Y., Park, K.S. and Kim, K.S., 2014. Analysis of minor and trace elements in milk and yogurts by inductively coupled plasma-mass spectrometry (ICP-MS). *Food Chemistry*, **147**, 220-224. https://doi.org/10.1016/j.foodchem.2013.09.147

Kılıç, M. and Bozkaya, O., 2017. Çiğ süt örneklerinde ağır metal ve metal kontaminasyonlarının belirlenmesi ve sağlık üzerine etkisi. *Ankara Sağlık Hizmetleri Dergisi*, **16**, 1-10. https://doi.org/10.1501/Ashd_0000000120

Licata, P., Trombetta, D., Crıstanı, M., Gıofre, F., Martıno, D., Calo, M. and Naccarı, F., 2004. Levels of "toxic" and "essential" metals in samples of bovine milk from various dairy farms in Calabria, Italy. *Environment International*, **30**, 1-6. https://doi.org/10.1016/S0160-4120(03)00139-9

Meshref, A.M., Moselhy, W.A. and Hassan, N.E.H.Y., 2014. Heavy metals and trace elements levels in milk and milk products. *Journal of food measurement and characterization*, **8**, 381-388.

Metin, M., 2010. Süt Teknolojisi Sütün bileşimi ve İşlenmesi (9. Baskı), Ege Üniversitesi Basımevi, 793.

Özlü, H., Atasever, M.A., Urçar, S. and Atasever, M., 2012. Erzurum'da tüketime sunulan kaşar peynirlerinin mineral madde içeriği ve ağır metal kontaminasyonu.

Kafkas Üniversitesi Veterinerlik Fakültesi Dergisi, **18**, 205-208. https://doi.org/10.9775/kvfd.2011.5258

Özturan, K. and Atasever, M., 2018. Süt ve ürünlerinde mineral maddeler ve ağır metaller. *Atatürk Üniversitesi Veteriner Bilimleri Dergisi*, **13**, 229-241. https://doi.org/10.17094/ataunivbd.317822

Öztürk, S., 2022. Süt örneklerinde bazı eser elementlerin indüktif eşleşmiş plazma-kütle spektrometri ile incelenmesi. Yüksek Lisans Tezi, Trakya Üniversitesi Sağlık Bilimleri Enstitüsü, Edirne, 72.

Patel, Y. and Joseph, J., 2020. Sodium intake and heart failure. *International journal of molecular sciences*, **21**, 9474. https://doi.org/10.3390/ijms21249474

Qin, L.Q., Wang, X.P., Li, W., Tong, X. and Tong, W.J., 2009. The minerals and heavy metals in cow's milk from China and Japan. *Journal of health science*, **55**, 300-305. https://doi.org/10.1248/jhs.55.300

Saei-Dehkordi, S.S. and Fallah, A.A., 2011. Determination of copper, lead, cadmium and zinc content in commercially valuable fish species from the persian gulf using derivative potentiometric stripping analysis. *Microchemical Journal*, **98**, 156-162. https://doi.org/10.1016/j.microc.2011.01.001

Safaei, P., Seilani, F., Eslami, F., Sajedi, S. R. and Mohajer, A., 2021. Determination of essential nutrients and heavy metal content of raw cow's milk from East Azerbaijan province, Iran. *International Journal of environmental analytical chemistry*, **101**, 2368-2378. https://doi.org/10.1080/03067319.2019.1702171

Safonov, V., 2020. Assessment of heavy metals in milk produced by black-and-white Holstein cows from Moscow. *Current research in nutrition and food science journal*, **8**, 410-415. https://dx.doi.org/10.12944/CRNFSJ.8.2.06

Sarsembayeva, N. B., Abdigaliyeva, T. B., Utepova, Z. A., Biltebay, A. N. and Zhumagulova, S. Z., 2020. Heavy metal levels in milk and fermented milk products produced in the Almaty region, Kazakhstan. *Veterinary world*, **13**, 609. https://doi.org/10.14202/vetworld.2020.609-613

Simsek, O., Gültekin, R., Öksüz, O. and Kurultay, S., 2000. The effect environmental pollution on the heavy metal content of raw milk. *Food/Nahrung*, **5**, 360-363. https://doi.org/10.1002/1521-3803(20001001)44:5<360::AID-FOOD360>3.0.CO;2-G

Sucak, M.G., Özkaya, A., Ağyar, O. and Yilmaz, E., 2020. Çiğ ve UHT Sütlerinde Kimyasal Parametre Değişimlerinin Tespiti. *Bitlis Eren Üniversitesi Fen Bilimleri Dergisi*, **9**, 1-6.

Tarakçı, Z. and Küçüköner, E., 2005. Süt ve süt ürünlerinin demir içeriği yönünden zenginleştirilmesi. *Gıda*, **30**, 363-368.

Temurci (Usta), H. and Güner, A., 2006. Ankara'da tüketime sunulan süt ve beyaz peynirlerde ağır metal kontaminasyonu. *Atatürk Üniversitesi Veteriner Bilimleri Dergisi*, **1**, 20-28.

Türközü, D. and Şanlıer, N., 2012. Gıdalardaki ağır metal kontaminasyonları: güncel bakış. *Selçuk Tarım ve Gıda Bilimleri Dergisi*, **26**, 73-80.

Türközü, D. and Şanlıer, N., 2014. Gıdalardaki ağır metal kontaminasyonları bulaşma kaynakları sağlık riskleri ve ulusal/uluslararası standartlar. *Gıda Teknolojileri Elektronik Dergisi*, **9**, 29-46.

Varol, M. and Sünbül, M. R., 2020. Macroelements and toxic trace elements in muscle and liver of fish species from the largest three reservoirs in Turkey and human risk assessment based on the worst-case scenarios. *Environmental research*, **184**, 109298. https://doi.org/10.1016/j.envres.2020.109298

Internet References

URL-1- TGK, Türk Gıda Kodeksi Bulaşanlar Yönetmeliği, 2011. https://www.resmigazete.gov.tr/eskiler/2011/12/20111229M3-8.htm . (13-Nov-2023).