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Research

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Research on Heavy Metal Content of Fattening and Dairy Feeds

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A B S T R A C T

Heavy metal pollution for the world is reaching more alarming dimensions every day. Soil, water and air are polluted due to industrial developments, industrial wastes and heavy metals are included in the food chain through crop production and pose a risk to all living things. Feed is one of the most important links in this chain. In this study, 25 feed samples, including 18 fattening feeds and 7 dairy feeds, which were on commercial sale in different provinces in Türkiye in 2023, were obtained and As, Cd, Cr, Cu, Fe, Ni and Pb concentrations were determined. As content varied between 0.00-0.06 mg kg^{-1}, Cd content ≤0.01 mg kg^{-1}, Cr content 0.00-0.74 mg kg^{-1}, Cu content 2.29-30.79 mg kg^{-1}, Fe content 13.16-43.99 mg kg^{-1}, Ni content 0.39-1.88 mg kg^{-1} and Pb metal was not detected. None of the heavy metal concentrations exceeded the permissible limit values. Although Fe and Cu concentrations did not exceed the permissible limit values, they were found to be even lower than the recommended amounts in feeds. No heavy metal contamination was found in the 25 feed samples examined, but it would be appropriate to check the heavy metal levels of feeds at regular intervals due to the rapid increase in environmental pollution and the risk of contamination of crop production and the food chain, particularly in regions where traditional fodder cultivation is constrained.

1. Introduction

Metals with a density exceeding 5 g cm^{-3} are defined as heavy metals (Gao et al., 2024). While trace elements such as manganese, copper and zinc are essential for the life of living organisms, heavy metals such as lead, cadmium, chromium, arsenic and nickel are not essential and do not play a vital role in the biological processes of living organisms. Heavy metals can naturally occur in trace amounts in soil and their excessive accumulation can degrade soil quality and harm to plants. Cr, As, Ni, Cd, Pb, Cu and Zn are recognized as priority toxic pollutants by the United States Environmental Protection Agency (USEPA) (Cheng et al., 2023). Heavy metals such as lead, cadmium, arsenic and mercury are released into the environment in large quantities by the developing industry and activities of various industrial branches and pose a danger to living organisms, including humans (Dinakar et al., 2008; Kusvuran et al., 2016; Alzahrani et al., 2018). At the same time, fertilizers used in agricultural production have long-term effects on heavy metal accumulation in soils. Some inorganic fertilizers contain a certain amount of heavy metal contamination and long-term application of fertilizers can lead to heavy metal accumulation in

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soils (Carnelo et al., 1997; Deng, 2024). Due to the intensive production methods applied in agriculture and the rapidly developing industry, it is stated that the problems related to heavy metal, aflatoxin, and pesticide contamination in the feedstuffs produced and their final product, compound feed, are increasing and need to be eliminated (Dagasan and Ozen, 2011). When animals consume contaminated feeds, harmful components such as heavy metals and pesticides can reach levels that threaten human health by passing into final products such as meat, eggs, and milk. In order to prevent animal foods from becoming harmful, the feeds used should be kept under control (Kurtoglu and Coskun 2001).

Merako (2010) reported that arsenic (As) was found in 11%, lead (Pb) in 22%, cadmium (Cd) in 78%, copper (Cu) and zinc (Zn) in 100% of 27 feed samples and that lead (Pb) content in two of the samples was above the limit values required in feeds. Dagasan and Ozen (2011) analyzed some heavy metals in milk, beef fattening, lamb fattening, egg cage, and broiler feed samples taken from compound feed factories in 5 regions where animal husbandry and compound feed production is the most intensive. They reported that the amount of Hg in two of the feed samples and Pb in one of them exceeded the maximum values allowed in the regulation.

There are different commercial feeds available in the market for ovine, bovine and poultry farming. The content of these feeds is under the influence of many factors. Heavy metal concentrations in feeds vary depending on the plant species, the heavy metal level of the soil in which the plant grows, the properties of feed additives and many other reasons.

As a result of the literature review, it was observed that similar studies on dairy and fattening feeds were conducted in 2011 and before. Due to the increasing environmental pollution and the increasing heavy metal contamination, there is a need for heavy metal screening of commercial feeds in the market and obtaining up-to-date data.

In this research, it was aimed to investigate the heavy metal contents of commercially available dairy and fattening feeds, to determine whether the results obtained exceed the permissible limit values in our country and in different countries and to evaluate the heavy metal risk in these feeds.

2. Materials and Method

This study investigated dairy and fattening feeds of 25 different companies in the market in 2023. In the study, 18 different fattening feeds and 7 different dairy feeds were used. The website of the Ministry of Agriculture and Forestry contains a list of feed facilities active in Türkiye (Anonymous, 2024). Feed samples were tried to be obtained by taking care to take one sample from each province from the regions where the enterprises are concentrated. In addition, care was taken to select the sampled firms from the largest establishments operating in that province.

The label information of a general dairy feed and a general fattening feed is presented in Table 1 for informative purposes.

Table 1. Nutrient content information of fattening and dairy feeds in general

Cattle fattening feed				Cattle dairy feed			
Crude protein	16%	Fe	50 mg kg^{-1}	Crude protein	21%	Fe	50 mg kg^{-1}
C. cellulose	11%	I	0.8 mg kg^{-1}	C. cellulose	8.50%	I	0.8 mg kg^{-1}
Ash	10%	Co	0.15 mg kg^{-1}	Ash	9.50%	Co	0.1 mg kg^{-1}
C. Oil	2.40%	Cu	20 mg kg^{-1}	C. Oil	3%	Cu	10 mg kg^{-1}
Sodium	0.45%	Mn	50 mg kg^{-1}	Sodium	0.40%	Mn	50 mg kg^{-1}
Vitamin D_3	2000 IU kg^{-1}	Zn	50 mg kg^{-1}	Vitamin D_3	3000 IU kg^{-1}	Zn	100 mg kg^{-1}
Vitamin E	20 mg kg^{-1}	Se	0.15 mg kg^{-1}	Vitamin E	40 mg kg^{-1}	Se	0.3 mg kg^{-1}
Vitamin A	7000 IU kg^{-1}			Vitamin A	9000 IU kg^{-1}		

Note: Compiled from the label information of private companies for informational purposes.

The provinces where the firms are located are given in Table 2 and shown in Figure 1. Approximately 100 g samples were taken from the feeds and dried in an oven at 70 °C and the dry weight feed samples were ground to achieve homogeneity. The dried and ground samples were subjected to microwave digestion (Miller, 1998) and then metal concentrations were determined by ICP-MS (Inductively Coupled Plasma Mass Spectrometry).

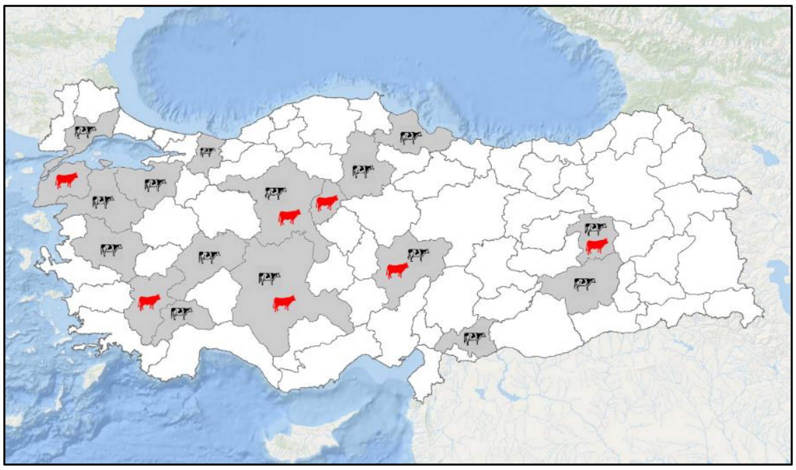

Figure 1. Map view of the provinces where fattening and dairy feed companies/factories are located (Red color represents dairy feed and black color represents fattening feed)

Table 2. Provinces where fattening and dairy feed companies/factories are located

Fattening feed / Province where the firm is located		**Dairy feed/ Province where the firm is located**
Afyon	Gaziantep	Ankara
Ankara	Gaziantep	Bingöl
Balıkesir	Kayseri	Çanakkale
Bingöl	Kayseri	Denizli
Burdur	Konya	Kayseri
Bursa	Manisa	Kırıkkale
Çorum	Sakarya	Konya
Diyarbakır	Samsun	
Gaziantep	Tekirdağ	

Microwave digestion: The digestion process was modified according to the method described in the literature (Miller, 1998). After the feed samples were dried and ground, they were weighed 1 g and transferred to the vessels of the microwave device (CEM-MARS 6) and 10 ml of nitric acid (HNO3) was added. Adjustments were made for the microwave digestion process. After appropriate dilution and filtration, the samples were measured by ICP-MS (Inductively coupled plasma mass spectrometry).

- Calculation process: Total As, Cd, Cr, Cu, Fe, Ni, Ni, Pb in feed (mg kg-1) = It x F (1)
- It = the measurement value of the feed solution adjusted according to the sample solution
- F= dilution factor/ sample amount

As a result of the necessary calculation procedures, heavy metals in feeds were determined as mg kg^{-1}.

3. Results

3.1.Heavy metal concentrations in fattening feeds (As, Cd, Cr, Cu, Fe, Ni and Pb mg kg^{-1})

As, Cd, Cr, Cu, Fe, Ni and Pb contents of fattening feeds obtained from eighteen (18) different companies were analyzed and shown in Table 3. The lowest As concentration was 0.00 mg kg^{-1} in feed sample number 15 from Manisa province, the highest As concentration was 0.06 mg kg^{-1} in feed samples from 9 provinces and the average As concentration was 0.05 mg kg^{-1} in all feed samples. Cadmium (Cd) concentration was ≤0.01 mg kg^{-1} in all feed samples. The lowest Cr concentration of 0.00 mg kg-1 was determined in feed samples from Bingöl, Kayseri and Tekirdağ provinces, while the highest Cr concentration of 0.74 mg kg^{-1} was determined in sample number 10 from Gaziantep province. The average Cr content of all feed samples was 0.31 mg kg^{-1}. The lowest Cu concentration of 2.63 mg kg^{-1} was determined in feed sample number 4 from Bingöl and the highest Cu concentration of 30.79 mg kg^{-1} was determined in sample number 7 from Çorum.

The average Cu content of all feed samples was 7.60 mg kg^{-1}. The lowest Fe concentration was determined as 13.16 mg kg^{-1} in feed sample number 3 from Balıkesir province and the highest Fe concentration was determined as 43.99 mg kg^{-1} in sample number 10 from Gaziantep province. The average Fe content of all feed samples was 22.72 mg kg^{-1}. The lowest Ni concentration of 0.39 mg kg^{-1} was determined in feed sample number 13 from Kayseri province and the highest concentration of 1.88 mg kg^{-1} was determined in sample number 10 from Gaziantep province. The average Ni content of all feed samples was 0.94 mg kg^{-1}. Pb metal was not detected in the analyzed fattening feed samples.

Table 3. Heavy metal concentrations of fattening feeds (mg kg^{-1})

		Concentrations (mg kg^{-1})						
Sample No.	**Province**	**As**	**Cd**	**Cr**	**Cu**	**Fe**	**Ni**	**Pb**
1	Afyon	0.05	0.01	0.32	11.32	20.04	1.16	ND
2	Ankara	0.05	0.01	0.30	8.20	16.74	0.81	ND
3	Balıkesir	0.05	0.01	0.30	6.50	13.16	0.92	ND
4	Bingöl	0.05	0.01	0.00	2.63	18.09	0.44	ND
5	Burdur	0.05	0.01	0.30	3.58	32.41	0.46	ND
6	Bursa	0.06	0.01	0.36	4.86	21.37	1.10	ND
7	Çorum	0.06	0.01	0.34	30.79	22.17	1.40	ND
8	Diyarbakır	0.06	0.01	0.66	2.78	35.04	1.14	ND
9	Gaziantep	0.06	0.01	0.42	4.74	13.62	0.97	ND
10	Gaziantep	0.06	0.01	0.74	3.08	43.99	1.88	ND
11	Gaziantep	0.06	0.01	0.52	4.54	31.24	1.12	ND
12	Kayseri	0.06	0.01	0.00	6.68	15.78	0.81	ND
13	Kayseri	0.05	0.01	0.00	4.28	15.84	0.39	ND
14	Konya	0.06	0.01	0.45	7.63	30.56	0.87	ND
15	Manisa	0.00	0.01	0.35	7.85	24.57	0.74	ND
16	Sakarya	0.05	0.01	0.27	7.34	19.46	0.94	ND
17	Samsun	0.06	0.01	0.28	6.04	19.01	0.72	ND
18	Tekirdağ	0.05	0.01	0.00	14.05	15.81	0.99	ND
	Minimum	0.00	0.01	0.00	2.63	13.16	0.39	
	Maximum	0.06	0.01	0.74	30.79	43.99	1.88	
	Mean	0.05	0.01	0.31	7.60	22.72	0.94	
	Standard Dev.	0.00	0.00	0.21	6.32	8.31	0.35	
Requirement for mineral nutrition (mg kg^{-1}) (Hejna ve ark., 2018)		nr	nr	-	10	50	-	nr
Maximum tolerable levels (MFAL,Notification, 2014/11) (mg kg^{-1})		2	1	-	-	-	-	10
Maximum tolerable level of trace elements (NRC, 2005) (mg kg^{-1})		30	10	100	40	500	100	100

ND:Not Detected, nr:not required

3.2. Heavy metal concentrations in dairy feeds (As, Cd, Cr, Cu, Fe, Ni and Pb mg kg^{-1})

The As, Cd, Cr, Cu, Cu, Fe, Ni and Pb contents of dairy feeds obtained from seven different companies were analyzed and shown in Table 4. The lowest As concentration was 0.05 mg kg^{-1} and the highest 0.06 mg kg^{-1} and the average As concentration was 0.06 mg kg^{-1} in all feed samples. Cadmium (Cd) concentration was ≤0.01 mg kg^{-1} in all feed samples. The lowest Cr concentration of 0.00 mg kg^{-1} was determined in feed samples from Bingöl, Çanakkale and Kayseri provinces, while the highest concentration of 0.39 mg kg^{-1} was determined in sample number 6 from Kırıkkale province. The average Cr content of all feed samples was 0.20 mg kg^{-1}. The lowest Cu concentration of 2.29 mg kg^{-1} was determined in feed sample number 2 from Bingöl and the highest Cu concentration of 23.42 mg kg-1 was determined in sample number 5 from Kayseri province. The average Cu content of all feed samples was 8.38 mg kg^{-1}. The lowest Fe concentration was 13.35 mg kg^{-1} in feed sample number 5 from Kayseri province and the highest Fe concentration was 25.24 mg kg^{-1} in sample number 7 from Konya province. The average Fe content of all feed samples was 18.36 mg kg^{-1}. The lowest Ni concentration was 0.56 mg kg^{-1} in the feed sample number 2 from Bingöl province and the highest was 1.41 mg kg^{-1} in the sample number 6 from Kırıkkale province. The average Ni content of all feed samples was 0.88 mg kg^{-1}. Pb metal was not detected in the analyzed dairy feed samples.

Table 4. Heavy metal concentrations of dairy feeds (mg kg^{-1})

		Concentrations (mg kg^{-1})						
Sample No.	**Province**	**As**	**Cd**	**Cr**	**Cu**	**Fe**	**Ni**	**Pb**
1	Ankara	0.06	0.01	0.34	6.86	19.72	1.09	ND
2	Bingöl	0.05	0.01	0.00	2.29	18.00	0.56	ND
3	Çanakkale	0.06	0.01	0.00	3.59	18.74	0.64	ND
4	Denizli	0.06	0.01	0.35	6.02	13.82	0.86	ND
5	Kayseri	0.06	0.01	0.00	23.42	13.35	0.76	ND
6	Kırıkkale	0.06	0.01	0.39	6.61	19.68	1.41	ND
7	Konya	0.06	0.01	0.30	9.90	25.24	0.86	ND
	Minimum	0.05	0.01	0.00	2.29	13.35	0.56	
	Maximum	0.06	0.01	0.39	23.42	25.24	1.41	
	Mean	0.06	0.01	0.20	8.38	18.36	0.88	
	Standard Dev.	0.00	0.00	0.17	6.54	3.72	0.27	
Requirement for mineral nutrition (mg kg^{-1}) (Hejna ve ark., 2018)		nr	nr	-	10	50	-	nr
Maximum tolerable levels (MFAL,Notification, 2014/11) (mg kg^{-1})		2	1	-	-	-	-	10
Maximum tolerable level of trace elements (NRC, 2005) (mg kg^{-1})		30	10	100	40	500	100	100

ND:Not Detected, nr:not required

The average heavy metal contents of fattening and dairy feeds are given in Figure 2. As seen in Figure 2, Fe was the most detected heavy metal, followed by Cu, Ni and Cr. The lowest values in fattening and dairy feeds were Cd and As. Pb was not detected in fattening and dairy feeds. As can be seen from the graph, Cr, Fe and Ni concentrations were higher in fattening feeds than in dairy feeds.

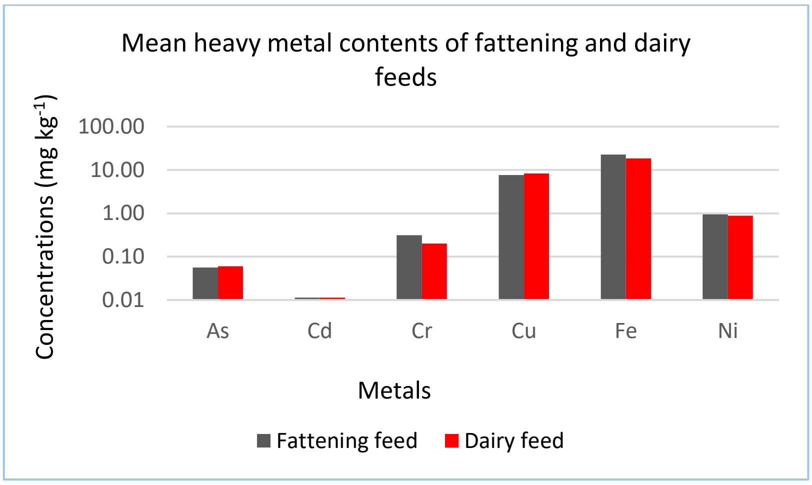

Figure 2. Graph of average heavy metal contents of fattening and dairy feeds

4. Discussion

Besides heavy metals (Cd, Pb, Hg, As, Cr), which are undesirable in animal nutrition, metals that are considered essential microelements (Fe, I, Co, Cu, Mn, Mo, Se) can also have direct potential negative effects on livestock. These metals can also enter the food chain through the consumption of animal products and thus pose a risk to humans (Järup, 2003). The As content in the 25 different dairy and fattening feed samples examined varied between 0.00-0.06 mg kg^{-1}. In the notification published by the Ministry of Food, Agriculture and Livestock (MFAL) (Regulation on Undesirable Substances in Feed, 2014/11), the maximum acceptable amount for As was reported as 2 mg kg-1 and the maximum tolerable As level was reported as 30 mg kg-1 according to NRC (2005) and none of the feed samples examined exceeded these permitted limit values. In 100 different dairy, fattening, egg and broiler feeds collected from different regions of Türkiye, As levels exceeded the permissible limit in only 2 samples (2.45 and 2.98 mg kg^{-1}) (Dagasan and Ozen, 2011). The average As content of fattening feeds produced in Texas between 2012 and 2015 was 0.15 mg kg^{-1} (Dai et al., 2016).

Cd content of the feeds was determined as ≤0.01 mg kg^{-1}. According to MFAL (2014/11), the maximum acceptable level of Cd was reported as 1 mg kg^{-1} and according to NRC (2005), the maximum tolerable level of Cd was reported as 10 mg kg^{-1} and none of the feed samples examined exceeded these permitted limit values. In previous studies, Cd levels in dairy feeds were determined as 0.005-0.082 mg kg^{-1} by Dai et al. (2016) in USA and 0.00-23.25 mg kg^{-1} by Zhang et al. (2012) in China.

Cr concentrations of dairy and fattening feeds examined varied between 0.00-0.74 mg kg^{-1}. According to MFAL (2014/11), the maximum acceptable amount of Cr was not stated, but according to NRC (2005), the maximum tolerable level of chromium (Cr3+) was reported as 100 mg kg^{-1} and none of the feed samples examined exceeded these permitted limit values. In a study by Dai et al. (2016), the average Cr concentration in 13 cattle feeds was 4.91 mg kg^{-1}. Besides the toxic and adverse effects of Cr(VI), there are studies showing that supplementation of Cr(III) at certain levels is beneficial. The US Food and Drug Administration Center for Veterinary Medicine has allowed Cr propionate (Cr Prop) to be used to supplement cattle diets up to 0.5 mg kg^{-1} DM. Chromium supplementation from Cr Prop was found to improve insulin sensitivity in growing cattle (Spears et al., 2012). Recent studies have shown that Cr Prop supplementation can improve the performance and health of calves under stress (Bernhard et al., 2012) and increase milk production in dairy cows (Vargas-Rodriguez et al., 2014; Rockwell and Allen, 2016). Spears et al. (2017) found Cr concentration below 0.05 mg kg^{-1} in all samples examined in 103 feed stuffs.

Cu is another important mineral closely related to animal production. When added to the diet of some animals, this trace element causes faster growth and better feed conversion rate (Polen and Voia, 2015) and prevents anemia in animals (Suleiman et al., 2015). However, high amounts of Cu are an environmental concern and can enter the human food chain through the consumption of contaminated products of animal food source (Alfthan et al., 2015). Cu concentrations of dairy and fattening feeds varied between 2.29-30.79 mg kg^{-1}. According to MFAL (2014/11), the maximum acceptable amount of Cu was not specified, while according to NRC (2005), the maximum tolerable Cu level was reported as 40 mg kg^{-1} and none of the feed samples examined exceeded these permitted limit values. However, the requirement of 10 mg kg^{-1} Cu in feeds in mineral nutrition has been reported (Hejna et al., 2018). While Cu content was <10 mg kg^{-1} in 15 of the 18 fattening feeds examined, Cu content was below 10 mg kg^{-1} in 6 of the 7 different dairy feeds examined. Among the 25 different dairy and fattening feeds produced in Türkiye, only 4 of them reached the recommended level for mineral nutrition, while 19 feeds were deficient in terms of Cu content. Tufan (2008) reported that Cu content in 30 feed raw materials in Tekirdağ province varied between 2.21-4.50 mg kg^{-1}. According to a study conducted by Wang et al. (2013) in China, Cu content in feeds was found to be 15.7 mg kg^{-1}. Fe concentrations of the feeds varied between 13.16-43.99 mg kg^{-1}. According to MFAL (2014/11), the maximum acceptable amount of Fe was not specified, but according to NRC (2005), the maximum tolerable Fe level was reported as 500 mg kg^{-1} and none of the feed samples examined exceeded these permissible limit values. However, it has been reported that feeds should contain 50 mg kg^{-1} Fe in mineral nutrition (Hejna et al., 2018). In 25 different fattening and dairy feeds examined, no toxic level of Fe content was found, but the recommended Fe content in feeds was not determined and only 1 fattening feed was found to have Fe concentration close to this recommended value. In Fe deficiency in animals, growth suppression and decreased blood levels are observed (Rincker et al., 2004). Again, iron deficiency in animals can lead to decreased animal performance, loss of appetite and weight, breathing spasms and ultimately death (Underwood, 2012; Byrne and Murphy, 2022). Fe content was determined as 0.6-6.2 mg kg^{-1} in feed samples taken as pallet feed, straw and barley mash (Bilgucu, 2010). Tufan (2008) examined wheat, barley and sunflower as feed raw materials and reported Fe contents as 29.11-109.13 mg kg^{-1}.

Fe and Cu concentrations in feeds were generally below the recommended level. The reason why Fe and Cu concentrations in the feeds were not at the recommended level is thought to be due to the limited uptake of Fe and Cu in the soils where the plants in the feed content grow. The pH of most of the soils in Türkiye is above 7 and the lime content is high (Ucgun et al., 2019). Microelement uptake is low in soils with high pH levels. The high pH value, low organic matter and moisture value of the soils of our country reduce the availability of microelements present in the soil to plants (Eraslan et al., 2010).

In Europe, Regulation 2002/32/EC sets limits for undesirable substances such as As, Cd, Pb and Hg in animal feed. Although maximum limits are set for As, Cd, Pb and Hg, animal feed can be contaminated with other heavy metals such as nickel (Ni) and Cr due to the production process. For example, Ni has been reported to be immunotoxic and neurotoxic and may be carcinogenic (ATSDR, 2011). The Ni concentrations of the feeds varied between 0.39-1.88 mg kg^{-1}. According to MFAL (2014/11), the maximum acceptable amount of Ni was not specified, but according to NRC (2005), the maximum tolerable Ni level was reported as 100 mg kg^{-1} and none of the feed samples examined exceeded these permitted limit values. The average Ni content of 154 fattening feeds was reported to be 2.81 mg kg^{-1} (Dai et al., 2016). Ni concentration levels have been studied in different feeds in Europe, England and Wales (Nicholson et al., 1999) and Bulgaria (Alexieva et al., 2007). These levels ranged from 0.1-11.2 mg kg^{-1} for dairy feed and 0.2-8.3 mg kg^{-1} for fattening feed. Notably, the highest Ni concentrations were measured in oats and barley (Nicholson et al., 1999). Alexieva et al. (2007) observed Ni levels of up to 16 mg kg^{-1} in other feed ingredients and found the highest levels in wheat (up to 14 mg kg^{-1}) in cereal feed (EFSA, 2019).

Exposure to high levels of Pb in animals causes harmful effects on many organs, as well as decreased feed consumption and growth ratio (Taha et al. 2019). Pb was not detected at ppm (mg kg^{-1}) level in all fattening and dairy feeds examined. Dagasan and Ozen (2011) stated that out of 100 different feed samples they examined, only 1 feed sample exceeded the permissible limit value. In earlier studies, it was found that lead levels measured in plants and soils growing on roadsides with high traffic density often exceeded safety limits. The decrease over the years is thought to be related to the use of unleaded petrol after 2004 (Ogutucu et al.,2021).

5. Conclusion

Twenty-five fattening and dairy feeds sold in the market in different provinces were examined in terms of some heavy metals and compared according to the limit values permitted by the institutions. Among the elements As, Cd, Cr, Cu, Fe, Ni, and Pb, Pb was not detected in the feeds, while As, Cd, Cr, and Ni were found much below the limit values. Although Fe and Cu contents are below the maximum permitted values, they are recommended to be used in animal nutrition at certain levels, but none of the 25 different feed samples examined had the recommended Fe content and 19 did not have the recommended Cu content. No heavy metal toxicity was found in the fattening and dairy feeds examined, but increasing environmental pollution causes an increase in heavy metals in soil, water, and air. There will always be a risk of heavy metals contaminating animal feed through crop production. In future studies, it is recommended to include other feed types in the study, to examine a much larger number of feed samples, to compare the results of this study with new data, and to take measures according to the predicted contamination rate.

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References

Alexieva, D., Chobanova, S., & Ilchev, A. (2007). Study on the level of heavy metal contamination in feed materials and compound feed for pigs and poultry in Bulgaria. Trakia J Sci, 5(2), 61-66.

Alfthan, G., Eurola, M., Ekholm, P., Venäläinen, E. R., Root, T., Korkalainen, K., ... & Selenium Working Group. (2015). Effects of nationwide addition of selenium to fertilizers on foods, and animal and human health in Finland: From deficiency to optimal selenium status of the population. Journal of Trace Elements in Medicine and Biology, 31, 142-147.

Alzahrani, Y., Kuşvuran, A., Alharby, H. F., Kuşvuran, S., & Rady, M. M. (2018). The defensive role of silicon in wheat against stress conditions induced by drought, salinity or cadmium. Ecotoxicology and environmental safety, 154, 187-196.

Anonymous (2024). Access date: 23.10.2024. Access link: https://www.tarimorman.gov.tr/Konular/Gida-Ve-Yem-Hizmetleri/Yem Hizmetleri/i%c5%9fletmeler .

ATSDR. (2011). Toxic Substances Portal , Agency for Toxic Substances & Disease Registry, http://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=44, webaccessed in June 2024.

Bernhard, B. C., Burdick, N. C., Rounds, W., Rathmann, R. J., Carroll, J. A., Finck, D. N., ... & Johnson, B. J. (2012). Chromium supplementation alters the performance and health of feedlot cattle during the receiving period and enhances their metabolic response to a lipopolysaccharide challenge. Journal of animal science, 90(11), 3879-3888.

Bilgucu, E. (2010). A research on the determination of the selected minerals and heavy metals contents in black and white spotted dairy cows? milk and fodder (Master's thesis, Namık Kemal University).

Byrne, L., & Murphy, R. A. (2022). Relative bioavailability of trace minerals in production animal nutrition: A review. Animals, 12(15), 1981.

Carnelo, L. G. L., de Miguez, S. R., & Marbán, L. (1997). Heavy metals input with phosphate fertilizers used in Argentina. Science of the Total Environment, 204(3), 245-250.

Cheng, B., Wang, Z., Yan, X., Yu, Y., Liu, L., Gao, Y., ... & Yang, X. (2023). Characteristics and pollution risks of Cu, Ni, Cd, Pb, Hg and As in farmland soil near coal mines. Soil & Environmental Health, 1, 100035.

Dagasan, O., & Ozen, N. (2011). Aflatoxin, heavy metal and pesticide residue contents of some compound feeds produced in Türkiye. Mediterranean Agricultural Sciences, 24(1), 9-13.

Dai, S. Y., Jones, B., Lee, K. M., Li, W., Post, L., & Herrman, T. J. (2016). Heavy metal contamination of animal feed in Texas. Journal of Regulatory Science, 4(1), 21-32.

Deng, S., Zhang, X., Zhu, Y., & Zhuo, R. (2024). Recent advances in phyto-combined remediation of heavy metal pollution in soil. Biotechnology Advances, 108337.

Dinakar, N., Nagajyothi, P. C., Suresh, S., Udaykiran, Y., & Damodharam, T. (2008). Phytotoxicity of cadmium on protein, proline and antioxidant enzyme activities in growing Arachis hypogaea L. seedlings. Journal of Environmental Sciences, 20(2), 199-206.

Eraslan, F., Inal, A., Gunes, A., Erdal, I., Coskan, A. (2010). Türkiye'de kimyasal gübre üretim ve tüketim durumu, sorunlar, çözüm önerileri ve yenilikler. TMMOB Ziraat Mühendisleri Odası, Ziraat Mühendisliği VII. Teknik Kongresi, 11-15 Ocak 2010, Ankara.

European Food Safety Authority (EFSA), Arcella, D., Gergelova, P., Innocenti, M. L., López-Gálvez, G., & Steinkellner, H. (2019). Occurrence data of nickel in feed and animal exposure assessment. EFSA Journal, 17(6), e05754.

Gao, X., Wei, M., Zhang, X., Xun, Y., Duan, M., Yang, Z., ... & Zhuo, R. (2024). Copper removal from aqueous solutions by white rot fungus Pleurotus ostreatus GEMB-PO1 and its potential in co-remediation of copper and organic pollutants. Bioresource Technology, 395, 130337.

Hejna, M., Gottardo, D., Baldi, A., Dell'Orto, V., Cheli, F., Zaninelli, M., & Rossi, L. (2018). Nutritional ecology of heavy metals. Animal, 12(10), 2156-2170.

Järup, L. (2003). Hazards of heavy metal contamination. British medical bulletin, 68(1), 167-182.

Kurtoglu, V., & Coskun, B. (2001). Factors that cause pollution in feed and affect its use II: Chemical substances and toxic elements. Konya Veteriner Kontrol ve Araştırma Enstitüsü Dergisi Veterinarium, 1, 25-34.

Merako, K. (2010). Determination of the Heavy Metal and Aflatoxin Content of the Trout Feeds Used in Trout Aquaculture (Master's thesis, Namık Kemal Üniversitesi).

Miller, R. O. (1988). Microwave Digestion of Plant Tissue in a Closed Vessel. In: Y P Kaira (Eds) Handbook of Reference Methods for Plant Analysis CRC Boca Raton pp. 69-74.

Nicholson, F. A., Chambers, B. J., Williams, J. R., & Unwin, R. J. (1999). Heavy metal contents of livestock feeds and animal manures in England and Wales. Bioresource Technology, 70(1), 23-31.

NRC (National Research Council), Division on Earth, Life Studies, Committee on Minerals, Toxic Substances in Diets, & Water for Animals. (2006). Mineral tolerance of animals: 2005. National Academies Press.

Ogutucu, G., Ozdemir, G., Acararicin, Z., & Aydin, A. (2021). Trend Analysis of Lead Content in Roadside Plant and Soil Samples in Türkiye/Turkiye'de Yol Kenarinda Bulunan Bitki ve Toprak Orneklerinde Kursun Iceriginin Egilim Analizi. Turkish Journal of Pharmaceutical Sciences, 18(5), 581-589.

Polen, T., & Voia, O. S. (2015). Copper effect of feed supplementation on growth performance in fattening pigs. Scientific Papers Animal Science and Biotechnologies, 48(2), 28-28.

Rincker, M. J., Hill, G. M., Link, J. E., & Rowntree, J. E. (2004). Effects of dietary iron supplementation on growth performance, hematological status, and whole-body mineral concentrations of nursery pigs. Journal of Animal Science, 82(11), 3189-3197.

Rockwell, R. J., & Allen, M. S. (2016). Chromium propionate supplementation during the peripartum period interacts with starch source fed postpartum: Production responses during the immediate postpartum and carryover periods. Journal of Dairy Science, 99(6), 4453-4463.

Spears, J. W., Lloyd, K. E., & Krafka, K. (2017). Chromium concentrations in ruminant feed ingredients. Journal of dairy science, 100(5), 3584-3590.

Spears, J. W., Whisnant, C. S., Huntington, G. B., Lloyd, K. E., Fry, R. S., Krafka, K., ... & Hyda, J. (2012). Chromium propionate enhances insulin sensitivity in growing cattle. Journal of dairy science, 95(4), 2037-2045.

Suleiman, N., Ibitoye, E. B., Jimoh, A. A., & Sani, Z. A. (2015). Assessment of heavy metals in chicken feeds available in Sokoto, Nigeria. Sokoto Journal of Veterinary Sciences, 13(1), 17-21.

Taha, H. S., Abdelnour, S. A., & Alagawany, M. (2019). Growth performance, biochemical, cytological and molecular aspects of rabbits exposed to lead toxicity. Journal of animal physiology and animal nutrition, 103(3), 747-755.

Tufan, M. (2008). Determination High Metal Levels of Feed Component Produced in Tekirdağ, (Master's thesis, Namık Kemal Üniversitesi).

Ucgun, K., Kelebek, C., Cansu, M., Altindal, M., & Yalcin, B. (2019). Using of Some Materials Affecting Soil pH in Cereal Cultivation. Soil water journal, 94-100.

Underwood, E. J. (2012). Trace elements in human and animal nutrition. Elsevier.

Vargas-Rodriguez, C. F., Yuan, K., Titgemeyer, E. C., Mamedova, L. K., Griswold, K. E., & Bradford, B. J. (2014). Effects of supplemental chromium propionate and rumen-protected amino acids on productivity, diet digestibility, and energy balance of peak-lactation dairy cattle. Journal of Dairy Science, 97(6), 3815-3821.

Wang, H., Dong, Y., Yang, Y., Toor, G. S., & Zhang, X. (2013). Changes in heavy metal contents in animal feeds and manures in an intensive animal production region of China. Journal of environmental sciences, 25(12), 2435-2442.

Zhang, F., Li, Y., Yang, M., & Li, W. (2012). Content of heavy metals in animal feeds and manures from farms of different scales in northeast China. International journal of environmental research and public health, 9(8), 2658-2668.