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First Assessment of Chemical Residues in Cattle Meat and Offal from North Sinai, Egypt: Implications for Food Safety

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Abstract | This study provides the first record of chemical residue levels in cattle meat, liver, and kidney from North Sinai Governorate, Egypt, comparing them with national and international standards. This article investigates the heavy metals, antibiotics and mycotoxins concentrations in cattle meat, liver, and kidney collected from North Sinai Governorate, Egypt. Therefore, a total of 60 cattle meat samples, 20 of each meat, liver and kidney were collected from different butcher's shops at North Sinai Governorate. The obtained results revealed that all (100%) meat, liver and kidney samples were positive for the presence of lead and cadmium. The mean lead concentration was highest in liver samples (0.072 ±0.008 mg/kg), followed by kidney (0.060 ±0.006 mg/kg), and then meat (0.028 ±0.004 mg/kg). The mean cadmium concentration was highest in kidney samples (0.070 ±0.001 mg/kg), followed by liver (0.068 ±0.007 mg/kg), and then meat (0.018 ±0.003 mg/kg). The mean determined residue levels of oxytetracycline and sulfonamides was highest in kidney samples: 57.85 ±10.44 and 54.95 ±7.31 μg/kg respectively. The mean determined residue levels of Aflatoxin was highest in liver samples (7.50 ±1.12 μg/kg). In conclusion, while most samples complied with safety standards, lead levels in some liver (20%) and kidney (5%) samples exceeded permissible limits, highlighting the need for stricter monitoring. The bioaccumulation of chemical substances is particularly pronounced in the liver and kidney, making these organs crucial targets for monitoring. Following the standards of Good Manufacturing Practices (GMP) for meat production is necessary in North Sinai Governorate.

Keywords | Heavy metals, Antibiotics, Aflatoxins, Meat, North Sinai

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INTRODUCTION

A vital component of the food markets, the free flow of safe, high-quality food which greatly improves the health and wellbeing of consumers. Meat plays a significant role in human nutrition as an excellent source of high-quality protein, essential minerals and vitamins (Haytowitz and Pehrsson, 2018).

Despite their considerable important, meat and its offal can be a source of chemical substances when accumulated in human body at a level increase than their permissible limits causing a sever public health hazards for meat consumers. The presence of chemical residues in meat poses significant risks to food safety and consumer health due to their toxicity, bioaccumulation, and biomagnification in the food chain (Santhi *et al*., 2008; Oladipo and Okareh, 2015).

Contamination of chemical residues of meat is a global health hazards for consumers. The expansion of advanced agricultural technology and the quick industrialization are among the foremost factors for food contamination by heavy metals (Milam *et al*., 2015). Chemical substances are transported to humans by consumption of meat and edible offal obtained from slaughtered animals exposure to theses chemical substances from different sources including, feeds, water and environment pollution.

Lead (Pb) and cadmium (Cd) are among of heavy metals which are particularly dangerous, because they have a tendency to bio-accumulate in the animal muscles and organs (Joseph *et al*., 2017). Pb and Cd are the most toxic heavy metals present in the environment from both natural and anthropogenic source (Aljerf and Aljurf, 2018). Animal exposure can occur through drinking water, feed, air, soil and dust from old paint (Ferner, 2001).

Many veterinary medicines, principally antibiotics, are administered for prophylaxis, treatment, and as feed additives to promote growth (Jones and Ricke, 2003; Fei *et al*., 2023). The most antimicrobials used in meat-producing animals are Tetracyclines and Sulfonamides (Liu *et al*., 2021). Meat contamination with oxytetracycline and sulfonamide seem to be a worldwide problem, the main source of theses antibiotics in meat is abusive use (overdosing, non-compliance with the withdrawal period) and inappropriate disposal of animal dung (Ghimpeteanu *et al*., 2022).

Mycotoxin is one of the problems threatening human and animal health in meat production (Kaynarca *et al*., 2019). Cattle exhibit greater resistance to aflatoxicosis compared to monogastric animals and poultry. Following ingestion of feed containing aflatoxin, it is rapidly absorbed in the intestines and transported to the liver, where metabolize it into aflatoxin M1, aflatoxin Q1, and aflatoxin P1 (Eaton *et al*., 2025).

Contamination of meat and offal with chemical substances may be a threat to consumer. Human consumption of this contaminated meat could be harm for human health due to their nervous, metabolic, and cardiovascular adverse effects (Bhardwaj *et al*., 2021). Lead and Cadmium have no known biological function in human and animals. Lead may cause damage to the kidneys, brain, and nervous system (Şahin *et al*., 2024). Consumer exposure to cadmium from contaminated food may be suffered from nephrotoxicity, osteoporosis, neurotoxicity, genotoxicity, and endocrine and reproductive effects (EFSA, 2009). Meat consumers exposure to Sulphonamides may suffer from skin reactions, hypersensitivity, blood dyscrasias and barcinogenicity (thyroid) meanwhile for oxytetracycline exposure possible influence of human intestine microbiome (De Briyne *et al*., 2020). Aflatoxins are potent carcinogens capable of damaging the liver and kidney, causing sever health complications, including human cancer and death (Elgioushy *et al*., 2020; Jiang *et al*., 2021).

Despite the nutritional value of meat and their edible organs to consumers, the toxic effect of chemical residues which may result due to heavy metals, antibiotic and aflatoxin contaminants is of great concern. Monitoring of chemical residues in meat and edible offal consumed in Middle East countries seems necessary (Emami *et al*., 2023).

Chemical substances in meat and edible offal are impossible to fully evaluated, but it is suggested that chemical contamination of meat is the main cause of great economic losses, food safety issues and public health hazards. Therefore, the determination of chemical residues accumulated in cattle's meat, liver and kidney is one of great concern for meat consumers in North Sinai, Egypt. This study is cross-sectional study on residues of lead, cadmium, oxytetracycline and sulfonamides and aflatoxins in meat, liver and kidney of cattle in trade in North Sinai, Egypt.

MATERIALS AND METHODS

Study area

The meat samples in this study belong to a representative butcher's shops of beef, located in the district of North Sinai Governorate which include four cities (Al-Arish, Ber-Albed, Al-shekh zouide and Gelbahna). The capital is the Al-Arish city, North Sinai Governorate is the eastern bulwark of Egypt, and links the East to the West. Its total area reaches 27,564 km^2, representing about 2.7% of Egypt's area. North Sinai Governorate is in the northeast of the Arab Republic of Egypt, between longitudes 32 and 34E and latitudes 29 and 31N. It is bordered to the north by the Mediterranean Sea by 220-km coast line, to the south by South Sinai Governorate, to the west by Port Said, Ismailia and Suez Governorates, and to the east by the international border with Palestine.

Sample size determination

Meat samples size for was calculated by taking into account the prevalence of antibiotic residues reported by earlier investigations that reported the chemical residues were 30 to 40% for antibiotics (Elsharawy *et al*., 2016), none available studies for heavy metals and aflatoxines in meat at North Sinai. Then, the sample size was calculated using the below formula by considering 95% confidence levels, a 5% degree of precision, and 10% for uncertainty.

$$n = Z\alpha / 2^2 \frac{p(1-p)}{d^2}$$

Where, n = sample size required. P = estimated prevalence.

d2 = degree of precision. $Z\alpha/2$ is the value of the standard score at 95% confidence interval (1.96); the assumptions of confidence level are at 95% = 1.96. Finally, 60 samples (20 each of meat, liver and kidney) were collected from 100 cattle carcass.

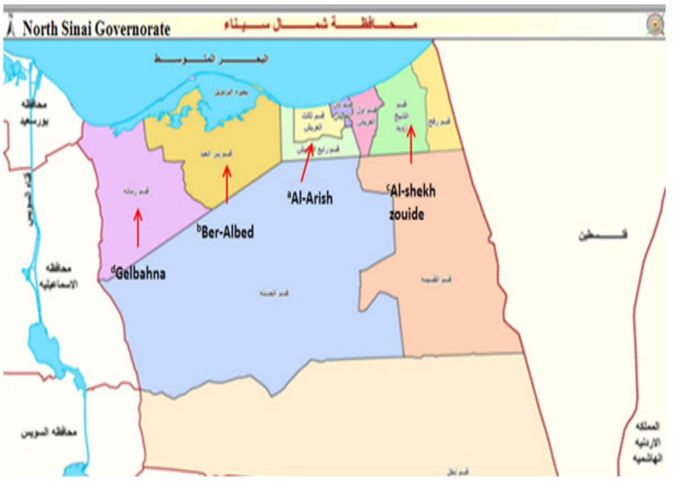

Figure 1: Maps of North Sinai (Google map). [a]Al-Arish; [b]Ber-Albed; [c]Al-shekh zouide; [d]Gelbahna.

Samples collection

A total of 60 fresh cattle samples (20 each of meat, liver, and kidney; 100g per sample) were randomly collected from different butcher's shops in the Al-Arish, Ber-Albed, Al-Shekh zouide and Gelbahna cities at North Sinai governorate (Figure 1). Each sample was identified and kept in polyethylene bag in ice-box then immediately transferred to Food Safety laboratory of Faculty of Veterinary Medicine, Suez Canal University for examination of heavy metals (lead and cadmium), antibiotices (oxytetracyline, sulphonamides) and mycotoxins (aflatoxins) residues.

Samples preparation for heavy metals evaluation

The instruments carefully washed before evaluation of meat samples. Meat samples were washed with deionized water. Each sample was separately wrapped in an acid washed polyethylene bag, given an identification number Collection site and date of collection were recorded. The samples were kept frozen. The samples were taken using stainless steel scalpel and forceps on a clean polyethylene work surface to minimize contamination of the samples. The technique of determination of heavy metal residues for lead and cadmium was applied according to Cowley (1978). Prepared samples and standard solution as well as blanks were directly aspirated into the flam for analysis of lead and cadmium. Analysis of lead and cadmium were conducted by air/ acetylene flow (5.5/1.11 /m) flame Atomic Absorption Spectrophotometer.

Sample preparation for antibiotic residues

The method described by Cristofani *et al.* (2009) was used for samples preparation. Two grams of each meat sample was weighed into a polypropylene tube after it was cut into small pieces and homogenized, and then 0.8 mL of 20% trifluoroacetic acid and 0.4 mL of 0.01 M EDTA were added. The extracts were heated in a water bath at 54°C then the mixture was vortexed for 2 minutes. After that, mixture of methanol 0.01M citrate was added to obtain a total volume of 5 mL., vortexed for 2 minutes and sonicated for 10 minutes at room temperature. Finally, it centrifuged at 3500 rpm for 15 minutes. The supernatant was filtered through a 0.22 µm nylon filter and injected into the HPLC for evaluation. Oxytetracycline and sulfonamides residues were analyzed using high performance liquid chromatography (Gaballah *et al.*, 2021) for quantification as per manufacturer protocol.

Determination of aflatoxins residues

Quantitative assessment of aflatoxins residues (B1, B2, G1, and G2) by HPLC. Verified reference acetonitrile solutions with aflatoxins standards (B1, B2, G1, and G2) at a concentration of 3g/ml provided by Sigma-Aldrich Co. The Association of Official Analytical Chemists (AOAC, 2000) technique was followed in the preparation of the stock standard solution and working standard solutions. Agilent HPLC equipment was used to analyze the AF (Quaternary pump, autosampler model 1200, USA). a pre-packaged Agilent LiChrospher C18 column measuring 250 mm, 4.6 mm in diameter, and 5 m in particle size. A post-column LC pump (zero-dead volume T piece, reaction pipe minimum 450 × 0.5 mm id in PTFE) (LC pump Lab flow 2000, Lab service Analytica, Bologna, Italy). Fluorescence Detector Jasco FP1520 (Jasco Corporation, Tokyo, Japan). The activation wavelength was 365 nm, and the emission wavelength was 442. A program developed by Agilent in the USA for automated data analysis.

Statistical analysis

Data were analyzed using one-way ANOVA to compare mean concentrations across tissues, with significance set at $P < 0.05$ (SPSS, 2007).

RESULTS AND DISCUSSION

Chemical substances persists in the environment may transfer through the meat chain, thereby posing a continuous threat to both animals and human. The occurrence of chemical compounds in cattle meat, liver, and kidney is a multifaceted food safety issue. Meat and offal contaminated with chemical substances is an important route of exposure of human to their residues and may cause serious health problems (Badis *et al.*, 2014; Obeid *et al.*, 2016). Cattle's meat, liver, and kidney can accumulate various chemical substances from their environment, feed, and veterinary drugs. These contaminants may attitude potential health risks to meat consumers.

Heavy metals in meat and offal

The present study was conducted for providing baseline data on concentration levels of Pb and Cd in meats samples (mg/kg) of cattle trade at North Sinai governorate as the first record. Toxic heavy metals are metallic elements with atomic weight between 63.5 and 200.6 and a specific gravity of more than 5 that have gradually. Heavy metals are insistent environmental pollutants that can accumulate in meat of slaughtered animals, particularly in organs like the liver and kidney, which play essential roles in detoxification and excretion.

Lead in meat and offal

Lead (Pb) is a heavy metal that occurs naturally and is found throughout the Earth's crust. Nevertheless, its extensive presence in the environment today is primarily due to centuries of human activities, such as its past use in gasoline, paints, plumbing, and numerous industrial processes. This enduring presence in the environment renders lead a major global contaminant.

Concentration of lead (mg/kg) in meat, liver and kidney of cattle in North Sinai Governorate were in Table 1. All (100%) meat, liver and kidney samples were Positive for the presence of lead. The mean lead concentration was highest in liver samples (0.072 ±0.008 mg/kg), followed by kidney (0.060 ±0.006 mg/kg), and then meat (0.028 ±0.004 mg/kg). The reported P-values indicate that these differences in mean lead concentrations among meat, liver, and kidney samples are statistically significant, confirming that lead accumulation varies considerably across these different organs.

Table 1: Mean ± SE Concentration of lead and cadmium (mg/kg) in meat, liver and kidney of cattle in North Sinai Governorate.

Elements	Positive No. (%)	Lead ± S.E.	Cadmium ± S.E.
Meat	20 (100)	**$0.028^a \pm 0.004$	$0.018^a \pm 0.003$
Liver	20 (100)	$0.072^b \pm 0.008$	$0.068^a \pm 0.007$
Kidney	20 (100)	$0.060^c \pm 0.06$	0.070^a 0.001

*S.E. Mean ± Standard Error. The f-ratio value is 12.43345. The p-value is .000033; ** Means with different superscript letters differ significantly (P < 0.05).

The elevated lead levels in liver and kidney may be attributed to environmental factors in the Sinai Peninsula, such as limited water resources and reliance on potentially contaminated groundwater. Despite of Governmental efforts for bringing the Nile water to the eastern deserts of North Sinai through El-Salam canal, most water used from underground water for agricultures projects which may polluted with lead in various level. Another sources of cattle's exposure to lead are paint and batteries which associated with short-term exposure (Thompson, 2018).

The results revealed the a significant differences (P<0.05) in the Pb concentrations were noted between liver and other tissue samples, in agreement with similar studies (Korenekova *et al*., 2002; Miranda *et al*., 2006; Akan *et al*., 2010; Akele *et al*., 2022). Apparently, cattle reared in the area may be highly exposed to potentially toxic metal contaminants via ingestion of polluted soil, vegetation and drinking water. The sources of Pb contamination of livestock come from the water they drink and food they eat (Aljerf *et al*., 2018).

Higher concentration of Pb (1.34 ±0.23 µg/g) was obtained by Spierenburg *et al*. (1998). Meanwhile, Khalafalla *et al*. (2015) recorded the means residue levels of lead in meat, liver and kidney of cattle, were 3.135 ±0.35, 3.99 ±0.1 and 1.76 ±0.30 ppm respectively. Recent study by Akele *et al*. (2022) recorded the mean concentrations of the lead in meat by were ranged from 0.42 to 1.5 mg/kg, which exceed the permissible limits.

The results of the study indicate varying lead concentrations in different cattle tissues within the cities of North Sinai governorate. The observed statistically significant differences (P< 0.05) among these tissues suggest that lead accumulation varies. The liver consistently showed the highest average concentration, followed by meat, and then the kidney. The liver serves as a key organ for detoxification, whereas the kidneys play an essential role in excretion. As a result, these organs often accumulate heavy metals while the body works to process and remove them. This biological fact holds significant implications for public health, particularly since edible offal is commonly eaten in Egypt as a valuable food source.

Compliance with Egyptian legislation (EOS, 2007) revealed that 20% of liver and 5% of kidney samples exceeded permissible lead levels, while all other meat samples were within safe limits. Different study in investigation of Hasballah (2019) reported that the average levels of heavy metals in all examined meat samples were higher than the regulatory limit set by FAO/WHO (2000).

Lead is one of the most common poisonous heavy metals (Gillis *et al*., 2012). Lead levels have been suggested to be controlled in both plant and animals because of its higher levels is considered a serious threat to human health (Kim *et al*., 2015). Lead poisoning also causes inhibition of the synthesis of haemoglobin, kidney dysfunctions, acute and chronic damage of nervous system (Ogwuegbu and Muhanga, 2005).

The daily intake of elevated levels of Pb beyond the threshold can lead to diminished cognitive growth and intellectual capabilities in children, as well as heightened blood pressure and cardiovascular issues in adults (EFSA, 2010).

Lead causes neurotoxicity, brain damage, immune and renal dysfunction, skin and eye diseases and consequently cancer (Jaishankar *et al*., 2014). While the biochemical processes underlying lead toxicity in the human body are not fully understood, it has been demonstrated that lead inhibits Ca2+-calmodulin-mediated neurotransmitter release, leading to neurodegeneration (Swulius and Waxham, 2008). Its effect against endogenous antioxidant such as Glutathione might be related to increases in risk of cancers (Wani *et al*., 2015).

Cadmium in meat and offal

Cadmium (Cd) is an extremely toxic heavy metal that has the ability to accumulate in animal tissues, thereby presenting potential health hazards to consumers. The monitoring of cadmium levels in food products is crucial for safeguarding public health. Concentration of cadmium (mg/kg) in meat, liver and kidney of cattle in North Sinai Governorate were in Table 1. All (100%) meat, liver and kidney samples were Positive for the presence of cadmium. The mean cadmium concentration was highest in kidney samples (0.070 ±0.001 mg/kg), followed by liver (0.068 ±0.007 mg/kg), and then meat (0.018 ±0.003 mg/kg). The cadmium concentrations between meat samples were not significantly different (P<0.05). Industrial processing and intensive agricultural methods lead to the contamination of forage, feed, and water, which are significant sources of cadmium exposure for farmed ruminants.

The highest concentrations of Cd were detected in the kidney samples, a high level of Cd is related to the species of the animal, the concentration of Cd in the feed, as well as binding of Cd to sulfhydryl groups in the protein metallothionein in the kidney and liver organs (Abou-Arab, 2001; Canty *et al*., 2014). Cadmium mainly accumulates in kidney, in the kidneys, the cadmium metallothionein complex (former metabolite in liver) is filtered in the glomeruli and thereafter reabsorbed in the renal tubules (Järup *et al*. 1998). Cadmium is effectively accumulated in mammalian tissues, particularly in the kidneys and liver, exhibiting an extended biological half-life that ranges from 10 to 30 years. As a result of this characteristic, cadmium can undergo biomagnification throughout the food chain, and its levels in animal tissues may serve as a proxy for cadmium presence in the environment (Tomović *et al*., 2013).

Cadmium is a cumulative toxic metal with important health implications for both humans and animals (Abd Elnabi *et al*., 2023). The means residue levels of cadmium in meat, liver and kidney of cattle, were 0.2±0.01, 3.4±0.31, and 1.41±0.23 ppm respectively (Khalafalla *et al*., 2015). The lowest mean Cd content was found in the meat which is consistent (0.02 ± 0.00 mg/kg), with the findings of Njoga *et al*. (2021). The levels of lead in cattle's liver and kidney ranged from 0.004 to 0.005±0.002 (µg/g), and 0.001 to 0.001±0.00006 (µg/g) Cd, generally, liver of cattle liver were found to have the highest levels of metals whereas kidney has lowest levels (Yakubu *et al*., 2017).

The lowest Cd content in kidneys was found in calves (0.06 mg/kg) followed by lambs (0.061 mg/kg), Higher values in kidneys were found for goats (0.655 mg/kg), and cows (0.64 mg/kg). The highest values of Cd were detected in sheep (1.255 mg/kg) (Drapal *et al*., 2021; Svobodova *et al*., 2024). In goats, a higher mean Cd content was found in kidneys (0.358 ± 0.091 mg/kg) and liver (0.100 ± 0.022 mg/kg) compared to muscles (0.005 ± 0.001 mg/kg) (P = 0.006 and P = 0.002, respectively) (Kružíková *et al*., 2025).

The results of accepted and rejected meat samples based of Egyptian legislations for cadmium residues in meat shown in Table 2. The Egyptian Organization for Standardization (EOS, 1993) set a maximum limit for cadmium in meat and edible offal at 0.50 mg/kg. Based on the Egyptian Organization for Standardization maximum limit All 20 meat, liver and samples kidney were accepted, with 0% rejected.

Table 2: Results of accepted and rejected meat samples based of Egyptian legislations for lead and cadmium residues in meat.

Elements	Accepted samples		Rejected samples	
	Lead	Cadmium	Lead	Cadmium
Meat	20 (100)	20 (100)	0 (0)	0 (0)
Liver	16 (80)	20 (100)	4 (20)	0 (0)
Kidney	19 (95)	20 (100)	1 (5)	0 (0)

EOS (2007) Maximum limit of lead in meat and edible offal is 0.10 mg/Kg; EOS (1993) Maximum limit of lead in meat and edible offal is 0.50 mg/Kg.

Chronic cadmium exposure is a major public health concern due to its long biological half-life in humans. The primary target organs for chronic cadmium toxicity kidney and liver. Some studies show cadmium interference with the parathyroid hormone or kidney enzymes which are involved in the activation of vitamin D (Akesson *et al*., 2006). Recently, Cd interferes with the metabolism of calcium, magnesium, iron, zinc and copper in human cells (Charkiewicz *et al*., 2023).

Antibiotics residues in meat and offal

The application of veterinary antibiotics in animals raised for meat production can result in the presence of residues in meat and edible offal when used inappropriately or unlawfully. Numerous factors contribute to the presence of residues in carcasses, including the pharmacokinetic properties of the antibiotics, the health status of the slaughtered animal, inadequate withdrawal periods, and the off-label use of these drugs. Even minimal amounts of residues in meat can have significant public health implications for consumers. The primary public health concerns associated with drug residues include the emergence of antibiotic resistance, hypersensitivity reactions, potential carcinogenic effects, disruption of normal intestinal flora, and the inhibition of fermentation processes within the meat industry (Pal1 *et al*., 2025).

Oxytetracycline residues in meat and offal

The oxytetracycline (OTC) are broad spectrum antibiotics active against many cattle pathogens. Oxytetracycline is a broad-spectrum antibiotic widely used in veterinary medicine for prevention and control of bacterial infections in food-producing animals. However, the improper use of OTC, particularly the failure to observe recommended withdrawal periods before slaughter, can lead to the accumulation of residues in edible animal tissues such as meat, liver, and kidney.

The residue of oxytetracycline in meat, liver and kidney of cattle in North Sinai Governorate were shown in Table 3. The positive samples for oxytetracycline in meat, liver and kidney were 10 (50%), 14 (70%) and 13 (35%) respectively. The mean determined residue levels of oxytetracycline was highest in kidney samples (57.85 ±10.44 μg/kg), followed by liver (54.75 ±7.43 μg/kg), and then meat (35.2 ±3.12 μg/kg).

Table 3: Mean ±SE of oxytetracycline (OTC) and sulphonamides (SAf) Residues in meat, liver and kidney (μg/kg) of cattle in North Sinai Governorate

Elements	Positive No. for OTC (%)	Positive No. for SAF (%)	Oxytetracycline ±*S.E.	Sulphonamides ±*S.E.
Meat	10 (50)	7 (35)	35.2^{a**} ± 3.12	23.65^{a}
Liver	14 (70)	12 (60)	54.75^{a} ± 7.43	46.9^{b}
Kidney	13 (35)	11 (55)	57.85^{a} ± 10.44	54.95^{b}

* S.E. Mean ± Standard Error. **0 means None detected. The f-ratio value is 1.20601, The p-value is .306913. ** Means with different superscript letters differ significantly ($P < 0.05$).

The reported P-values ($P > 0.05$) indicate that these differences in mean oxytetracycline residue among meat, liver, and kidney samples are statistically not significant, confirming their distribution might be somewhat uniform within the meat and offal of slaughtered cattle at the point of detection. The observed oxytetracycline residues in the current study probably reflects cattle have sold for slaughter whilst under a therapeutic or prophylactic regimen or being slaughtered before the end of the withdrawal period.

The findings of this study were quite in line with the data recoded in study of Elsharaw *et al.* (2016). Higher results of oxytetracycline residue in meat were recorded in Iran which 75% of meat samples positive for tetracycline (Baghani et al., 2019). On the other hand, lower results were recorded by Uma and Ashenef (2023) in beef samples which only 10 % if examined meat samples had detectable level of residues of oxytetracycline, their results were much lower than the Maximum Residue Limit established for Tetracyclines either by EU (100 μg/kg) or Codex (200 μg/kg) guidelines. Recently, Mohammed *et al.* (2025) detected in 84% of the meat samples, oxytetracycline residue levels ranged from 57 to 607 μg/kg for the kidney and 10.14 to 435 μg/kg for muscle samples. About 22.0% of muscle samples collected had oxytetracycline residues above maximum residue limits.

North Sinai Governorate, like other place with significant cattle farming activities, is susceptible to the issue of antibiotic residues in meat. oxytetracycline is widely used in these areas of research, probably due to their affordability, accessibility, and broad-spectrum effect. Previous studies in North Sinai Governorate indicated the potential for their presence in the meat chain (Elsharaw *et al*., 2016). Oxytetracycline excreted in bile come to be reabsorbed through entero-hepatic circulation, and may keep on in the animal's body for a long time after administration. When oxytetracycline is improperly administered or if the withdrawal period for treated cattle is not considered, the drug and its metabolites may persist in meat and edible offal, posing potential health risks to meat consumers (Baran *et al*., 2023).

The Egyptian Organization for Standardization and Quality Control (EOS, 2008), No. 2360-1, is set a permissible limit for tetracycline residues in meat and offal which must be not exceed than 200 μg/Kg. Consequently, all meat samples (100%) examined in the current study were within the permissible limit for tetracycline residues based on Egyptian legislations. Meat trade in North Sinai did not pose an immediate public health risk based on national standards for tetracycline residues.

The emergence of antimicrobial resistance resulting from the use of antimicrobials is a significant public health concern globally, in both human and veterinary medicine (Pal1 *et al*., 2025). *Salmonella* spp., *Campylobacter* spp. and *Escherichia coli* are the most cattle's pathogens linked to antimicrobial resistance issue (Serrano, 2005). Resistance can result from mutations in bacterial cells structural or foreign genetic information (Addis, 2015).

Tetracycline residues can result in permanent discoloration of teeth in kids (Bhavsar and Thaker, 2012; Lemke and Williams, 2012). In addition, the long exposure to Oxytetracycline through meat may adversely affect a wide range of intestinal flora and consequently cause gastrointestinal disturbance (Landers *et al*., 2012).

Sulfonamides residues in meat and offal

Generally, antibiotics are used for three main purposes, therapeutic, prophylactic, and as feed additives or growth promoters (Padol *et al*., 2015; Song *et al*., 2016). Sulfonamides (SAs) are a class of synthetic antimicrobial agents widely used in veterinary medicine for their broad-spectrum activity, efficacy against various bacterial and parasitic infections, and low cost. Sulfonamides among the oldest classes of antimicrobials, have been used in cattle production for over six decades. A recent study conducted identified sulfonamides as the third most commonly worldwide used class of antimicrobials in veterinary medicine following tetracyclines (Zheng *et al*., 2021).

The residue of sulfonamides residues in meat, liver and kidney of cattle in North Sinai Governorate were revealed in Table 3. The positive samples for sulfonamides in meat, liver and kidney were 7 (35%), 12 (60%) and 11 (55%), respectively. The mean determined residue levels of sulfonamides was highest in kidney samples (54.95 ±7.31 µg/kg), followed by liver (46.9 ±5.44 µg/kg), and then meat (23.65 ±3.87 µg/kg).

The reported P-values (P< 0.05) that these differences in mean sulfonamides residues among meat, liver, and kidney samples are statistically significant, confirming that sulfonamide accumulation varies considerably across meat from their edible offal. The results could interpreted as liver and kidney are particularly susceptible to sulfonamides residues accumulation. The liver is the primary site of drug metabolism, and the kidney is the main organ for excretion, leading to a higher sulfonamides residues compared to meat (Sadi *et al*., 2017).

A study in Pakistan found that 43% of meat samples had detectable levels of SAs, with 23% exceeding the recommended guideline level of 100 µg/kg (Mehtabuddin *et al*., 2012). In Malaysia detected SAs in chicken breast and liver samples, with concentrations ranging from 0.006-0.062 µg/g in meat and 0.08-0.193 µg/g in liver (Muthuma *et al*., 2018).

Commission Regulation (EU, 2010), is set a permissible limit for sulfonamide residues in meat and offal which must be not exceed than 100 µg/Kg. Consequently, all meat samples (100%) examined in the current study were within the permissible limit for sulfonamide residues based on European legislations. The current study confirmed that sulfonamide residue in meat, liver and kidney of cattle in North Sinai Governorate samples imposed negligible harm to people's health.

Generally, the presence of sulfonamides residues in tissue of slaughtered animal is a major public health concern. Sulfadimidine has been linked to a high percentage of sulfonamides residues in animal tissues and a surge in resistant bacterial strains (Van Boeckel *et al*., 2015). Exposure of human beings to sulfadiazine residue in animal products may produce allergic or anaphylactic reactions in susceptible and sensitized individuals which develop antibiotic allergy which restricted to a reaction mediated by immunoglobulin IgE (Kirbis, 2007; Huang *et al*., 2020).

Aflatoxins residues in meat and offal

Aflatoxins are among the most important mycotoxins produced by *Aspergillus* spp. The residue of Aflatoxin residues in meat, liver and kidney of cattle in North Sinai Governorate were revealed in Table 4. The positive samples for aflatoxins in meat, liver and kidney were 7 (35%), 14 (70%) and 11 (55%), respectively and the negative samples for aflatoxins in meat, liver and kidney were 13 (65%), 6 (30%) and 9 (45%), respectively. The mean determined residue levels of Aflatoxin was highest in liver samples (7.50 ±1.12 µg/kg), followed by kidney (5.30 ±0.85 µg/kg), and then meat (3.65 ±0.32 µg/kg).

Table 4: Mean ±SE of aflatoxin residues (µg/kg) in meat, liver and kidney of cattle in North Sinai Governorate.

Elements	Positive No. (%)	Negative No. (%)	Mean	±*S.E.
Meat	7 (35)	13 (65)	3.65^{a**}	0.32
Liver	14 (70)	6 (30)	7.50^{a}	1.12
Kidney	11 (55)	9 (45)	5.30^{a}	0.85

*E. Mean ± Standard Error. **0 means None detected, ** Means with different superscript letters differ significantly (P < 0.05).

The reported P-values (P > 0.05) indicate that these differences in mean Aflatoxin residues among meat, liver, and kidney samples are not statistically significant, confirming that Aflatoxins accumulation even distributed across meat and edible offal. Shaltout *et al*. (2014) found that aflatoxin levels in 100 meatballs, sausages, luncheon and pastrami samples were 13.38 ± 1.52, 9.03 ± 1.14, 8.80 ± 0.95 and 4.53 ± 0.61 µg/kg, respectively. Recent study done by Ponnusamy *et al*. (2025) detected Aflatoxin residues in 50% of animal feeds, with 70% of positive samples exceeding the maximum permissible limit of 20 µg/kg.

Aflatoxins B1, B2, G1 and G2 of are synthesized by mould including *Aspergillus flavus* and *Aspergillus parasiticus*. They formed in wide range of foods including cereals, peanuts, cotton seeds, dried fruits and spices (Isleyici, 2017). Liver is the target organ for aflatoxins residues fi\followed by kidney then meat (Amirkhizi *et al*., 2015; Darwish *et al*., 2016; Hassan *et al*., 2017; Sineque *et al*., 2017).
The results of the study were evaluated against the standards set by the Egyptian Organization for Standardization

(EOS, 2007b), which established a maximum permissible limit of 20µg/kg for aflatoxin in meat and edible offal. Based on this standard, all samples were found to be in compliance and All 20 samples (100%) were accepted and safe for consumers.

Mycotoxins considered as a serious problem when there are lack of some control measures during numerous steps of handling, transportation, and processing of the animal feeds (Stepman, 2018). There are several factors that might enhance aflatoxin production in animal feeds including the temperature and relative humidity (Kamika and Tekere, 2016), poor governmental control in feeds industry and inadequate ventilation (Pozarska *et al.*, 2024). Consequently, if aflatoxin produced in the animal feeds, it is difficult to be circumvented and donate to a massive economic losses in the agriculture industry global (Alshannaq and Yu, 2017).

Aflatoxin B1 has been classified by the International Agency for Research on Cancer (International Agency for Research on Cancer, 2010), in carcinogenic effect Group 1 which incremented in human hepatocellular carcinoma (Mahato *et al.*, 2019; Rushing and Selim, 2019).

CONCLUSION AND RECOMMENDATIONS

In conclusion, This study provides the first comprehensive assessment of chemical residues in cattle meat and offal from North Sinai, Egypt. While most samples complied with safety standards, lead levels in liver (20%) and kidney (5%) exceeded permissible limits, underscoring the need for enhanced monitoring of water and feed sources. The liver and kidney were identified as critical organs for residue bioaccumulation, warranting targeted surveillance. Adherence to Good Manufacturing Practices (GMP) and stricter regulatory enforcement are recommended to mitigate risks. Future studies should expand sampling to assess seasonal and geographical variations in residue levels.

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NOVELTY STATEMENT

This study is the first to assess heavy metals, antibiotics, and aflatoxin residues in cattle meat and offal from North Sinai, Egypt, providing critical baseline data for regional food safety policies.

AUTHOR'S CONTRIBUTION

The research strategy did by Prof. Hosny A. Abedlrahman. While composed the article and conduct the experimental conditions by Mohamed Dahy Abdelrahman and Dr. Nada Ibrahiem Hussein Ahmed, the statistics done and language revision by Mariam A. Abde-Wahab. The finished manuscript was examined and revised by Prof. Ali Meawad Ahmed.

Generative AI and AI-assisted technology statement

All authors of this work declare that generative AI technologies including large language models (e.g., ChatGPT, Copilot) and text-to-image generators were not utilized in any capacity during the preparation, writing, or editing of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Abd Elnabi, M.K., Elkaliny, N.E., Elyazied, M.M., Azab, S.H., Elkhalifa, S.A., Elmasry, S., Mouhamed, M.S., Shalamesh, E.M., Alhorieny, N.A., Abd Elaty, A.E., Elgendy, AIM, Ertman, A.E., Saad, K.E., Tsigkou, K., Ali, S.S., Kornaros, M. and Mahmoud, Y.A.G. 2023. Toxicity of heavy metals and recent advances in their removal: A review. Toxics, 11: 580. https://doi.org/10.3390/toxics11070580

Abou-Arab, A. 2001. Heavy metal contents in Egyptian meat and the role of detergent washing on their levels. Food and Chemical Toxicology, 39: 593–599. https://doi.org/10.1016/S0278-6915(00)00176-9

Addis, M, 2015. A review on antibiotic resistance and its implication on the food chain, Journal of Food Science, 42: 9-11.

Akan, J.C., Abdulrahman, F.I., Sodipo, O.A. and Chiroma, Y.A., 2010. Distribution of heavy metals in the liver, kidney and meat of beef, mutton, caprine and chicken from Kasuwan Shanu Market in Maiduguri Metropolis, Borno State, Nigeria. Res. J. Appl. Sci. Eng. Technol., 2: 743–748.

Akele, M.L., Desalegn, S.K., Asfaw, T.B., Assefa, A.J., Alemu, A.K. and de-Oliveira, R. 2022. Heavy metal contents in bovine tissues (kidney, liver and muscle) from Central Gondar Zone, Ethiopia. Heliyon, 8: 12416. https://doi.org/10.1016/j.heliyon.2022.e12416

Akesson, A., Bjellerup, P., Lundh, T., Lidfeldt, J., Nerbrand, C., Samsioe, G., Skerfving, S. and Vahter, M. 2006. Cadmium induced effects on bone in a population-based study of women. Environ Health Persp, 114: 830-834. https://doi.org/10.1289/ehp.8763

Aljerf, L., AlMasri, N. and Prince, U., 2018. Statistical relationship between milk constituents used in breeding programs during lactation: French case study. Madridge J. Case Rep. Stud., 2: 90–93. https://doi.org/10.18689/mjcrs-1000123

Alshannaq. A. and Yu. J.H. 2017. Occurrence, toxicity, and analysis of major mycotoxins in food. Int. J. Environ. Res. Public Health, 14(6): 63. https://doi.org/10.3390/ijerph14060632

Amirkhizi. B., Arefhosseini. S.R., Ansarin. M. and Nemati. M. 2015. Aflatoxin B1 in eggs and chicken livers by dispersive liquid–liquid microextraction and HPLC. Food Addit. Contam. Part B Surveill, 8: 245-249. https://doi.org/10.1080/19393210.2015.1067649

Badis, B., Rachid, Z., and Esma, B. 2014. Levels of selected heavy metals in fresh meat from cattle, sheep, chicken and camel produced in Algeria. Annual Research andReview in Biology, 1260–1267. https://doi.org/10.9734/ARRB/2014/7430

Baghani, A., Mesdaghinia, A., Rafieiyan, M., Soltan Dallal, M.M., Douraghi, M. 2019. Tetracycline and ciprofloxacin multiresidues in beef and chicken meat samples using indirect competitive ELISA. Journal of Immunoassay and Immunochemistry, 40, 328-342.

Bahmani, K, Shahbazi, Y. and Nikousefat Z. 2020. Monitoring and risk assessment of tetracycline residues in foods of animal origin. Food Sci. Biotechnol., 29:441-448. https://doi.org/10.1007/s10068-019-00665-x

Baran, A., Kwiatkowska, A. and Potocki, L., 2023. Antibiotics and bacterial resistance. A short story of an endless arms race. International Journal of Molecular Sciences, 24, 6: 5777. https://doi.org/10.3390/ijms24065777

Bhardwaj, H., Singh, C., Kumar, B., and Singh, D. 2021. Role of metallothionein to moderate heavy metals toxicity in animals: A review. Cancer, 8.

Bhavsar, S.K. and Thaker, A.M. 2012. Pharmacokinetics of antimicrobials in food producing animals. In Readings advanced pharmacokinetics Theory, methods and applications, pp.158–178.

Canty, M.J., Scanlon, A. and Collins, D.M. 2014. Cadmium and other heavy metal concentrations in bovine kidneys in the Republic of Ireland. Sci. Total Environ., 9: 223–231. https://doi.org/10.1016/j.scitotenv.2014.03.065

Charkiewicz, A.E., Omeljaniuk, W.J., Nowak, K., Garley, M. and Nikliński, J. 2023. Cadmium toxicity and health effects. A brief summary. Molecules, 28: 6620. https://doi.org/10.3390/molecules28186620

Commission Regulation (EC) 2006. No 1881/2006 setting maximum levels for certain contaminants in foodstuffs. Official Journal of the European Communities, L364, 5-24.

Commission Regulation (EU). 2009. (No 37/2010 of 22 December 2009 on Pharmacologically Active Substances and Their Classification Regarding Maximum Residue Limits in Foodstuffs of Animal Origin; European Commission: Brussels, Belgium, Volume 72.

Council of the European Union Council Directive, 1996. 96/23/EC on measures to monitor certain substances and residues thereof in live animals and animal products and repealing Directives 85/358/EEC, 86/469/EEC, Decisions 89/187/EEC and 91/664/EEC. Off. J. EU L., 125: 10-32.

Cowley, K.M., 1978. Atomic Absorption Spectroscopy in food Analysis. Developments in food analysis techniques -1- Applied Science Publishers, 1 td. England.

Cristofani, E., Antonini, C., Tovo, G., Fioroni, L., Piersanti, A., Galarini, R. 2009. A confirmatory method for the determination of tetracyclines in muscle using high-performance liquid chromatography with diode-array detection. Anal. Chim. Acta., 637: 40-46. https://doi.org/10.1016/j.aca.2008.10.029

Darwish, W.S., Bayomi, R.M.E., El-Moaty, A.M.A. and Gad, T.M., 2016. Mould contamination and aflatoxin residues in frozen chicken meat-cuts and giblets. Jpn. J. Vet. Res., 64: 167-171.

De Briyne, N., Iatridou, D., Vanderhaeghen, W. and Ignate, K. 2020. Use of Antimicrobials in Practice (Targeted on Cattle, Pigs, Poultry, Horses). In Antimicrobials in Livestock 1: Regulation, Science, Practice: A European Perspective; Springer: Berlin/Heidelberg, Germany, pp. 43–79. https://doi.org/10.1007/978-3-030-46721-0_4

Drapal, J., Steinhauser, L., Stastny, K., and Faldyna, M. 2021. Cadmium concentration in cattle tissues in the Czech Republic. Vet. Med-Czech., 66: 369-375. https://doi.org/10.17221/218/2020-VETMED

Eaton, D.L., Williams, D.E. and Coulombe, R.A. 2025. Species differences in the biotransformation of aflatoxin B1: Primary determinants of relative carcinogenic potency in different animal species. Toxins (Basel), 1: 30. https://doi.org/10.3390/toxins17010030

EFSA, 2010. Panel on Contaminants in the Food Chain, Scientific opinion on lead in food. The EFSA Journal, 8: 1570. https://doi.org/10.2903/j.efsa.2010.1570

EFSA, 2009. Scientific opinion cadmium in food scientific opinion of the panel on contaminants in the food chain. The EFSA Journal, 980, 1-139.

Elgioushy, M.M., Elgaml, S.A., El-Adl, M.M.,Hegazy, AM. and Hashish, EA. 2020. Aflatoxicosis incattle: Clinical findings and biochemical alterations.Environ. Sci. Pollut. Res., 27, 28: 35526–35534. https://doi.org/10.1007/s11356-020-09489-3

Elsharaw, Ahmed, A.M. and Ismail, S.A. 2016.A survey on some antibiotics residues in edible offal traded in North Sinai. Mansoura Veterinary Medical Journal, 17, 2: 1-9. https://doi.org/10.21608/mvmj.2016.129837

Emami, M.H., Saberi, F., Mohammadzadeh, S., Fahim, A, Abdolvand, M., Dehkordi, S.A., Mohammadzadeh, S. and Maghool., F., 2023. A Review of Heavy Metals Accumulation in Red Meat and Meat Products in the Middle East. Journal of Food Protection, 86, 100048. https://doi.org/10.1016/j.jfp.2023.100048

EOS, 1993. Egyptian Standard for requirement of Fresh meat. No.63, Min of Ind, Cairo. pp. 5-11.

EOS, 2007a. Egyptian Organization for Standardization and Quality. Maximum levels for heavy metals, part 1 :Maximum levels for lead in food. Arab Republic of Egypt, ES: 2360-1,

EOS, 2007b. Egyptian Organization for Standardization and Quality control, Maximum Levels for Mycotoxin in Food and Feed Part: 1 Aflatoxins, ES No. 1875 – 1,

EOS, 2008. Egyptian Organization for Standardization and Quality control, maximum residue limits for vet. Drugs in foods. Chlortetracycline/Oxytetracycline, ES No. 3692,

Erofeeva, V., Zakirova, Y., Yablochnikov, S., Prys, E. and Prys, I. 2021. The Use of Antibiotics in Food Technology: The Case Study of Products from Moscow Stores. E3S Web Conf., 311: 10005. https://doi.org/10.1051/e3sconf/202131110005

EU (Commission Regulation), 2010. No 37/2010 of 22 December 2009 on Pharmacologically Active Substances and Their Classification Regarding Maximum Residue Limits in Foodstuffs of Animal Origin; European Commission: Brussels, Belgium, Volume 72.

FAO/WHO, 2000. Evaluation of certain food additives and contaminants TRS 901-JECFA, 55. http://whqlibdoc.who.int/trs/WHO_TRS_901.pdf 13.

Fei, Z., Song, S., Gao, J., Song, Y., Xiao, X., Yang, X., Jiang, D., and Yang, D. 2023. Antibiotic residues in chicken meat in China: Occurrence and cumulative health risk assessment. Journal of Food Composition and Analysis, 116, 105082.

https://doi.org/10.1016/j.jfca.2022.105082
Ferner, D.J., 2001. Toxicity, Heavy Metals. eMed. J., 2, 5: 1.
Gaballah, M.S., Li, X. and Zhang, Z. 2021. Determination of tetracycline, oxytetracycline, sulfadiazine, norfloxacin, and enrofloxacin in swine manure using a coupled method of on-line solid-phase extraction with the UHPLC-DAD. Antibiotics, 10: 1397. https://doi.org/10.3390/antibiotics10111397
Ghimpet,eanu, O.M., Pogurschi, E.N., Popa, D.C., Dragomir, N., Dragotoiu, T., Mihai, O.D. and Petcu, C.D. 2022. Antibiotic use in livestock and residues in food a public health threat: A Review. Foods, 11: 1430. https://doi.org/10.3390/foods11101430
Gillis, B.S., Arbieva, Z., and Gavin, I.M. 2012. Analysis of lead toxicity in human cells. BMC Genomics, 13: 1. https://doi.org/10.1186/1471-2164-13-344
Hasballah, A.F. 2019. Evaluation of some Heavy Metals in Cows Meat and some Chicken Organs in Damietta Governorate Markets and Effect of the Heat on their Levels. Journal of Environmental Sciences. Mansoura University, 48: 131–143. https://doi.org/10.21608/joese.2019.158399
Hassan, M.N., Hassan, A.A.E.A., Tartor, Y.H. and Ali. S. 2017. FAflatoxin producing moulds and aflatoxin residues in meat and meat products in Egypt. Zag. Vet. J., 42: 43-55. https://doi.org/10.21608/zvjz.2014.60042
Haytowitz, D.B., and Pehrsson, P.R. 2018. USDA's National Food and Nutrient Analysis Program (NFNAP) produces high-quality data for USDA food composition databases: Two decades of collaboration. Food Chemistry, 238: 134–138. https://doi.org/10.1016/j.foodchem.2016.11.082
Huang, V., Clayton, N.A. and Welker, K.H. 2020. Glycopeptide hypersensitivity and adverse reactions, Pharmacy, 8, 2: 70. https://doi.org/10.3390/pharmacy8020070
International Agency for Research on Cancer. 2010. Agents classified by the IARC monographs. 1-100. WHO, Fransa.
Isleyici O. 2017. The most important mycotoxins, characteristics and the factors influencing formation. J. Food Hyg. Technol-Special Topics, 3: 1-12.
Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B.B. and Beeregowda, K.N. 2014. Toxicity, mechanism and health effects of some heavy metals. Interdiscip. Toxicol., 7: 60–72. https://doi.org/10.2478/intox-2014-0009
Järup, L., Berglund, M., Elinder, C.G., Nordberg, G. and Vahter, M. 1998. Health effects of cadmium exposure. A review of the literature and a risk estimate. Scand J Work Environ Health, 24: 1-51.
Jiang, Y., Ogunade, I.M., Vyas, D. and Adesogan, A.T. 2021. Aflatoxin in dairy cows: Toxicity, occurrence infeedstuffs and milk and dietary mitigation strategies. Toxins (Basel), 13, 4: 283. https://doi.org/10.3390/toxins13040283
Jones, F.T. and Ricke, S.C. 2003. Observations on the history of the development of antimicrobials and their use in poultry feeds. Poultry Science, 82, 4: 613–617. https://doi.org/10.1093/ps/82.4.613
Joseph, I., Maina, H.M., Isah, P.A. and Eneche, J.E. 2017. Comparative Analysis of Some Digestion Methods Used in the Determination of Metalsin Soil and Sediments, Chemical Science International Journal, 19, 4: 1-4. https://doi.org/10.9734/CSJI/2017/34652
Kamika, I. and Tekere, M. 2016. Occurrence of aflatoxin contamination in maize throughout the supply chain in the Democratic Republic of Congo. Food Control, 69: 292–296. https://doi.org/10.1016/j.foodcont.2016.05.014
Kaynarca, H.D., Hecer, C. And Ulusoy, B. 2019. Mycotoxin Hazard in Meat and Meat Products. Atatürk Üniversitesi Vet. Bil. Derg., 14, 1: 90-97. https://doi.org/10.17094/ataunivbd.449705
Khalafalla F.A., Abdel-Atty N.S., Abd-El-Wahab, M.A., Ali. O.I. and Abo-Elsoud, R.B. 2015. Assessment of heavy metal residues in retail meat and offal. Journal of American Science, 11: 5.
Kim, H.C., Jang, T.W., Chae, H.J., Choi, W.J., Ha, M.N., Ye, B.J., Kim, B.G., Jeon, M.J., Kim, S.Y. and Hong, Y.S. 2015. Evaluation and management of lead exposure. Ann. Occup. Environ. Med., 27: 30. https://doi.org/10.1186/s40557-015-0085-9
Kirbis, A. 2007. Residues of antimicrobial drugs in foods of animal origin. Slovenian Veterinary Research, 44, 2: 59-71.
Korenekova, B., Skalick, M. and Nad', P. 2002. Concentration of some heavy metals in cattle reared in the vicinity of a metallurgic industry. Vet. Arh., 72: 259–267.
Kružíková, K.N., Haruštiaková, D, Vlasáková, V., Jozefová, J., Svobodová, Z., Chloupek, P., and Svoboda, M. 2025. Long-term study on cadmium concentrations in the tissues of kids and goats in the Czech Republic (Central Europe). Acta Vet. Brno, 94: 051–056. https://doi.org/10.2754/avb202594010051
Landers, T.F., Cohen, B., Wittum, T.E. and Larson, E.L. 2012. A review of antibiotic use in food animals: Perspective, policy, and potential, Public Health Reports, 127, 1: 4-22. https://doi.org/10.1177/003335491212700103
Lane, E.A., Canty, M.J. and More, S.J. 2015. Cadmium exposure and consequence for the health and productivity of farmed ruminants. Research in Veterinary Science, 101: 132-139. https://doi.org/10.1016/j.rvsc.2015.06.004
Lemke, T.L., and Williams, D.A. 2012. Foye's principles of medicinal chemistry. 7th ed., Lippincott Williams and Wilkins.
Liu, J., Yu, F., Call, D.R., Mills, D.A., Zhang, A. and Zhao, Z. 2021. On-farm soil resistome is modified after treating dairy calves with the antibiotic florfenicol. Science of the Total Environment, 750, 141694. https://doi.org/10.1016/j.scitotenv.2020.141694
Mahato, D.K., Lee, K.E., Kamle, M., Devi, S., Dewangan, K. and Kumar, P. 2019. Aflatoxins in food and feed: an overview on prevalence, detection and control strategies. Front. Microbiol., 10: 2266. https://doi.org/10.3389/fmicb.2019.02266
Mehtabuddin, A., Mian, A. and Ahmad, T. 2012. Sulfonamide residues determination in commercial poultry meat and eggs. Journal of Animal and Plant Sciences, 22, 2: 473-477.
Milam, C., Dimas, B.J., Jang, A.L. and Eneche, J.E. 2015. Determination of Some Heavy Metals in Vital Organs of Cows and Bulls at Jimeta Abattoir, Yola, Adamawa State, Nigeria. American Chemical Science Journal, 8, 4: 1-7. https://doi.org/10.9734/ACSJ/2015/17012
Miranda, M., Alonso, M.L. and Benedito, J.L. 2006. Copper, zinc, iron, and manganese accumulation in cattle from Asturias (northern Spain). Biol. Trace Elem. Res., 10: 135–144. https://doi.org/10.1385/BTER:109:2:135
Mohammed, N., Mengistu, D.A., Abdurehman, A., Belina, D., and Mengistu, S. 2025. Determination of Tetracycline Residues in Kidney and Muscle of Beef Cattle Slaughtered in Dire Dawa and Harar Municipal Abattoirs, Eastern Ethiopia. Environmental Health Insights, 16: 1-11. https://doi.org/10.1177/11786302221109720

Muthuma, E.N., Aboge, G.O., and Gitau, G.K. 2018. Sulfonamides residues detected in broiler meat from poultry farms in Peri-Urban, Nairobi, Kenya. American Journal of Research Communication, 6, 11: 63-71.

Njoga, E.O., Ezenduka, E.V., Ogbodo, C.G., Ogbonna, C.U., Jaja, I.F., Ofomatah, A.C. and Okpala, C.O.R. 2021. Detection, distribution and health risk assessment of toxic heavy metals/metalloids, arsenic, cadmium, and lead in goat carcasses processed for human consumption in South-Eastern Nigeria. Foods, 10: 798. https://doi.org/10.3390/foods10040798

Obeid, P.J., Younis, M., and El-Nakat, C.S. 2016. Distribution levels of lead and cadmium within various fresh meat tissues of beef, goat and lamb and their consumption risk assessment. WIT Transactions on Ecology and the Environment, 203: 101–111. https://doi.org/10.2495/EID160101

Ogwuegbu, M.O. and Muhanga, W. 2005. Investigation of Lead Concentratio in the Blood of People in the Copperbelt Province of Zambia J. Environ., 1: 66 – 75.

Oladipo, T.A. and Okareh, O.T. 2015. Determination of heavy metals in selected tissues and organs of slaughtered cattle from Akinyele central abattoir, Ibadan, Nigeria. J. Biol. Agric. Healthcare, 5: 25–30.

Padol, A.R., Malapure, C.D., Domple, V.D., and Kamdi, B.P. 2015. Occurrence, public health implications and detection of antibacterial drug residues in cow milk. Environmental We International Journal Science Technology, 10: 7–28.

Pal1, M., Zende, R., Bekele, A., Rebuma, T., Ragasa, T., Nair, A., and Kanthe, P. 2025. Antibiotic Residues in Animal Source Foods: Its True Challenge on Public Health and Concomitant Analytical Techniques. Journal of Environment Pollution and Human Health, 13, 1: 8-17. https://doi.org/10.12691/jephh-13-1-2

Ponnusamy, P., Rajendran, U.S., Nair, M.G., Sambath, U., Kumar, R., Thanislass, J., Lakkawar, A.W., Padmanaban, V. and Subbarayan, P. 2025. Veterinary World, 18, 5: 1297–1305. https://doi.org/10.14202/vetworld.2025.1297-1305

Pozarska, A., Karpiesiuk, K., Kozera, W., Czarnik, U., Da̧browski, M. and Zielonka, L. 2024. AFB1 Toxicity in Human Food and Animal Feed Consumption: A Review of Experimental Treatments and Preventive Measures. Int. J. Mol. Sci., 25: 5305. https://doi.org/10.3390/ijms25105305

Rushing, B.R. and Selim, M.I. 2019. Aflatoxin B1: a review on metabolism, toxicity, occurrence in food, occupational exposure, and detoxification methods. Food Chem. Toxicol., 124: 81–100 https://doi.org/10.1016/j.fct.2018.11.047

Sadi, A., Rahimi, E., and Shakeriyan, A. 2017. Determination of Sulfonamide Antibiotic Residues in Milk, Meat, and Egg Using ELISA Method, Navid No, 20, 63: 1-8.

Şahin S., Azarkan S.Y. and Türksoy V.A. 2024. Evaluation of the effect of cannabidiol on the THLE-2 iver cell line exposed to lead. Science of the Total Environment, 923: 170901. https://doi.org/10.1016/j.scitotenv.2024.170901

Santhi, D., Balakrishnan, V.B., Kalaikannan, A. and Radhakrishnan K.T. 2008. Presence of heavy metals in pork products in Chennai (India). Am. J. Food Technol., 3: 192–199. https://doi.org/10.3923/ajft.2008.192.199

Serrano, P., 2005. Responsible use of antibiotics in aquaculture, FAO Fisheries Technical Paper, 469: 12-97.

Shaltout, F.A., Amin, R.A., Nassif, M.Z. and Abd-Elwahab, S.A. 2014. Detection of aflatoxins in some meat products. Benha Vet Med. J., 27, 368-374.

Sineque, A.R., Macuamule, C.L. and Dos Anjos, F.R. 2017. Aflatoxin B1 contamination in chicken livers and gizzards from industrial and small abattoirs, measured by ELISA technique in Maputo, Mozambique. Int J Environ Res Public Health, 14, 951. https://doi.org/10.3390/ijerph14090951

Song, C., Zhang, C., Fan, L., Qiu, L., Wu, W., Meng, S., Hu, G., Kamira, B., and Chen, J. 2016. Occurrence of antibiotics and their impacts to primary productivity in fishponds around Tai Lake, China. Chemosphere, 161: 127–135. https://doi.org/10.1016/j.chemosphere.2016.07.009

Spierenburg, T.J., De-Graaf, G.J. and Braars, A.J. 1988. Cadmium, zinc, lead and copper in livers and kidney of cattle in the neighbourhood of zinc refineries. Environ. Monit. Assess., 11: 107-114. https://doi.org/10.1007/BF00401723

SPSS, 2007. Statistical Package for Social Science ver. 16 for Windows. SPSS Inc., Chicago, IL.

Stepman, F. 2018. Scaling-up the impact of aflatoxin research in Africa. The role of social sciences. Toxins, 10, 4: 136. https://doi.org/10.3390/toxins10040136

Svobodova, Z., Drapal, J., Vlasakova, V., Harustiakova, D., Illek, J., Svoboda, M. 2024. A multi year study monitoring the cadmium content in the tissues of lambs and sheep sampled in the Czech Republic between 12001 and 2022. Vet Med-Czech, 69: 1-7. https://doi.org/10.17221/45/2024-VETMED

Swulius, M.T. and Waxham, M.N., 2008. Ca (2+)/Calmodulin-dependent Protein Kinases. Cell. Mol. Life Sci., 65: 2637–2657. https://doi.org/10.1007/s00018-008-8086-2

Thompson, L.J. 2018. Lead. In: Gupta RC. ed. Veterinary Toxicology, 3rd, Academic Press, 439-443. https://doi.org/10.1016/B978-0-12-811410-0.00029-5

Tomović, V., Jokanović, M., Šojić, P., Škaljac, S., Tasić, T. and Ikonić, P. 2013. Cadmium levels in meat. International 57th Meat Industry Conference, Belgrade, Serbia.

Uma, G. and Ashenef, A., 2023. Determination of some antibiotic residues (tetracycline, oxytetracycline and penicillin-G) in beef sold for public consumption at Dukem and Bishoftu (Debre Zeyit) towns, central Ethiopia by LC/MS/MS. Cogent Food and Agriculture, 9: 2242633. https://doi.org/10.1080/23311932.2023.2242633

Van Boeckel, T.P., Bwer, C. and Gilbert, M. 2015. Global trends in antimicrobial use in food animals. Proceedings of the National Academy of Sciences, 112, 18: 5649-5654. https://doi.org/10.1073/pnas.1503141112

Wani, A.L., Ara, A. and Usmani, J.A., 2015. Lead toxicity: A review. Interdiscip. Toxicol., 8: 55–64. https://doi.org/10.1515/intox-2015-0009

Yakubu, M., Dyola, N., Andrew, M., Sara, G., Hitler, L., Joseph, I. 2017. Determination of the Level of Heavy Metals in Liver and Kidney of Cow and Goat Used As Meat Source in Mubi Adamawa State. International Journal of Research in Environmental Science, 3, 3: 1-8. https://doi.org/10.20431/2454-9444.0303001

Zheng, Y., Fan, L., Dong, Y., Li, D., Zhao, L., Yuan, X., Wang, L. and Zhao, S., 2021. Determination of sulfonamide residues in livestock and poultry manure using carbon nanotube extraction combined with UPLC-MS/MS, Food Analytical Methods, 14: 641-652. https://doi.org/10.1007/s12161-020-01910-4