



Animal Health Research Journal

P-ISSN : 2356-7767 On Line-ISSN : 2535-1524

Journal Homepage: <https://animalhealth.ahri.gov.eg/>

Review Article

Antibiotic Residues in Food: Sources, Health Implications, and Detection Strategies

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Received in 14/7/2025
Received in revised from
17/8/2025
Accepted in 14/9/2025

Keywords:

*Antibiotic residues,
Detection methods,
Health implications,
Mitigation strategies,
Control measures.*

Abstract
Ensuring the safety of food is a critical aspect of public health, yet the presence of antibiotic residues in food products remains a considerable global alarm. These residues primarily originate from the extensive application of antibiotics in animal rearing as treatment, prevention and growth promoting. Inadequate adherence to withdrawal periods, improper drug administration, insufficient awareness among farmers is one of the factors that fuel the presence of antibiotic residues in meat, milk, eggs, and aquaculture products and consumption of foods contain antibiotic residues poses direct health threats including allergic reactions, hepatotoxicity, disruption of gut microbiota, teratogenicity, and carcinogenicity as well as indirect risks by promoting the extension and spreading of antimicrobial resistance. The review highlights the various sources and pathways of antibiotic residues contaminating the food chain, the associated health implications, and the current detection methods. It also examines regulatory standards, mitigation strategies, and the importance of consumer and producer awareness in minimizing risks. Addressing this issue requires coordinated efforts involving regulatory enforcement, education, improved animal husbandry practices, and the adoption of alternative disease control measures to ensure food safety and protect public health.

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Introduction

Human health and well-being are fundamentally rooted in the consumption of safe and nutritious food. However, the extremely pointed challenges to ensuring food safety is the existence of antibiotic residues within the food supply that enter through various pathways (Yusuf and Abraham, 2024). The most prominent pathway is through using veterinary drugs during livestock production as increase milk production, for therapeutic purpose to treat diseases, or for improvement of growth as improvement of feed proficiency and productivity (Aidara-Kane *et al.*, 2017; Ezenduka *et al.*, 2019). The antibiotic drugs are primarily eliminated from the body through urine and occasionally through feces. However, in many cases this residue may be detected in egg, milk, and meat products (Stella *et al.*, 2020). This is primarily because of ignorance of the farmers with the acceptable withdrawal period that must be considered after treatments with antibiotics (Rossi *et al.*, 2018). The withdrawal period is primarily referred to as the interval that must be spent waiting to ascertain the food sample is not going to be contaminated with the given antibiotics (Sachi *et al.*, 2019).

Consuming foods contaminated with antibiotic residues result in different health issues, including immunological disorders, congenital anomalies, mutagenic effects, and bone marrow dysfunction (Bitar *et al.*, 2022; Naser *et al.*, 2022; Sachi *et al.*, 2019). Additionally, these residues can disrupt the microbiota of the digestive system, either through direct destruction or by facilitating the relocation of resistance to humans (Ramatla *et al.*, 2017). Other potential health effects include allergies (penicillin), cancers associated with specific antibiotics (like sulfamethazine, oxytetracycline, and furazolidone), anaphylactic shock, nephropathy (linked to gentamicin), bone marrow toxicity, mutagenic effects, and reproductive disorders (associated with chloramphenicol) in humans (Bacanli and Başaran, 2019). Thus, the veterinary drug residues have been labeled as pervasive food contaminant problem (Pavliček and Lugomer, 2019). Such residues can be due to misuse or additional use of labeling drugs, failure to observe the withdrawal periods as stipulated, or poor livestock man-

agement (Tajick and Shohreh, 2006). Also, the metabolism of some used drugs may play a role in exacerbating the residuals problem, as some drug may metabolize fast and efficient while others may take a longer time and accumulated in the edible portion of the animal. More than 80% of the food animals undergo antibiotic therapy for part or most of their life (Bayou and Haile, 2017).

The great issues caused by such contamination in both economic and public health spots mitigate the veterinarian to enhance farmers awareness about the problems that will occur from the excessive use of antibiotics during reproduction and neglecting the withdrawal time before animal slaughtering to be sure that consumed meat free from any residues. Therefore, this review goal is to point out the origin of antibiotic residues in food products, health effects that may arise in case of their consumption, detection techniques applied to identify their presence in food products, the tolerable limit in a food product, and the awareness of people about its riskiness.

Sources of antibiotics residue in food

Antibiotics are one of the key compounds of veterinary medicine that is linked to food animal production, which means those substances that can destroy or hinder the growth of bacteria (Bacanli and Başaran, 2019). It is classified into different classes based on their chemical structure. Each class has a normal core structure associated with it and the different members of the class vary due to the presence or absence of secondary chemicals on the core structure (Tilahun *et al.*, 2016). They were applied to animals by many routes in the form of injections, orally in feed or water, on skin topically, and through intramammary and intrauterine infusions (Mitchell *et al.*, 1998). Subcutaneous and intramuscular administration methods have the risk of causing the drugs contributed to the adipose tissue, thus reducing metabolism and the excretion of this drug, therefore, may cause them to remain in the tissue of animals despite being slaughtered (Berends *et al.*, 2001).

The American Food and Drug Administration has shown that eighty percent of antimicrobials are applied on livestock that yields food prod-

ucts of animal origin (Rahman *et al.*, 2021). Other antimicrobials have been used as livestock growth promoters (Qian *et al.*, 2021; Chen *et al.*, 2022). These medicines can end up concerning the tissues of animals that produce food due to the lack of withdrawal period observation, not keeping any records of the treatment, its overdosing, or using banned drugs in animals to treat them economically (Beyene *et al.*, 2016). Animal feedstuffs contaminated with drugs also plays a significant role in providing drug residues (Peeters *et al.*, 2016; Rafiq *et al.*, 2022). In addition, some antibiotics that contaminate the environment may find their way to accumulate on the plant system and represent as a source of pollution to the plant feeding animals (Riley *et al.*, 2013). Also, the pollution of water by this residue acts as an extra source for the contamination of both animal and human (Pogurschi *et al.*,

2015).

The movement of antibiotic residual between animal and human may occur directly or indirectly. Direct transmission is the transmission that takes place when antibiotics are administered to the animals or it is added to plant cultures, some of them remain in the food after processing. However, interactions happen when antibiotic residues in manure or human excretions end up in foods (mostly vegetables by watering or when in contact with animal excreta) (Phillips *et al.*, 2004). Several studies concluded that significant antibiotic residues are found in the soil from manure, which can make its way to plant foods (Chen *et al.*, 2017; Zhou *et al.*, 2020) as seen in figure (1).

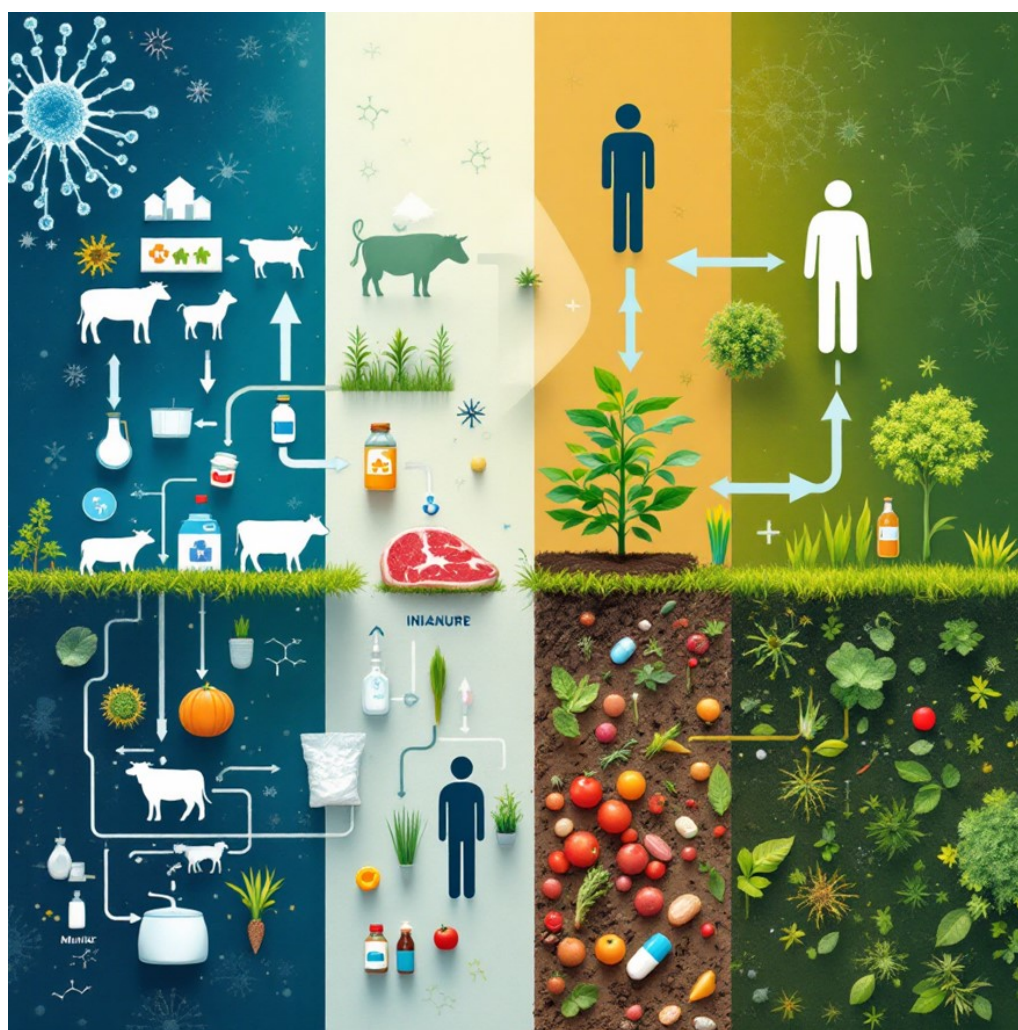


Figure (1). The transmission of antibiotic residues in between the human, animal, and environment.

Animal products include food of animal origin, which is edible tissue or muscle, liver and kidneys as well as animal products that include eggs and milk (Subirats *et al.*, 2019), represent as a source for antibiotic residues. Several studies demonstrate detection of some of veterinary drugs from the intestine of healthy people like enrofloxacin, chlortetracycline, sulfachlorpyridazine, and sulfadimethoxine, that indicate its consumption with feeding of animal by products (Duan *et al.*, 2020).

Veterinary drug residues in milk is a highly sensitive topic, which has raised serious concerns among farmers, processors, milk regulatory societies, and consumers, with milk being highly perishable protein, and consumed by a very diverse group of people at varying ages (Shaker and Elsharkawy, 2015). Milk production and milk products form an interlink with the environment, which is in some way shaped by human persons (Khaniki, 2007). Therefore, milk contamination begins immediately when an animal consumes polluted pasture and water (Akhtar and Ahad, 2017; Bedi *et al.*, 2018).

In an Indian study, approximately 11.3 percent of the raw milk analyzed harbored antibiotic residues as enrofloxacin and oxytetracycline which were frequently observed in milk samples analyzed during the study (Moudgil *et al.*, 2019). In a different study, 45% of chicken samples were found to have antibiotic residue like amoxicillin, enrofloxacin, and sulfamethoxazole that are used in poultry sector more often than other antibiotics (Lee *et al.*, 2018). It is also believed that antibiotic residues may be reported in aquatic products since they are frequently found in aquatic environments (Liu *et al.*, 2017). In this regard, Willis *et al.* (1999) found trimethoprim remaining in shrimp products.

When laying hens receive drugs, their drug metabolites might be found within yolk and albumen “egg content” (Pavliček and Lugomer, 2019). The process of drug movement involves the absorption of the drug in the intestine, from where it enters the bloodstream and is transported to the ovaries. Once there, the drug is stored within the inner yolk in the magnum of the oviduct, facilitating its distribution into the albumen, uterus, and oviduct. After the eggs are plumped, the drug residues are

stored within them (Donoghue and Myers, 2000). Most of the time, raw eggs are not safe to eat without being chilled and exposed to heat. Heat treatment decreases moisture, protein structure changes and pH values that may contribute to reducing the amount of residues, adjusting its chemical content and hindering its solubility (GFA, 2012).

Health implications of antibiotic residues in food

The idea of “One Health,” advocated by the World Health Organization and World Organization for Animal Health, shows the possibility of a unique health concept because of robust relationships linking people, animals, and their surrounding ecosystems. For this reason, any imbalance can be avoided if recovery, diagnosis, and treatment are carefully managed using medicinal products at every level [Regulation (EU), 2019].

Nowadays, people are aware of the problems that can arise when antibiotics are frequently used in livestock farming (Papatsiros, 2013). If microorganisms develop resistance to antibiotics, it leads to reduced treatment options, making it easier for such organisms to grow and causing more deaths in humans (Ganguly *et al.*, 2011; Xie *et al.*, 2018). Foods derived from animals are widely acknowledged as key sources of antibiotic residues, largely due to the use of antibiotics in livestock raised for industrial purposes. This practice has a notable role in the worldwide escalation of antibiotic resistance. Resistant bacteria have been found not only in animal-based food products but also in animal feed and human populations. Moreover, significant regional variations exist globally in the prevalence of antibiotic-resistant bacteria and resistance genes linked to animal-origin foods (Founou *et al.*, 2016).

Presence of drug residues in food over the maximum residual limits (MRLs) which differ from one antibiotic to another can lead to great complications that are difficult to control. Therefore, these complications may be divided into direct or indirect consequences.

Direct consequences

Allergic reactions.

Almost all studies have reported that antibiotic residues can provoke allergic reactions, with

the majority of these linked to beta-lactam antibiotics like penicillin and cephalosporins. The allergic responses documented include skin eruptions, serum sickness, low platelet counts, erythema multiforme, destruction of red blood cells, vasculitis, acute interstitial kidney inflammation, Stevens-Johnson syndrome, and toxic epidermal necrolysis (Kyuchukova, 2020). Those responses have been documented in individuals after milk consumptions' (Darwish *et al.*, 2013; Kyuchukova, 2020), meat (Baynes *et al.*, 2016), and pork (Raison-Peyron *et al.*, 2001) containing penicillin residues. Additionally, some research suggests that another group of antibiotics like aminoglycosides, sulfonamides, and tetracyclines residues may also provoke allergic response (Donkor *et al.*, 2011; Bacanlı and Başaran, 2019).

Hepatotoxicity

Several antibiotics exhibit hepatotoxic effects in liver as reported by Hautekeete, (1996) who found that penicillin, oxacillin, cloxacillin, flucloxacillin, and amoxicillin-clavulanate could cause hepatitis (mainly cholestatic). In addition, tetracyclines could cause a syndrome mimicking acute fatty liver of pregnancy, indicating the potential of erythromycin and several other macrolides to cause hepatitis (usually cholestatic). Moreover, ceftriaxone is capable of drugging gall stones and quinolone cholelithiasis and sulfamethoxazole/ trimethoprim can bring about severe hepatotoxicity in a situation where there is acquired immunodeficiency syndrome.

Van Gerven *et al.* (2016) proved that nitrofurantoin could induce chronic hepatitis that resembles chronic autoimmune hepatitis and hepatocellular responses.

Teratogenicity or reproductive disorders.

Any chemical or drug that causes adverse effects to the embryo or fetus during pregnancy leads to congenital disorders that impact human fertility (Beyene, 2016). Teratogenic drugs include several classes such as chemotherapeutic agents like thalidomide, anthelmintics such as albendazole, antibiotics including tetracyclines and aminoglycosides, antiepileptics like carbamazepine, hormone-like com-

pounds such as diethylstilbestrol and misoprostol, as well as other medications like angiotensin-converting enzyme inhibitors, cyclophosphamide, and methimazole (Rogers and Kavlock, 2013; Tilahun *et al.*, 2016). Additionally, Botsoglou and Fletouris (2001) found that drugs such as doxorubicin can cause mutagenic effects. Moreover, Kyuchukova (2020) and Darwish *et al.* (2013) reported that antibiotic residues may lead to reproductive problems and teratogenic outcomes

Carcinogenicity

The presence of carcinogenic antibiotic residuals may be hazardous because they can establish covalent linkages with numerous intracellular molecules, such as glycogen, glutathione (GSH), DNA, RNA, proteins, and phospholipids, producing a hidden danger in the process (Beyene, 2016). Food that contains chloramphenicol residues has been associated with cancer (Shahid *et al.*, 2021). In addition, nitrofurans, nitroimidazoles, and (quinoxaline) have the capacity to react or become covalently combined with a rather large number of internal cells, such as proteins, ribonucleic acid, glycogen, phospholipids, and glutathione. This interaction might lead to transformation of the contents of the cell which include DNA as well (Bayou and Haile 2017).

Indirect consequences

The masked action of the drug remainders in food is the enhancement of antibiotic resistance. This occurs due to the displaying of bacteria to small doses of antibiotics which outcome bacterial alteration, converting them to be highly resistant and virulent (Baseri *et al.*, 2021; Puangseree *et al.*, 2021). The acquisition of resistance primarily occurs through spontaneous mutations and positive selection (Pantosti *et al.*, 2007; Arsene *et al.*, 2021). This process involves several mechanisms, including alterations to the antibiotic target that reduces its affinity (Pantosti *et al.*, 2007; Schaenzer and Wright, 2020), the establishment of substitute metabolic routes (Pollock *et al.*, 2020), changes in membrane permeability, and the activation of efflux pumps (Dopcea *et al.*, 2020; Xu *et al.*, 2020).

Antibiotic resistance in bacteria can be spread both vertically through the integration of re-

sistance traits into a bacteria cell carried on to the next generation and horizontally between bacteria through the exchange resistance genes carried on conjugative plasmids horizontally between bacteria. Such horizontal movement enhance the transmission of resistance genes (**Lundborg and Tamhankar, 2007**). These direct or indirect human-to-animal contacts may promote zoonotic spread of antibiotic-resistant through animal strains and genes to the human population (**Sharma et al., 2018**). Antibiotics, especially that used in poultry and veterinary sectors, that are subjected to selective pressure, assume a position in increasing the likelihood of bacteria surviving under the antibiotic pressure and lead to progression of multidrug-resistant (MDR) strains. Which are common in different niches (**Shahid et al., 2021**).

The most recorded pathogens exhibit resistant to different antibiotics was discovered in breeding and food like resistant strains of *Salmonella*, glycopeptide or streptogramin-resistant enterococci, multidrug-resistant *Escherichia coli*, and *Campylobacter* species resistant to macrolides or fluoroquinolones (**Bacanli and Başaran, 2019**).

Detection methods

The emergence of antibacterial treatment in veterinary medicine sets the focus on the inspection of various products of animal-origin to the presence of their residues in food. The dairy industry is the major targeted in monitoring such residues, mainly to avoid the impact of the residues in fermentation of milk production but thereafter later on in early 1970s the screening of residual in slaughtered livestock received increased regulation to. The proficient screening method used requests to be cheap, and capable of high-throughput processing, efficiently identifying potential noncompliant samples from a large collection of negative samples (**Ture et al., 2019**). Screening methods are generally affordable, user-friendly, fast, ideal for analyzing large numbers and have high sensitivity, specificity and detection ability (cc β) with an error rate lower than 5% (**Ibrahim et al., 2016**).

Investigation and verification of antibiotic residues in animal-products depends on using various analytical techniques. The techniques ap-

plied are microbial inhibition tests, biosensors, enzyme-linked immunosorbent assays (ELISA), high-performance liquid chromatography (HPLC), liquid chromatography coupled with mass spectrometry (LC-MS), liquid chromatography-tandem mass spectrometry (LC-MS/MS) and ultra-performance liquid chromatography-mass spectrometry (UPLC-MS). For confirming and estimating the amount of certain drug residues in milk, meat and eggs, these methods are commonly applied (**Jayalakshmi et al., 2017**).

Microbial inhibition test

The microbial inhibition tests are able to test multiple antibiotics just once. The most common ways to conduct these tests are with either a tube or a multi-plate. Its principle depends on culturing sensitive bacterium within certain growth medium in test tubes with a pH or redox indicator. Within the proper temperature, the cultures bacteria begin to grow and so change the color of the indicator. While in case of presence of even low amount of antimicrobial residues, the bacterial growth will be inhibited or take prolonged time and so the color will not change. It is regularly applied to see if milk is safe and is now used more often with samples other than milk (**Ture et al., 2019**).

Unlike immunoassays and instrumental approaches, microbial tests are effective at locating any type of antibiotic that is useful for treating infections. But generally, these tests suffer from low selectivity, making them less sensitive and their incubation time takes longer. Consequently, microbial inhibition assays are not effective for detecting prohibited antibiotics such as chloramphenicol (CAP) (**Ibrahim et al., 2016**).

The most common tube microbial inhibition test known was Delvo test, that used mainly in exposure of the antibiotic residue in dairy products. As screened in study done on Somalia, in which one hundred of milk samples were examined "half of them obtained from dairy farms and the others from the market" by using Delvotest SP kits, and the results illustrated that the residues were detected in (30%) from dairy farm samples while in only 18% from the collected market samples. This discrepancy may be attributed to the likelihood that milk samples sent to the market undergo treatments

such as pasteurization, which can eliminate some heat-sensitive antibiotic residues. The comparison of samples from various farms indicated differing levels of contamination, with some farms exhibiting fewer positive samples than others. This difference may be attributed to the survey results, which revealed a widespread deficiency in knowledge and awareness about the proper use of antibiotics and the necessity of following withdrawal periods. Notably, only 10% of farmers were aware of these withdrawal periods and adhered to them, while merely 30% consulted veterinarians about antibiotic usage (**Mohamed *et al.*, 2020**).

Enzyme linked immunosorbent assay

This approach depends on the classical reaction between antigen and antibody in the presence of a conjugate. Creating the antibody against a certain antigen using different substances called adjuvants, that help enhance their production (**Barinova *et al.*, 2017**). For checking food for antibiotic traces, this test is the most commonly used, since its sensitivity can sometimes be better than the other confirmatory assays (**Cháfer-Pericás *et al.*, 2011**). There were two methods of ELISA, direct competitive(dc)-ELISA and indirect competitive (ic)-ELISA, with (ic)-ELISA considered the advanced one. The past ten years have seen this high-throughput technique being used by many researchers to check for different veterinary drugs in food of animal origin. Its mode of action depends on joining an immunological reaction with an enzyme reaction which multiplies the original response of the immune system (**Samsidar *et al.*, 2018**).

ELISA is recognized as the most effective and specific method for screening drug residues in meat, milk, and eggs. Competitive ELISA is frequently employed for the quantitative analysis of tetracyclines, fluoroquinolones, and chloramphenicol (CAP) residues in meat, as well as chloramphenicol residues in milk and chicken muscle. The sensitivity of chemiluminescent ELISA (CL-ELISA) is reported to be 2–3 times greater than that of conventional ELISA, enabling the detection of trace amounts of chloramphenicol as low as 3.19 ng/kg in chicken muscle (**Jayalakshmi *et al.*, 2017**).

ELISA technique is used mainly in dairy products to notice residue of tetracycline and Peni-

cillin mentioned by **Gaurav *et al.* (2014)** who assessed the presence of tetracycline residues in milk by using competitive ELISA. A total of 133 cattle milk samples from various regions in Punjab were analyzed, revealing that 18 samples contained tetracycline residues. The amounts of these residues ranged from 16 to 134.5 µg/L, with three samples exceeding the maximum permitted residue limits (MRLs). Furthermore, a prospective study conducted by **Kabrite *et al.* (2019)**, 66 samples from Lebanese market in the area of Keserwan were used to evaluate the level of penicillin and tetracycline in pasteurized, raw, and UHT cow milk and in other dairy products. The findings displayed all samples to be positive to tetracycline and 44 samples (67%) were detected to contain penicillin. It should be mentioned that when the result is positive it implies that the measured concentration is above the limit of detection (LOD).

An additional investigation was conducted on 88 samples from 22 sheep carcasses, including liver, kidney, longissimus dorsi, and diaphragmatic muscle. ELISA testing was employed to detect residues of various antibiotics such as gentamycin, streptomycin, tetracycline, and penicillin G. The findings revealed that all 22 carcasses contained at least one antibiotic residue, with around 17 showing multiple residues. Moreover, some positive samples had residue concentrations exceeding the EU's maximum residue limits (**Yousif and Jwher, 2021**).

High-performance liquid chromatography

HPLC is a widely used technique for detecting drug residues in food, offering high sensitivity, specificity, and compliance with regulatory standards. It has been effectively employed for both qualitative and quantitative identification of multiple residues in food samples. Visualizing of the food components occur by using either spraying an appropriate chromogenic reagent or under UV light. The intensity of the examined sample in the plate spot is measured against that of the internal standard by scanning densitometry to quantitatively determination of the residue (**Yusuf and Abraham, 2024**).

Several developments were done in the automation of HPLC through using an appropriate equipment led to appearance of various types of HPLC like HPTLC, that applied to detect

numerous residues such as thyreostatic drugs, clenbuterol and other agonists, nitroimidazol, and sulfonamides in animal tissues. HPLC characterized by its simplicity, rapid multi-sample analysis may analyze up to 20 samples per plate and so reduce the processing time required, compliance with regulatory standards, sensitivity that achieved by its ability to detect limits as low as 5 ng/spot for antibiotics like oxytetracycline, enrofloxacin, and ciprofloxacin in fish samples. Also, it requires minimal solvent consumption and simpler equipment, making it economically cost effective for routine screening (Lakshminarayanan *et al.*, 2019; Sani *et al.*, 2023).

HPLC with Diode-Array Detection (HPLC-DAD) is another type of HPLC that is handled to reveal multiple antibiotics such as amoxicillin, ciprofloxacin, and chloramphenicol in diverse matrices like milk, meat, and environmental samples. It achieves limits of detection (LOD) as low as 0.07–0.15 µg/L and recovery rates of 87.3–100.8% (Christoforidou *et al.*, 2020; Kumar *et al.*, 2022). HPLC-DAD detected oxytetracycline (0.5–1.4 µg/g) and ciprofloxacin (0.02–0.03 µg/g) in Egyptian chicken products, with oxytetracycline exceeding MRLs (Ahmed and Gareib, 2016). In Indian milk, residues were found at 0.13–2.67 µg/mL, prompting health risk assessments (Kumar *et al.*, 2022).

Liquid Chromatography–Tandem Mass Spectrometry (LC-MS/MS)

These represent the extremely popular and modern method of analysis of antibiotic residues. It is a chromatographic technique combined with mass spectrometric detection that offers a high sensitivity, specificity, and the possibility to detect and quantify many antibiotics and metabolites simultaneously in very complex food matrices (Dawadi *et al.*, 2021; Getahun *et al.*, 2023).

LC-MS/MS methods have been expounded to detect up to 30 antibiotics residues in meat and environmental samples in a single run (Chan *et al.*, 2022). It achieves very low limits of detection (LODs) of nanograms per gram (ng/g) or even lower, allowing identification of trace antibiotic residues well below regulatory maximum residue limits (MRLs) (Meklati *et al.*,

2022). In addition, it provides high selectivity through multiple reaction monitoring (MRM), enhancing accuracy in quantifying antibiotic residues and confirming their identity even in complex matrices (De Alwis *et al.*, 2021; Ha-keem *et al.*, 2024).

LC-MS/MS has been successfully applied to detect antibiotics in diverse foods including meat, milk, eggs, cereals, vegetables, fruits, and processed products supporting food safety compliance and surveillance programs (Hu *et al.*, 2021; Chan *et al.*, 2022).

Regulatory Standards and Compliance

Regulatory standards and compliance mechanisms are established globally and nationally to monitor, limit, and control the antibiotic residues in food products of animal origin such as meat, milk, eggs, and aquaculture products (Arsène *et al.*, 2022).

International and national regulatory bodies, as Food and Agriculture Organization (FAO), World Health Organization (WHO), Food and Drug Administration (FDA), Canadian Food Inspection Agency, Australian Pesticides and Veterinary Medicines Authority, European Commission, European Food Safety Authority, and country-specific health ministry are constantly seeking to regulate the use of antibiotics in line with international standards, against the background of country-specific situations. The main parameters normally controlled through this harmonization include:

1. Acceptable Daily Intake (ADI): A critical standard that is based on toxicological research and that is determined using the no-observable-effect level supported by a safety factor (Okocha *et al.*, 2018).

2. Withdrawal Period (WT): This is the shortest time needed between the last application of medication and the rendering out of meat or other animal food sources (Okocha *et al.*, 2018; Aroeira *et al.*, 2021).

3. Maximum Residue Limit (MRL): This is the uppermost legally allowed concentration of antibiotic residues or its metabolites in food, so long as the antibiotics are used properly according to Good Agricultural and Veterinary Practices (Yang *et al.*, 2020).

Egypt has established regulatory frameworks to control antibiotic residues in food, aiming to protect public health and support international

trade. Oversight is primarily managed by the National Food Safety Authority (NFSA) and the Egyptian Drug Authority (EDA), which set maximum residue limits (MRLs) and enforce compliance through monitoring and enforcement mechanisms (**United States Department of Agriculture, Foreign Agricultural Service, 2020; EL Asely *et al.*, 2024**). The NFSA issued Decision No. 13/2020, which sets specific MRLs for various veterinary drugs, including antibiotics, in food products. Egyptian MRLs are often harmonized and Codex Alimentarius with European Union regulations (**EL Asely *et al.*, 2024**).

The Egyptian Drug Authority (EDA) maintains an updated national antimicrobial formulary, categorizing antibiotics and supporting stewardship programs to prevent misuse (**Egyptian Drug Authority, 2023**). The EDA and healthcare authorities have launched programs to rationalize antibiotic use in both human and veterinary medicine, aiming to reduce the risk of AMR and ensure food safety (**Egyptian Drug Authority, 2023; Egypt Healthcare Authority, 2023**).

Mitigation Strategies

Mitigating antibiotic residues in food requires a multifaceted approach combining strict regulatory frameworks, responsible antibiotic use, effective food processing, and adoption of alternative animal health strategies. Strict regulatory frameworks occur through limiting antibiotic use to necessary cases under veterinary prescription reduces and prohibiting highly toxic or resistance-inducing antibiotics (e.g., chloramphenicol, nitrofurans), establishing and enforcing MRLs for antibiotics in food products combined with routine residue testing before slaughtering and marketing, and maintaining the required withdrawal times after antibiotic treatment before animal products arrive the foodchain (**Arsène *et al.*, 2022; Izah *et al.*, 2025**).

The effective food processing through using different techniques of cooking process that may reduce the antibiotic residue in food as high-temperature cooking methods such as boiling, grilling, roasting, frying, and microwaving significantly reduce or degrade antibiotic residues in animal products by breaking

down heat-sensitive antibiotics like tetracyclines and sulfonamides (**Adegbeye *et al.*, 2024; Izah *et al.*, 2025**). In addition, other techniques that are used in enhancing food safety like activated-charcoal, resin adsorption, and UV irradiation can inactivate or degrade antibiotic residues (**Oliver *et al.*, 2020; Arsène *et al.*, 2022**).

Furthermore, the global direction toward using other alternatives like microbial based probiotics and plant-based compounds that may improve animal health and immunity, reducing the need for antibiotic use and subsequent residues (**Adegbeye *et al.*, 2024; Izah *et al.*, 2025**). The replacement of antibiotics with other alternatives like essential oils (**Kaur *et al.*, 2024**), plant derived compounds (**Kigigha *et al.*, 2018; Colorado and Henkin, 2024**), and bacteriophages (**Khan *et al.*, 2016; Bi *et al.*, 2022**) throw light on the new ways that may reduce the development of antibiotic resistant.

Consumer Awareness and Education

Prevention of antibiotic residues in food initially requires improving understanding among individuals and institutions about related concerns through educational efforts, leveraging scientific literature, digital databases, veterinary oversight, and national regulatory guidelines. (**Riviere and Sundlof, 2001**). The responsible authorities pointing out the regulations that must be followed by the individuals to reduce the antibiotic residues in food (**Aytenfsu *et al.*, 2016**). According to Section 31 of the FSS Act, 2016, “no individual shall initiate or operate any food business without a license.” To safeguard consumers, the Codex Alimentarius has established Maximum Residual Limits (MRLs) and Acceptable Daily Intakes (ADIs) for various veterinary drugs in various food products. The Codex specifies that certain drugs, such as chloramphenicol (CAP), chlorpromazine, furazolidone, dimetridazole, metronidazole, and nitrofurantoin, do not have safe residue levels and therefore should not be administered to food-producing animals (**Codex Alimentarius (FAO/WHO), 2023**).

The knowledge the action, concentration of the drugs, and even the vehicle or excipient used in its formulation is mandatory to be considered by the veterinarian before use as the phar-

macokinetics of a drug are influenced by the vehicle or excipient used in its formulation, meaning that the withholding time is specific to that formulation. Consequently, varying withholding periods may be necessary for the same drug when used in different veterinary preparations (**Padol *et al.*, 2015**). Additionally, most countries require drug manufacturers to indicate a withdrawal time on the product label (**Archimbault, 1983**).

Disease processes such as nephritis, mastitis, and hepatitis can significantly alter the standard withdrawal times. Therefore, it is essential for veterinary practitioners to possess a thorough understanding of the various factors that can affect drug excretion in order to determine appropriate withdrawal periods tailored to the specific cases they encounter (**Shaikh and Patil, 2020**).

Conclusion

Antibiotic residues in food pose a critical and complex risk to public health. This issue mainly arises from the extensive and sometimes improper use of veterinary drugs in animal production. These residues found its way to the human food chain through various sources. The persistence of these residues is often linked to farmers' insufficient awareness of withdrawal periods, improper drug administration, and inadequate regulatory oversight. The health risks of consuming foods containing antibiotic residues are considerable. Direct effects include allergic-reactions, liver toxicity, disruption of beneficial gut microbiota, teratogenic and reproductive disorders, and carcinogenicity. Moreover, continuous exposure to sub-therapeutic antibiotic levels indirectly promotes the development and spread of antibiotic-resistant bacteria, which threatens the effectiveness of antimicrobial therapies and public health worldwide. Addressing this problem requires strict multifaceted approach. Strengthening regulatory frameworks, enforcing maximum residue limits, and ensuring complete observance of withdrawal timeframes. Equally important is raising awareness among farmers, veterinarians, and consumers about the dangers of antibiotic misuse and the importance of food safety measures. Enhanced surveillance, improved detection methods, and utilization of

probiotics and other substitute methods and vaccination in animal husbandry can further reduce risks. Ultimately, safeguarding food safety and public health demands coordinated efforts from food safety authorities, regulatory agencies, the agricultural sector, and consumers. By prioritizing responsible antibiotic use and robust monitoring systems, it is possible to reduce antibiotic residues in food and curb the growing threat of antimicrobial resistance.

References

- Adegbeye, M.J.; Adetuyi, B.O.; Igirigi, A.I.; Adisa, A.; Palangi, V.; Aiyedun, S.; Alvarado-Ramírez, E.R.; Elghandour, M.M.M.Y.; Molina, I.M.; Oladipo, A.A.; Abdelfattah, Z.M. and Salem, A.Z.M. (2024)**. Comprehensive insights into antibiotic residues in livestock products: Distribution, factors, challenges, opportunities, and implications for food safety and public health. *Food Control*, 163, 110545. <https://doi.org/10.1016/j.foodcont.2024.110545>.
- Ahmed, A.M. and Gareib, M.M. (2016)**. Detection of Some Antibiotics Residues in Chicken Meat and Chicken Luncheon. *Egypt. J. Chem. Environ. Health*, 2 (2): 315 -323.
- Aidara-Kane, A.; Angulo, F.J.; Conly, J.M.; Minato, Y.; Silbergeld, E.K.; McEwen, S.A. and Collignon, P.J. (2017)**. World Health Organization (WHO) guidelines on use of medically important antimicrobials in food-producing animals. *Antimicrob Resist Infect Control*.7:1–8.
- Akhtar, S. and Ahad, K. (2017)**. Pesticides residue in milk and milk products: mini review. *Pak J Anal Environ Chem*. 18(1):37–45.
- Archimbault, P.H. (1983)**. Persistence in milk of active antimicrobial intramammary substances. In: Ruckebusch Y, Toutain PL, Koritz GD (eds.). *Veterinary pharmacology and toxicology*, Springer, Dordrecht, The Netherlands, 647–57.
- Aroeira, C.N.; Feddern, V.; Gressler, V.; Contreras Castillo, C.J. and Hopkins, D.L. (2021)**. Growth promoters in cattle and pigs: A review of legislation and implications for

- human health. *Food Rev. Int.*, 39: 2507-2529. <https://doi.org/10.1080/87559129.2021.1961268>.
- Arsène, M.M.J.; Davares, A.K.L.; Viktorovna, P.I.; Andreevna, S.L.; Sarra, S.; Khelifi, I. and Sergueïevna, D.M. (2022).** The public health issue of antibiotic residues in food and feed: Causes, consequences, and potential solutions. *Vet World.* 15(3):662-671.
- Arsene, M.M.J.; Viktorovna, P.I.; Grigorievna, V.E.; Davares, A.K.; Sergeevna, D.M. and Nikolaevna, S.I. (2021).** Prolonged exposure to antimicrobials induces changes in susceptibility to antibiotics, biofilm formation and pathogenicity in *Staphylococcus aureus*. *J. Pharm. Res. Int.*, 33 (34B): 140-151.
- Aytenfsu, S.; Mamo, G. and Kebede, B. (2016).** Review on chemical residues in milk and their public health concern in Ethiopia. *J Nutr Food Sci.*, 6(4):1–1.
- Bacanlı, M. and Başaran, N. (2019).** Importance of antibiotic residues in animal food. *Food Chem. Toxicol.* 125: 462-466.
- Barinova, K.V.; Khomyakova, E.V.; Kuravsky, M.L.; Schmalhausen, E.V. and Muronetz, V.I. (2017).** Denaturing Action of Adjuvant Affects Specificity of Polyclonal Antibodies. *Biochem. Biophys. Res. Commun.* 482, 1265–1270.
- Baseri, N.; Najar-Peerayeh, S. and Bakhshi, B. (2021).** The effect of subinhibitory concentration of chlorhexidine on the evolution of vancomycin-intermediate *Staphylococcus aureus* and the induction of mutations in *walKR* and *vraTSR* systems. *Infect Genet Evol.* 87:104628.
- Baynes, R.E.; Dedonder, K.; Kissell, L.; Mzyk, D.; Marmulak, T.; Smith, G.; Tell, L.; Gehring, R.; Davis, J. and Riviere, J.E. (2016).** Health concerns and management of select veterinary drug residues. *Food Chem Toxicol.* 88:112-122.
- Bayou, K. and Haile, N. (2017).** Review on antibiotic residues in food of animal origin: economic and public health impacts. *Appl J Hygiene*, 6(1):1–8.
- Bedi, J.S.; Gill, J.P.; Kaur, P. and Aulakh, R.S. (2018).** Pesticide residues in milk and their relationship with pesticide contamination of feedstuffs supplied to dairy cattle in Punjab (India). *J Anim Feed Sci.* 27(1):18–25.
- Berends, B.R.; Van den Bogaard, A.E.; Van Knapen, F. and Snijders, J.M. (2001).** Human health hazards associated with the administration of antimicrobials to slaughter animals. Part II. An assessment of the risks of resistant bacteria in pigs and pork. *Vet Q.* 23(1):10–21.
- Beyene, T. (2016).** Veterinary drug residues in food-animal products: its risk factors and potential effects on public health. *J Vet Sci Technol.* 7(1):1–7.
- Bi, H.; Zhao, C.; Zhang, Y.; Zhang, X.; Xue, B.; Li, C.; Wang, S.; Yang, X.; Li, C. and Qiu, Z. (2022).** IVT cell-free biosensors for tetracycline and macrolide detection based on allosteric transcription factors (aTFs). *Anal. Methods.* 14 (44): 4545–4554.
- Bitar, I.; Salloum, T.; Merhi, G.; Hrabak, J.; Araj, G.F. and Tokajian, S. (2022).** Genomic characterization of multi-drug resistant *Pseudomonas aeruginosa* clinical isolates: Evaluation and determination of ceftolozane/ tazobactam activity and resistance mechanisms. *Front Cell Infect Microbiol.* 12: 922976.
- Botsoglou, N. and Fletouris, D. (2001).** Drug Residues in Foods *Pharmacology: Food Safety and Analysis.* Marcel Dekker, New York. 98-150.
- Cháfer-Pericás, C.; Maquieira, Á.; Puchades, R.; Miralles, J. and Moreno, A. (2011).** Multiresidue Determination of Antibiotics in Feed and Fish Samples for Food Safety Evaluation. Comparison of Immunoassay vs. LC-MS-MS. *Food Control.* 22, 993–999.
- Chan, C.L.; Wai, H.K.; Wu, P.; Lai, S.W.; Chan, O.S. and Tun, H.M. (2022).** A Universal LC-MS/MS Method for Simultaneous Detection of Antibiotic Residues in Animal and Environmental Samples. *Antibiotics (Basel).* 11(7):845.

- Chen, C.Q.; Zheng, L.; Zhou, J.L. and Zhao, H. (2017).** Persistence and risk of antibiotic residues and antibiotic resistance genes in major mariculture sites in Southeast China. *Sci. Total Environ.*, 580: 1175-1184.
- Chen, Y.; Jiang, C.; Wang, Y.; Song, R.; Tan, Y.; Yang, Y. and Zhang, Z. (2022).** Sources, environmental fate, and ecological risks of antibiotics in sediments of Asia's longest river: a whole-basin investigation. *Environ Sci Technol.* 56(20):14439–14451.
- Christoforidou, S.; Karageorgou, E.; Ioannidou, M.; Psomas, E.; Maggira, M. and Samouris, G. (2020).** Detection of antibacterial residues in milk by HPLC-DAD and microbial inhibitor tests. *Czech J. Food Sci.*, 38: 63–71.
- Codex Alimentarius (FAO/WHO) (2023).** International Food Standard. Maximum residue limits (MRLS) and risk management recommendations (RMRS) for residues of veterinary drugs in foods. *Int J Livest Res* 2023; doi:<http://dx.doi.org/10.5455/ijlr.20200410>.
- Colorado, H.A. and Henkin, J.M. (2024).** Fire-resistant plants: a review of plant morphology, tissues, habits, ecological adaptations, and other factors contributing to bio-derived environmental solutions and technologies, *Eng. Sci.* 27, 1024.
- Darwish, W.S.; Eldaly, E.A.; El-Abbasy, M.T.; Ikenaka, Y.; Nakayama, S. and Ishizuka, M. (2013).** Antibiotic residues in food: The African scenario. *Jpn. J. Vet. Res.*, 61 (Suppl): S13-S22.
- Dawadi, S.; Thapa, R.; Modi, B.; Bhandari, S.; Timilsina, A.P.; Yadav, R.P.; Aryal, B.; Gautam, S.; Sharma, P.; Thapa, B.B.; Aryal, N.; Aryal, S.; Regmi, B.P. and Parajuli, N. (2021).** Technological Advancements for the Detection of Antibiotics in Food Products. *Processes.* 9(9), 1500. <https://doi.org/10.3390/pr9091500>
- De Alwis, H.G.; Nochetto, C. and Kijak, P.J. (2021).** An LC-MS/MS Method for the Determination of Antibiotic Residues in Distillers Grains: Collaborative Study. *J AOAC Int.* 104(5):1213-1222.
- Donkor, E.S.; Newman, M.J.; Tay, S.C.; Dayie, N.T.; Bannerman, E. and Olu-Taiwo, M. (2011).** Investigation into the risk of exposure to antibiotic residues contaminating meat and egg in Ghana. *Food Control*, 22 (6): 869-873.
- Donoghue, D.J. and Myers, K. (2000).** Imaging residue transfer into egg yolks. *J Agric Food Chem.* 48(12):6428–6430.
- Dopcea, G.N.; Dopcea, I.; Nanu, A.E.; Diguță, C.F. and Matei, F. (2020).** Resistance and cross-resistance in *Staphylococcus* spp. strains following prolonged exposure to different antiseptics. *J. Glob. Antimicrob. Resist.*, 21: 399-404.
- Duan, Y.; Chen, Z.; Tan, L.; Wang, X.; Xue, Y.; Wang, S.; Wang, Q.; Das, R.; Lin, H.; Hou, J.; Li, L.; Mao, D. and Luo, Y. (2020).** Gut resistomes, microbiota and antibiotic residues in Chinese patients undergoing antibiotic administration and healthy individuals. *Sci. Total Environ.* 705, 135674.
- Egypt Healthcare Authority. (2023, August 23).** Egypt launches second medical conference to optimize antimicrobial and anti-infection use. <https://eha.gov.eg/en/news/23august2023/>
- Egyptian Drug Authority. (2023).** Egyptian National Antimicrobial Formulary. Egyptian Drug Authority. Available at: <https://edaegypt.gov.eg/media/qzvhsrl/egyptian-national-antimicrobial-formulary-2023-v1.pdf>
- El Asely, M.M.; Fath Elbab, G.F. and Shaltout, F.A.E. (2024).** Antibiotic Residues in Commercially Available Freshwater and Marine Fish: A Risk Assessment. *Egyptian Journal of Aquatic Biology & Fisheries*, 28 (1): 397 – 410.
- Ezenduka, E.V.; Okorie-Kanu, O.J. and Nwanta, J.A. (2019).** Comparative analysis of two microbiological tests in the detection of oxytetracycline residue in chicken using ELISA as gold standard. *Journal of Immunoassay and Immunochemistry.* 40(6): 617–629.
- Founou, L.L.; Founou, R.C. and Essack, S.Y. (2016).** Antibiotic Resistance in the

- Food Chain: A Developing Country-Perspective. *Front Microbiol.* 7:1881.
- Ganguly, N.K.; Arora, N.K.; Chandy, S.J.; Fairuze, M.N.; Gill, J.P.; Gupta, U.; Hossain, S.; Joglekar, S.; Joshi, P.C.; Kakkar, M.; Kotwani, A.; Rattan, A.; Sudarshan, H.; Thomas, K.; Wattal, C.; Easton, A. and Laxminarayan, R. (2011).** Global Antibiotic Resistance Partnership (GARP) - India Working Group. 2011. Rationalizing antibiotic use to limit antibiotic resistance in India. *Indian J Med Res.* 134(3):281-94.
- Gaurav, A.; Gill, J.P.; Aulakh, R.S. and Bedi, J.S. (2014).** ELISA based monitoring and analysis of tetracycline residues in cattle milk in various districts of Punjab. *Vet World.* 7(1):26.
- Getahun, M.; Abebe, R.B.; Sendekie, A.K.; Woldeyohannis, A.E. and Kasahun, A.E. (2023).** Evaluation of Antibiotics Residues in Milk and Meat Using Different Analytical Methods. *Int J Anal Chem.* 2023:4380261.
- GFA, F.E. (2012).** Residues of some antibiotics in table eggs in some private farms. *J Egypt Med Assoc.* 72:69–80.
- Hakeem, M.K.; Elangovan, S.; Rafi, M.; George, S.; Shah, I. and Amiri, K.M.A. (2024).** Advancing Antibiotic Residue Analysis: LC-MS/MS Methodology for Tetracycline Degradation Products in Tomato Leaves. *Antibiotics (Basel).* 13(2):133.
- Hautekeete, M.L. (1996).** Hepatotoxicity of antibiotics. *Acta Gastroenterol. Belg.,* 58(3): 290-296.
- Hu, M.; Ben, Y.; Wong, M.H. and Zheng, C. (2021).** Trace Analysis of Multiclass Antibiotics in Food Products by Liquid Chromatography-Tandem Mass Spectrometry: Method Development. *J Agric Food Chem.* 69 (5):1656-1666.
- Ibrahim, I.G.; Khalafalla, A.E.; Yarsan, E.; Altintas, L. and Tumer, I. (2016).** Methods for screening veterinary drug residues in animal products: a review. *Sudan J Vet Res.* 31:1–9.
- Izah, S.C.; Toktarbay, Z.; Nurmahanova, A.; Umirbayeva, Z.; Ogwu, M.C.; Ussen, K.; Koibasova, L.; Nazarbekova, S.; Tynybekov, B. and Guo, Z. (2025).** Public health risks associated with antibiotic residues in poultry food products. *Journal of Agriculture and Food Research,* 21 (2025), 101815.
- Jayalakshmi, K.; Paramasivam, M.; Sasikala, M.; Tamilam, T.V. and Sumithra, A. (2017).** Review on antibiotic residues in animal products and its impact on environments and human health. *J Entomol Zool Stud.* 5(3):1446–1451.
- Kabrite, S.; Bou-Mitri, C.; Fares, J.E.H.; Hassan, H.F. and Boumosleh, J.M. (2019).** Identification and dietary exposure assessment of tetracycline and penicillin residues in fluid milk, yogurt, and labneh: A cross-sectional study in Lebanon. *Vet World.* 12 (4):527-534.
- Kaur, A.; Singh, M.V.; Bhatt, N.; Arora, S. and Shukla, A. (2024).** Exploration of chemical composition and biological activities of the essential oil from *Ehretia acuminata* R. Br. Fruit, *ES Food Agrofores.* 15, 1068.
- Khan, A.A.; Randhawa, M.A.; Butt, M.S. and Nawaz, H. (2016).** Impact of various processing techniques on dissipation behavior of antibiotic residues in poultry meat, *J. Food Process. Preserv.* 40 (1):76–82.
- Khaniki, G.J. (2007).** Chemical contaminants in milk and public health concerns: a review. *Int J Dairy Sci.* 2(2):104–15.
- Kigigha, L.T.; Selekere, R.E. and Izah, S.C. (2018).** Antibacterial and synergistic efficacy of acetone extracts of *Garcinia kola* (Bitter kola) and *Buchholzia coriacea* (Wonderful kola), *J. Basic Pharmacol. Toxicol.* 2 (1):13–17.
- Kumar, A.; Panda, A.K. and Sharma, N. (2022).** Determination of antibiotic residues in bovine milk by HPLC-DAD and assessment of human health risks in Northwestern Himalayan region, India. *J Food Sci Technol.* 59(1):95-104.
- Kyuchukova, R. (2020).** Antibiotic residues and human health hazard-review. *Bulg. J. Agric. Sci.,* 26(3): 664-668.

- Lakshminarayanan, A.; Sarathchandra, G.; Marx, K.; Kaliyamurthi, V.; Uma, A. and Kandharam, P. (2019).** Standardization of high performance thin layer chromatographic (HPTLC) technique for detecting antibiotic residues in carp (*Catla catla*) and Gold fish (*Carassius auratus*). *The Pharma Innovation Journal*. 8(12): 394-400.
- Lee, H.J.; Cho, S.H.; Shin, D. and Kang, H.S. (2018).** Prevalence of antibiotic residues and antibiotic resistance in isolates of chicken meat in Korea. *Korean J. Food Sci. Anim. Resour.* 38, 1055–1063.
- Liu, X.; Steele, J.C. and Meng, X.Z. (2017).** Usage, residue, and human health risk of antibiotics in Chinese aquaculture: A review. – *Environmental Pollution*. 223: 161-169.
- Lundborg, C.S. and Tamhankar, A.J. (2017).** Antibiotic residues in the environment of South East Asia. *BMJ*, 358: j2440.
- Meklati, F.R.; Panara, A.; Hadeif, A.; Meribai, A.; Ben-Mahdi, M.H.; Dasenaki, M.E. and Thomaidis, N.S. (2022).** Comparative Assessment of Antibiotic Residues Using Liquid Chromatography Coupled with Tandem Mass Spectrometry (LC-MS/MS) and a Rapid Screening Test in Raw Milk Collected from the North-Central Algerian Dairies. *Toxics*, 10, 19. <https://doi.org/10.3390/toxics10010019>.
- Mitchell, J.M.; Griffiths, M.W.; McEwen, S.A.; McNab, W.B. and Yee, A.J. (1998).** Antimicrobial drug residues in milk and meat: causes, concerns, prevalence, regulations, tests, and test performance. *J Food Prot.* 61(6):742–56.
- Mohamed, M.A.; Sheikh Elmi, A.A.; Dubad, A.B.; Hassan, Y.H.S.; Osman, A.M.; Bitrus, A.A. (2020).** Antibiotic residue in raw milk collected from dairy farms and markets in Benadir, Somalia. *PAMJ - One Health*. 2(19). 10.11604/pamj-oh. 2020. 2.19.24814.
- Moudgil, P.; Bedi, J.S.; Aulakh, R.S. and Gill, J.P.S. (2019).** Antibiotic residues and mycotoxins in raw milk in Punjab (India): a rising concern for food safety. *J. Food Sci. Technol.* 56, 5146–5151.
- Naser, R.; Dilabazian, H.; Bahr, H.; Barakat, A. and El-Sibai, M. (2022).** A guide through conventional and modern cancer treatment modalities: A specific focus on glioblastoma cancer therapy (Review). *Oncol Rep.* 48(5):190.
- Okocha, R.C.; Olatoye, I.O. and Adedeji, O.B. (2018).** Food safety impacts of antimicrobial use and their residues in aquaculture. *Public Health Rev.*, 39(1): 21.
- Oliver, J.P.; Gooch, C.A.; Lansing, S.; Schueler, J.; Hurst, J.J.; Sassoubre, L.; Crossette, E.M. and Aga DS. (2020).** Invited review: Fate of antibiotic residues, antibiotic-resistant bacteria, and antibiotic resistance genes in US dairy manure management systems. *J. Dairy Sci.* 103:1051–1071. <https://doi.org/10.3168/jds.2019-16778>.
- Padol, A.; Malapure, C.; Dimple, V. and Kamdi, B. (2015).** Occurrence, public health implications and detection of antibacterial drug residues in cow milk. *Environ Int J Sci Technol.* 10: 7–28.
- Pantosti, A.; Sanchini, A. and Monaco, M. (2007).** Mechanisms of antibiotic resistance in *Staphylococcus aureus*. *Future Microbiol.*, 2(3): 323-334.
- Papatsiros, V.G. (2013).** Alternatives to Antibiotics for Farm Animals. *CAB Reviews*. 8, 1–15.
- Pavliček, D. and Lugomer, M.D. (2019).** Monitoring of veterinary medicinal product residues and other substances in poultry and eggs in the European Union during the 2009-2016 period. *Zbornik*. 2019:159–65.
- Peeters, L.E.; Daeseleire, E.; Devreese, M.; Rasschaert, G.; Smet, A.; Dewulf, J.; Heyndrickx, M.; Imberechts, H.; Haesebrouck, F.; Butaye, P. and Croubels, S. (2016).** Residues of chlortetracycline, doxycycline and sulfadiazine-trimethoprim in intestinal content and feces of pigs due to cross-contamination of feed. *BMC Vet Res.* 12(1):1–9.
- Phillips, I.; Casewell, M.; Cox, T.; De Groot, B.; Friis, C.; Jones, R. and Waddell, J. (2004).** Does the use of antibiotics in food animals pose a risk to human health? A criti-

- cal review of published data. *J. Antimicrob. Chemother.*, 53(1): 28-52.
- Pogurschi, E.; Ciricb, A.; Zugravc, C. and Patrascu, D. (2015).** Identification of antibiotic residues in raw milk samples coming from the metropolitan area of Bucharest. *Agriculture and Agricultural Science Procedia*, 6, 242–245.
- Pollock, J.; Low, A.S.; McHugh, R.E.; Muwonge, A.; Stevens, M.P.; Corbishley, A. and Gally, D.L. (2020).** Alternatives to antibiotics in a one-health context and the role genomics can play in reducing antimicrobial use. *Clin. Microbiol. Infect.*, 26(12): 1617-1621.
- Puangserree, J.; Jeamsripong, S.; Prathan, R.; Pungpian, C. and Chuanchuen, R. (2021).** Resistance to widelyused disinfectants and heavy metals and cross-resistance to antibiotics in *Escherichia coli* isolated from pigs, pork and pig carcass. *Food Control*, 124:107892.
- Qian, M.; Wang, J.; Ji, X.; Yang, H.; Tang, B.; Zhang, H.; Yang, G.; Bao, Z. and Jin, Y. (2021).** Sub-chronic exposure to antibiotics doxycycline, oxytetracycline or florfenicol impacts gut barrier and induces gut microbiota dysbiosis in adult zebrafish (*Danio rerio*). *Ecotoxicol. Environ. Saf.* 221, 112464. doi: 10.1016/j.ecoenv.2021.112464
- Rafiq, K.; Hossain, M.T.; Ahmed, R.; Hassan, M.M.; Islam, R.; Hossen, M.I.; Shaha, S.N. and Islam, M.R. (2022).** Role of different growth enhancers as alternative to in-feed antibiotics in poultry industry. *Front. Vet. Sci.* 8, 1675.
- Rahman, M.S.; Hassan, M.M. and Chowdhury, S. (2021).** Determination of antibiotic residues in milk and assessment of human health risk in Bangladesh. *Heliyon* 7, e07739.
- Raison-Peyron, N.; Messaad, D.; Bousquet, J. and Demoly, P. (2001).** Anaphylaxis to beef in penicillin-allergic patient. *Allergy*. 56 (8):796-797.
- Ramatla, T.; Ngoma, L.; Adetunji, M. and Mwanza, M. (2017).** Evaluation of antibiotic residues in raw meat using different analytical methods. *Antibiotics*. 6(4):34.
- Regulation (EU). (2019)/4** of the European Parliament and of the Council of 11 December 2018 on the Manufacture, Placing on the Market and Use of Medicated Feed, Amending Regulation (EC) No 183/2005 of the European Parliament and of the Council and Repealing Council Directive 90/167/EEC (Text with EEA Relevance); European Commission: Brussels, Belgium, 2018; Volume 4.
- Riley, L.W.; Raphael, E. and Faerstein, E. (2013).** Obesity in the United States dysbiosis from exposure to low-dose antibiotics? *Front. Public Health*. 1, 69.
- Riviere, J.E. and Sundlof, S.F. (2001).** Chemical residues in tissues of food animals. *Vet Pharmacol Ther.* 7:1148–1157.
- Rogers, J.M. and Kavlock, R.J. (2013).** Developmental toxicology. In: Klaassen CD, Amdur MO, Doull J (eds.). *Casarett and Doull's toxicology: the basic science of poisons*. 8th edition, McGraw Hill Education, New York, NY, 481–523.
- Rossi, R.; Saluti, G.; Moretti, S.; Diamanti, I.; Giusepponi, D. and Galarini, R. (2018).** Multiclass methods for the analysis of antibiotic residues in milk by liquid chromatography coupled to mass spectrometry: A review. *Food Additives & Contaminants: Part A*. 35(2): 241–257.
- Sachi, S.; Ferdous, J.; Sikder, M.H.; Azizul, Karim and Hussani, S.M. (2019).** Antibiotic residues in milk: Past, present, and future. *Journal of advanced veterinary and animal research*. 6(3): 315.
- Samsidar, A.; Siddiquee, S. and Shaarani, S.M. (2018).** A review of extraction, analytical and advanced methods for determination of pesticides in environment and foodstuffs. *Trends Food Sci Technol*. 71:188–201.
- Sani, A.A.; Rafiq, K.; Hossain, M.T.; Akter, F.; Haque, A.; Hasan, M.I.; Sachi, S.; Mustari, A.; Islam, M.Z. and Alam, M.M. (2023).** Screening and quantification of antibiotic residues in poultry products and feed in selected areas of Bangladesh, *Veterinary World*. 16(8): 1747–1754.

- Schaenzer, A.J. and Wright, G.D. (2020).** Antibiotic resistance by enzymatic modification of antibiotic targets. *Trends. Mol. Med.*, 26(8): 768-782.
- Shahid, A.; Ali, M.; Muzammil, S.; Raza, A.; Iqbal, M.N.; Riaz, M. and Khurshid, M. (2021).** Antibiotic residues in food chains; impact on the environment and human health: a review. *Appl Ecol Environ Res.* 19(5):3959–3977.
- Shaikh, J.R. and Patil, M.K. (2020).** Drug residues in milk and milk products: sources, public health impact, prevention and control. *International Journal of Livestock Research*, 10(6), 24-36.
- Shaker, E.M. and Elsharkawy, E.E. (2015).** Organochlorine and organophosphorus pesticide residues in raw buffalo milk from agroindustrial areas in Assiut, Egypt. *Environ Toxicol Pharmacol.* 39(1):433–40.
- Sharma, C.; Rokana, N.; Chandra, M.; Singh, B.P.; Gulhane, R.D.; Gill, J.P.S.; Ray, P.; Puniya, A.K. and Panwar, H. (2018).** Antimicrobial resistance: Its surveillance, impact, and alternative management strategies in dairy animals. *Front. Vet. Sci.*, 4:237.
- Stella, O.I.O.; Ezenyaka, E.V. and Anelom, N.J. (2020).** Screening for tylosin and other antimicrobial residues in fresh and fermented (nono) cow milk in Delta state, South-South, Nigeria. *Veterinary World.* 13(3): 458.
- Subirats, J.; Domingues, A. and Topp, E. (2019).** Does dietary consumption of antibiotics by humans promote antibiotic resistance in the gut microbiome? *J. Food Prot.* 82: 1636–1642.
- Tajick, M.A. and Shohreh, B. (2006).** Detection of antibiotics residue in chicken meat using TLC. *Int J Poult Sci.* 5(7):611–612.
- Tilahun, A.; Jambare, L.; Teshale, A. and Getachew, A. (2016).** Review on chemical and drug residue in meat. *World J Agric Sci.* 12(3):196–204.
- Ture, M.; Fentie, T. and Regassa, B. (2019).** Veterinary drug residue: the risk, public health significance and its management. *Vet Sci J.*, 13:555–856.
- United States Department of Agriculture, (2020).** Foreign Agricultural Service. Egypt: Egypt Endorses a Science-Based Decision on Veterinary Drugs. 3 Dec. 2020, <https://www.fas.usda.gov/data/egypt-egypt-endorses-science-based-decision-veterinary-drugs>
- Van Gerven, N.M.; de Boer, Y.S.; Mulder, C.J.; van Nieuwkerk, C.M. and Bouma, G. (2016).** Auto immune hepatitis. *World J Gastroenterol.* 22(19):4651-4661.
- Willis, C.; Booth, H.; Westacott, S. and Hawtin P. (1999).** Detection of antibacterial agents in warm water prawns. *Commun. Dis. Public Health.* 2, 210–214.
- Xie, R.; Zhang, X.D.; Zhao, Q.; Peng, B. and Zheng, J. (2018).** Analysis of global prevalence of antibiotic resistance in *Acinetobacter baumannii* infections disclosed a faster increase in OECD countries. *Emerg Microbes Infect.* 7(1):31.
- Xu, L.; Zhou, Z.; Zhu, L.; Han, Y.; Lin, Z.; Feng, W. and Chen, H. (2020).** Antibiotic resistance genes and microcystins in a drinking water treatment plant. *Environ. Pollut.*, 258: 113718.
- Yang, Y.; Qiu, W.; Li, Y. and Liu, L. (2020).** Antibiotic residues in poultry food in Fujian Province of China. *Food Addit. Contam. Part B Surveill.*, 13(3): 177-184.
- Yousif, S.A. and Jwher, D.M.T. (2021).** Detection of multiple presence of antibiotic residues in slaughtered sheep at Duhok abattoir, Iraq. *Iraqi Journal of Veterinary Sciences.* 35 (1), 49–55.
- Yusuf, K. and Abraham, I. (2024).** Review on the Impacts of Drug Residue in Animal Products on Human Health Issues. *Journal of research in veterinary sciences.* 2 (1): 10-20.
- Zhou, X.; Wang, J.; Lu, C.; Liao, Q.; Gudda, F.O. and Ling, W. (2020).** Antibiotics in animal manure and manure-based fertilizers: Occurrence and ecological risk assessment. *Chemosphere.* 255: 127006.