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REVIEW ARTICLE

Anthelmintic Toxicity in Camels: Emerging Risks and Clinical Consequences

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ABSTRACT

Anthelmintic drugs play a significant role in controlling parasitic infections in camels and are important in ensuring animal health, productivity, and welfare. Benzimidazoles, macrocyclic lactones and other anthelmintics are used extensively and are often based on dosage regimes extrapolated from other species of livestock because of limited camel specific data. These anthelmintic drugs are proven effective against multiple parasites, including nematodes, cestodes, and trematodes. The indiscriminate use of anthelmintic drugs causes serious problems, including drug toxicity, extended tissue and milk residues, and unintended clinical consequences. However, drug toxicity and residue-related issues pose significant public health concerns. Camels have unique physiologic and metabolic features which impact their absorption, distribution, metabolism, and excretion of drugs and may predispose camels to adverse drug reactions if traditional dosing regimens are used. This article presents a critical review of the use of anthelmintic drugs and their reported evidence of toxicity in camels. Greater awareness and focused research are critical to optimize parasite control with a minimum of toxicological and public health consequences.

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INTRODUCTION

The camels (*Camelus dromedarius* and *Camelus bactrianus*) are economically and culturally significant to most of the parts of Africa, Middle East and Asia as they contribute to food security in terms of meat, milk and transport (Kandil *et al.*, 2023; Boukrouh *et al.*, 2025). Helminthic and ectoparasitic infestations remain persistent constraints on the health and productivity of camels, particularly gastrointestinal nematodes (Toaleb *et al.*, 2025). The anthelmintic medicines are thus a part of both preventive and curative treatment in veterinary care in camel production systems (Kandeel and Al-Mubarak, 2022; El-Bahy *et al.*, 2023). The high levels of broad-spectrum anthelmintics available in the last few decades have significantly resulted in better levels of control of parasites but it has also brought new problems of drug safety and behaviour and the issue of drug residues (Longo and de Moraes, 2025). Unlike cattle, sheep, and goats, the camel has unique anatomical and physiological structures such as peculiar digestive adaptations of the camel, fat distribution in camel and other hepatic metabolism (Kandeel *et al.*, 2022; Kebir *et al.*, 2024). These factors affect the pharmacokinetics and pharmacodynamics of anthelmintic drugs (Suárez *et al.*, 2022; Vaidhya *et al.*, 2024). Despite this fact, most common anthelmintic treatment protocols used in camels are extrapolated from data produced in other ruminant species (Kultscher *et al.*, 2019; Morgan *et al.*, 2023). Such extrapolation is often unavoidable because of the limited amount of camel specific toxicological and pharmacological studies but raises concern for inappropriate dosage and altered drug clearance, resulting in greater susceptibility to adverse effects of drugs (Anwar *et al.*, 2021; Nassar *et al.*, 2024).

Anthelmintic toxicity in camels has received limited attention, partly because overt clinical signs of toxicity are considered uncommon when the drugs are administered at recommended doses (Adil *et al.*, 2023). Nevertheless, emerging research has identified issues as diverse as the long-term presence of the drug in milk and tissue, occasional reports of acute intoxication after misuse or overdose of the drug, and the indirect effects of treatment intensification because of resistance (Ranjkeshzadeh *et al.*, 2024). These concerns may be especially relevant in the case of dairy camels, where most of the milk is frequently consumed as raw milk and is a major component in the diet of pastoral communities (Kena, 2022; Oselu *et al.*, 2022). The increased awareness of the risk of anthelmintic resistance in camel parasites adds to the complexity of the issue (Brown *et al.*, 2022;

Kapo *et al.*, 2025). The reduction in effectiveness of commonly used drugs may lead to either an increase in frequency of treatment or higher doses of drugs, which can increase the potential for toxic effects and the accumulation of residues (Lampl *et al.*, 2023). In parallel, the development of commercial camel farming has intensified the dietary scrutiny of food safety and the need to comply with residue regulating programs developed largely for other species of livestock (Boukrouh *et al.*, 2025; Ibrahim *et al.*, 2025).

This review provides a comprehensive and evidence-based occurrence of anthelmintic toxicity in camels. By integrating findings from pharmacokinetic studies, clinical reports, and residue investigations, we can evaluate the emerging risks and clinical consequences associated with anthelmintic use in this species.

Anthelmintic Use in Camels: The treatment of camels by anthelmintics is mainly against gastrointestinal nematodes, cestodes, trematodes, and a few ectoparasites (El-Bahy *et al.*, 2023; Toaleb *et al.*, 2025). The most common classes of drugs used include benzimidazoles e.g. albendazole and fenbendazole and macrocyclic lactones i.e. ivermectin and doramectin (Muniz *et al.*, 2023; Tahlan *et al.*, 2025). These drugs are highly effective because of their own wide spectrum of activity, convenience to use, and comparatively high therapeutic margins (Pignatti *et al.*, 2022; Sun-Waterhouse *et al.*, 2024). Field experience of treatment choices and decision making in most camel rearing areas are not decisions made using laboratory-based diagnostics but rather decisions based on routine and even indiscriminate application (Chadha *et al.*, 2023; Sacarrão-Birrento *et al.*, 2024). The albendazole is also given orally and has activity against various nematodes and cestodes (Whittaker *et al.*, 2022; Marchenko *et al.*, 2023). It can be administered in doses like those suggested for cattle or sheep in camels. Macrocyclic lactones, which include ivermectin, are widely used in the management of endo as well as ectoparasites and are delivered by either oral or subcutaneous delivery (Panayotova-Pencheva, 2024). Although these drugs are well tolerated at therapeutic levels, their lipophilic character and extended half-lives cast doubt on their accumulation and persistence, particularly under repeated treatment use (Stielow *et al.*, 2023; Binder and Skerra, 2025).

The use of anthelmintics in large pastoral regimes is often unmonitored, and dosage accuracy could be lost because of inaccurate body weight assessment (Playford and Besier, 2025). Resistance is enhanced by under-dose, and toxicity is enhanced by over-dose (Chekole *et al.*, 2023). Moreover, the problem of off-label use, which includes administration without the approval of the administration routes, has also been noted, which makes the matters of safety even more difficult (Jensen and Sjøgren, 2020). This is worsened by the lack of labelling and withdrawal guidelines of camel specific labelling (Konuspayeva *et al.*, 2023; Maitra *et al.*, 2025).

Systematic anthelmintic evaluation safety is limited in camels even though their usage is extensive (Panayotova-Pencheva, 2024; Kimeli *et al.*, 2025). Published data indicate that camel might be slow in the metabolism and excretion of some drugs within the rumen as compared to other ruminants, which has its consequences on toxicity and persistence of the residues (Kandeel *et al.*, 2022; Ibrahim *et al.*, 2025). It is thus crucial to understand the behaviour of such commonly used anthelmintic in the camel to balance between parasite control and efficacy, and safety and public health (El-Bahy *et al.*, 2023; Hamid *et al.*, 2023).

Pharmacokinetics and Drug Residue Dynamics: Pharmacokinetic studies in camels have shown that absorption, distribution, metabolism, and excretion of anthelmintic drugs are different than other livestock species (Hou *et al.*, 2024; Konuspayeva *et al.*, 2025). These differences are affected by unique physiological traits such as differences in gastrointestinal transit time, hepatic enzyme activity, and body composition of fat (Milhem and Komarnytsky, 2023). Such factors can have a significant effect on drug bioavailability and clearance rates (Patel and Patel, 2023; Stielow *et al.*, 2023). Albendazole and ivermectin have been shown to be having a prolonged persistence in camel tissue and milk (Toaleb *et al.*, 2025). Because of the rapid metabolism of albendazole to its active sulfoxide metabolite, which may remain detectable for prolonged periods of time, the administration of albendazole is followed by rapid metabolism (Ignacio *et al.*, 2023). Studies of residue depletion have shown that both parent compounds and metabolites may be present in camel milk for a period greater than withdrawal periods typically used for cattle (Riaz *et al.*, 2022; Hajrulai-Musliu *et al.*, 2023). This prolonged excretion pattern raises concerns regarding chronic low-level exposure of human consumers (Hassan *et al.*, 2024; Thakur *et al.*, 2025).

Macrocyclic lactones are very fat-soluble and are prone to being deposited in adipose tissue (DeMel *et al.*, 2022). In camels, this trait may be enhanced by differences in the storage and mobilization of fat and hence may result in prolonged elimination half-lives (DeMel *et al.*, 2022). Consequently, ivermectin residues have been detected in milk weeks or months after treatment (Konuspayeva *et al.*, 2025). Such kind of finding does not only highlight the inadequacy of extrapolated withdrawal periods, but it can also be reiterated in this specific case of camel (Jawad *et al.*, 2025).

Such findings highlight the inadequacy of extrapolated withdrawal periods and their potential implications for drug persistence in camels. From a toxicological point of view, prolonged exposure of the system could lead to an increased possibility of cumulative adverse effects, especially in repeated dosing schemes (Sewell *et al.*, 2022; Lustberg *et al.*, 2023). Residue persistence therefore represents both a food safety concern and a contributor to long-term health consequences in treated animals (Arsène *et al.*, 2022; Mesfin *et al.*, 2024).

Mechanisms of Toxicity and Clinical Manifestations: Anthelmintic toxicity in camels is due by pharmacological interactions of the drugs with specific cellular and systemic targets, which are often affected by physiological and metabolic features that are specific for the camel (Kandeel *et al.*, 2022; Mukherjee *et al.*, 2023). Macrocyclic lactones like ivermectin and doramectin work by binding to glutamate gated chloride channels in the nervous system of parasites causing hyper polarization paralysis and death of the parasite (Löscher,

2023; Pandit and Tarkeshwar, 2023). In camels, over exposure or over dosage of these lipophilic compounds results in the possibility of crossing the blood-brain barrier, and potential interactions with mammalian gamma amino-butyric acid (GABA) receptor and other central inhibitory pathways (Salman *et al*., 2022; Hassan *et al.*, 2023). This can lead to neurotoxicity involving depression of the central nervous system activity, tremors, ataxia, hypersalivation and, in extreme cases, coma and death. The neuro-susceptibility is increased in young, debilitated or stressed animals because of altered blood-brain-barrier permeability and reduced metabolism (Fig. 1) (Alajangi *et al.*, 2022; Davidson and Stevenson, 2024).

Benzimidazoles, such as albendazole and fenbendazole, exert their action by binding to β-tubulin of parasitic cell, inhibiting microtubule polymerization, interfering with glucose uptake and ultimately energy depletion and death of parasite (Xin *et al.*, 2022; Borchert *et al.*, 2024). In camels, high, or repeated doses may have an unintended effect on microtubule dynamics in the host - especially in rapidly dividing cells, i.e. gastrointestinal epithelium and bone marrow (Dkhil *et al.*, 2024; Mukani, 2024) - causing gastrointestinal disturbances, anorexia, and, in extreme cases, cytopenias (Abdulrasak *et al.*, 2025). The metabolic processes of transforming albendazole into sulfoxide metabolite prolong the systemic exposure duration, which may increase subclinical toxic effects in the case of doses not modified according to species-specific pharmacokinetics.

Levamisole is another drug that kills worms in the int estines (Campillo *et al.*, 2022; Williams *et al.*, 2024). It is sometimes used in camelids, similar nicotinic acetylcholine receptor agonists, which cause spastic paralysis in nematodes (Mishra *et al.*, 2025). Purely cholinergic intoxication (cholinesterase inhibitors) Excessive exposure in camels may overstimulate cholinergic pathways in the host, causing tremors, salivation, muscle fasciculations, and respiratory distress. The severity of these effects is dependent on dose, route used, and the camel's metabolic and physiological status (Abdelrahman *et al.*, 2022; Ali *et al.*, 2023). Clinically, there is a possibility that the toxicity may appear with neurological symptoms, gastrointestinal or systemic symptoms depending on which drug they were using, how much in what number of times they took them (Alhamadani *et al.*, 2022). Neurological signs most usually related to macrocyclic lactones may be depression, ataxia, tremors, seizures, mydriasis, and coma (Ooboshi *et al.*, 2024). Disturbances in the stomach, such as anorexia, diarrhea, and bloating, are common problems associated with benzimidazole toxicity. In cases of intoxication in children, severe exposure may impair vital organ functions, particularly the cardiovascular system, leading to hypotension and, in rare cases, death (Chukwuka *et al.*, 2022).

The toxicity may be worsened by factors such as disease, dehydration, malnutrition, or concurrent drugs with similar metabolic pathways. The prolonged lipophilic residence of macrocyclic lactones in adipose tissue may also cause delay in appearance of clinical sign and thus complicate the diagnosis and management (Perdomo *et al.*, 2023; Carobbio *et al.*, 2024). These mechanistic pathways, if recognized, is critical for veterinary practitioners to anticipate, diagnose and manage an adverse drug event in camels, especially those that are under an intensive parasite control program or remote anthelmintic resistance developing regions.

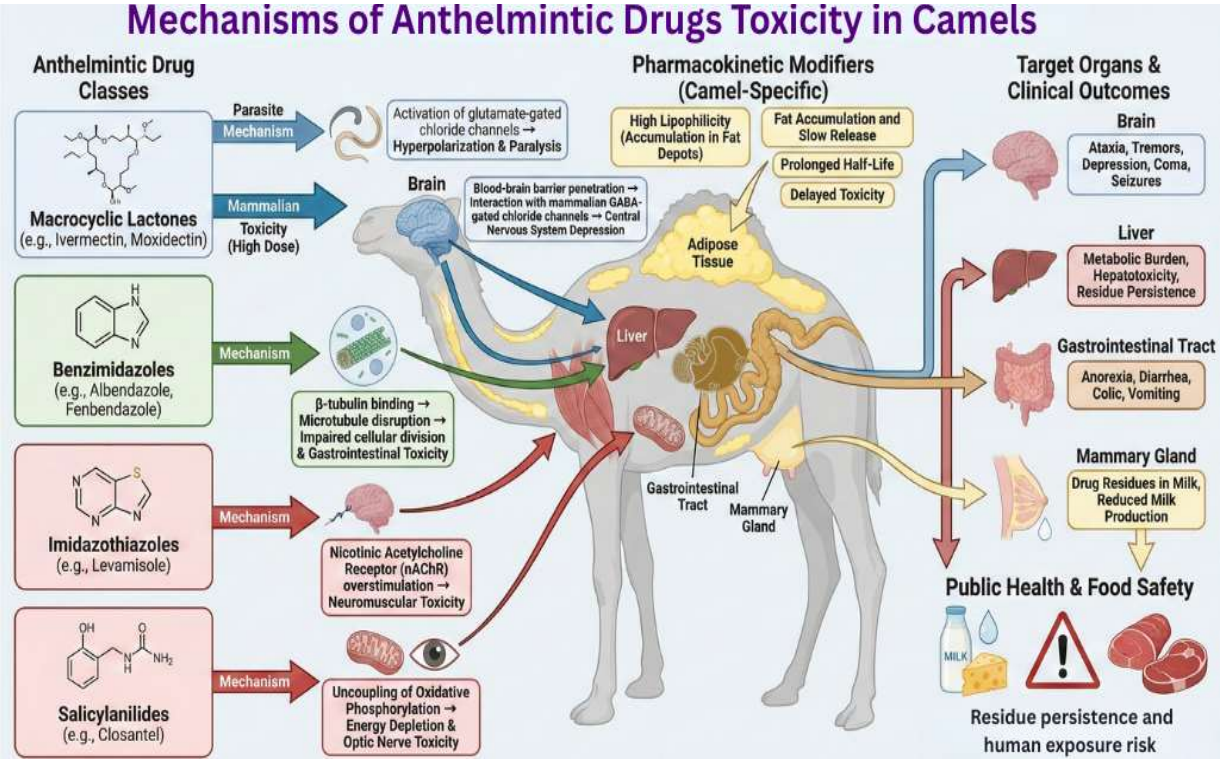

Fig. 1: Mechanism of anthelmintic drug toxicity in camels.

Table 1: Mechanisms of different anthelmintics, their pharmacokinetics and toxicity

Sr. No.	Anthelmintic Drug	Drug Class	Mechanism of Action	Target Parasite Type	Therapeutic Dose	Route of Administration	Pharmacokinetics	Toxicity and Clinical Signs	Species Sensitivity	Withdrawal / Residue	Resistance Status	Human Food Safety Concerns	References
1.	Albendazole	Benzimidazole	Binds β-tubulin → inhibits microtubule assembly	Nematodes, cestodes, trematodes	5–10mg/kg orally (livestock)	Oral	Rapidly absorbed, metabolized to sulfoxide, hepatic metabolism	High doses: GI upset, lethargy, bone marrow suppression, teratogenic risk	Sensitive in young pregnant animals	Meat and milk withholding required	Resistance reported in some nematodes	Milk and meat residues possible if withdrawal not observed	(Onakpoya, 2023)
2.	Fenbendazole	Benzimidazole	Binds β-tubulin → inhibits microtubule assembly	Nematodes, Cestodes	5mg/kg orally	Oral	Poorly absorbed; high safety margin	Very rare GI disturbances at very high doses	Generally safe	Standard withdrawal; low residues	Some resistance documented in small ruminant nematodes	Low risk if withdrawal observed	(Borchert *et al.*, 2024; Tenorio, 2025b)
3.	Ivermectin	Macrocyclic lactone	Activates glutamate-gated Cl- channels → paralysis	Nematodes, Ectoparasites	0.2mg/kg SC/PO	Subcutaneous, Oral	Lipophilic, long half-life, metabolized in liver	CNS depression, ataxia, tremors, coma at overdose	Sensitive in collies and camelids at high doses	Long meat/milk withdrawal	Resistance increasing in nematodes	Residues in milk	(Salman *et al.*, 2022)
4.	Levamisole	Imidazothiazole	Nicotinic acetylcholine receptor agonist → parasite paralysis	Nematodes	7.5–10mg/kg orally	Oral	Rapid absorption; hepatic metabolism	Salivation, tremors, ataxia, respiratory distress at high doses	Narrow margin in ruminants; pregnant animals sensitive	Longer meat withdrawal; milk caution	Resistance reported in some nematodes	Low if withdrawal observed	(Demelash *et al.*, 2014; Hamid *et al.*, 2023)
5.	Moxidectin	Macrocyclic lactone	Activates glutamate-gated Cl- channels	Nematodes, Ectoparasites	0.2mg/kg	Oral, SC	Long half-life; lipophilic	CNS depression at overdose	Sensitive in camelids	Long meat/milk withdrawal	Resistance emerging in nematodes	Residues can persist	(Schneider, 2025)
6.	Closantel	Salicylanilide	Uncouples oxidative phosphorylation → energy depletion	Nematodes, Liver flukes	7.5mg/kg	Oral, SC	Highly protein-bound; long plasma half-life	Optic nerve damage, blindness, neurologic signs at overdose	Sensitive in sheep and camelids	Long withdrawal due to plasma protein binding	Limited resistance reported	High residue risk; caution with milk	(Wiggins *et al.*, 2024)
7.	Praziquantel	Isoquinoline	Increases Ca2+ permeability → parasite paralysis	Cestodes, Trematodes	5–10mg/kg	Oral	Rapid absorption; hepatic metabolism	Mild GI upset occasionally	Generally safe	Short withdrawal	Resistance rare	Low residues; low human risk	(Pollock and Fernandez-Prada, 2025; Tenorio, 2025a)
8.	Pyrantel	Tetrahydropyrimidine	Nicotinic acetylcholine receptor agonist → spastic paralysis	Nematodes	5–10mg/kg	Oral	Poor systemic absorption; acts locally	High safety margin; rare GI upset	Safe in most livestock	Short withdrawal	Resistance emerging in small ruminants	Low residues; low human risk	(Pollock and Fernandez-Prada, 2025)
9.	Monepantel	Amino-acetonitrile derivative	Targets nematode-specific receptors → paralysis	Nematodes	2.5mg/kg orally	Oral	Rapid absorption; metabolism via liver	Very low host toxicity	Safe in sheep and camelids	Standard withdrawal; low residues	Emerging resistance limited	Low human risk	(Cantón *et al.*, 2023)

Anthelmintic Resistance and Emerging Risks: The development of anthelmintic resistance in camel parasites is also a major indirect risk factor involved in toxicity (Hamid *et al.*, 2023; Mukherjee *et al.*, 2023). Reduced efficacy of drugs may enhance increased frequency of treatment or higher drug doses, practices that increase systemic exposure to drugs and increase the likelihood of unwanted effects (Brachmann *et al.*, 2025; Pirojiya and Dudhat, 2025; Shaibie *et al.*, 2025). Resistance to several frequently used anthelmintics has been reported, and the current control methods may not be sustainable (Hassan and Ghazy, 2022; Höglund and Gustafsson, 2023). In addition to both the animal health implications, but beyond that are also the ramifications for public health once that resistance driven misuse occurs (Miller *et al.*, 2022; Caneschi *et al.*, 2023; Endale *et al.*, 2023). Increased residues in milk and meat can be an outcome of more intensive regimens of treatments compromising food safety (Arsène *et al.*, 2022; Adegbeye *et al.*, 2024; Mashauri *et al.*, 2025). The resistance, toxicity, and residues are presenting another serious issue and signify the complicated risk management of anthelmintics in camels (Hamid *et al.*, 2023; Kapo *et al.*, 2025; Konuspayeva *et al.*, 2025). Attending to the challenges involves integrated parasite control strategies, which includes moving away from chemical treatments and toward usage of plant-based drugs (Abbas *et al.*, 2025; Bhangale *et al.*, 2025; Molapo *et al.*, 2025).

Clinical Management and Preventive Strategies: Effective prevention of anthelmintic toxicity in camels is dependent on rational use of drugs and decision making during clinical status (Hamid *et al.*, 2023). Where possible, diagnostic evidence should guide treatment, rather than schedule treatment (LeBoff *et al.*, 2022; van Doorn *et al.*, 2023; Nelson *et al.*, 2024). Veterinary professionals should know the long-lasting nature of the residus of some anthelmintics in camels and make appropriate recommendations to producers (Al-Sabbagh and Shreaz, 2025; Makwarela *et al.*, 2025). Prolonged withdrawal periods may be required based on breed (e.g. dairy camels). Educating farmers and herders plays a crucial role in minimizing misuse and preventing accidental overdosing (Benaissa and Iglesias Pastrana, 2024).

Resistance can be reduced by using integrated parasite management strategies such as pasture management, selective use of treatment, and acting on the effectiveness of the drugs to reduce the cumulative use of drugs (Picot *et al.*, 2022; Munir *et al.*, 2024; Giuliotti *et al.*, 2026). Besides strengthening the idea of sustainability, such plans reduce the chances of toxicity and related issues of residues (Ostad-Ali-Askari, 2022; Raza *et al.*, 2022).

Implications for Public Health and Food Safety: The use of anthelmintic drugs in camels has important implications in terms of the public health implications, especially via consumption of milk, meat and other camel derived products (Arain *et al.*, 2023; Mohamed *et al.*, 2024; Ibrahim *et al.*, 2025). Prolonged presence of residues from the commonly used drugs, e.g., albendazole and ivermectin, in camel milk has been reported, which is often much longer than withdrawal periods for cattle and small ruminants (Atta *et al.*, 2022; Khalifa *et al.*, 2024; Bilal *et al.*, 2025). This persistence can result in human consumers being at risk of exposure to pharmacologically active compounds with risks including allergy, gastrointestinal disturbance, and with low-level exposure to compounds over long-term exposures with unknown compound cumulative effects (Batterman *et al.*, 2023; Mohajer and Culty, 2025). Raw milk consumption, common in many camel-rearing communities, increases the risk of ingesting drug residues. Careful monitoring and the education of producers are essential for ensuring safety (Holloway *et al.*, 2023; Anandhi and Iyapparaja, 2024).

Residue presence is affected by specific pharmacokinetic properties of the camel, such as a slower rate of metabolism and excretion, lipophilic accumulation of the drug, and long half-life (Nassar *et al.*, 2024; Nathani *et al.*, 2024). These biological characteristics require species-specific withdrawal guidelines to ensure that safe milk and meat come into the human food chain that people can consume (Dolezel *et al.*, 2025). Regulatory oversight across various parts of the world is poor and farmers may inadvertently collect milk or slaughter animals before safe withdrawal periods are met, and therefore without adequate control may increase risks to public health (Seyoum *et al.*, 2024).

The emergence of anthelmintic resistance tends to make this an even more complicated issue (Nielsen *et al.*, 2023; Walshe *et al.*, 2023). If parasites become resistant and the drug is ineffective, producers may use higher doses or treat more frequently (Plowe, 2022). Such practices are not only worsening the problem of residues in foodstuffs but also forming a circle of developing resistance and treatment failures (Arsène *et al.*, 2022; Al-Khalaifah *et al.*, 2025). It is therefore necessary for the public health authorities to cover both concerns of immediate exposure to residues but also the broader scope of drug abuse (Khalifa *et al.*, 2024; Ljubojević Pelić *et al.*, 2024).

Beyond chemical residues, lack of control against parasites from resistance can indirectly affect the safety of food by affecting animal health (Arsène *et al.*, 2022; Shurson *et al.*, 2022). Infected camels may have reduced immunity and increased susceptibility to other infectious agents, some of which may be zoonotic (Khalafalla, 2023; Toaleb and Shaapan, 2024). This makes integrated approaches to parasite management which involve judicious use of anthelmintics in conjunction with non-chemical management strategies such as pasture management, selective treatment and routine performance monitoring of the animals important (Abbas *et al.*, 2023; Munir *et al.*, 2024).

Ultimately, the protection of public health must be multifaceted one (Shorrab *et al.*, 2024; Tomoh *et al.*, 2024). This includes developing data on depletion of residues in camels, implementation of evidence-based receptors withdrawal period (Alharbi, 2025; Ullah *et al.*, 2026), producer education on safe drug administration, strengthening regulatory framework for monitoring milk cow and milk meat residues (Khalifa *et al.*, 2024; Kamal *et al.*, 2025). By implementing these measures, the risks of anthelmintic residues in camels can be reduced, and effective parasite control and consumer safety of camel food products can continue to be maintained (Brachmann *et al.*, 2025; Ibrahim *et al.*, 2025).

Conclusions: Anthelmintic drugs are still essential for the control of parasitic infections in camels, and their continued use plays a key role in protecting camels from diseases in a wide range of production systems. However, evidence synthesized in this review clearly demonstrates that the use of these compounds is not without risk. Camels are known to describe specific physiological and metabolic characteristics that affect the levels of anti-worm medications, leading to extended drug staying power, altered drug clearance landing patterns and subsequent chance of more negative effects when broad dosing patterns are administered from other livestock species. These factors combined point to the importance of species-specific considerations when using veterinarians to administer drugs for pharmacotherapy. The development of anthelmintic resistance further increases the risk of toxicity because it promotes more frequent treatment and doses. This presents a feedback mechanism where less efficacy leads to practices that increase both toxicological and regarding residue hazards. Integrated parasite management strategies, with a combination of judicious drug use and implementation of non-chemical control measures, are therefore crucial to minimize the necessity for anthelmintics and to ensure that they remain effective. Optimizing the anthelmintic use in camels requires a balanced approach which incorporates effective anthelmintics but also safety. Investment in camel specific pharmacokinetic, toxicological and residue work is now urgently needed to provide information for evidence-based guidelines. Enhanced awareness of the issue by vets, producers and policymakers will play a key role in reducing the risk of toxicity while maintaining the health of camels and the public health of camel-dependent communities.

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