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EFFECTIVENESS OF CHEMICAL AND BIOLOGICAL PREPARATIONS AGAINST IXODIDAE CANAE

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Abstract
Ixodidae canals are ectoparasites whose populations are growing due to climatic changes, anthropogenic factors and environmental imbalances, through which diseases such as Lyme fever, canna fever and babesiosis are spread. This analysis examines the biochemical efficiency and resistance mechanisms of chemical (pyrethroids, organophosphates, fipronil, amitraze) and biological (entomopathogenic fungi, bacteria, plant extracts) preparations based on modern (2022–2025) scientific sources. The results show that chemical acaricides show an 80–95% efficacy by acting on acetylcholinesterase, GABA receptors, and sodium channels, but resistance via detoxification enzymes (cytochrome P450, glutathione S-transferases, esterases) reduces their effect by 30–60%. Biologic preparations (extracts of Metarhizium anisopliae, Beauveria bassiana, Azadirachta indica) act through oxidative stress, lipid peroxidation and erosion of cell membranes, reducing the risk of resistance by 2–4 times. In Uzbekistan, chemical acaricides are widely used, but biological methods have not been sufficiently studied. The article recommends the development of integrated control strategies, molecular biomarkers, and the expansion of local research.

Keywords: Ixodidae channels, chemical acarcides, biological preparations, Metarhizium anisopliae, Beauveria bassiana, acetylcholinesterase, detoxification enzymes, carboxylesesterases, entomopathogenic fungi, oxidative stress, resistance.

Introduction

The family Ixodidae is a blood-sucking ectoparasite with a specific morphological and physiological structure, parasitizing in mammals, birds and sometimes reptiles. These canals have become a serious problem in the global health and veterinary field, as they are transmitted by zoonotic diseases such as Lyme (Borrelia burgdorferi), encephalitis virus, babesiosis, anaplasmosis and ehrlichiosis. In recent years, the population of canals has been increasing significantly due to the acceleration of global climate warming, urbanization, and intensification of agriculture. This situation raises serious scientific challenges not only from an epidemiological point of view, but also from the point of view of biochemical adaptation and resistance mechanisms [1].

The vital activity of Ixodidae canae relies on their complex biochemical system. Their hemocyalic metabolism, antioxidant protective system and detoxification enzymes (especially cytochrome P450 mono-oxygenases, glutathione S-transferases and carboxylesterases) are highly active. These enzymes are involved in neutralizing the toxic substances that enter the duct body, being able to break down lipid peroxidation products, and maintaining cell stability [2]. Therefore, many of them have generated a high degree of biochemical adaptability relative to conventional chemical acaricids [3].

Chemical acquacides that are currently widely used in the control of canal populations — compounds such as pyrethroids, organophosphates, fipronyl, amitrase — mainly affect nervous system enzymes (e.g., acetylcholinesterase), ion channels (Na^+, Cl^-), and mitochondrial respiratory chain activity. As a result of their toxic effects, intracellular ATP synthesis of canes is disrupted, oxidative stress increases, and as a result, the cell dies by apoptosis. However, the long-term and large-scale use of these drugs gives rise to a number of ecological problems: there is a decrease in the number of beneficial entomofauna (bees, ants, spiders), bioaccumulation processes and accumulation of residual toxins in animal products [4, 8].

Therefore, in recent years, biological preparations — environmentally friendly, biodegradation agents susceptible to biodegradation — have been intensively studied. Entomopathogenic fungi (Metarhizium anisopliae, Beauveria bassiana), bacteria (Bacillus thuringiensis), and phytochemical extracts (Azadirachta indica, Allium sativum, Artemisia absinthium) are recognized as effective natural remedies against canae [3, 5, 6]. With the help of its secondary metabolites, alkaloids, terpenoids, and proteolytic enzymes, these agents break down the channelular cell membrane, disrupt energy metabolism, and cause disruption of the detoxification system.

Thus, the relevance of this study arises from the need to analyze the effectiveness of biological agents at the biochemical level, taking into account the toxic environmental effects of chemical acaricides and the biochemical adaptation mechanisms of canes. This article analyzes the molecular targets, enzymatic responses, and oxidative stress mechanisms of various chemical and biological preparations used to treat Ixodidae canae on the basis of the literature.

Research methodology

In this analytical study, the mechanisms of biochemical action of chemical (pyrethroids, organophosphates, fipronil, amitraze) and biological (entomopathogenic fungi, bacteria, plant extracts) drugs used against the canal populations of the Ixodidae family are investigated.

The following methodologies were used in the analyzed studies:

- Biological testing in laboratory conditions - determination of the effect of drugs on the vital activity of canes;
- molecular deposition modeling method — evaluation of the binding affinity of active substances with enzymes (cholinesterase, cytochrome P450);
- field tests — verification of the effectiveness of drugs in natural conditions;
- Meta-analysis — statistical integration of the results of several studies.

The effectiveness rate was assessed based on the percentage ratio, odds ratio (OR), and confidence interval (95% CI). Data on conditions of Uzbekistan are summarized on the basis of statistical analyzes of local livestock reports, veterinary control centers and the Ministry of Health.

Results and discussion

28 species of the family Ixodidae (Hyalomma – 7, Rhipicephalus – 7, Ixodes – 5, Haemaphysalis – 5, Dermacentor – 3) have been identified in Uzbekistan. They parasitize mainly in livestock (camels, cattle) and wild mammals (Canis aureus, Vulpes vulpes). Apanaskevich et al. (2006) According to S. et al. (2023), analyzes conducted in 12 regions of Uzbekistan found 758 species of ectoparasites, including 12 species from the family Ixodidae. The most common are the species Haemaphysalis and Rhipicephalus, which have a direct impact on the ecological balance in biogeocenosis.

In 2025, in a morphological study conducted by Mechouk et al. in the Navoi region, an anomaly of eccromelia (underdevelopment of the limbs) was detected in the female tick Dermacentor niveus. It has been assumed that such structural changes can directly affect the physiology and enzyme systems of the parasite, increasing the degree of pathogenic transport.

See also Korotkov et al. (2010). Termez et al. (2024) identified Ixodes eldmanica in the vicinity of Termez , indicating that it can spread Laimus pathogens. Sharipov et al. (2006) Zhang et al. (2025) found the presence of KCHFV (Crimean–Congo hemorrhagic fever virus) in the species Dermacentor marginatus and Hyalomma anatolicum in the border areas of southern Kazakhstan and Uzbekistan . Molecular analyses showed 92–98% similarity of the viral genome, indicating a correlation between acaricide resistance and virus-carrying strains.

In Uzbekistan, cattle are infected with 11 species of Ixodidae, and in total, more than 30 thousand samples have been studied. Although chemical acaricids (organophosphates and pyrethroids) are effective in the short term, detoxification processes have been accelerated and resistance has been formed due to the overexpression of cytochrome P450 enzymes. Therefore, biological methods – biopreparations based on entopathogenic fungi (Beauveria bassiana, Metarhizium anisopliae) and plant extracts – are offered as a promising direction. [14]

According to the Livestock and Veterinary Committee of the Republic of Uzbekistan, in 2023, losses in livestock due to canals increased by 10-15%. These results indicate that an integrated approach (chemical + biological) is needed in the fight against canes, and that the establishment of enzymatic resistance mechanisms and monitoring of biochemical markers (GST, esterace, acetylcholinesterase) is of urgent importance in the development of this system.

The chemical acaricides show their effect in hard-shell canal (Ixodidae) cells mainly by affecting the nervous system, ion channels, and metabolic pathways. Studies have also revealed that their biochemical mechanism differs in substances belonging to different classes, but as a final result, disruption of nerve impulses, impaired energy metabolism, and increased oxidative stress are observed.

For example, pyrethroids — specifically permethrin, deltamethrin, and cypermethrin — keep voltage-dependent sodium channels open for long periods of time. This makes the depolarization of the cell membrane uninterrupted, culminating in the channels being paralyzed. A study by Costa and co-authors (2023) found that ATF consumption doubled after permethrin exposure in ricinus species, while the amount of reactive oxygen forms (ROS) increased by 1.5 times ($p<0.01$). At the same time, the lipid peroxidation rate is increased to 40% while the activity of antioxidant enzymes such as superoxide dismutase and catalase decreased by 30%. This indicates that pyrethroids not only affect the nervous system, but also disrupt the integrity of the cell membrane through oxidative stress. Martinez-Torres et al. v. In the case of Rhipicephalus microplus, S-transferase et al. (2022) found that increased activity of the enzymes gluthione S-transferase and cytochrome P450 increased resistance to pyrethroids by 50% — a clear example of the process of genetic adaptation in insects.

Organophosphates (dichlorvos, malation, chlorpyrifos), on the other hand, mainly disrupt nerve impulses by phosphorylation of the enzyme acetylcholinesterase. As a result, acetylcholine accumulates in the synaptic spaces, and a state of constant muscle contraction — that is, paralysis occurs. A study by Karanja et al. (2023) showed that in the cane of Rhipicephalus sanguineus, the level of lipid peroxidation increased by 35%, while the activity of SOD and glutathione peroxidase decreased by 40% ($p<0.05$). At the same time, some channels form a protective mechanism against these poisons through the activation of detoxification enzymes, which reduces the effectiveness of drugs by 30–60%.

Phenylpyrazole derivatives, notably fipronyl, block GABA receptors, block chlorine channels, and reduce mitochondrial complex I (NADH-dehydrogenase) activity. As a result, energy deficiencies and oxidative stress arise in cells. Studies on Hyalomma marginatum by Hassan et al. (2024) showed that SOD and GPx activity decreased by 50% and the ROS amount doubled ($p<0.01$).

Similarly, amitrase, which belongs to the class of amidins, inhibits the enzyme monoamine oxidase (MAO) by affecting octopamine receptors. In 2023, experimental studies in Rhipicephalus sanguineus cana showed a 45% increase in lipid peroxidation (TBARS) under the influence of amitrase, while antioxidant protection decreased by 30% ($p<0.05$).[7, 10]

In general, such complex effects of the chemical acaricids lead to intense oxidative stress, enzymatic imbalance, and disruption of energy metabolism at cell level in canes. Therefore, their long-term or repeated use can lead not only to a decrease in effectiveness, but also to the development of resistance (resistance) mechanisms. This situation highlights the need to seek biological and integrated methods of protection in the years to come.

Biological preparations have environmentally friendly and targeted mechanisms of action compared to chemical acaricids, which disrupt different biochemical pathways in the body of the acarcides. Studies show that entomopathogenic fungi, bacterial toxins and plant extracts have a significant influence on canine cell structure, enzymatic activity as well as levels of oxidative stress.

Entomopathogenic fungi such as Metarhizium anisopliae and Beauveria bassiana produce proteases, chitinases, and destructsins. This substance breaks the rigid cuticle and cell membranes of the canes, allowing access to the internal environment. In a field-based study conducted by Kalayou et al. (2024), the Metarhizium-based

Tickoff® drug showed 70–80% efficacy against the species Ixodidae ($p<0.01$). In a similar vein, Fernandes et al. (2006) S. et al. (2023) noted that superoxide dismutase (SOD) and glutamine peroxidase (GPx) activity decreased by 40–60% in Rhipicephalus microplus cans treated with Beauveria bassiana, while lipid peroxidation increased by 2-fold. These fungi disrupt cell metabolism by causing intense oxidative stress.

Bacterial drugs also have similar biochemical mechanisms. Cry-toxins produced by Bacillus thuringiensis (Bt) disrupt ion ion permeability in the midgut of canes and cause excessive accumulation of calcium ions in the cell. A 2023 study found a 50% reduction in the activity of adenylate cyclase as well as Na^+/K^+-ATPase in the Hyalomma anatolicum species when exposed to Bt ($p<0.05$). At the same time, the prodigiosin pigment produced by the bacterium Serratia marcescens inhibited DNA synthesis and oxidoreductase enzymes, increasing the amount of reactive oxygen forms by 1.8 times (Kumar et al., 2023). These bacterial components paralyze canes biochemically "from the inside," meaning they target the most important enzyme complexes of metabolism.

And plant extracts have a great potential as a natural bioinsecticide. For example, Azadirachta indica (neem tree) produces the substance azadirachtin, which blocks the synthesis of chitin and stops the canes' bark from forming. Allicin in allium sativum (garlic) inhibits oxidoreductase enzymes, while 1,8-cineole in Eucalyptus globulus disrupts the ion balance of the cell membrane. Naveed et al., 2019 S. et al. (2025) found that Cirsium arvense extracts bind to GABA receptors, reducing synaptic activity by 60–70% ($p<0.05$). Also, according to data published in the journal Frontiers in Veterinary Science (2024), SOD and catalase activity was reduced by 50% in Ixodes ricinus species treated with garlic extract, while lipid peroxidation product (MDA) increased by 1.5 times.

In recent years, the direction of achieving synergistic effects through the combined use of biological and chemical preparations has also been developing. In a study conducted by Pereira et al. (2024), the use of synthetic acarcides in combination with essential oils (eucalyptus, lavender) reduced acetylcholinesterase activity by 80% and increased the amount of reactive oxygen forms by 2.5 times (OR=2.5; 95% CI: 1.8–3.2). This approach allows you to reduce the dosage and environmental risk of the chemical by up to 30%.

The problem of resistance has also been studied at the biochemical level. Dzemo et al. (2023) and Kumar et al. (2023). According to a study by Rhipicephalus (2024), increased activity of cytochrome P450, glutathione S-transferase (GST), and esterases in Rhipicephalus microplus cans increased resistance by 40–60% to chemical

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acarides. However, biological preparations affect these processes lessly: they do not activate detoxification enzymes, so the level of resistance is 2–4 times lower.

In the context of Uzbekistan, these areas are only beginning to be studied. According to local observations, in species of Rhipicephalus microplus and Ixodes scapularis, which are common in livestock, the incidence of resistance to organophosphate preparations reached 40%. At the same time, the effectiveness and environmental safety of biological methods has not yet been fully assessed. This indicates the need in the future to develop biological preparations and integrated protection strategies suitable for the conditions of Uzbekistan.

Chemical acharicides affect the nervous system (AChE, GABA receptors, Nav channels) and mitochondrial metabolism, showing an efficacy of 80–95% [7, 9, 10]. However, resistance developed through detoxification enzymes (cytochrome P450, GST, esterases) significantly reduces their action [3, 19]. The enzymes hydrolyze the acaricid molecules, ensuring a biochemical adaptation.

Biological preparations (fungi, bacteria, plant extracts) act through oxidative stress, lipid peroxidation, and erosion of cell membranes [12, 13, 16]. For example, the destructins of Metarhizium anisopliae disrupt the mitochondrial electron transport chain, while the toxins of Bacillus thuringiensis disrupt the ion balance [14]. Plant extracts (azadirachtin, allicin) inhibit chitin synthesis and oxidoreductase enzymes, which is preferred as an environmental-friendly approach [16, 17].

Synergistic approaches combine the biochemical advantages of chemical and biological preparations, reducing doses and reducing the risk of resistance [18]. The widespread use of chemical acaricides in Uzbekistan strengthens resistance, and research on biological methods is limited. The development of integrated control strategies (IPMs) and molecular biomarkers are critical in addressing this challenge.

Conclusion

Complex biochemical adaptation mechanisms in the body of Ixodidae — including cytochrome P450, glutathione S-transferase (GST), esterases, and activation of antioxidant enzymes — make them resistant (resistant) to many chemical acaricids. Although chemical acaricids (pyrethroids, organophosphates, fipronil, amitraze) have proven to be highly effective through nerve impulse transmission and induction of oxidative stress, their long-term use reduces the effectiveness as a result of activation of the enzymatic detoxification system to 30–60%.

However, biological preparations — in particular entomopathogenic fungi (Metarhizium anisopliae, Beauveria bassiana), bacterial toxins (Bacillus thuringiensis) and plant extracts (Azadirachta indica, Allium sativum, Eucalyptus globulus) — exert an effective acicidal effect by inhibiting enzymes of cell metabolism, lipid peroxidation, and oxidoreductase in cans. They are less harmful to the environment, reduce the development of resistance by 2–4 times.

Studies in recent years show that the most effective strategy against Ixodidae canae is the integration of chemical and biological methods, i.e., the formation of a synergistic approach. Such a combination reduces the dose of acarcids, increases environmental safety and ensures stable parasite control in livestock.

In the conditions of Uzbekistan, the work carried out in this direction is still limited, and the in-depth study of the mechanisms of biochemical resistance of local species of cana, the development of biological agents based on entopathogenic microorganisms and their field testing is relevant as a promising scientific direction.

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