

**Review Article****Red Mite Infestation in Poultry: Morphology, Control and Prevention**

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ABSTRACT

Despite being an ectoparasite of birds, *Dermanyssus gallinae* (*D. gallinae*) has no specific host range. Without a natural host, the mite can feed on mammals, including humans, due to its lack of specificity. As a result of red mite infestations, poultry industry economies have been negatively affected, egg production has declined, and chickens' welfare has been compromised. Several *in vitro* studies have demonstrated the effectiveness of diesel, petroleum, mineral, and plant oils (orange and rapeseed) in controlling poultry red mites. It is possible to develop vaccines against arthropods; however, this process takes a long time due to its complexity and the possibility of inducing stronger and longer-lasting immune responses in the host. This review paper aimed to comprehensively understand the morphology, the factors contributing to red mite infestation, and the life cycle. It also provides an overview of various methods for preventing and controlling the infestation of red mites in poultry farming, including several chemical and non-chemical approaches that can be used. Chemical interventions, such as acaricides, exhibit immediate efficacy in red mite control, but their long-term sustainability and potential resistance development are significant concerns. Non-chemical methods, including enhanced biosecurity measures and natural predators, demonstrate promise in reducing red mite populations, offering environmentally friendly alternatives with potential long-term benefits. In order to minimize the negative impact of red mites on poultry flocks, poultry producers must understand the biology of these parasites and implement effective management strategies.

1. Introduction

Infestations of red mites (*Dermanyssus gallinae*) within the poultry industry are one of the most challenging problems faced by the productivity of birds and welfare, exerting a significant negative impact on animal health and industry^{1,2}. These infestations are associated with compromised egg production, economic losses, and increased disease susceptibility^{3,4}. Developing effective strategies to control and prevent red mite infestations requires understanding their morphology, behavioral patterns, and life cycle⁵. As part of this review, researchers combine scientific insights with pragmatic approaches to

tackle the widespread problem of red mite infestations in poultry. With its flattened and eight-legged body, the red mite *Dermanyssus gallinae* (*D. gallinae*) can infest poultry due to its distinctive morphology. The life cycle of an insect is nuanced, undergoing several developmental stages, including the egg, larvae, nymph, and adult⁶. With favorable conditions and rapid population growth, each stage possesses intrinsic vulnerabilities that can be targeted through strategic intervention. During favorable conditions, the life cycle can be completed within a week. A blood meal is required to transition from protonymph to deutonymph

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and finally to adulthood⁷.

It has been reported that hens that suffer from mite infestations are less likely to produce eggs, gain weight, and have a higher feed conversion efficiency. Mites also cause feather loss and skin lesions, which can lead to stress and other health issues. Mites can also transmit disease to other hens and to humans⁸. In addition, mites can adversely affect animal health by stress, compromised immunity, weight loss, increasing mortality, and anemia⁹. In order to build effective management practices, it is necessary to analyze and document these phases thoroughly. Mites can transmit many infectious diseases caused by bacteria and viruses in poultry¹⁰.

Egg-laying productivity is severely adversely affected by poultry mite infestations¹¹. European farms suffer severe problems due to the mite's worldwide distribution¹². There are many factors that influence egg production. Some of them are the production of eggs, the quality of eggs, and the growth rate of the eggs. Egg production is also affected by the environment, climate, and diet of the chickens.

Other factors include genetic selection, stress, and illness. Acaricides such as organophosphates and pyrethroids are the main treatments for poultry red mite (PRM)¹³. The Food and Drug Administration (FDA) recently approved that hens be administered by oral systemic ectoparasiticides, like fluralaner¹⁴. Among the alternative treatments available for red mites, herbal compounds are very popular. Today, herbal compounds are used to treat many parasitic diseases in poultry like coccidiosis¹⁵⁻¹⁷.

Regarding human health and the environment, synthetic acaricides have been restricted due to their adverse effects, including carcinogenic properties and impairment of mental function¹⁶. A natural pesticide or phytochemical, botanicals (also called botanicals or natural remedies) are an alternative to conventional pest control methods that are usually less harmful to the environment¹⁷. There are many advantages of PRM control with vaccination, such as reduced use of pesticides, lower chance for developing resistance, and less environmental or animal product contamination¹⁸. The current study will compressively review PRM infections, their clinical effects on chickens, their role as disease vectors, and their management in terms of human health.

2. Morphology and life cycle

In the *Dermanyssidae* family of parasites, *D. gallinae* is an obligate hematophagous ectoparasites that causes substantial damage to poultry populations due to their nutrient requirements¹⁹. A notable characteristic of their morphology is their flattened bodies, with eight well-organized legs, which have allowed them to adopt an ambush and cling behavior that is remarkably well adapted to their environment²⁰. In addition, the segmented structure of their bodies allows them to be maneuverable and flexible. They do this to avoid detection and feathers and navigate through the forest without getting detected. Their flattened bodies are conducive to their preference for habitats within cracks, crevices, and nesting material, allowing them to

remain cryptic²¹. Their blood-feeding behavior is at the core of their parasitic lifestyle, which poses a significant risk to avian hosts. A piercing-sucking mouthpart, adapted for this kind of hematophagy, helps in the penetration of the host skin and facilitates the consumption of blood. Poultry health and productivity decline due to this behavior, which causes anemia and irritability⁵. As *D. gallinae* progresses through its life cycle, it becomes increasingly vulnerable, which makes it potential for targeted control. Within the poultry housing environment, eggs are deposited in secluded niches to ensure protection from predators. After hatching, the eggs become larvae with three pairs of legs, called hexapods²².

Early instars generally remain near their hatching sites because they have limited mobility. A fourth pair of legs is acquired by protonymphs when the larvae molt into protonymphs. During the molting, protonymphs can enhance mobility, allowing them to search for food wherever they are located. They eventually find avian hosts where they feed on their blood as a result of which, they eventually locate avian hosts. Following the protonymphal phase comes the deutonymphal phase, in which sexual dimorphism is acquired through a further molt. There is a visual difference between males and females; females have a larger body size after blood meals. After molting, the adult stage begins, where the molt has been completed, and the body begins to take shape. A female can lay up to 200 eggs during her lifetime with the help of blood meals²³.

Red mite populations must be managed effectively to have a high probability of exponential growth in the future. Strategic exploits can be made of mobility, attachment, and blood-feeding behaviors to control red mite populations. Taking action during the critical stages of a bird's life cycle can disrupt its life cycle, reducing the severity of the infestation and the subsequent impact on the bird.

3. Poultry infection with red mite

Anemia caused by repeated mite bites is the first clinical sign of animal infestation²⁴. As a result of PRM infestations, hens can die of severe anemia due to the disease in extreme cases. In addition to its direct effect on mammals (including humans), PRM is an essential vector for several bacteria and viruses. These include the paramyxovirus that causes Newcastle disease, the Western, Eastern, avian influenza A virus, Venezuelan equine encephalomyelitis viruses, and bacteria such as *Erysipelothrix rhusiopathiae*, *Escherichia coli*, *Salmonella gallinarum*, *Pasteurella multocida* (*P. multocida*), and *Salmonella enteritidis*²⁵⁻²⁸. Eastern equine encephalomyelitis virus and *P. multocida* were isolated from mites after ingesting blood from infected chickens 30 days and two months after ingestion, respectively²⁵.

4. Poultry industry, environment and human health

4.1. Poultry industry

Since the broiler industry has a short production cycle,

poultry red mites do not pose a significant threat. However, the egg-laying industry faces considerable threats from this mite, except in layer farms in the US, where *Ornythonyssus sylviarum* is the most prevalent mite species²⁹. The United States, however, has experienced a significant increase in infestations of *D. gallinae* in recent years³⁰. Although *O. sylviarum* is also present in wild birds of European countries, *D. gallinae* is the species responsible for farm infestations³¹. There have been reports of mixed infestations in countries outside of Europe²⁴. Europe has a high prevalence of infestations, with an average prevalence of more than 80% and a few countries exceeding 90%. Despite this, PRM prevalence differs from region to region, even within the same country, as many regions exhibit different prevalence levels³². An inverse relationship exists between farming intensification and the risk of infestation in less-intensive farming systems³³. Therefore, PRM prevalence is higher in backyards and free-range animals, followed by barns and enriched animals³³. Enriched cages usually show higher levels of infestation when compared to traditional pens in those countries where they are still allowed. In that case, they tend to show higher levels of infestation than traditional pens, providing safer areas for mites and treating them simultaneously as promoting the welfare of the hens, allowing these systems to improve mite survival³⁴. The level of infestation varies according to the season. Different seasons in each region are more likely to have more severe infestations³⁵. There is usually a correlation between mild temperatures and high relative humidity inside the layer house and less fluctuation in these parameters, which allows the mites to thrive and produce more severe infestations³⁶. As a result, the peak of infestation usually occurs in the summer months in northern countries, while spring and autumn are the most prevalent seasons in temperate zones. Moderate or low infestations do not significantly impact the production parameters of layer hens independent of what type of production system is employed³⁷.

On the other hand, a severe infestation is associated with significant losses in production, though there are differences between housing systems³⁷. It has been demonstrated that PRM has a detrimental effect on the egg weight and laying hens, the number of first-choice eggs in enriched cage facilities³⁸. When eggs are bloodstained, PRM infestations devalue them. There are spots on the eggs because fed mites were crushed under them as they walked or hidden on the conveyor belt, which caused the eggs to be damaged³⁹. There are many confirmed vectors of bacterial and viral pathogens in *dermanyssus* mites. It has been reported that several pathogenic bacteria have been detected in PRM, including *E. rhusiopathiae*, *P. multocida*, *Coxiella burnetii*, *Listeria monocytogenes*, *Chlamydophila psittaci*, *Mycoplasma gallisepticum*, and *Spirochetes*⁴⁰⁻⁴². Despite this, its ability to act as a biological vector for transmitting these pathogens has yet to be thoroughly examined, and further research is needed. *Salmonella enteritidis* is transmitted by PRMs under laboratory conditions after ingesting washed mites contaminated with cuticular debris or blood⁴³. The etiological agent of fowl

typhoid, *S. enterica* subsp. *enterica* serovar *gallinarum* biovar *gallinarum* (*S. gallinarum*) was also found to survive in the blood of infected mites for up to 4 months following infection⁴⁴.

After an outbreak of fowl typhoid, the mites survived in two different production cycles, even after a sanitary break and vaccination against the second flock of birds following a sanitary break. This suggests that the mites maintained the infection across two production cycles. A recent study found that mites had different bacterial populations depending on the antibody levels of the vaccinated hens²⁸. Host, parasite, and bacterial pathogens interact in a complex way in this finding. After feeding bloodmeal to infected hens, PRM has the potential to act as a mechanical vector for the avian influenza virus, avipox virus, Marek's disease virus, and Eastern, Western, and Venezuelan equine encephalomyelitis virus because mites are capable of surviving among successive flocks and persisting in a fasting state for extended periods of time³.

4.2. Environment and wildlife historically

A significant source of mite infestations in poultry houses was historically wild birds— It was, however, found that mitochondrial cytochrome oxidase I (mt-COI) gene sequencing, which enabled a secure species identification of *D. gallinae*, did not locate any species of *D. gallinae* that parasitize wild birds in poultry farms, indicating that synanthropic populations are only found among *D. gallinae*⁴⁵. Further, a study demonstrate that *D. gallinae* populations found near poultry farms were associated with different genetic lineages⁴⁵. Moreover, based on a genetic comparison, recent research has indicated no mites exchange between layer houses and wild sparrow nests in the United States⁴⁶. It is possible, however, that wild bird nests near hen houses can act as a reservoir for mites and cause re-infestation⁴⁶. Using a risk analysis, Mul et al.⁴⁷ found that poultry farmers and employees posed the highest risk of PRM introduction and spread, followed by hen cadavers and manure aeration. Sharing manure belts among barns increases the risk of spreading PRM. The presence of pests, including rodents and insects, is a potential source of mites in layer farms. However, the role of pests in introducing and spreading the disease in layer farms is still unclear⁴⁶.

4.3. Zoonotic risks

Despite being an ectoparasite of birds, *D. gallinae* has no specific host range⁴⁸. Without a natural host, the mite can feed on mammals, including humans, due to its lack of specificity⁴⁹. Gamasoidosis and dermanyssosis are diseases associated to human parasites caused by PRM⁴⁹. The typical clinical signs of gamasoidosis are erythematous papules on the skin and urticarial lesions. Most pruriginous skin lesions are located in the arms, legs, and upper trunk, but they can occur anywhere on the body and describe two epidemiological scenarios related to occupational and urban human gamasoidosis caused by *D. gallinae*⁴⁹. There is some

suspicion that *D. gallinae* are the most commonly identified ectoparasites in gamasoidosis cases, but identifying *D. gallinae* is difficult for those untrained in ectoparasite identification. More precise analyses will be needed to determine whether climate change, host expansion, and globalization will lead to the expansion of other similar mite species, such as *Ornythonyssus* spp.⁵⁰.

5. Pathogen incubation periods

Understanding the incubation time of pathogens is essential for optimal timing when introducing mites to hosts, increasing their likelihood of infection. An example involves experimental infection with *E. rhusiopathiae*, where chickens showed no clinical signs 3 days after infection, but mites introduced a day later still transmitted the bacteria⁵¹. Despite chickens developing signs 3 days post-infection, they tested negative after 6 days. When hens were experimentally infected 7 days prior with *S. gallinarum*, and then infested with *D. gallinae*, the percentage of mites increased accordingly, which corresponds with the peak of bacteremia 7 days after infection onset⁵². A previous blood meal digested by mites may enhance their aggressiveness and host-seeking behavior, making them susceptible to infection upon starvation⁵³. Furthermore, it has also been found that temperature can also have a profound effect on the feeding rates, as in the case of mites that have been kept at room temperature for 7 days, as well as those that have been starved and cooled at $5 \pm 1^\circ\text{C}$ for 30 days⁵⁴. However, a separate experiment showed that starvation for two weeks at 4°C significantly reduced feeding rates⁵⁵.

6. Pathways of pathogen transmission

Despite the importance of establishing the path of mite-mediated infection in patients, few studies have been conducted on this issue^{43,56}. Most hematophagous vectors, such as mosquitoes and ticks, transmit pathogens when they bite⁵⁷. For instance, the tick-transmitted pathogen *Borrelia lusitaniae* crosses the hemocoel and reaches the salivary glands, where it is eventually transmitted to another host via blood transfusion after consuming blood and migrating to the gut⁵⁸. For these arthropods to be competent vectors, they must colonize salivary glands. Until recently, oral entry paths for pathogens into the host have been described sporadically by ingesting mites infected with the pathogen⁵⁹. Birds cannot peck or eat the mites they infest on the host due to the artificial feeding devices *in vivo*⁵⁵. Additionally, mites might spread pathogens vertically (to their progeny) by invading their ovaries and ovarian germinal tissue. The *S. enteritidis* colonizes *D. gallinae* via transovarial and transstadial routes, but how bacteria colonize mites is not yet known. The *D. gallinae* pathogen localization remains unknown because mites are difficult to dissect⁶⁰. Furthermore, immunohistochemistry, fluorescent *in situ* hybridization, and direct immunofluorescence are available to study pathogen localization in ticks⁶¹. It may, therefore, be

possible to explore the occurrence and biology of PRM pathogens using the scientific knowledge of ticks⁶².

7. Conventional control by inorganic materials

Synthetic acaricides have been widely used to control PRM infestations and prevent mite transmission¹. Despite this, chemical acaricides are restricted from use by humans due to safety concerns. A lower efficacy has also been observed in PRM due to increased resistance⁶³. Plant-based products, plant-derived compounds, vaccines, and biological approaches have been adopted as alternative non-chemical treatments for PRM and are being tested in many laboratories (see further below). There is no adequate treatment for PRM in any of these options¹². According to previous reports, integrated pest management (IPM) programs using multi-tactic approaches are the only sustainable way to control PRM infestations⁶⁴. Although this approach is practical and widely used in poultry farming, it still needs to be expanded⁶⁵.

7.1. chemical control

A standard method of controlling PRM growth is chemical treatment with organic compounds. The following is a brief overview of synthetic essential oils and pesticides.

7.1.1. Pesticides

Selecting the right acaricide for the pest prevents resistance in the pest and optimizes dosages. Aside from that, there is also a possibility of reducing or avoiding side effects on non-target species. As a result, there are no available synthetic chemical products that are selective for PRM, indicating a toxic effect on other insects and arachnids as well¹². There are limitations on using synthetic acaricides for specific applications, like against PRM, and different biocides and veterinary medicines regulations. Due to the dynamic nature of these pesticides' registrations, monitoring their status regularly and even requiring their approval during production is necessary, with some restrictions. Veterinary medicine for ectoparasite control of livestock and layer hens has been developed using the organophosphate phoxim (ByeMite R)⁶⁶.

7.1.2. Essential oils

In poultry red mite control, several oils have proven effective, including diesel, petroleum, mineral, and vegetable oils (orange and rapeseed)⁶⁷. When exposed to these oils, mites cannot breathe normally because they induce physical stigmata. Nevertheless, farmers have only used certain oils for a long time because oils stain eggs, affect egg belts, and are difficult to clean¹². Using oils as a barrier against mite infestations is effective because mites avoid oil spots. A biocide registration is currently unavailable for these oils, so PRM treatment is not permitted⁶⁸. In a study carried out in the laboratory by

Lundh et al. the oil of *Azadirachta indica*, more commonly known as neem oil, exhibited both good acaricide and low repellent properties at 15-20% concentration⁶⁹.

7.2. Biological control

Food production commonly uses biological control. Spinosad (Elector R) is an organically registered, biologically active acaricide that affects both nervous systems⁶⁹.

7.2.1. Natural enemies

PRM can be controlled using naturally occurring enemies, such as ectoparasites, that share living environments⁷⁰. Ectoparasites, which share living environments with PRM, are suitable candidates as naturally occurring enemies. A controlled enclosed system allows for the confinement of some natural enemies, which can then be evaluated for their effectiveness at the release site⁷¹. *Androlaelaps casalis*, *Hypoaspis aculeifer*, *Hypoaspis miles*, and *Stratiolaelaps scimitus* (previously *H. miles*) naturally inhabit layer cages. They are genuine predators of PRM, despite not being specific predators of PRM, affecting their ability to be implemented as a control strategy in the long run⁷².

7.2.2. Entomopathogens and endosymbionts

Entomopathogenic fungi, nematodes, and bacterial endosymbionts can potentially be a non-chemical means of controlling PRM in poultry farms. However, their use in poultry houses still needs to be solved, and commercial products are still being developed⁷³. It has been proven that fungi infect mites by germinating, penetrating, spreading into their bodies, and adhering to their cuticles, which are specifically susceptible to *Metarhizium anisopliae*, *Beauveria bassiana*, and *Trichoderma album* under laboratory conditions⁷⁴. However, the pesticide's effectiveness has been found to be unsatisfactory in some semicommercial experiments, mainly because the humidity levels were too low for fungal transmission and the doses were too low in poultry farms⁷⁵. In the poultry industry, nematodes have often been used to control mites. However, they require a particular environment, such as free water and high humidity levels, so they have been challenging to use in poultry houses^{1,64}.

7.2.3. Semiochemicals and growth regulators

A promising avenue for controlling poultry red mites (PRM) involves harnessing a repellent allomone derived from ducks, with host-related kairomones serving as attractants.⁷⁶ In PRM control; however, this attribute would not be helpful in attracting or repelling insects due to its practical application as an allomone that is synthesized from duck uropygial glands. Growth regulators either interfere with the development of exoskeletons in invertebrates (chitin) or mimic or inhibit juvenile hormones, causing pups

or adults to develop improperly or prematurely⁷⁷. It has recently been considered to use growth regulators to control PRM. As an acaricide used in conjunction with triflumuron, it disrupts embryonic development, indicating it is potentially efficient in controlling mites. The United Kingdom currently markets Triflumuron as a general pesticide against domesticated animal pests⁷⁸.

7.2.4. Plant-derived compounds

Acaricides, toxic plants, repellents, and attractants have promising properties as non-chemical alternatives to PRM. Integrated pest management (IPM) strategies are best applied when using plant-based products because most have low toxicity to mammals, short environmental persistence, and low environmental effects, thus making them suitable for use in IPM strategies⁷⁹. A total of 15 different plant species have been tested to date, including *Conocarpus erectus* extracts, *Commiphora holtziana* ssp *holtziana*, and fractions and extracts from *Cnidium officinale* that are capable of repelling PRM, even though they are all plants from different plant families⁸⁰. These substances are expected to have relatively safe repellent properties for non-target organisms, but the chemical compounds in various batches exhibited varying quality and quantity. *Cnidium officinale* rhizome extracts and fractions were shown to have 91.3% repellent activity on PRM when methanolic extracts and fractions of the rhizome were given⁸¹. Moreover, Kim et al.⁸² demonstrated that water and alcohol extracts of *Conocarpus erectus* repulsed PRM. As part of an additional study, the repellent properties of (Z)-ligustilide, which was isolated from the roots of *C. officinale*, showed an almost 100% repellent response when measured with a T-tube olfactometer⁸⁰.

7.2.5. Vaccines

In the fight against and prevention of avian diseases, a wide range of strategies has been employed, including the help of nanotechnology, vaccination, and improved poultry hygiene in poultry farms^{82,83}. The development of vaccines against arthropods is extremely challenging due to the time requirement and the possibility of inducing new immune reactions in the host⁵⁴. It has been shown in several studies that both native (autogenous) and recombinant antigens may be effective for vaccination⁸⁴. However, it is still unclear what type(s) of autogenous vaccines are available and which antigens are effective. There is no quantification of the efficacy of autogenous vaccines, indicating that results varied from batch to batch. It has been proposed to offer hens an alternative approach to using somatic mite proteins by immunizing them with tick or mosquito recombinant proteins (Bm86 or subleasing)⁸⁵. There was a 35% *in vitro* mortality rate for subleasing- vs. 23% for Bm86-immunized *D. gallinae*. Vaccine candidates investigated against *D. gallinae* from a genomics approach using both Dg-HRF-1 (*D. gallinae* histamine release factor protein) as well as both Dg-CatD-1 and Dg-CatL-1 (recombinant cathepsin D-/L-like proteinases)⁸⁶. These proteins are orthologues of the tick

HRF identified in *D. gallinae*. Mortality increased 7% *in vitro* following Dg-HRF-1 vaccination of hens with polyclonal IgY-spiked blood⁸⁶. A similar study found that mite mortality was significantly higher in Dg-CatD-1 treatment groups than in Dg-CatL-1 treatment groups and control groups 120 hours after initial mite feeding had commenced. Antigen studies have shown that vaccines against *D. gallinae* may be using recombinant or somatic proteins, which showed that a vaccine against PRM could potentially be effective. However, commercially viable vaccines have yet to overcome significant technical hurdles⁸⁷.

7.3. Physical control

Although manual cleaning is included in physical control, focusing on temperature, lighting, and inert substances only, hygiene practices are discussed in the following section.

7.3.1. Temperature

The *D. gallinae* are expected to die when temperatures exceed 45°C and drop below 20°C. In order to control *D. gallinae*, poultry houses should be heated between flocks to 55°C; however, excessive heat exposure can damage structures⁸⁸. The high mortality rate of *D. gallinae* often occurs at 35°C, so lower temperatures are possible for more extended periods. A combination of heat and chemical treatment has proved effective when controlling poultry populations in Dutch poultry houses; however, temperature treatment has been less effective when used alone. An oversized unit will also cost more to heat because it is challenging to keep it evenly heated. Despite the potential benefits of this technique (heat exposure), economic considerations remain one of the main constraints⁸⁸.

7.3.2. Lighting regimen

Short intermittent light and dark cycles can significantly reduce *D. gallinae* numbers since they disrupt their nocturnal feeding cycle more than standard regimens⁸⁹. It is thought that *D. gallinae* begin their search for hosts an hour after the beginning of darkness, but most activity occurs 5–11 hours later during the dark period⁹⁰. It is difficult to envision intermittent lighting regimens in practice due to EU legislation requiring a statutory 8-hour darkness period. The use of intermittent lighting, however, might be more desirable during normal daylight hours, with (presumably) fewer welfare implications. In the same way, farmers might be able to use specific wavelengths to target *D. gallinae* in normal dark periods without disrupting the hen's normal sleep schedule⁹¹. Evidence suggests that such measures may not have a long-term effect, as mites will continue to feed even under unforced lighting conditions. Under conditions resembling poultry facilities, an effect could also be reduced due to the high intensity of light used in studies, which is usually higher than anticipated commercially⁹².

7.3.3. Inert substances

Inert substances include primarily diatomaceous earth (DE), kaolin, and silicas⁹³. It is still possible to obtain fine-particle powders, but dust formation and application issues drive liquid formulations forward⁹⁴. It is already possible to buy standard products commercially, and they are commonly used in many countries (such as BIOFA, InsectoSec, Germany, and Decimite+, Germany BASF)⁹⁵. Essentially, leads to the dehydration of mites by adsorbing lipids from their surfaces.

Researchers have found that raw materials have a significant impact on the efficacy of *D. gallinae* in inert substances. These products in poultry units may require higher application rates due to low efficacy at high humidity levels (> 85%)⁹⁶. According to experiments with *O. sylviarum*, both DE and kaolin were limited in their effectiveness as acaricides (although kaolin was effective after repeated application to birds for 2–3 weeks)⁹⁷.

8. Conclusion

As indicated, *D. gallinae* is a serious threat to the welfare of hatching hens and the production of eggs in many parts of the world, and acaricide resistance and changes in pesticide and hen welfare legislation are likely to exacerbate this problem in many of these countries. With the increasing understanding of the role of *D. gallinae* as a disease vector, its pest status also increases as a result. *D. gallinae* has been reported to inhabit a range of alternative hosts in recent reports, which further adds to its status as an emerging threat. Understanding of PRM biology and ecology has improved as a result of increased interest in control and eradication research. As a result of advances in microbiology, effective vaccines have been developed, and natural enemies, growth regulators, and biopesticides as alternatives to conventional pesticides have been developed. However, many of these approaches require testing and approval by governmental authorities before they are registered for safe use and application, and may even require scaling up production to reduce production costs.

Declarations

Competing interest

The authors declare no conflict of interest.

Authors' contribution

In terms of author contributions, the conceptualization of the project was primarily led by Nima Komeili, with input from all authors. Methodology development involved the collective effort of Mohammad Amin Salim, as did formal analysis and investigation. The initial draft of the manuscript was a collaborative endeavor involving Sattar Lohrasb, Sepideh Abrishami, Ali Sahab, Zahra Babaei, Fatemeh Heshmati, and Nima Komeili, and subsequent revisions and editing were also carried out collectively. Finally, the project was overseen by Nima Komeili in a

supervisory role. This distribution of responsibilities highlights the collaborative nature of the work, where each author played a vital role in different aspects of the research and manuscript preparation. All authors checked and approved the final version of the manuscript for publication in the present journal.

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Availability of data and materials

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethical considerations

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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