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DERMANYSSUS GALLINAE STILL POSES A SERIOUS THREAT FOR THE REARING OF LAYING HENS

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A b s t r a c t

Dermanyssus gallinae (poultry red mite) is a temporary parasitic mite which feeds on the blood of many species of domestic, wild and exotic birds. It can also attack mammals and humans. It is widely dispersed throughout the world and is a major problem in poultry production, mainly for laying hens. Under the suitable conditions of farms, the parasite population grows quickly and becomes difficult to control. Invasion of *D. gallinae* in chickens causes chronic stress, anxiety, irritability, increased cannibalism and mortality (6–8%), and a decrease in laying performance (approx. 15–20%). The possibility of the transmission of many pathogens can affect the spread of epidemiological risks in poultry. *D. gallinae* has exhibited resistance to adverse environmental conditions and eradication formulas. It is estimated that losses caused by the invasion of *D. gallinae* and eradication costs in the EU amount to about EUR 130 million annually. To combat *D. gallinae*, synthetic acaricides, products containing natural or synthetic silica, and the Thermo-kill method are commonly applied. Due to some limitations, alternative methods are still being sought, e.g. substances of natural origin (thuringiensin, spinosad, garlic extract and neem tree, geraniol, eugenol and citral) and vaccinations (subolesin and protein Bm86), as well as the biological control of natural enemies, or the introduction of a condensed light cycle. It seems that today the best results can be achieved by the application of the principles of IPM (Integrated Pest Management). One of the actions which should be jointly implemented by specialists from various fields is the construction of sheds to hinder the settlement of the parasite and to facilitate its liquidation.

DERMANYSSUS GALLINAE NADAL POWAŻNYM ZAGROŻENIEM W CHOWIE KUR NIOSEK

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Abstrakt

Dermanyssus gallinae (poultry red mite) to okresowe pasożytnicze roztocze, które odżywia się krwią wielu gatunków ptaków domowych, dzikich oraz egzotycznych. Może atakować ssaki oraz ludzi. Jest szeroko rozpowszechniony na świecie i stanowi poważny problem w chowie i hodowli drobiu, głównie kur niosek. W warunkach ferm populacja pasożyta szybko narasta i jest trudna do zwalczenia. Inwazja *D. gallinae* u kury powoduje stan stresu chronicznego, niepokój, rozdrażnienie, wzrost kanibalizmu i liczby upadków (6–8%) oraz spadek nieśności (ok. 15–20%). Ze względu na możliwość transmisji wielu czynników chorobotwórczych może wpływać na szerzenie się zagrożeń epidemiologicznych wśród drobiu. Wykazano oporność *D. gallinae* na niekorzystne warunki środowiska oraz preparaty do jego zwalczania. Straty wywołane inwazją *D. gallinae* oraz koszty zwalczania w UE szacowane są na ok. 130 mln euro rocznie. Do zwalczania *D. gallinae* powszechnie stosowane są syntetyczne akarycydy, preparaty zawierające naturalną lub syntetyczną krzemionkę oraz metoda Thermo-Kill. Ze względu na pewne ograniczenia ciągle poszukuje się metod alternatywnych jak: substancje pochodzenia naturalnego (thuringiensyna, spinosad, ekstrakt z czosnku oraz drzewa neem, geraniol, eugenol i citral), a także szczepienia ochronne (subolesina i białko Bm86), jak również kontrolę biologiczną z wykorzystaniem naturalnych wrogów, czy wprowadzanie skróconego cyklu świetlnego. Wydaje się, że najlepsze rezultaty można osiągnąć stosując zasady IPM (Integrated Pest Management). Jednym z działań powinno być wspólne opracowanie przez specjalistów z wielu dziedzin konstrukcji kurników w celu utrudnienia zasiedlenia ich przez pasożyta i ułatwienie jego likwidacji.

Introduction

Dermanyssus gallinae (De Geer, 1778) (*D. gallinae*), Poultry Red Mite (PRM), is a parasitic mite belonging to the class: Arachnoidea, row: Acarina, suborder: Mesostigmata, family: Gamasidae, type: Dermanyssus. *Dermanyssus gallinae* feeds primarily on the blood of chickens, but also on many other species of domestic birds, as well as approx. 30 species of wild birds and exotic birds (CHMIELEWSKI 1982, CENCEK et al. 2000, 2002, ROMANIUK and OWCZARZAK-PODZIEMSKA 2002, ROY and CHAUVE 2007, SMITH et al. 2014). In the absence of specific hosts, it also attacks mammals, mostly rodents, dogs, cats and farm animals, especially horses (MIGNON and LOSSON 2008). There are also numerous reports of an invasion of mites in humans, primarily in poultry farms workers, in whom the mite can induce severe itching, allergies, dermatitis and lesions of the skin (AUGER et al. 1979, ARENDS 1997, ROSEN 2002, AKDEMIR et al. 2009, HAAG-WACKERNAGEL and BIRCHER 2010).

Dermanyssus gallinae is widely distributed in the world, and occurs in the areas north to 60° latitude, where it poses a significant threat to poultry production and hen health (HOGLUND et al. 1995, WOJCIK et al. 2000, CENCEK 2003, GUY et al. 2004, FIDDES et al. 2005, SPARAGANO et al. 2009, 2014). The *D. gallinae* population grows very quickly, especially under conditions of factory farms, and is difficult to control due to the specific behaviour and favourable environmental conditions and facilities of farm, such as the large number of hiding places, high density of birds in the limited space, and permanent high temperature and humidity (CHAUVE 1998, SOKÓŁ and ROMANIUK 2007, SPARAGANO et al. 2009). Mite invasion is difficult to control due to the colonisation sites, which are poorly accessible, resistance to adverse environmental conditions, and used preparations (CHAUVE 1998).

Dermanyssus gallinae occurs in all types of farming system, independently of the destination and size of the flock (SPARAGANO et al. 2009). The mite population in laying hen factory farms reaches a higher level than in flocks of broilers due to the longer production cycle, which usually takes 80–90 weeks (ROY et al. 2010). The battery cage system promotes *D. gallinae* invasion due to it being a more favourable habitat for mites and a greater challenge for decontamination between flocks. It is the system which currently predominates in the poultry industry (HARRINGTON et al. 2011). For example, annual production of poultry in this system in Denmark, France and Italy is about 56%, 76.5%, and 96.4%, respectively (SPARAGANO et al. 2009). Damage caused by the mites, and associated costs of control only in the EU amount to about 130 million euros per year (SPARAGANO et al. 2009, 2014). In poultry flocks in the USA and in some countries in South America and Asia the following ectoparasites of poultry are found more common: *Ornitonyssus sylviarum* (Canestriniand Fanzago 1877), Mesostigmata: Dermanyssoidea: Macronyssidae, known as Northern fowl mite (AXTELL, ARENDS 1990, MULLENS et al. 2001). *Dermanyssus gallinae* density in battery cage system can be up to approx. 50 000 parasites per bird, and in severe cases even approx. 500 000 per bird. The most massive invasions have been observed during warm and humid months (KILPINEN et al. 2005, OTHMAN et al. 2012).

The scale of the problem of *D. gallinae* is very serious, which is proved by the fact that in November 2014 an international research consortium was formed to combat PRM. The project, called COREMI (Improving current understanding and research for sustainable control of the poultry red mite *Dermanyssus gallinae*), brings together scientists from over 17 European countries (http://www.cost.eu/COST_Actions/fa/Actions/FA1404 February 2015).

Characteristics, biology and behaviour of *Dermanyssus gallinae*

The adult *D. gallinae* is from 0.7 to 1 mm long and from 0.4 to 0.5 mm wide. The body is pear-shaped, dorsoventrally flattened, and covered with transparent, greyish chitinous armour. After sucking blood it is red, and when the blood is digested it turns brown and the intestines are clearly visible. It has four pairs of legs, ending with two claws, and oral apparatus of the piercing and sucking type, ending with long stiletto chelicerae, which puncture the skin of the host (SIKES and CHAMBERLAIN 1954).

Dermanyssus gallinae is a periodic ectoparasite which spends on the host usually from 0.5 to 1.5 h only during sucking blood. It feeds every 2–4 days, mainly at night, when birds are less active (WOOD 1917, NAKAMAE et al. 1997, CHAUVE 1998, ROMANIUK and SOKÓŁ 2007). *Dermanyssus gallinae* locates its host using a combination of several stimuli: temperature, chemical signals, vibration, and carbon dioxide (ZEMAN 1988, KILPINEN and MULLENS 2004, KILPINEN 2005). Led by the smell of pheromones secreted by other individuals, an engorged individual mite goes back to the hideout, where all the parasites aggregate together (ENTREKIN and OLIVIER et al. 1982, KOENRAADT and DICKE 2010). *Dermanyssus gallinae* prefers inaccessible places, shielded from light, mainly cracks and crevices in the construction of poultry houses, where it proliferates. Its development cycle consists of 5 stages: egg, larva, protonymph, deutonymph and adults (male or female). Protonymph, deutonymph and mature females must feed on blood. Males feed on the blood occasionally. Adult mites mate after the last moult, and the females lay eggs within 3 days after sucking blood. The number of eggs laid depends on the environmental conditions and reaches up to eight clutches. (WOOD 1917, MOSS 1978). The egg is oval, smooth, pearl white coloured, and it is 400x270μ. After approx. 1.5–2 days it hatches into a larva, which after approx. 12 h undergoes moulting and turns into a protonymph. The protonymph, within 24 h after sucking blood, moults again and turns into a deutonymph. It moults and becomes mature after approx. 2 days after the last feeding. The larva is of a white-grey colour and has 3 pairs of legs, while the nymph and imago has 4 pairs of legs (WOOD 1917).

The length of the *D. gallinae* lifecycle depends on the availability of the host, the ambient temperature and relative humidity. It usually takes about 2 weeks. Under favourable conditions, such as 20–25°C and high relative humidity (> 70%), this may be shortened to approx. 7–10 days. As a result, the population may double in one week (MAURER and BAUMGARTNER 1992, HOGLUND 1995). In less favourable environmental conditions its lifecycle may be extended, and in the absence of the host it does not take place. *Dermanyssus gallinae* is very resistant to adverse environmental conditions, e.g. in anticipation for the host. While waiting for the host it can survive 8–9 months at temp. 5°C, and at 25°C – approx. 6 weeks. Temperature below -20°C and above 45°C is fatal. The female lays eggs in temperatures from 5 to 45°C. At 5°C the time required for the larvae to hatch exceeds 50 days if the egg maintains the proper humidity, and they can hatch into larvae under appropriate conditions. Relative humidity (RH) is also important for the development of *D. gallinae*, e.g. at a temp. of 20°C and 23% RH it can survive for only 6 weeks, and at 11% RH larvae hatch is inhibited due to the drying of the eggs (MAURER and BAUMGARTNER 1992, NORDENFORS et al. 1999).

Analysis of the COI mitochondrial gene (cytochrome oxidase subunit1) and the 16S rRNA gene showed genetic variation between closely related species of the genus Dermanyssus and geographically distant populations of the species *D. gallinae*. The nuclear gene ITS was also submitted to the analysis. COI proved to be the best marker in phyleogeographic studies, as it allowed the differentiation of genetically low taxonomic levels. Differences within the ITS gene were not significant. The genetic diversity of the population of the species *D. gallinae* may be a consequence of the development of resistance to pesticides used in individual countries or geographical regions (ROY et al. 2009, MARANGI et al. 2009). It is believed that due to genetic variation *D. gallinae* can exhibit certain plasticity in relation to the host (but still remaining associated primarily with birds, and in particular laying hens) and shows tolerance to changing environmental conditions and adaptation to selecting factors (CHAUVE 1998, ROY et al. 2009, SPARAGANO et al. 2014).

Dermanyssus gallinae invasion impact on hens

Dermanyssus gallinae is the most serious ectoparasite affecting laying hens. Upon puncturing the skin of the host, it introduces a toxic saliva that can cause itching and irritation. Under heavy invasion, the welfare of the laying hens significantly decreases, which is reflected in the birds being restless and irritable. Consequently, they develop characteristic behaviour called self-grooming, or the ability to clean the skin and feathers, and increase the frequency of feather pecking (CHAUVE 1998, KILPINEN et al. 2005). An increased prevalence of cannibalism and mortality is also observed. It is estimated that the mortality ratio ranges from 6 to 8% (CENCEK 2003, KILPINEN et al. 2005). There has been a case of a tenfold increase in death rates following severe infestation (COSOROABA 2001).

Intense infestation of *D. gallinae* on hens gives rise to chronic stress condition which activates the hypothalamic-pituitary-adrenal axis. As a result, hormones which suppress the hypothalamic-pituitary-gonadal axis responsible for egg laying are secreted. This results in reduced egg laying. PILARCZYK et al. (2004) reported an approx. 15–20% reduction in egg laying. In addition, depending on the severity of stress, especially in young chickens, infestation can cause small, tangible physiological and pathological changes that lower overall health status and immunity. In infested chickens reduction in the level of corticosterone, β- and γ- globulin (KOWALSKI and SOKÓŁ 2006, 2009) is reported. Heavy infestations may adversely affect the development of the immune response against pathogens in chickens, reduce post-vaccination antibody titre, or inhibit the production of antibodies (KOWALSKI and SOKÓŁ 2009, KAOUD 2010, SPARAGANO et al. 2014). An increase in the consumption of food and water, with simultaneous loss of weight have been observed (CHAUVE 1998, MUL et al. 2009).

Dermanyssus gallinae attacks the hen once every 2–4 days, and feeds on approx. 0.2 mg of blood, which, with an estimated 25 000–50 000 mites per bird, leads to a loss of approx. 4 g of blood per day, i.e. approx. 3% of the total hen blood volume (VAN EMOUS 2005). *Dermanyssus gallinae* can thus contribute to the development of anaemia and, in extreme cases, to severe anaemia (KIRKWOOD 1967, COSOROABA 2001, WOJCIK et al. 2000, KILPINEN et al. 2005). In other studies, the haematological blood indices of infected chickens were not significantly different from hens free from invasion, and did not prove the mites to be the main factor causing anaemia (KOWALSKI and SOKÓŁ 2006).

Dermanyssus gallinae as a vector of pathogenic agents

Dermanyssus gallinae may contribute to increased epidemiological risks due to the probable transmission of many pathogens (VALIENTE-MORO et al. 2005, 2009, DE LUNA et al. 2008, SPARAGANO et al. 2009).

In 1944, Smith was the first to isolate the *Dermanyssus gallinae* St. Louis encephalitis virus (SLEV- Flaviviridae). From that moment investigations into the possibility of the transmission of various pathogens commenced. It has been shown that the mite is a reservoir and vector of pathogenic bacteria for chickens and other animals and humans: *Salmonella gallinarum*, *Listeria monocytogenes, Erysipelothrix rhusiopathiae, Chlamydia* spp., *Escherichia coli*, *Staphylococcus* spp., *Streptomyces* spp., as well as a virus: Avian paramyxovirus type1 (Newcastle disease). It was experimentally demonstrated that the mite can transmit other bacteria: *Pasteurella multocida*, *Coxiella burnetii*, Spirochetes, *Salmonella enteritidis,* and viruses: Fowl poxvirus smallpox, Eastern equine encephalitis virus – EEEV, Western equine encephalitis virus – WEEV, Venezuelan Equine Encephalitis Virus, Russian spring virus, and summer tick-borne encephalitis. (DE LUNA et al. 2008, VALIENTE-MORO et al. 2009, SPARAGANO et al. 2009).

Methods and agents proposed to control and combat invasion of *D. gallinae*

The basis for the control of *D. gallinae* is to follow the rules of hygiene in the poultry house, and prevention of the introduction of the parasite from the outside. Poultry houses should be carefully disinfected after each production cycle. Structural elements of the poultry house should be washed with warm water with the addition of oil-penetrating agents and egg-lethal additives.

Newly introduced flocks of hens and means of transport should be free of mites. Wild birds and rodents can be potential carriers of *D. gallinae,* especially in barn, free-range or another traditional breeding system (VAN EMOUS 2005). It is also important to regularly monitor *D. gallinae* populations. Different systems of traps placed on the structural elements of the poultry house can be used for this purpose (NORDENFORS and CHIRICO 2001, ZENNER et al. 2009). The structure of the population can be determined based on the number of individual developmental forms of the parasite (SOKÓŁ 2006). These proceedings make the following deacarization easier.

Synthetic acaricides are commonly used in cases of *D. gallinae* infestation. Thirty-five acaricidal compounds were tested and proved effective in cases of *D. gallinae,* and they included: organochlorines, organophosphates, pyrethrin, pyrethroids, carbamates, amitraz, and endectocides (CHAUVE 1998). They are effective, but their use is limited due to food safety, because their residues or metabolites may accumulate in the meat and eggs of hens (MUL et al. 2009). Most of these products are dedicated for empty poultry houses, but a few of them, which have received marketing authorisation, can be applied directly to the birds. It is important to abide by the grace period because incompliance poses a threat to the life and health of hens, as well as the consumers of the eggs and meat (MARANGI et al. 2012). In addition, long-term use of these agents, associated with the application of high concentrations, leads to the resistance of *D. gallinae* to these agents (CHAUVE 1998, NORDENFORS et al. 2001, CENCEK et al. 2011, ZDYBEL al. 2011). Products containing foxim (foxim-based) were authorised for marketing in 2010. A case of the development of resistance of *D. gallinae* to this substance was reported a year later (ZDYBEL et al. 2011). Effective acaricides should penetrate into the gaps, stay active on the exposed surfaces, act selectively on the parasite, and should induce resistance (CHAUVE 1998).

Other agents which are used as often as acaricides are products comprising natural or synthetic silica (silicon dioxide, SiO_2), which fall into the category of physical methods. Their acaricidal activity is based on the absorption properties of silica particles that adhere to the body shells of *D. gallinae* and absorb lipids from the exoskeleton. This leads to drying out, and results in the death of the parasite. The effectiveness of these measures depends on the quality of the applied chemicals and the relative humidity (RH). It has been shown that a high level of RH reduces the efficacy of the silica products. In poultry houses where RH is high the efficacy of these products can be reduced (MAURER and PERLER 2006, KILPINEN and STEENBERG 2009, ZDYBEL et al. 2011).

The thermal method of parasite elimination is also a physical method. This method consists in applying high temperatures in an empty hen house for several days. On the first day the temperature in the house rises gradually to at least 45°C due to the use of a heating device, and it is maintained at this level constantly for another two days. Then it slowly decreases (VAN EMOUS 2005). This method is also very efficient, and eliminates most of the *D. gallinae* eggs, but does not allow for limitation of the invasion during the cycle. In addition, excessive heat can destroy the shed's structure and equipment.

The above-described methods of elimination and controlling the *D. gallinae* invasion are among the most efficient, but due to their limitations, researchers are still seeking better, more effective, cheaper and less toxic methods.

Alternatives to synthetic acaricides are substances of natural origin (HARRINGTON et al. 2011, SPARAGANO et al. 2014). SPARAGANO et al. (2014) describes these as new acaricides, which include biopesticides and plant-derived products. Biopesticide formulations are based on the natural properties of bacteria and their components. The insecticidal properties of thuringiensin *from Bacillus thuringiensis* bacteria have long been known and successfully used in agriculture to control pests of agricultural crops (VAN DER GEEST et al. 2000). The toxicity of these bacteria was confirmed with respect to ticks and *O. sylviarum* (MCKEEN 1988, HASSANAIN et al. 1997). Bacterial exotoxin was also shown to be toxic for vertebrates, and therefore it cannot be used against *D. gallinae* (SPARAGANO et al. 2014). In 2010, another natural acaricide based on spinosad, which is produced as a result of fermentation carried out by bacteria *Saccharopolyspra spinosa,* was approved for use. The brand name of the product is Elector (HOLT 2005, GEORGE et al. 2010). Spinosad has also been used in agriculture for the control of many species of pest insects. In contrast to thuringiensin, it has shown a low toxicity to mammals and birds, as well as for insects which play a positive role in the ecosystem (ANASTAS et al. 1999, HARINGTON et al. 2011).

Among the plant-derived substances garlic extract has been shown to be very effective. It is the basis of garlic preparations such as Barrier and Breck-a-Sol (BIRRENKOTT et al. 2000, FAGHIHZADEH et al. 2014). There is also a product based on an extract of the neem tree, which is available under the brand name MiteStop, and it has shown higher efficiency than foxim (LUNDH and CHIRICO 2005, ABDEL-GHAFFAR et al. 2009). Strong acaricidal properties have also been shown by geraniol, eugenol and citral (SPARAGANO et al. 2013).

Attempts to develop a vaccine have failed. A marginal protective effect was obtained by immunizing chickens with a vaccine based on the somatic antigens of mites and other arthropods – a recombinant protein called subolesin (Subolesin SUB) or the Bm86 protein. Ingestion of blood with the antibodies by mites was expected to hinder the development of the mites. *D. gallinae* mortality was 23% after immunization with Bm86, and 35% after subolesin immunization. However, at present no *D. gallinae* vaccines have been authorised for marketing (HARRINGTON et al. 2009).

Biological control of *D. gallinae* involves the use of their natural enemies, such as predatory mites and entomopathogenic fungi (SPARAGANO et al. 2014).

Predatory mites occur naturally in the nests of wild birds, and can also spontaneously colonize hen houses. This method of control relies on the introduction of selected species of mites into the environment infested by *D. gallinae* A few mite species, such as *Androlaelaps casalis, Stratiolaelaps scimitus, Hypoaspis aculeifer, Hypoaspis miles* (LESNA et al. 2009, 2012, ALI et al. 2012), have shown the potential to destroy *D. gallinae*. This method has been commercially applied but research is still needed to confirm its efficacy in the field, consequences of its long-term use, and the limiting impact of high temperature and alternative preys on its efficacy (SPARAGANO et al. 2014).

Fungi such as *Beauveria bassiana, Metarhizium anisopliae, Paecilomyces album and Trichoderma fumosoroseus* also show a detrimental impact on *Dermanyssus gallinae.* Satisfactory results have been obtained after inoculation with a high dose of conidia under laboratory conditions, but experiments under semifield conditions have revealed unsatisfactory results (STEENBERG et al. 2006, TAVASSOLI et al. 2011, STEENBERG and KILPINEN 2015).

One of the methods to control *D. gallinae* infestation consists in intramuscular or intraperitoneal administration of ivermectin and moxidectin to birds. This method has been referred to as a systemic application, i.e. through the host body and the ingested blood. The effective dose was too toxic in birds. In addition, the operating time was too short. Control of mite infestation based on this method would be risky and unprofitable due to the necessity to apply a high dose of the active substance, time consumption, and repeated applications. (ZEMAN 1987, POPIÓŁ and OLIVER 1989).

High potential has been seen in the introduction of short-cycle intermittent light/dark periods in poultry houses. This method could reduce *Dermanyssus gallinae* invasion, probably by disrupting its normal nocturnal feeding cycle. The law, however, prohibits shortening the period of darkness below 8 hours, which in practice prevents the introduction of this type of control (STAFFORD et al 2006).

One idea is to develop the IPM (integrated pest management) system, incorporating the whole variety of the above *D. gallinae* elimination methods, which are described as using a combination of the methods and bringing tangible benefits (AXTELL 1999, CHATTERTON 2000).

In 2013, in accordance with an EU Council Directive (EU 1999.74/EC) on the welfare of laying hens, conventional cages were withdrawn from use and are now replaced by enriched cages incorporating more complex environments. It should be mentioned that enriched cages for laying hens entered under the supervision of the EU to poultry production farms have definitely improved the welfare of the birds; however, it appears to contribute to quite a significant growth of *D. gallinae* populations due to the extensive system of cracks and crevices which allow mite populations to grow more rapidly. One of the actions which should be jointly undertaken is the development of a cage design which will allow the elimination of hiding places while facilitating washing the surface. The same applies to air ventilation systems. To summarize, the construction of poultry houses must be carefully thought out and designed by specialists from various fields.

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