

## INFLUENCE OF ESSENTIAL OILS AS NATURAL POULTRY RED MITE (*Dermanyssus gallinae*) REPELLENTS

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**ABSTRACT:** In the world where technology is upcoming very fast with the production of different chemicals such as acaricides, pesticides and etc., the real question is: Could essential oils, spices and herbs serve as natural solutions in constant struggle against chemically resistant drugs? The poultry red mite (*Dermanyssus gallinae*) is a growing epidemiological problem for the poultry industry that causes losses in the performance of laying hens and consequently major economic losses. It has been suggested that adding essential oils to laying hen diets may be an efficient and natural alternative to chemical repellents and acaricides for *D. gallinae*. Although some essential oils are effective repellents, their effectiveness usually lasts a short time, which is likely related to their volatile nature. The exact mechanism of the acaricidal effect of essential oils is not yet clear, but it is thought that some essential oils could inhibit *D. gallinae* cytochrome P450 and thus reduce detoxification of xenobiotics. However, most *D. gallinae* repellent activity appears to come from neurotoxic effects, blocking  $\gamma$ -aminobutyric acid neurons and reducing the ability of cells in the nervous system to form cyclic adenosine 3',5'-monophosphate. To date, most studies have been conducted in vitro and there is a lack of information on the effect of essential oils on laying hen performance under the challenge of *D. gallinae*. The paper aims to review current knowledge of *D. gallinae* biology and the possibilities and significance of inclusion of selected essential oils into laying hens diet as a natural repellent of hematophagous predator.

**Key words:** poultry, nutrition, essential oils, poultry mites, natural alternative

## INTRODUCTION

*Dermanyssus gallinae* (De Geer, 1778) also known as a poultry red mite, poultry mite, red mite or chicken mite, represents an important pest of poultry in worldwide aviculture production. Poultry red mite can cause significant challenges regarding the health and welfare of domestic poultry (Jansson et al., 2014; Puvača et al., 2018). Poultry red mite stays hidden in cracks and crevices in the poultry house during the day and comes out to feeding on the poultry at night. Mite infestations, in addition to being a nuisance for humans and egg handlers, cause reductions in egg production, feed conversion efficiency, body weight gains and may affect egg size (Nobo et al., 2012). The use of chemical pesticides for mite treatment in the veterinary field is a problematic challenge. Chemical applications can result in a multitude of problems, including mite resistance, the ineffectiveness of active ingredients, undesirable residues in the environment and unacceptable risks on nontarget organisms. Botanicals, so called natural pesticides, represent an alternative control strategy (George et al., 2014; Puvača et al., 2018), as reputedly phytochemicals are less harmful to the environment and human health (Isman, 2006; Puvača et al., 2017).

The last three decades have seen substantial growth in aromatic plants product markets across the world. Rapidly rising exports of medicinal plants during the past decade attests to worldwide interest in these products as well as in traditional health systems. According to the Secretariat of the Convention on Biological Diversity, global sales of herbal products totalled an estimated 60 000 million \$ in 2002 (WHO, 2003). A consequence of red mite infestation in a layer is estimate for the cost of mite control and production losses is 130 € million annually according the Mul (2013).

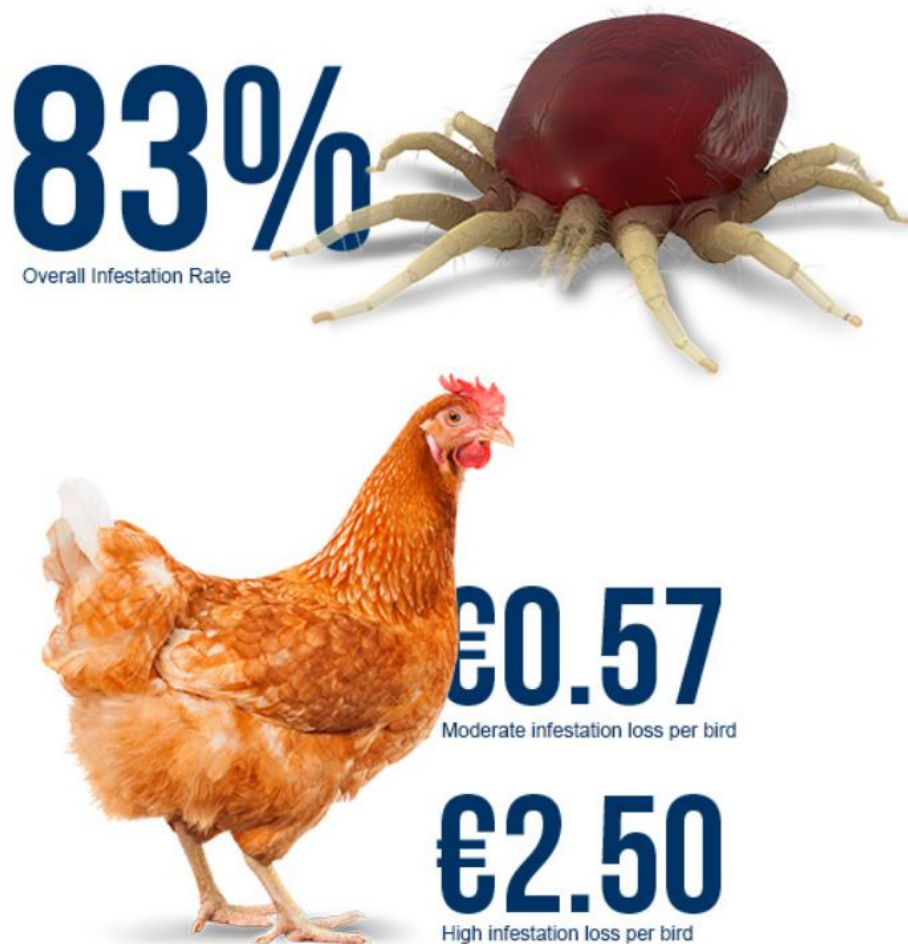
The paper aims to review current knowledge of *D. gallinae* biology and the possibilities and significance of inclusion of selected essential oils into laying hens diets as a natural repellent of hematophagous predator.

## ECONOMIC ISSUES ON THE SUSTAINABILITY OF TABLE EGG PRODUCTION AFFECTED BY *D. gallinae*

Economic losses from poultry mite infestation severely affect the productivity of the egg industry. Recent surveys have confirmed the extremely high and increasing prevalence of infestations with poultry red mites in Europe (Picture 1, Figure 1). In fact, the average overall infestation rate of European layer houses is 83% (Mul, 2013).

Consequences of red mite infestation in a layer operation include primarily a negative impact on feed conversion ratio, a drop in egg production, an increase in downgraded eggs, a higher susceptibility to poultry diseases, and more dead animals. A still widely quoted estimate for the cost of mite control and production losses is 130€ million annually. Because this commonly used number was calculated in 2005, it underestimates the cost of red mite infestation in Europe at the present time. First, the laying hens population, estimated at 350 million heads in 2005 (Van Emous, 2005), has increased significantly. In 2013–2014, the Statistics Division of the Food and Agricultural Organization of the United Nations has estimated the number of layer chickens in the 17 largest egg producing countries in Europe to be 431 million (FOASTAT, 2016). Second, the high infestation rate in European farms has become an increasingly important concern. Several European countries have recently reported

prevalence rates of more than 90% (Mul, 2013), compared to 80% for the most affected countries about a decade ago (Van Emous, 2005; Sparagano et al., 2009). Van Emous (2005) estimated the impact of mite infestations on productivity to be 43€ per hen, including 0.14€ for mite treatment as a direct costs, and 0.29€ for productivity losses as an indirect costs.



Picture 1. Poultry red mite infection rate and loss per bird in Europe (Mul, 2013; Kilpinen, 2005)

The estimation of the evolution of direct treatment costs is complex due to the changes in the acaricidal treatments arsenal available to farmers in the past decades. Recently, Van Emous (2017) estimated that the current total cost of red mite infestation is 0.60€ per hen per year in the Netherlands from which 0.15€ was for direct costs, and 0.45€ presented productivity losses, which represents an increase of about 40% compared to 2005 for the total cost of mite control per one layer hen. Overall, the damage caused by mites in Europe is now estimated at about 231€ million (Van Emous, 2017). The same research explained that this higher damage by the conversion of traditional cages to alternative housing systems, the longer production life cycles of the animals, and the ban of beak trimming, what is in accordance with the opinions of Puvača et al. (2018). Beside economic damages, mite infestations cause major physiological damages in animals as

well. According to studies, productivity losses can reach 0.57€ per hen per year in case of moderate mite infestation and up to 2.50€ (Figure 1) in high infestations (Kilpinen, 2005).

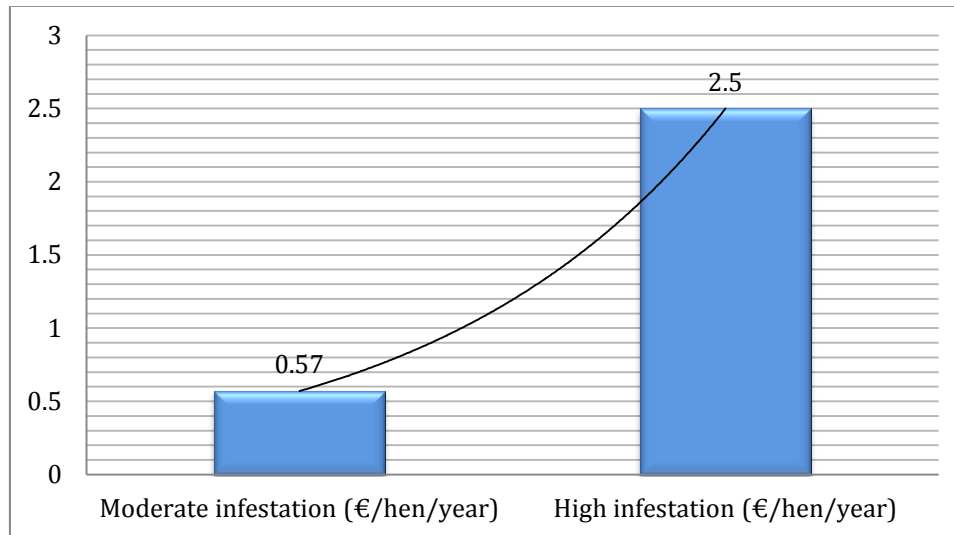


Figure 1. Economic losses in laying hens production influenced by poultry mites (Kilpinen, 2005)

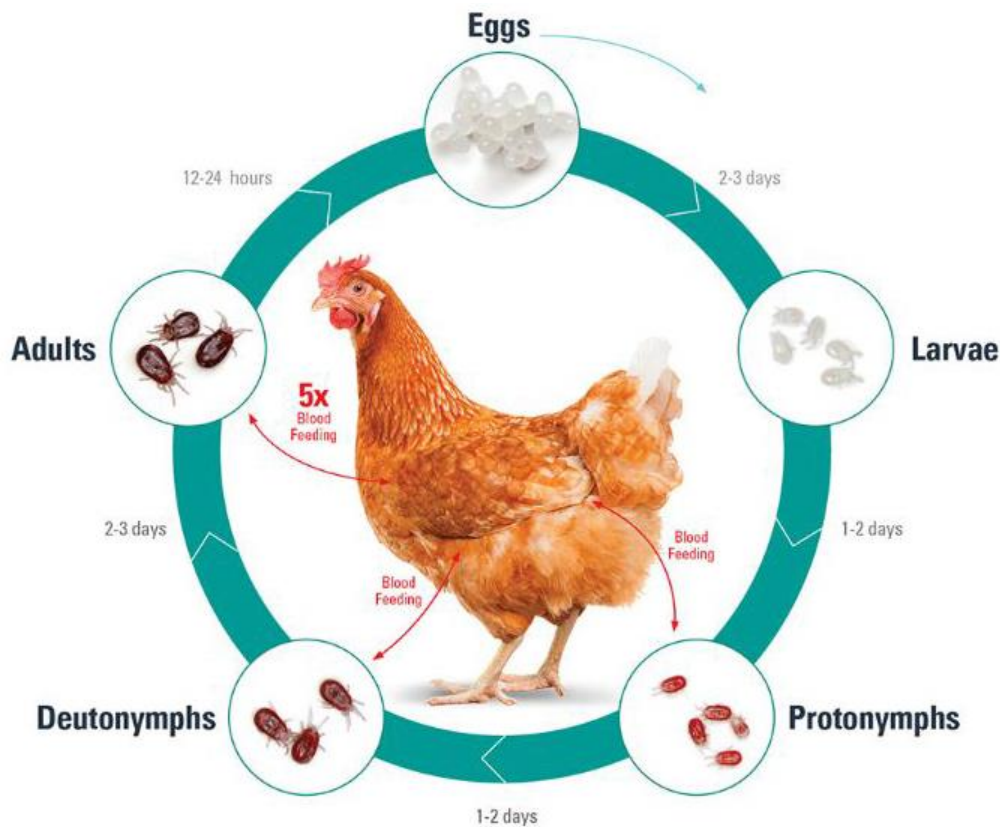
In Europe alone, the approximate total annual cost of red mite infestations totals 360€ million, with more than 300 million hens in all production types suffering from infestations (Mozafar, 2014).

### THE BIOLOGY AND THE VECTOR POTENTIAL OF *D. gallinae*

*Dermanyssus gallinae* is the most economically deleterious parasite of laying hens in Europe and worldwide (Flochlay et al., 2017). It is a hematophagous ectoparasite of both domestic and wild birds and is known to obtain its blood meal on a range of alternative species, including man (Bruneau et al., 2002). Although not entirely species specific, *D. gallinae* are seen most frequently in systems for laying hens. This is largely attributed to the lengthy turnover of approximately 72 weeks, which provides time for large populations to establish. The mite has a five stage life cycle: egg, larva, protonymph, deutonymph and adult as shown in Picture 2 (Sparagano et al., 2014). Under favorable conditions the life cycle can be completed within seven days, allowing for rapid population growth.

*Dermanyssus gallinae* is described as a temporary parasite, since it is only found on the host when feeding, with the majority of its life cycle spent concealed in cracks and crevices of the poultry facilities. The adult female measures approximately 1 mm in length and 0.4 mm in width, varying in color from grey to red (typically white or greyish in color, becoming darker or redder when engorged with blood) depending on engorgement. A study by Guy et al. (2004) confirmed the widespread prevalence of *D. gallinae* in laying hens in the United Kingdom, with 87.5% of premises infested, and a higher population in free range units compared to laying cage systems. It should be noted that considerable variation in mite population was observed within housing

systems, suggesting that there may be features of the housing environment which affect the scale of *D. gallinae* infestation. Consequences of infestation by *D. gallinae* are severe for both the welfare of the birds and economic sustainability (Puvača et al., 2018).



Picture 2. Development cycle of the poultry red mite (Sparagano et al., 2014)

As a result of feeding, mites can cause irritation, restlessness and either mild or severe anemia, occasionally resulting in death. Behavioural observations have also shown increases in cannibalistic feather pecking associated with *D. gallinae* infestation. Production is affected through reduced growth rates, reduced egg production and reduced egg quality such as poor shell integrity and blood staining (Puvača et al., 2017). In a study of a caged housing system, mortality ranged from 1 to 4% on units due to the parasitism by *D. gallinae* and egg production was reduced by 10% (Wojcik et al., 2000). Similar results from another study of caged hens recorded a significant decrease in egg production (95% to 75%) and an increase in mortality of 5% to 52% (Cosoroaba, 2001). *D. gallinae* pose a threat in the spread of diseases, since they may act as a vector for a number of pathogenic poultry infections (Chirico et al., 2003), both bacterial and viral. These include St Louis encephalitis virus (Smith et al., 1946), *Salmonella spp.*, (Čabarkapa et al., 2015) spirochaetosis, chicken pox, Newcastle disease, fowl typhoid, fowl cholera, as well as agents of other animal diseases. A number of incidents of *D. gallinae* parasitizing humans have been recorded, since humans come into contact with the mite whilst working in the poultry houses. When bitten, symptoms in humans range from minor irritation to skin lesions and dermatitis. However, the primary effect of *D. gallinae* is as a direct pest, as an obligatory blood sucking parasite (Bruneau et al., 2001; Chauve, 1998; Nordenfors et al., 1999; Puvača et al., 2018).

## CONTROL METHODS OF *D. gallinae*

Management tools are essential to keep *D. gallinae* infestations under control. To avoid transmission of mites, poultry facilities should have a hygiene zone where personnel change clothes and shoes before entering the poultry facilities. Between flock cycles, the poultry house should be thoroughly washed and disinfected (George et al., 2014). All possible hiding and resting places for *D. gallinae* should be sealed and those which cannot be sealed must be carefully rinsed and vacuumed. Furthermore, there should be an "all-in-all out" principle between flock cycles according to the research of Perricone et al. (2015). Temperatures above 45°C are lethal to *D. gallinae*, so heat can effectively be used in the poultry houses as a control method. When using heat treatment, the temperature must be at least 55°C to reach high enough temperatures everywhere. Heat is mainly used between rounds, when hens are present it could only be used selectively in locations which are particularly exposed. According to Mul et al. (2009), heating in combination with chemical treatment, is the most promising control method against *D. gallinae*, but the research of Puvača et al. (2017) suggests that natural methods, with medical plants and essential oils offer a strong alternative for the future when considering *D. gallinae* resistance to chemical substances. Focus should primarily be to clean the house between rounds when the house is empty of hens. However, if there are problems during ongoing production cycle, treatment of the facilities is necessary to ensure hens welfare.

## THE ESSENTIAL OILS AS THE NATURAL REPELLENTS OF *D. gallinae*

The use of chemical pesticides for pest treatment in the veterinary field is a problematic challenge. Chemical application can cause complications, including pest resistance, the ineffectiveness of active ingredients, undesirable residues in the environment and unacceptable risks on non-target organisms. Botanical pesticides offer a strong alternative to chemical control (George et al., 2014) because phytochemicals are reputedly less detrimental to the environment and human health (Isman, 2006) due to their beneficial bioactive ingredients, antibacterial properties (Perricone et al., 2015) or volatile constituents. According to Rajabpour et al. (2018), aquatic and ethanolic leaf extracts of *Conocarpus erectus* had some toxic effects on *D. gallinae* but not *Portulaca oleracea* and *Pistacia atlantica* extracts. Their findings have verified the results of earlier investigation by Roy et al. (2014), who showed that extract of *Terminalia chebula* Retz., another tree belonging to the Combretaceae family, could be used as a botanical acaricide against *Oligonychus coffeae* Nietner (Acari, Tetranychidae). In a similar study, contact and fumigant toxicities of 40 oriental medicinal plant extracts against *D. gallinae* were evaluated with different variations of acaricidal effects, but all of them were positive with some promising for further investigations. A study by Camarda et al. (2018) investigated the efficacy of neem oil against *D. gallinae* on a heavily infested commercial laying hen farm. A novel formulation of 20% neem oil, diluted from a 2400 ppm azadirachtin concentrated stock, was administered by nebulization three times per week. Using corrugated cardboard traps, mite density was monitored before, during and after treatment and results were statistically analysed. The mite populations in the treated block showed 94.6%, 99.6% and 99.8% reductions after the first, second and third product administrations, respectively. The rate of reduction of the mite population was significantly higher in the treated block compared with the control and buffer blocks. The results suggest the strong bioactivity of neem against *D. gallinae*. The

treatment was most effective after the 10 days following the first application and its effects persisted for over 2 months. Tabari et al. (2017) explored the potential of *Artemisia sieberi* essential oil against *D. gallinae*. The oil toxicity through contact and fumigant assays on adult mites was evaluated in their study. The oil repellent activity was assessed on adult mites over different time intervals. Lastly, the residual toxicity of various doses of the oil was evaluated on *D. gallinae* until 14 days post treatment. Gas chromatography (GC) and GC-MS showed that the oil was rich in  $\alpha$ -thujone (31.5%),  $\beta$ -thujone (11.9%), camphor (12.3%), and 1,8-cineole (10.1%). Contact toxicity on adult mites showed 50% lethal concentration LC50, LC90, and LC99 of 15.8, 26.6, and 35.4  $\mu\text{g}/\text{cm}^3$ . Tabari et al. (2017) in fumigant assays have also shown that the oil was toxic on *D. gallinae*, and mortality was significantly higher in open containers over closed ones, underlining the key role of highly volatile constituents. Repellent assays showed that after 24h from the treatment, all doses of the *A. sieberi* essential oil led to significant repellent activity over the control. After 48h, all doses of *A. sieberi* essential oil tested led to significant repellent activity compared to the control. The residual toxicity assays showed that the time exposure and concentration tested had a significant impact on the mite mortality after 1, 2, 5, and 7 days from the treatment. Notably, mortality remained significantly higher over the control for 7 days after spraying with oil at 2%. The resistance to conventional synthetic pesticides has been widely reported in *D. gallinae* in different aviary systems. Barimani et al. (2016) assessed field efficacy of traps containing carvacrol in the control and reduction of *D. gallinae* in laying hens farm. Two different carvacrol-based formulations were tested for their toxicity and possible repellent activity on *D. gallinae* to determine the most appropriate formulation and concentration to be used in the field study. *In vitro* tests confirmed that 1% carvacrol formulation with ethoxylated castor oil as emulsifier was significantly toxic to *D. gallinae* without any dissuading effect in comparison to ethanol and higher concentrations of carvacrol. A subsequent *in vivo* experiment in a cage system laying farm demonstrated significant acaricidal activity for traps containing 1% carvacrol. Throughout the study, untreated cardboard traps were used for monitoring mite populations. Carvacrol-impregnated traps were efficacious in the control of *D. gallinae* and led to over 92% reduction in mite population after 2 weeks of application according to Barimani et al. (2016). The toxic effects of carvacrol maintained through 2 weeks after the last application of traps. According to George et al. (2008), managing *D. gallinae* by conventional means such as synthetic acaricides has become increasingly problematic. As a possible alternative, research has identified several plant essential oils that are toxic to *D. gallinae*. However, essential oils are highly volatile and any acaricidal effect they exert could be short-lived in practice (Tomičić et al., 2018). George et al. (2008) investigated the short-lived toxicity of six lavender essential oils to *D. gallinae*. In sealed Petri dishes, mites were exposed to filter papers impregnated with essential oils at a concentration of 0.14mg/cm<sup>3</sup>. When filter papers were used immediately after impregnation, 66-90% *D. gallinae* mortality was observed after 24h, depending upon the essential oil used. If impregnated filter papers were left in a fume cupboard for 24h prior to use, mortality rates of *D. gallinae* fell to 11% or less. The similar results were obtained by Puvača et al. (2018) in their study which aimed to discover new ways to control *D. gallinae*. One promising alternative method of control focuses on employing repellent effects of selected essential oils against *D. gallinae* which have been examined by Puvača et al. (2018) an *in vitro* experiment to investigate the repellent effects of thyme (*Thymus vulgaris* L.), lavender (*Lavandula angustifolia* L.) and oregano (*Origanum vulgare* L.)

essential oils on *D. gallinae* in controlled laboratory conditions. The best results were observed for lavender essential oil (96% mortality after 72h) and thyme (82% mortality after 72h) at a dose of 0.15 mg/cm<sup>3</sup>. In addition, thyme and lavender essential oils showed significant persistent toxic effects 15 and 30 days post application to filter papers. Thyme was the most effective (100% mortality at 72h), followed by lavender (78% mortality after 72h). Results have shown that the thyme and lavender essential oils exhibited promising results when tested *in vitro* for toxic and repellent effects against *D. gallinae*. Beside *D. gallinae*, the northern fowl mite (*Ornithonyssus sylviarum*) is also an ectoparasite that can lower egg production and cause anemia and even death in laying hens. Birrenkott et al. (2000) have shown that 10% of garlic juice dilution in water is highly effective against this parasite as well as Ranjbar-Bahadori et al. (2014) in their research with garlic against poultry red mite.

## CONCLUSIONS

Summarizing the results obtained through multiple research projects using alternative *D. gallinae* products, further confirms the possibility that essential oils may be useful in control of this pest. This approach may be enhanced if essential oils were employed as part of an integrated pest management approach. Thus, essential oils, spices, medicinal plants and aromatic herbs offer an effective alternative to chemical acaricides, as well as powerful growth promoters and natural instruments for improvement of the final product (e.g. meat or eggs) for human consumption, as well in increase of economical and profitable production. However, further investigation of their beneficial mechanisms is still necessary in *in vivo* experiments.

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## REFERENCES

- BARIMANI, A., YOUSSEFI, R. and TABARI, A. (2016) Traps containing carvacrol, a biological approach for the control of *Dermanyssus gallinae*. *Parasitology Research*, **115**: 3493.
- BIRRENKOTT, G., BROCKENFELT, G., GREER, J. and OWENS M. (2000) Topical application of garlic reduces northern fowl mite infestation in laying hens. *Poultry Science*, **79**: 1575–1577.
- BRUNEAU, A., DERNBURG, A., CHAUVE, C. and ZENNER, L. (2001) First *in vitro* cycle of the chicken mite, *Dermanyssus gallinae* (DeGeer 1778), utilizing an artificial feeding device. *Parasitology*, **123**: 583-589.
- ČBARKAPA, I., ŠKRINJAR, M., LEVIĆ, J., KOKIĆ, B., BLAGOJEV, N. and MILANOV, D. (2015) Biofilm forming ability of *Salmonella* Enteritidis *in vitro*. *Acta Veterinaria*, **65**(3): 371-389.
- CAMARDA, A., PUGLIESE, N., BEVILACQUA, A., CIRCELLA, E., GRADONI, L., GEORGE, D., SPARAGANO, O. and GIANGASPERO, A. (2018) Efficacy of a novel neem oil formulation (RP03™) to control the poultry red mite *Dermanyssus gallinae*. *Medical and Veterinary Entomology*, doi.org/10.1111/mve.12296.
- CHAUVE, C. (1998) The poultry red mite *Dermanyssus gallinae* (De Geer, 1778): current situation and future prospects for control. *Veterinary Parasitology*, **79**: 239–245.



- CHIRICO, J., ERIKSSON, H., FOSSUM, O. and JANSSON, D.** (2003) The poultry red mite, *Dermanyssus gallinae*, a potential vector of *Erysipelothrix rhusiopathiae* causing erysipelas in hens. *Medical and Veterinary Entomology*, **17**: 232-234.
- COSOROABA, I.** (2001) Massive *Dermanyssus gallinae* invasion in battery-husbandry raised fowls. *Revue de Médecine Vétérinaire*, **152**: 89-96.
- FAOSTAT** (2016) Food and Agriculture Organization of the United Nations. <http://www.fao.org/faostat/en/home>.
- FLOCHLAY, S., THOMAS, E. and SPARAGANO, O.** (2017) Poultry red mite (*Dermanyssus gallinae*) infestation: a broad impact parasitological disease that still remains a significant challenge for the egg-laying industry in Europe. *Parasites & Vectors*, **10**: 357. doi: 10.1186/s13071-017-2292-4
- GEORGE, R., CALLAGHAN, K., GUY, H. and SPARAGANO, O.** (2008) Lack of prolonged activity of lavender essential oils as acaricides against the poultry red mite (*Dermanyssus gallinae*) under laboratory conditions. *Research in Veterinary Science*, **85**: 540-552.
- GEORGE, R., FINN, D., GRAHAM, M. and SPARAGANO O.** (2014) Present and future potential of plant-derived products to control arthropods of veterinary and medical significance. *Parasites & Vectors*, **7**: 1-12.
- GUY, J.H., KHAJAVI, M., HLALELE, M.M. and SPARAGANO, O.** (2004) Red mite (*Dermanyssus gallinae*) prevalence in laying units in Northern England. *British Poultry Science*, **45**: 5-6.
- ISMAN, B.** (2006) Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. *Annual Review of Entomology*, **51**: 45-66.
- JANSSON, S., OTMAN, F., LUNDQVIST, L., HOGLUND, J., ENGSTROM, A. and CHIRICO, J.** (2014) Northern fowl mite (*Ornithonyssus sylviarum*) in Sweden. *Medical and Veterinary Entomology*, **28**: 443-446.
- KILPINEN, O.** (2005) How to obtain a blood meal without being eaten by a host: the case of poultry red mite, *Dermanyssus gallinae*. *Physiological Entomology*, **30**: 232-240.
- MOZAFAR, F.** (2014) Die rote vogelmilbe, eine grosse herausforderung für eierproduzenten. Frühjahrveranstaltung. Book of Abstract of Deutschen Vereinigung für Geflügelwissenschaft, Leipzig, pp. 89.
- MUL, M.** (2016) Fact sheet: The Poultry Red Mite, *Dermanyssus gallinae* (De Geer, 1778). A small pest that packs a big punch 2013. [https://www.researchgate.net/publication/258553789\\_Fact\\_sheet\\_Poultry\\_Red\\_Mite\\_in\\_Europe](https://www.researchgate.net/publication/258553789_Fact_sheet_Poultry_Red_Mite_in_Europe).
- MUL, M., VAN NIEKERK, T., CHIRICO, J., MAURER, V., KILPINEN, O., SPARAGANO, O., THIND, B., ZOONS, J., MOORE, D., BELL, B., GJEVRE, A.G. and CHAUVE, C.** (2009) Control methods for *Dermanyssus gallinae* in systems for laying hens: results of an international seminar. *World Poultry Science Journal*, **65**: doi:10.1017/S0043933909000403.
- NOBO, G., MOREKI, C. and NSOSO, J.** (2012) Feed intake, body weight, average daily gain, feed conversion ratio and carcass characteristics of helmeted Guinea fowl fed varying levels of Phane Meal (*Imbrasia belina*) as replacement of fishmeal under intensive system. *International Journal of Poultry Science*, **11**: 378-384.
- NORDENFORS, H., HOGLUND, J. AND UGGLA, A.** (1999) Effects of temperature and humidity on oviposition, molting, and longevity of *Dermanyssus gallinae* (Acari: Dermanyssidae). *Journal of Medical Entomology*, **36**: 68-72.
- PERRICONE, M., ARACE, E., CORBO, R., SINIGAGLIA, M. and BEVILACQUA, A.** (2015) Bioactivity of essential oils: a review on their interaction with food components. *Frontiers in Microbiology*, **6**: doi:10.3389/fmicb.2015.00076.
- PUVAČA, N., PETROVIĆ, A., HORVATEK TOMIĆ, D., MARANGI, M., SHTYLLA KIKA, T., VASILJEVIĆ, M. and SPARAGANO, O.** (2017) Control of the poultry red mite by dietary essential oils: laying hens production and welfare. Book of Abstracts of the 21<sup>st</sup> European Symposium on Poultry Nutrition, Salou.

**PUVAČA, N., PETROVIĆ, A., NIKOLOVA, N., POPOVIĆ, A., ČABARKAPA, I., BURSIĆ, V., POPOVIĆ, S., ĐURAGIĆ, O. and SHTYLLA KIKA, T.** (2018) Influence of selected essential oils as a natural repellent of poultry red mites: in vitro study. *Macedonian Journal of Animal Science*, **8**: 55-59.

**RAJABPOUR, A., MASHHADI, A.R.A. and GHORBANI, M.R.** (2018) Acaricidal and repellent properties of some plant extracts against poultry red mite, *Dermanyssus gallinae* (Mesostigmata: Dermanyssidae). *Persian Journal of Acarology*, **7**: 85-91.

**RANJBAR-BAHADORI, S., FARHADIFAR, N. and MOHAMMADYAR, L.** (2014) Assessment of susceptibility of the poultry red mite, *Dermanyssus gallinae* (Acari: Dermanyssidae) to some plant preparations with focus on exposure time. *International Journal of Animal and Veterinary Sciences*, **8**: 573-576.

**ROY, S., RAHMAN, A., PHUKAN, K. and MURALEEDHARAN, N.** (2014) Terminalia chebula Retz. (Combretaceae): source of a botanical acaricide against *Oligonychus coffeae* Nietner (Acarina: Tetranychidae). *International Journal of Acarology*, **40**: 138-144.

**SMITH, M.G., BLATTNER, R.J. and HEYS, F.M.** (1946) St. Louis encephalitis: Infection of chicken mites, *Dermanyssus gallinae*, by feeding on chickens with viraemia; transovarian passage of virus into the second generation. *The Journal of Experimental Medicine*, **84**: 1-6.

**SPARAGANO, O., GEORGE, D.R., HARRINGTON, D. and GIANGASPERO, A.** (2014) Biology, epidemiology, management and risk related to the poultry red mite, *Dermanyssus gallinae*. *Annual Review of Entomology*, **59**: 447-466.

**SPARAGANO, O., PAVLIĆEVIĆ, A., MURANO, T., CAMARDA, A., SAHIBI, H., KILPINEN, O., MUL, M., VAN EMOUS, R., LE BOUQUIN, S., HOEL, K. and CAFIERO, M.A.** (2009) Prevalence and key figures for the poultry red mite *Dermanyssus gallinae* infections in poultry farm systems. *Experimental and Applied Acarology*, **48**: 3-10.

**TABARI, A., YOUSSEFI, R. and BENELLI, G.** (2017) Eco-friendly control of the poultry red mite, *Dermanyssus gallinae* (Dermanyssidae), using the  $\alpha$ -thujone-rich essential oil of *Artemisia sieberi* (Asteraceae): toxic and repellent potential. *Parasitology Research*, **116**: 1545. doi: 10.1007/s00436-017-5431-0.

**TOMIČIĆ, R., ČABARKAPA, I., VARGA, A. and TOMIČIĆ Z.** (2018). Antimicrobial activity of essential oils against *Listeria monocytogenes*. *Food and Feed Research*, **45(1)**: 37-44.

**VAN EMOUS, R.** (2005) Wage war against the red mite. *Poultry International*, **44**: 26-33.

**VAN EMOUS, R.** (2017) Verwachtte schade bloedluis 21 miljoen euro.  
<https://www.pluimveeweb.nl/artikelen/2017/01/schade-bloedluis-21-miljoen-euro>.

**WHO** (2003) World Health Organization guidelines on good agricultural and collection practices (GACP) for medicinal plants. <http://apps.who.int/medicinedocs/pdf/s4928e/s4928e.pdf>.

**WOJCIK, A.R., GRYGON-FRANCKIEWICZ, B., ZBIKOWSKA, E. and WASIELEWSKI, L.** (2000) Invasion of *Dermanyssus gallinae* (De Geer, 1778) in poultry farms in the Torun region. *Wiadomosci Parazytologiczne*, **46**: 511-515.