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THE CONTROL PROGRAM OF RED POULTRY MITE (*DERMANYSSUS GALLINAE*), TODAY

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Abstract

Dermanyssus gallinae control has so far been predominantly based on acaricides (insecticides) and their efficacy has been decreasing in time due to the development of resistance. *D. gallinae* is a species that has developed resistance to all current acaricides. Considering this, we can assume that the new acaricide - fluralaner with its evident efficacy, but also with some downsides, will improve the situation in *D. gallinae* control in the short term. The control of red poultry mite population in intensive poultry production has had an unfavourable tendency for decades. In order for this trend to be stopped and reversed, certain measures must be taken to the control of this disease. It is necessary to eliminate toxicological risks; define the short-term objective (efficient suppression) and the long-term one (eradication); introduce the principles of biosecurity, prevention, and rational control; provide a professional application of formulations and increase the quality of monitoring. The *D. gallinae* program control integrates all the above specified elements into a whole. In our opinion, the currently used program currently used on farms, based on mechanical control and active influence on technological processes, has a bright future. This type of control can be combined with other efficient methods of mite suppression on farms.

Key words: program, control, *Dermanyssus gallinae*

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ПРОГРАМСКА КОНТРОЛА ЦРВЕНЕ КОКОШИЈЕ ГРИЊЕ (*DERMANYSSUS GALLINAE*), ДАНАС

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Kratak sadržaj

Kontrola *D. gallinae* se do sada dominantno zasnivala na akaricidima (insekticidima), čija efikasnost je tokom vremena slabila zbog razvijanja rezistencije. *D. gallinae* je vrsta koja je razvila otpornost na sve do sada korišćene akaricide. Sa tog stanovišta, pretpostavka je da će novi akaricid fluralaner, i pored evidentne efikasnosti, ali i nedostataka, dovesti do kratkotrajnog poboljšanja situacije u kontroli *D. gallinae*. Kontrola populacije crvene kokošije grinje u živinarskoj proizvodnji tokom više decenija ima nepovoljnu tendenciju, i da bi taj trend zaustavili i preokrenuli u drugom smeru, moraju se preduzeti određene mere u samom pristupu kontroli ove bolesti. Potrebno je: isključiti toksikološke rizike; odrediti kratkoročan (efikasnog suzbijanja) i dugoročan cilj (eradikacije); uvesti principe biosigurnosti, preventive i racionalne kontrole; obezbediti stručnu primenu formulacija i povećati kvalitet monitoringa. Navedene elemente u celinu objedinjuje program kontrole *D. gallinae*. Aktuelni program koji se koristi na farmama i po našem mišljenju ima perspektivu, bazira se na fizičkoj kontroli i aktivnim uticanjem na tehnološke procese. Takav vid kontrole je moguće kombinovati sa drugim takođe efikasnim metoda suzbijanja grinja na farmama.

Ključne reči: program, kontrola, *Dermanyssus gallinae*

INTRODUCTION

Dermanyssus gallinae is the most significant poultry ectoparasite (Figure 1). The results of several decades of control are the following: high prevalence (Sparagano et al, 2009), health problems disturbance, stress, impact on the general health status of the flock (Emous 2005; Kowalski and Sokol, 2005; Kaoud, 2010), progression of conditional diseases, transferring agents of infec-

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tious diseases (Moro et al, 2005, Huong et al, 2014), decrease in production results, increase of economic loss (Emous 2005, 2017; Flochlay et al, 2017) and evident toxicological risk to human health (Marangi et al, 2012; Giangaspero et al, 2011, 2017), poultry health and the environment. The extent and tendency of all the above mentioned factors prove that current *D. gallinae* control is inadequate and the approach is improper.

“The extent to which the probability of events has changed under the influence of a message can be used as a measurement of the quantity of information contained in that message“- this is an interpretation from the mathematical information theory by Shannon (1948). In addition to the information about the current situation in *D. gallinae* control, we will provide two more examples. In the last few decades of the 20th century, an intensive development of poultry industry started. This is when timely information about the risk and possible spreading of *D. gallinae* should have been provided.



Figure 1. *Dermanyssus gallinae*

Biosecurity measures should have been introduced and mass farm infestations would have been prevented. This information was not provided, and the consequences of this failure are now widely known. The second example is the change of the conventional cage system for housing layers in the EU. That was the moment when the eradication of *D. gallinae* could have easily been affected

in old poultry houses or initial infestation could have been prevented in newly built ones. Despite an extraordinary opportunity to change the situation, necessary information was again not provided. The aim of this paper is to point out the chance to change the widely accepted approach to *D. gallinae* control in order to stop the unfavorable trend, improve practical results, and direct the development towards the permanent solution.

THE BASIC PRINCIPLES OF THE PROGRAM APPROACH FOR CONTROL OF RED POULTRY MITES

The existing *D. gallinae* control needs improvement (Schulz et al, 2014a; Pritchard et al, 2015; Flochlay et al, 2017). Most products for *D. gallinae* control available on the market are not efficient enough. However, even an efficient product is not sufficient for successful control on its own. It also needs to be properly applied. Furthermore, what is necessary is a program - a comprehensive plan that would have a properly defined objective and that would tackle all other factors important for the control. The importance of a program approach to *D. gallinae* control is rarely emphasized, and the efforts to design and implement a program are rarely made. Emous (2005) lists 4 main elements of a program: thorough cleaning of a poultry house between two flocks, prevention of a new infestation, constant monitoring and implementation of efficient control methods. This program proscribed monitoring on a weekly basis (checking the same 20-30 spots) and its aim was suppression. Users are not familiar with its practical value.

The program approach to *D. gallinae* control has been developed in Serbia since 2000 (Pavličević et al, 2018a).

The objectives of the program are the following:

1. To prevent *D. gallinae* infestation on uninfected farms
2. On infested farms: a) primarily to eliminate safety risks and introduce rational control, and then to raise the level of efficacy and cost-effectiveness of *D. gallinae* control in the short term b) to eradicate *D. gallinae* from production facilities and farms and to introduce biosecurity measures in the long term.

The task of the program is to get a comprehensive overview of all important questions in *D. gallinae* control and to provide the answers. It should cover the following areas: *D. gallinae* biology; environmental characteristics of poultry farms; laboratory tests and clinical trials; detection and monitoring; choice of formulations and methods; preparation of farms and professional application

and introduction of biosecurity measures. This task should be completed in accordance with the principles of preventive veterinary medicine and rational *D. gallinae* control. The program helps to obtain and share important information. Providing quality information to experts and farmers is a way for them to be properly involved in the control program and make an active contribution to the solution.

LIFECYCLE, PHYSIOLOGY OF *D. gallinae* AND IMPACT ON THE EFFICIENCY OF THE CONTROL

D. gallinae biology itself determines the approach and procedure of the control program:

1. Adults are the most problematic stage of *D. gallinae* on which the control measures are focused. They have a great ability to survive. The reasons for this are: ability to hide, mobility, receptors, ability to starve (in some cases for more than a year - Pavličević et al, 2007), tolerance to environmental conditions (Nordenfors et al, 1999), possibility of alternative nutrition (Nordenfors, 2000).
2. Due to their ability to hide, a prolonged effect of the formulation or method is the key property of an efficient product (Pavličević et al, 2016). High efficacy on directly exposed mites is obligatory, because without that there is no prolonged effect either.
3. Eggs are resistant to some formulations, but in a properly designed program, this bears no clinical significance. This is due to the fact that egg development is continuous and short (usually from 1 to 3.2 days, depending on the environmental conditions - Nordenfors et al, 1999), and the next developmental stages soon become exposed to the formulation residual effect.
4. Control efficacy must be high due to the great reproductive potential (Pavlovic et al, 2017) and short life cycle of *D. gallinae* (Nordenfors, 2000).
5. *D. gallinae* develops resistance to insecticides (acaricides), but also adapts in other ways (Ebeling, 1971; Zeman and Zelezny, 1985; Zeman, 1987; Marangi et al, 2012; Pavličević, 2005; Pavličević et al, 2016; 2018a; Abbas et al, 2014).
6. Molecular diagnostic tests showed that infestation mostly originates from the intensive poultry production, whereas *D. gallinae* originating from the natural environment is secondary (Roy, 2009). This information is important for biosecurity. With the change in the method of poultry housing, infestation from the nature could become more significant.

THE ENVIRONMENT

The environment is one of the key factors in *D. gallinae* control program (Figure 2.). Experts assessed the changes in the method of layer housing in the EU as unfavorable from the aspect of *D. gallinae* control (Flochlay, 2017). In addition to that, the existing practice in *D. gallinae* control does not pay enough attention to the importance of the farm's environment. Not only the method of layer housing, but also the complexity and construction of some models of cages and equipment impose very demanding conditions for *D. gallinae* control, so farmers have long-term indirect losses if they buy those. Poultry experts have not warned farmers about these cases. Regarding *D. gallinae* control, simplicity and functionality are the requirements for every manufacturer of cages and equipment. The model Q – Perch by Vencomatic is designed for active *D. gallinae* control (Dick van de Ven, 2016). The efficacy of this concept is questionable. This approach is not in accordance with the control program that proscribes only security measures for new farms.

In previously used infested poultry houses, the change of cages and equipment provides good conditions for the eradication of *D. gallinae*, and subsequently the introduction of biosecurity measures. The program is especially being developed in the direction of improving the environmental conditions, and in the upcoming period we are expecting results in this area.



Figure 2. An example of improved environmental conditions – the deep gutter on the inner edge of the feed trough is irrelevant for *D. gallinae* control if it is permanently filled with a neutral substance

EFFICACY OF FORMULATIONS

Information on the efficacy of formulations and methods is provided by laboratory tests and clinical trials. Laboratory tests need to determine the effect of a formulation on directly exposed mites, residual effect (on subsequently exposed mites on the treated surface) and resistance (in cases when it occurs). The information we obtain in the lab has a limited, approximate significance. We can form a full profile of a formulation only through clinical trials. The results of clinical trials are influenced by the effect of the formulation, and by other factors depending on the specific conditions as well. Because of this, various factors need to be included and perceived comprehensively by repeating the tests in different conditions. The following factors need to be acknowledged in clinical trials: the results of laboratory tests of the formulation; housing technology; complexity and structure of the environment; hygienic conditions; temperature and humidity (time of year); infestation intensity and extensity; application (the moment of application, concentration and dosage, method of application, controllability); presence of adaptation systems; length of the housing down time; biosecurity measures; monitoring; side effects, flaws, complications and, if necessary, other. The final assessment of a formulation's efficacy should include the whole production period of a layer, a full year (Pavličević, 2018b).

THE RIGHT CHOICE OF FORMULATION AND METHODS OF *D. gallinae* CONTROL

Laboratory tests and clinical trials provide information which is used in accordance with the criteria of rational control to choose the formulation and method. The choice of the formulation and method should be based on the arguments of safety, efficacy, and cost-effectiveness. In addition to this, it is necessary to define all other features relevant for the successful application in practical conditions.

Prior to the external application of formulations, poultry housing needs to undergo a detailed hygienic preparation, cleaning, washing and disinfection. After the housing has been examined and all necessary conditions fulfilled, a formulation is applied with care. Together with the choice of formulations and methods of *D. gallinae* control, professional application is another precondition for successful control. If necessary, auxiliary measures are taken simultaneously in order for the procedure to be a complete success.

MONITORING THE EFFICACY OF *D. gallinae* CONTROL

Detection and monitoring provide a relevant insight into the presence of *D. gallinae* and infestation intensity and extensity. Detection procedure can be based on methods that provide information from a wider area or from specific spots. An example for the latter are traps, which require multiple repetitions and adequate timing of assessment in order to provide reliable information. Visual examination and early dust detection (in cage systems) are particularly operative methods (Pavličević et al., 2017). We advocate comprehensive monitoring (staff's observations, anamnestic data, flock's health status, production results) and multiple detection methods which should be implemented throughout the production period at monthly intervals (or more frequently, if necessary). Descriptive presentation of results is preferable to numerical. Complex diagnostic methods such as automated mite counter for *Dermanyssus gallinae* (Mul et al, 2015) are unnecessary expenditures for farmers and we do not think they are justified.

BIOSECURITY MEASURES

Biosecurity measures are supposed to prevent the introduction of *D. gallinae* into the farm or into the poultry house. This measure is essential to the program. It reaches its full purpose in uninfected facilities, and in the examples where eradication has been successfully performed. In infested facilities, biosecurity measures can enhance the effects of suppression. For the biosecurity to be effective, it needs to be based on timely, accurate, and complete information. It is implemented outside and inside the farm alike. The factors that are particularly important for biosecurity in *D. gallinae* control are population of a young flock (the flock itself and transportation cages), removing old flock (transportation cages and vehicles) and purchasing used cages and equipment. When purchasing a young flock, it is important to carry out the forensic assessment correctly. Dermanyssosis is a hidden fault and if not looked for, it usually goes unnoticed. Debris from transportation cages should be shaken off the cages, collected and covered with paper. In the end it should be unloaded and inspected in the presence of the supplier (Pavličević et al., 2003).

INTEGRATED PEST MANAGEMENT / INTEGRATED HEALTH CARE (IPM/ IHC)

The integrated pest management (IPM) Axtell approach (1998) includes measures that would integrate pest management in the poultry industry: iden-

tification, monitoring and control. The control program is in accordance with the mentioned principles. In large infestations *D. gallinae* can coexist with the housefly - *Musca domestica* (Pavlovic et al, 2016), and very frequently with rodents. P 547/17 has a general acaricide and insecticide effect. However, a more significant coordination with the program is yet to be performed. The development of the program is directed towards integrated health care (IHC), especially by connecting and integrating into the general health care, disease control and toxicology (Pavličević et al, 2018a,b,c). External machine application of formulations has been successfully performed in order to improve the application of disinfectants. The reasons are excluding manual labor and human error as well as being functional. Disinfection in the true sense of the word cannot be considered successful if there are infestation vectors left in the environment. Therefore, *D. gallinae* control measures need to be synchronized with disease control (Moro et al, 2005; Huong et al, 2014). We must emphasize the significance of salmonellosis that can parasitize in *D. gallinae* for up to 4 months (De Luna, 2008). Housing down time imposed in case of infectious disease can be used to eradicate *D. gallinae* (Pavličević et al, 2018a).

THE ULTIMATE GOAL OF THE PROGRAM FOR THE CONTROL OF THE POULTRY RED MITE

The possibility of *D. gallinae* eradication from production facilities is the key issue for red poultry mite control, and it is rarely mentioned and considered. The generally accepted expert approach states that eradication is not possible. The control program proves that it is (Pavličević et al, 2018a). Eradication is the ultimate goal of the program and the final solution for *D. gallinae* control. It eliminates toxicological risk arising from inadequate *D. gallinae* control, the role of *D. gallinae* vectors in intensive poultry production, the adverse effect of *D. gallinae* on the flock's health status. Also, to the greatest possible extent, it protects farmers' economic interest, consumers' health and economic interest and farm staff's interest. Finally, it prevents the development of resistance and further spreading of dermanyssus.

THE CURRENT SELECTION OF ACTIVE SUBSTANCES

The control program (in the narrow sense) is based on mechanical effect, especially on inert substances and during the housing preparation period before the population of the flock. SiO₂ formulations are an alternative to acaricides (Kilpinen and Steenberg, 2009; Schulz, 2014a). Their effect focuses on

the absorption by the mites' epicuticular layer and the subsequent dehydration (Ebeling, 1971). In some SiO₂ formulations necessary properties have been recorded in lab conditions (Schulz et al, 2014b) and confirmed in practice (Pavličević et al, 2018b). There are pros and cons of powdered and liquid forms. What is original in the program of "*D. gallinae*", Cluster, Serbia is the combined application of both liquid and powdered forms of SiO₂. Optimization of their application includes the correct choice of formulations and their combined professional application in both forms during the housing preparation, when there is sufficiently long down time in the temperature conditions when mites are active. Application of powdered and liquid forms of SiO₂ requires special applicators and expertise. Too complex cages and equipment question the rationality of the procedure. In a populated house efficacy is low due to the problem of formulation distribution, low penetrability into the dirt, small biocide capacity per surface unit, the ability to lay eggs even in lethally exposed mites, removing and compromising of the surface layer, influence of moisture (Pavličević et al, 2018b). Even though successful results of SiO₂ during preparation period have been confirmed, their flaws and demanding application have limited their use to the smaller part of the poultry industry. The flaws have mostly been corrected with the new generation of inert substances P 547/17 (product Pulcap, manufacturer Pulsil LLC "*D. gallinae*" Cluster, Serbia) - Pavličević et al, 2018a,b,c). The P 547/17 is an emulsion concentrate applied in the form of 20% water emulsion (Figure 3). It is used for the preparation of cages, equipment and environment in general. It is registered as a product for general use. It is not abrasive and does not require special applicators, but the existing spraying applicators for water solutions can be used if they contain the mechanism for mixing while in operation. P 547/17 immobilizes directly exposed mites and prevents *D. gallinae* respiration. Moreover, it probably penetrates the body and disturbs life functions of *D. gallinae*. Comprehensive effect of the formulation on *D. gallinae* is yet to be tested. So far, it is based on the general information about the effect of oils (Agnello, 2002). Liquid form of the emulsion enables better distribution and penetrability. In addition to the high efficacy on directly exposed mites, on unabsorbent surfaces, it forms a layer with long extended effect which is most emphasized in empty poultry houses. Lab tests and clinical trials show that P 547/17 has the necessary properties for highly efficient suppression, but also the potential for eradication (Pavličević et al, 2018c). The first cases of eradication were recorded in practical conditions (2). Performing eradication in complete systems of intensive poultry production will start in Serbia in 2019 as part of the project funded by The Innovation Fund Serbia (ID = 1115), "Red poultry mite control with a mixture of

inert oils". It will include two production cycles of table eggs with the capacities of 400,000 and 200,000 layers. With the optimization of this concept and the development of the next stages of mechanical control, in the future it will be possible to completely exclude synthetic neurotoxic compounds from egg production.

D. gallinae control program focuses on mechanical methods and housing preparation. In production systems, the program starts on rearing farms. After the rearing finishes, poultry housing is prepared for the production period. A young, uninfested flock is populated in the poultry housing, using uninfested transportation cages. Formulation P 547/17 is proscribed for the treatment of transportation cages, and, if necessary, for used cages and equipment. For the procedure of *D. gallinae* eradication, an important factor is the housing down time (a break after cleaning, washing, disinfection and applying a layer of the substance) in temperature conditions that enable the mite' activity. The recommended length of the down time is 14 days, and optimally 30 days (these figures are approximate, and depend on the temperature conditions).



Figure 3. A cage covered with a layer of Pulcap

Veterinary profession obliges us not only to work on long-term development, but also to constantly look for short-term answers to all the situations that are pressuring the poultry industry. Because of this, in addition to the basic direction of development based on mechanical control, it is our task to adapt the eradication procedure to the current moment and make it less demanding and thus more available for farmers. Especially for those farms where the environmental conditions of alternative methods of layer housing have made *D. gallinae* control more difficult. Isoxazoles are insecticides with specific effect. The assessment of their insecticide potential is announced as “the golden age” (Casida, 2015). Isoxazol Fluralaner is potent inhibitor of parts of arthropod nervous system and acts antagonistically on ligand-gated chloride channels (GABA- receptor and glutamate-receptor). It is registered as a veterinary medicine Exzolt, made by MSD Animal Health. It is administered in drinking water in the dosage of 0.5 mg of fluralaner/kg BW, twice over the period of 7 days. When applied in this way, Exzolt starts to produce its effect in 4 hours, and it reaches its full effect over the period of 14 days, including two development cycles of *D. gallinae* (Technical Manual, Exzolt, MSD Animal Health). However, in our opinion, this residual effect (14 days) is not long enough for a complete *D. gallinae* control. In practical conditions, the development cycle lasts longer than the period stated in the manual for this medicine, which is the minimal length of *D. gallinae* cycle. For example, at the temperature of 25°C the development of a *D. gallinae* generation will end in 16.8 days (Maurer and Baumgartner, 1992). This lasts even longer in winter, at least for the part of the infestation located in the lower levels of cages, floors and walls. In infestations of high intensity and extensity, *D. gallinae* distribution also includes places which are not in the immediate vicinity of hens. Those mites do not have the same feeding dynamics as those close to the hens, which is proven by their colour and dimensions. Toxicological opinion prevents any repeated treatments with the same veterinary medicine within the period shorter than 3 months (instructions for application of Exsolt, MSD Animal Health). Efficacy of fluralaner recorded in laboratory conditions is 90% mortality (LC_{90}) values, the laboratory isolate was susceptible to fluralaner (15.6–62.5 parts per million, ppm). Mite LC_{90} when exposed to fluralaner by blood feeding was < 0.1 ppm (Thomas et al., 2017) and in clinical conditions 99.99% in 4 weeks (Sleeckx et al., 2018), and suppression effect ranges from 56 to 238 days (Thomas et al, 2018). Despite the obvious efficacy manifested by fluralaner, at the same time, it has evident flaws. In cases where conditions for optimal application of inert substances cannot be ensured, it is suggested that inert substances be applied in combination with veterinary medicines based on the

insecticide fluralaner (Pavličević et al, 2018a). Correct application of insecticides can exclude any further insecticide use, prevent frequent treatments and slow down the development of resistance. The whole procedure needs to be optimized and confirmed in practice. Program application of the chosen inert substances and the new veterinary medicine based on the active substance fluralaner at this moment provides the necessary preconditions for *Dermanyssus* to become a controllable health and economic problem. Otherwise, we expect that fluralaner application as currently prescribed, will cause resistance and prevent its further use in the purpose of achieving full efficacy. Therefore, we should immediately switch to its controlled and planned application in the form of a program.

COST BENEFIT ANALYSIS

Despite larger initial expenditures and more effort, eradication is cost-effective for farmers because in this way they can eliminate further spending. We will take a farm of 100,000 hens as an example. Total expenditures incurred by *D. gallinae* are estimated at €0.6 per hen (Emous, 2017; Flochlay et al, 2017). If we take 0.5 € per hen as the annual expenditure caused by red poultry mite, the total amount will be 50,000 €. In case of eradication, this farm would save half a million euros in ten years.

HOW TO CONTRIBUTE TO THE IMPLEMENTATION OF THE PROGRAM?

Reporting *D. gallinae* infestation in poultry houses would be useful for multiple reasons. It would provide information and practical protection for uninfected farms and prevent re-infestation in cases of eradication. It would differentiate the prices of infested and uninfected young flocks and motivate farmers to design a plan of eradication. It would also improve the residue monitoring, provide a continual overview of prevalence, enable the preparation for systematic implementation of *D. gallinae* control program on horizontal and vertical levels, provide assessment of effects of the implemented control measures and monitor the influence on the flock's health status, especially infectious diseases (Pavličević et al, 2018a). Furthermore, there is a need for an international scientific-expert-business project that would take responsibility for control results on poultry farms, suggest the choice of formulations and methods in accordance with the principles of rational control, and provide adequate application and monitoring in practice. This way it would eliminate

errors that cause health and economic problems, and actively protect the common interest of the poultry industry. At the same time it would contribute to the development of formulations and methods until the final solution of this problem is found (Pavličević et al, 2018d).



Figure 4. Mites extinct due to a disease of unknown etiology

FINAL CONSIDERATIONS AND EXPECTATIONS

The approach for the control of the poultry red mite has resulted in inadequate control of *D. gallinae* to date. We suggest that existing practice be improved by adopting the *D. gallinae* program control principle. Conditions have been met for Dermanyssosis to become a controlled health and economic problem.

In the future it will be possible to completely exclude all synthetic neurotoxic compounds from egg production. We are expecting new improvements of the control program, especially in the field of mechanical control. In addition to this, there is a great potential in studying mite diseases that can cause the extinction of mites in poultry houses (Figure 4.). This phenomenon was recorded in the clinical experience in Germany, Italy and Serbia during the summer period.

The program is open to all new improvements of *D. gallinae* control. Regular tasks are constant testing of new formulations and methods, reviewing, improving and adapting the program to farms' specific conditions and needs.

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