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Preventing introduction and spread of *Dermanyssus gallinae* in poultry facilities using the HACCP method

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Abstract Preventing the establishment of ectoparasitic poultry red mite (*Dermanyssus gallinae*) populations is key in ensuring welfare and egg production of laying hens and absence of allergic reactions of workers in poultry facilities. Using the Hazard Analysis and Critical Control Point method, a panel of experts identified hazards and associated risks concerning the introduction and spread of this mite in poultry facilities. Together we provide an overview of possible corrective actions that can be taken to prevent population establishment. Additionally, a checklist of the most critical control points has been devised as management tool for poultry farmers. This list was evaluated by Dutch and British poultry farmers. They found the checklist feasible and useful.

Keywords Control · Corrective actions · Monitoring · Checklist · Risks · Farm processes

Introduction

Dermanyssus gallinae (De Geer 1778) is the most common ectoparasite in poultry. It belongs to the subclass Acari and is known under the common name poultry red mite (PRM) or chicken mite. Adult poultry red mites are on average 751 microns in length and 461 microns in width when engorged and are found in cracks and crevices within the poultry facilities in the vicinity of the hens. In these cracks and crevices the mites mate, deposit their eggs and molt. The life cycle of the mite contains five stages: egg, larva, protonymph, deutonymph, and adult (Wood 1917). The protonymph, deutonymph, and

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adult feed on blood of poultry and other birds, but also of other animals, including humans (Sikes and Chamberlain 1954). The poultry red mite usually stays at the hen for a bloodmeal during the dark period. Within 8 weeks one female may produce an estimated amount of two and a half thousand offspring (Wood 1917).

Infestations with the poultry red mite can reduce the welfare of chickens, increase mortality and initiate allergic reactions of workers in the poultry facilities (Baselga et al. 1996; Chauve 1998; Kilpinen et al. 2005; Nordenfors 2000). The mite is a potential vector of various pathogens, such as *Salmonella* and the causative agents of fowl cholera, Newcastle disease and eastern equine encephalitis (Moro et al. 2005). Control of *D. gallinae* has become more difficult due to development of resistance to permethrin (Chauve 1998; Marangi et al. 2008; Nordenfors et al. 2001) and a ban on other acaricides in some countries such as carbaryl (a carbamate). Therefore, recent research has been focused on alternative control methods for *D. gallinae* such as the use of entomopathogenic fungi, silica, improved hygiene (e.g., heat cleansing, washing) and the use of natural predators (Gjevre, personal communication; Maurer and Hertzberg 2001; Maurer and Perler 2006; Nordenfors 2000; Steenberg et al. 2005). However, control could be more efficiently employed if prevention of the introduction and spread of *D. gallinae* was more rigorously enforced.

The Hazard Analysis and Critical Control Points (HACCP) system was introduced in the 1960s by NASA for design and manufacturing of food for spaceflights. Since then HACCP has been recognized internationally as a logical tool in the adaptation of traditional inspection methods to a modern, science-based, food safety system (Mayes 1993, 1998; Sun and Ockerman 2005). The advantages of such a structured and formalized concept was recognized and adapted for use in safeguarding animal welfare and health (Bonde and Sørensen 2004; Noordhuizen and Frankena 1999). For example, HACCP allows one to identify the risk factors for introduction and spread of bacteria and parasites such as *Salmonella* and *Toxoplasma gondii* (Kijlstra et al. 2004; Mul and Van der Gaag 2003). Moreover, it has been employed in risk assessment of the introduction of unwanted organisms on passenger ships (Mouchtouri et al. 2008) and it has been nominated for the prevention of fire ant introduction and spread in Australia (Rayment 2006). It is hypothesized that, in a similar way, the HACCP method can be used for risk factor assessment concerning introduction and spread of *D. gallinae* on poultry farms. Earlier work demonstrated that poultry red mites are considered the most severe and most frequent hazard in relation to 9 other poultry-related hazards such as pasteurellosis and cannibalism (Hegelund and Sørensen 2007). This paper further elaborates on the identification of the risk factors and critical control points, and presents suggestions for corrective actions. Based on this information and evaluation by farmers, we have developed a checklist that can be used to control *D. gallinae* more readily and effectively on poultry facilities.

HACCP development

HACCP is a method of controlling hazards and reducing risks. It comprises seven principles (Mayes 1998): (1) conduct a hazard analysis, (2) identify critical control points, (3) establish critical limits for each critical control point, (4) establish critical control point monitoring requirements, (5) establish corrective actions, (6) establish record keeping procedures, and (7) establish procedures to ensure that the HACCP system is working as intended (validation and verification). In order to apply this method to achieve insight in the hazards for introduction and spread of *D. gallinae* some adjustments were required. For example, instead of eradication or control of a critical control point (demand of HACCP), a reduction of the hazard had to be accepted and instead of analyzing the risk of a product we analyzed the risk of the potential (rate and extent) introduction or spread of *D. gallinae* in the poultry facility.

Hazard analysis

A hazard analysis is conducted by compiling a schedule of all farm processes. Due to the scarcity of quantitative information on epidemiological risk factors for introduction and spread of *D. gallinae* infestations, an expert opinion study was performed as others have in the past (Bonde and Sørensen 2004; Noordhuizen and Frankena 1999). Assessment of the risk of *D. gallinae* infestation and spread was judged by four experts. Three of them were experts in poultry husbandry and two of them were experts on *D. gallinae*. The farm processes under assessment were divided into 13 hazard categories (Table 1). In total 41 hazards were identified. Risk was calculated by multiplying likelihood and severity. Likelihood was classified into three categories: (1) occurring seldom or only theoretically, (2) occurring approximately once a year, and (3) occurring repeatedly or more than once a year throughout the year. Severity was classified as (1) low when only a single place in the poultry facility becomes infested with *D. gallinae*, (2) moderate, when the poultry facility becomes infested with *D. gallinae* at more than one location or (3) high, when *D. gallinae* infestation occurs at almost all places within the poultry facility. The panel of experts made several suggestions for possible corrective action. Details of the hazards are shown in Table 2.

Critical control point identification

A critical control point (CCP) is a step, point or procedure in any production procedure. This can also be applied to the egg production facility to identify and manage potential

Table 1 Overview of hazard categories, number of hazards and critical control points (CCPs) per category and associated total and average risk (details of the hazards are shown in Table 2)

Hazard category	Risk of introduction	Risk of spread	No. of hazards	No. of CCPs	Total risk score	Average risk score
Environment	x	x	7	5	28	4.0
Feed	x	x	4	1	10	2.5
Litter	x	–	1	1	3	3.0
Growing hens	x	–	4	3	23	5.8
Material/equipment	x	x	3	2	13	4.3
Manure	x	x	3	2	16	5.3
Eggs	x	x	4	4	21	5.3
Manure aeration	x	x	2	2	12	6.0
Cadavers	x	x	2	2	12	6.0
Visitors/external personnel	x	x	3	3	14	4.7
Poultry farmer/ employee	x	x	3	3	24	8.0
Ventilation	x	x	3	1	7	2.3
Unproductive hens	x	–	2	2	6	3.0

Table 2 Explanation of hazards and associated risks for introduction and spread of *Dermanyssus gallinae* in poultry systems

Hazard category	Hazard	Likelihood	Severity	Risk	Motivation	Corrective action
Environment	Introduction of mites via pests and vermin such as rats, mice, etc.	2	2	4	Poultry houses are attractive to rats, mice etc. because of the presence of food, water and opportunities for shelter. These animals are potential carriers of mites.	Professional pest/vermin control No storage in immediate vicinity poultry house Strip (2 m wide zone) along the poultry house free of vegetation Hard pavement (e.g., gravel or cobblestones) next to poultry house instead of grass
Environment	Introduction of mites into poultry house via wild birds	2	2	4	Mites may be present by a wild bird straying from the nest	Close poultry house for birds (bird-proof) Install springs on doors No shelter/runs for hobby poultry/birds next to poultry house
Environment	Introduction of mites via bird nests attached to the building	2	2	4	Many wild bird nests are infested with mites. After fledging of young birds in spring, mites starve and seek new hosts inside the poultry house.	Fill space underneath the (corrugated) roof to prevent breeding of birds No vegetation alongside poultry house that could house bird nests No nesting boxes against wall of poultry house
Environment	Introduction of mites into poultry house via pets	1	2	2	In the absence of birds or chickens, mites can chose dogs or cats as host, but the likelihood is considered low.	Do not allow pets in poultry house or associated spaces Install springs on outside doors
Environment	Spread of mites via rats, mice, flies, etc.	2	3	6	Pest animals such as rats and mice are potential carriers of mites. They can spread mites within a poultry house. Severity is higher, because mites have already been introduced before further spread occurs.	Professional pest/vermin control

Table 2 continued

Hazard category	Hazard	Likelihood	Severity	Risk	Motivation	Corrective action
Environment	Spread of mites via wild birds	2	3	6	Wild birds could carry mites and spread them within the poultry house. The likelihood depends on infestation pressure among wild birds. Wild birds could reach many areas within the poultry house.	If possible, remove wild birds from poultry house
Environment	Spread of mites via pets	1	2	2	Pets could carry and spread mites.	Do not allow pets in poultry house or associated spaces
Feed	Introduction of mites into poultry house via road transport	1	2	2	Feed trucks visit different farms and could theoretically carry mites from one farm to another. Likelihood and severity are low, because even if infested, it will be hard for mites to move from truck to poultry house	Keep distance between truck and poultry house
Feed	Introduction of mites into poultry house via feed bags	1	1	1	Although prepared clean from the factory, feed bags could be infested at visits to different farms during transportation.	Store feed bags in different area
Feed	Spread between barns via feed transport system	1	1	1	The feed transport system is a very low hazard for transport of mites between barns.	Seal holes where transport system enters/leaves the barn with cement
Feed	Spread within barn via feeding system	2	3	6	Mites hide in (bent) edges/rims of the feeding system and may end up in the food or on the transporting chain and thus spread throughout the poultry house.	Treat feeding system with control agent Seal edges and rims of feeding system with silicone sealant
Litter	Introduction of mites in poultry house through scattering litter	1	3	3	Litter is clean and generally not a good hiding place for mites (low likelihood). However, if litter is infested, it will be spread throughout the entire poultry house (high severity)	Only use dry, clean litter

Table 2 continued

Hazard category	Hazard	Likelihood	Severity	Risk	Motivation	Corrective action
Growing hens	Introduction of mites with new flock of growing hens	3	3	9	Chickens from production farms are caught early in the morning. If the production farm is infested, some chickens could carry the mites to the laying facility.	More attention for prevention and monitoring of mites during growing phase Switch lights on 1 h before collection in battery systems Switch lights on 1 h before and switch to blue light during collection in free-range and aviary systems Mix garlic in drinking water several days before transport
Growing hens	Introduction of mites with containers/crates	3	3	9	A large proportion of mites that are on the chicken during collection, will move from the chicken and hide in containers/crates. These crates are placed throughout the entire poultry house when new flock is introduced (high severity).	Containers/crates should be cleaned
Growing hens	Introduction of mites by driver	2	1	2	Mites could move from chickens onto the truck driver.	Driver should not enter poultry house
Growing hens	Introduction of mites by employees	1	3	3	Teams that introduce new flocks visit different farms and could thus carry an infestation from one location to the other.	Personnel should be clean upon arrival at the farm (clean clothing)
Material/ equipment	Introduction of mites via material or equipment	1	1	1	New equipment or maintenance tools will not have mites.	Equipment should be cleaned
Material/ equipment	Spread of mites between barns via shared material/equipment	3	2	6	Material or equipment from another barn could spread mites. Maintenance of the poultry house occurs regularly and at various locations leading to a relatively high risk.	Tools that could harvest mites such as a broom should be kept in the same barn and regularly cleaned or disinfected

Table 2 continued

Hazard category	Hazard	Likelihood	Severity	Risk	Motivation	Corrective action
Material/equipment	Spread of mites within a barn via material/equipment	3	2	6	Infested equipment could spread mites within a barn. Cleaning takes place regularly, leading to relatively high risk.	Regularly clean equipment that may harvest mites Keep equipment located centrally and attached to a board
Manure	Introduction of mites via manure conveyor belts	1	1	1	If manure storage is not close to the barn, the likelihood and severity are considered very small.	Clean manure conveyor belt regularly
Manure	Spread of mites between barns via cross-belts	3	2	6	Many mites can be encountered on manure conveyor belts. Between barns mites could spread where conveyor belts cross.	Regularly treat transfer points between manure belts and cross-belts with control agent
Manure	Spread of mites in poultry house via manure belts	3	3	9	In practice, many mites are encountered on manure belts. Mites could also hide on the inside and thus spread throughout the entire poultry house.	Automated control during transport of manure
Eggs	Introduction of mites via egg containers and pallets	3	1	3	Containers and pallets move from farm to farm. Containers/pallets have lots of hiding opportunities. However, these materials will not move further than the egg collection compartment on the farm (low severity).	Egg containers and pallets should be cleaned and disinfected by the packing station
Eggs	Introduction of mites via egg trays	3	1	3	Used trays have lots of hiding opportunities. However, trays will not move further than the egg collection compartment on the farm (low severity).	Use new trays Packing station should clean plastic egg trays
Eggs	Spread of mites between barns via egg cross-belts	3	2	6	Frequently, mites are encountered on eggs and egg remains. Cross-belts between main belts may carry mites from barn to barn. Especially transfer points between cross and main belts can harvest large mite colonies.	Treat transfer points between main and cross belts regularly Remove egg remains from conveyor belts.

Table 2 continued

Hazard category	Hazard	Likelihood	Severity	Risk	Motivation	Corrective action
Eggs	Spread of mites within poultry house via conveyor belts	3	3	9	The likelihood that mites hide on egg conveyor belts is relatively large, especially for woven belts.	Remove egg remains Keep conveyor belts free of dust Do not use woven belts Treat belts with silica dust
Manure aeration	Spread of mites via manure aeration pipes	3	3	9	With intermittent aeration, pipes offer a good hiding place for mites. After a period of non-aeration, mites could be spread throughout the barn if aeration is switched on again.	Use continuous aeration Blow silica dust through the aeration system
Manure aeration	Spread of mites via air mixing box	1	3	3	Mites could hide in ventilation shafts and end up in the air mixing box. This may result in spread of the mites throughout the barn. Likelihood is low, because there is only one air mixing box per barn.	Treat air mixing box with control agent.
Cadavers	Introduction of mites from infested cadaver dump	3	1	3	If the cadaver dump is located alongside the poultry house, mites could enter from here.	Do not place cadaver dump alongside the poultry house Provide a barrier of silica dust between cadaver dump and poultry house
Cadavers	Spread of mites via removal of cadavers	3	3	9	Cadavers that remain in the poultry house for an extended period (>24 h) offer excellent hiding places for mites. During cadaver removal, mites could drop on other surfaces and infest other places in the poultry house.	Remove cadavers the same day Collect cadavers in a clean plastic bag or bucket
Visitors/external personnel	Introduction of mites via visitors or external personnel	2	2	4	If visitors/external personnel have been in contact with mites, these mites could be transmitted to the next farm. Occasional visits should be limited to only a few places (medium likelihood and severity).	Prohibit visitors from poultry house as much as possible Visitors should shower, wear work clothing and a hairnet

Table 2 continued

Hazard category	Hazard	Likelihood	Severity	Risk	Motivation	Corrective action
Visitors/ external personnel	Spread of mites between barns via visitors or external personnel	2	2	4	Mites may land or crawl onto visitors/ external personnel during their visit. Mites may thus be carried to other barns that are visited.	Prohibit visitors as much as possible Change outer clothing per barn Possibly shower per barn visited
Visitors/ external personnel	Spread of mites within poultry house via visitors or external personnel	3	2	6	Similarly, visitors or external personnel may spread mites within the poultry house. They will probably visit only a limited number of places.	Do not allow visitors.
Poultry farmer/ employee	Introduction of mites via poultry farmer/employee	2	3	6	Farmers and employees could carry mites into the poultry house after contacts outside of their poultry house. Severity is high, because these persons move freely throughout the entire poultry facility	Showering, wearing work clothing and a hair net.
Poultry farmer/ employee	Spread of mites between barns via poultry farmer/employee	3	3	9	Farmer and employees touch hens and the housing system. Thus, there is a high likelihood of infestation and transport of mites to other barns. Severity is high, because these persons move freely throughout the entire poultry facility.	Change outer clothing per barn
Poultry farmer/ employee	Spread of mites within barn via poultry farmer/employee	3	3	9	Similarly, mites may be spread within a barn	Limit movement throughout the barn
Ventilation	Introduction of mites via intake of outside air that is infested with mites	2	2	4	Mites are extremely light (adults $\sim$ 0.075 mg; nymphs $\sim$ 0.01–0.025 mg). Mites that are in the direct surroundings of the poultry house could be sucked in through the ventilation system.	Keep direct surroundings of the poultry house free of bird nests that may harbour mites Do not use pressurized ventilation Air inlet through top of the roof

Table 2 continued

Hazard category	Hazard	Likelihood	Severity	Risk	Motivation	Corrective action
Ventilation	Spread of mites between barns via air ventilation currents	1	2	2	Air that is withdrawn from the barn via the ventilation fans, could be carried to other barns. However, the likelihood of this happening is small.	
Ventilation	Spread of mites within barns via air currents	1	1	1	Air currents within a barn are small and the likelihood for spread via these currents is low.	
Unproductive hens	Introduction of mites via hen collecting teams	1	3	3	Hen collection teams visit several farms and could transfer an infestation. Hen collection takes place only once per round (low likelihood), but personnel visit the entire barn (high severity).	Because hen collection staff visit several farms, they should arrive clean or take a shower Wear clean work clothing
Unproductive hens	Introduction of mites via containers or crates	1	3	3	Containers and crates used for transport of hens visit different farms and could carry an infestation. This only happens once per round (low likelihood), but containers/crates are used throughout the entire barn (high severity).	Containers/crates for transport of hens should be cleaned

hazards or reduce them to an acceptable level. In our study, a point, step or procedure was regarded as a CCP when the calculated risk had a value of 3 or higher on a scale of 1–9. Based on these criteria, 31 of the 41 hazards could be regarded as CCPs. Table 2 shows the results of the hazard analysis and identification of CCPs together with suggestions for control measures (corrective actions) for prevention of *D. gallinae* infestations and spread in poultry facilities.

Establishing critical limits

Establishment of critical limits for each CCP for infestation and spread of *D. gallinae* in poultry facilities is difficult. The logical aim is a critical limit of zero mites, because under optimal conditions, introduction of only a few mites could develop into a major infestation within a few weeks, especially when measures for effectively killing the mites are not available. However, the current literature does not quantify the relationships between mite infestation level and the risk factors present in and outside the poultry facility and poultry welfare/health.

Monitoring

Monitoring of CCPs is a matter of regular and thorough checking of possible entry routes for mites, either in relation to the structure of the poultry facility (barn design and immediate surroundings, ventilation system, etc.) or to those elements that regularly enter or leave the poultry facility (feed, manure, workers, etc.; Table 2). In addition to monitoring the flocks for poultry red mite presence it is of utmost importance that a subsequent quick response is possible to limit an increase of the mite population. Detrimental effects of *D. gallinae* and extra costs of mite eradication can be reduced when early awareness leads to isolation of restricted infected zones rather than a complete layer house (Mul et al. unpublished data). Due to the small size of the mite and vast number in which it aggregates, it is difficult for existing monitoring methods to provide accurate estimates of actual *D. gallinae* numbers (Nordenfors and Chirico 2001). At present, infestations of *D. gallinae* are mostly noticed when farmers or workers are bitten by *D. gallinae*, when mites are seen on the belt and feeders, clumps of mites are seen or when blood spots are detected on eggs. In the Netherlands, farmers were made more aware of *D. gallinae* infestations by using traps consisting of PVC tubing containing a wooden stick as an attractive hiding place for mites (Van Emous, personal communication). These traps were installed throughout the houses of the laying hens to identify the best location. The scale for scoring mite density (score 0–5; no poultry red mites—very many poultry red mites) is quite rough and insensitive to small changes in infestation level. Therefore cases of extreme infestations (higher than "many") remain difficult to quantify. Similar monitoring tools involve corrugated cardboard traps (Nordenfors and Chirico 2001), the ADAS monitoring trap and a trap consisting of a tube containing a fabric or cloth (Maurer et al. 1993). An alternative trap is treated with acaricides (Chirico and Tauson 2001; Lundh et al. 2005). Applying traps in the poultry house alone will not prevent the introduction and spread of *D. gallinae*, but is merely intended to detect infestations and monitor population trends. The farmer needs to be aware that improvements in hygiene (extra cleaning) will reduce the number of mites, but only for a limited period (Maurer, personal communication).

Corrective actions

An overview of possible corrective actions is provided in Table 2. Establishing corrective actions is a continuing process that should be repeated regularly. A farmer should check his farm by going through a checklist (see below) every few months. If the checklist indicates that corrective action is required, then this should be performed immediately in order to limit infestation and spread of *D. gallinae*.

Documentation and validation

From a practical point of view, farmers can plan in advance on a calendar when to go through the checklist. These checklists should be archived and well documented to show whether they are performed regularly and if necessary when and where corrective actions have been carried out. Documentation of date and place of treatment within the poultry facilities provide information concerning the effectiveness of treatments and indicate emergence of resistance to chemical control agents, especially when compared to records from other (nearby) poultry facilities. Validation of the corrective actions should be tested in research or farm trials. Collection of all available farm data on a regional and national basis may prove to be a valuable tool in the evaluation of corrective actions.

Checklist

As an extra management aid to farmers, we have prepared a checklist to help identify the most important points of action in the prevention of *D. gallinae* infestations and spread. This checklist was evaluated during an in depth workshop by five Dutch poultry farmers and briefly by 40 British poultry farmers during a course on *D. gallinae*. The five Dutch farmers identified the checklists added value and improved it. They owned family farms, their laying hens were housed in Dutch barn systems, in free range systems and in cage layer systems with between 20,000 and 100,000 birds. The Dutch farmers described their current prevention measures with regard to infestation and spread of *D. gallinae* at their poultry farm. Before providing the checklist, farmers were encouraged to discuss their measures. During the discussions, several preventive actions were suggested and added to the farmers own lists of preventive measures. Their suggestions included:

- Heating the henhouse to temperatures above 55°C.
- Regular washing down of the housing system.
- Treatment of the walls and floors with silica dust or carbolineum prior to introduction of the new hens.

Subsequently, the farmers received the checklist and were asked to fill it out to ensure its feasibility and usefulness and to indicate which measures were additional to their list of preventive measures made prior to receiving the checklist. The farmers' advice led to a new draft in which questions were removed and/or adapted. All five farmers indicated that the checklist had encouraged them to take new or alternative preventive measures including:

- Checking if all persons and material entering the farm were free of *D. gallinae*.
- Placement of cobblestones directly around the poultry facilities in order to reduce the number of pests that are potential carriers of mites.
- Treating the edges of the feeding troughs with silica dust or glue.

- Treatment of the manure conveyor belt.
- Checking the cleanliness of egg trays.
- Treating the air mixing box.
- Order *D. gallinae* free growing hens.
- Monitoring poultry facilities for *D. gallinae*.

The overall conclusion of the five farmers was that the checklist was potentially a useful tool.

In the UK, the checklist was adapted to the egg production system in the UK. Of the 40 British poultry farmers, 28 own battery units with between 40,000 and 100,000 birds, 8 poultry farmers own free-range units with between 3,000 and 8,000 birds and 4 poultry farmers produce eggs in barns with houses for between 5,000 and 8,000 birds. The most interesting remarks of the egg producers were that (1) UK egg producers never have hobby birds at the site, (2) corrugated roofs are always insulated, (3) only very few farms have a shower, (4) cadaver dumps are not used in the UK, (5) workers often wear the same overalls all week and do not change between units, and (6) the use of silica dust on conveyor belts was thought to be a useful recommendation. They mentioned that the checklist stimulated them to be more critical about the way they run their units and highlighted things that could be improved. All found the checklist feasible and useful. The adjusted and final checklist can be obtained through the first author.

Conclusions and discussion

Because poultry red mite is considered a major hazard to the health and welfare of poultry (Hegelund and Sørensen 2007), we elaborated on all possible risk factors for introduction and spread of *D. gallinae* by conducting an analysis using the HACCP method. In general, this method was evaluated as very helpful. We should note that the checklist is based on opinions of a limited number of experts and poultry farmers who were involved in this study. For example, it is possible that other experts would assign different likelihood and severity scores because of differing conditions in other regions or countries (e.g., differences in housing systems or environment in the vicinity of the poultry facility) or other judgements. Therefore, we consider it desirable to evaluate the developed procedures for other (European) countries. However, a farmer will only use the developed checklist when he is aware of the variety of effects of a *D. gallinae* infestation. Therefore, we argue that educative measures should be undertaken. For example, educative illustrations that show the possible points of introduction and routes of further spread of *D. gallinae* may be a good way to spread information. A major challenge remains in determination of critical limits of control points in unique situations, and, when and how to take action when such limits are exceeded. More quantitative, epidemiological studies are essential for the provision of clear targets for effective on-farm mite control. Additionally, more studies are needed that elucidate the various behaviors of *D. gallinae*, such as host seeking and aggregation. Insights obtained from such studies could be used to improve understanding of the various routes of infestation and spread. Moreover, this information will facilitate the development of alternative and environmentally safe control methods such as those based on the attract and kill principle (Stetter and Lieb 2000). Finally, although the HACCP process may seem cumbersome and extensive, we agree with an earlier statement that: “the concept is structuring and formalizing what truly good farmers are doing anyway” (after Ryan 1997, in: Noordhuizen and Frankena 1999).

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References

Baselga E, Drolet BA, Esterly NB (1996) Avian mite dermatitis. Pediatrics 97(5):743–745

Bonde MJ, Sørensen JT (2004) Herd health management in organic pig production using a quality assurance system based on hazard analysis and critical control Points. NJAS-Wag J Life Sci 52:133–143

Chauve CM (1998) The poultry red mite *Dermanyssus gallinae* (De Geer, 1778) : current situation and future prospects for control. Vet Parasitol 79:239–245. doi:10.1016/S0304-4017(98)00167-8

Chirico J, Tauson R (2001) Traps containing acaricides for the control of *Dermanyssus gallinae*. Vet Parasitol 110:109–116. doi:10.1016/S0304-4017(02)00310-2

Hegelund L, Sørensen JT (2007) Developing a HACCP-like system for improving animal health and welfare in organic egg production—based on an expert panel analysis. Animal 1:1018–1025. doi:10.1017/S1751731107000213

Kijlstra A, Meerburg BG, Mul M (2004) Animal-friendly production systems may cause re-emergence of *Toxoplasma gondii*. NJAS-Wag J Life Sci 52(2):119–132

Kilpinen O, Roepstorff A, Permin A, Nørgaard-Nielsen G, Lawson LG, Simonsen HB (2005) Influence of *Dermanyssus gallinae* and *Ascaridia galli* infections on behaviour and health of lying hens (*Gallus gallus domesticus*). Br Poult Sci 45(1):26–34. doi:10.1080/00071660400023839

Lundh J, Wiktelius D, Chirico J (2005) Azadirachtin-impregnated traps for the control of *Dermanyssus gallinae*. Vet Parasitol 130:337–342. doi:10.1016/j.vetpar.2005.02.012

Marangi M, Giangaspero A, Raele D, Assunta Cafiero M, Camarda A, Sparagano OAE (2008). Evaluation of poultry red mite susceptibility, *Dermanyssus gallinae* (Acarina: Dermanyssidae), to some acaricides in Italy. In: Abstracts of the BSP Spring, Trypanosomiasis/Leishmaniasis & Malaria Meetings. Newcastle upon Tyne, UK 168, 30 March, 2 April

Maurer V, Hertzberg H (2001) Ökologische Legehennenhaltung. Was tun die kleinen Vampire? DGS-Mag 40:49–52

Maurer V, Perler E (2006). Silicas for control of the poultry red mite *Dermanyssus gallinae*. Paper presented at the Joint Organic Congress, Odense, Denmark, 30–31 May (http://orgprints.org/7274/01/Maurer_Dermanyssus_Odense.pdf)

Maurer V, Baumgärtner J, Bieri M, Fölsch DW (1993) The occurrence of the chicken mite *Dermanyssus gallinae* in Swiss poultry houses. Mitt Schweiz Entomol Ges 66:87–97

Mayes T (1993) The application of management systems to food safety and quality. Trends Food Sci Technol 4:216–219. doi:10.1016/0924-2244(93)90154-3

Mayes T (1998) Risk analysis in HACCP: burden or benefit? Food Contr 9:171–176. doi:10.1016/S0956-7135(97)00055-8

Moro CV, Chauve C, Zenner L (2005) Vectorial role of some Dermanyssoid mites (Acari, Mesostigmata, Dermanyssoidea). Parasite 12:99–109

Mouchtouri VA, Anagnostopoulou R, Samanidou-Voyadjoglou A, Theodoridou K, Hatzoglou C, Kremastinou J, Hadjichristodoulou C (2008) Surveillance study of vector species on board passenger ships risk factors related to infestations. BMC Public Health 8:100. doi:10.1186/1471-2458-8-100

Mul M, Van der Gaag M (2003). Control of Salmonella at pig finishing farms with a farm decision tree. Proceedings of the 5th International Symposium on the Epidemiology and Control of Foodborn Pathogens in Pork, Crete, Greece, 149–151

Noordhuizen JPTM, Frankena K (1999) Epidemiology and quality assurance: applications at farm level. Prev Vet Med 39:93–110. doi:10.1016/S0167-5877(98)00151-2

Nordenfors H (2000). Epidemiology and control of the Poultry Red Mite, *Dermanyssus gallinae*. Doctoral thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden, 19–20

Nordenfors H, Chirico J (2001) Evaluation of a sampling trap for *Dermanyssus gallinae* (Acari: Dermanyssidae). J Econ Entomol 94:1617–1621

Nordenfors H, Höglund J, Tauson R, Chirico J (2001) Effect of permethrin impregnated plastic strips on *Dermanyssus gallinae* in loose-housing systems for laying hens. Vet Parasitol 102:121–131. doi:10.1016/S0304-4017(01)00528-3

Rayment GE (2006) Australian efforts to prevent the accidental movement of pests and diseases in soil and plant samples. Commun Soil Sci Plant Anal 37:2107–2117. doi:10.1080/00103620600817069

Sikes RK, Chamberlain RW (1954) Laboratory observations on three species of bird mites. J Parasitol 40:691–697. doi:10.2307/3273713

Steenberg T, Kilpinen O, Jespersen JB, Soler-Cruz MD, Vega-Robles C, Birkett M, Dewhirst S, Pickett J (2005) Advances in the development of novel control methods against chicken mites (*Dermanyssus gallinae*). Bull-OILB/SROP 28:89–91

Stetter J, Lieb F (2000) Innovation in crop protection: trends in research. Angew Chem Int Ed 39:1724–1744. doi:10.1002/(SICI)1521-3773(20000515)39:10<;1724::AID-ANIE1724>;3.0.CO;2-5

Sun YM, Ockerman HW (2005) A review of the needs and current applications of hazard analysis and critical control point (HACCP) system in foodservice areas. Food Contr 16:325–332. doi:10.1016/j.foodcont.2004.03.012

Wood HP (1917). The chicken mite: its life history and habits. USDA Bulletin No. 553