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Synanthropic diptera affecting layer poultry farms: a review

Dípteros sinantrópicos de importância para a avicultura de postura: uma revisão

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ABSTRACT: The poultry farm of posture is an economic activity of great relevance to Brazil. Health aspects of flocks of laying chickens, such as the occurrence of infestations by parasites and poultry pests, influence significantly the productivity indicators. In this context, the control of synanthropic diptera is one of the challenges of the poultry farmers and professionals of this area. In Brazil, the control of flies in poultry environments is based mainly on the use of pesticides, while other alternatives are less frequent. Among the flies' species most regularly found in poultry farms are the *Musca domestica*, *Chrysomya* spp., *Fannia* spp., and others. This review aims at compiling the literature on the occurrence, impact on poultry systems, biology, epidemiology and control of the species of synanthropic flies considered important for the Brazilian poultry industry.

KEYWORDS: poultry farm; *Musca domestica*; *Chrysomya* spp.; *Fannia* spp.; synanthropic diptera.

RESUMO: A avicultura de postura é uma atividade econômica de grande relevância para o Brasil. Aspectos sanitários dos plantéis de galinhas poedeiras, tais como infestações por parasitos e pragas avícolas, influenciam significativamente os indicadores de produtividade desse setor. Nesse contexto, o controle de dípteros sinantrópicos constitui um dos desafios de avicultores e profissionais da área. No Brasil, o controle de moscas em ambientes avícolas é baseado, sobretudo, no uso de pesticidas, ao passo que o uso de outras alternativas é menos recorrente. Entre as espécies de moscas mais frequentes em granjas avícolas de postura, destacam-se *Musca domestica*, *Chrysomya* spp., *Fannia* spp., entre outras. O objetivo desta revisão é realizar a compilação da literatura existente sobre a ocorrência, o impacto nos sistemas avícolas, a biologia, a epidemiologia e o controle das espécies de dípteros sinantrópicos consideradas importantes para a avicultura de postura brasileira.

PALAVRAS-CHAVE: granjas; *Musca domestica*; *Chrysomya* spp.; *Fannia* spp.; dípteros sinantrópicos.

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INTRODUCTION

Muscoid diptera are considered important vectors of pathogens for humans and animals due their eating and reproductive habits and synanthropic behavior. They have wide movement and ability to fly long distances (BARREIRO et al., 2013; BLAAK et al., 2014; ALMEIDA et al., 2014; CHAIWONG et al., 2014). Diptera is one of the major orders within the class Insecta, with more than 120 thousand species described. The main morphological characteristics of diptera are the presence of a pair of functional wings in the mesothorax, the transformation of the second pair of wings in halteres and the development of feeding mouth structures (TRIPLEHORN; JOHNSON, 2005; YEATES et al., 2007; TAYLOR et al., 2010).

The adult diptera or their larval may use substrates such as food debris, animal carcasses, broken eggs and accumulated feces for their development and survival (NUORTEVA, 1963; PECK; ANDERSON, 1970; PRADO, 2003). They are relatively small insects and have soft body of great sanitary importance, since they are biological and mechanical vectors of pathogens of diseases that affect man and domestic animals, besides significant cause discomfort when present (PRADO, 2003; TRIPLEHORN; JOHNSON, 2011).

In modern egg production systems, laying hens are housed in high densities, leading to the accumulation of manure on the surface under the cages. This substrate is ideal for the development of synanthropic flies (LOPES et al., 2008). According to NORTH; BELL (1990), a laying hen weighing approximately 1.8 kg produces an average of 113 g of moist feces per day, enough to support at least 100 larvae of *Musca domestica*.

Main diptera associated with excrement from poultry farms

The muscoid flies, especially those of Muscidae, Fanniidae and Anthomyiidae families, are among the insects most commonly associated with human and animal production environments (CARVALHO et al., 2002). According to POVOLNY (1971), the most commonly found species in manure and near of this substrate in poultry farms is *M. domestica* (Diptera: Muscidae). In addition to *M. domestica*, other species and genus can be found, such as *Stomoxys calcitrans* (Diptera: Muscidae), *Chrysomya* spp. (Diptera: Calliphoridae) and *Fannia* spp. (Diptera: Fanniidae) (AXTELL; ARENDS, 1990; LOMÔNACO; PRADO, 1994; AXTELL, 1999; LOPES et al., 2007).

LOMÔNACO; PRADO (1994), in a survey conducted in layer poultry farms in Uberlândia, Minas Gerais, Brazil, concluded that *M. domestica* is the most abundant dipterous in this type of exploration and also verified the presence of *Fannia pusio* and *Fannia trimaculata* in the aviaries visited. BRUNO et al. (1993) found *Fannia canicularis*, *F. trimaculata* and *F. pusio* in avian establishments in the state of São Paulo, Brazil. In 2007, LOPES et al. (2007) in a study performed in a layer poultry farm in the state of São Paulo verified other species besides *Fannia* spp., such as specimens of *M. domestica*, *Chrysomya megacephala*, *Hermetia illucens* (Diptera: Stratiomyidae) and diptera of the families Sepsidae and Syrphidae, in which the *M. domestica* was the most prevalent species. However, AVANCINI; SILVEIRA (2000) carried out a research in poultry facilities in southeastern Brazil and found, more frequently, *Muscina stabulans* (Diptera: Muscidae), *M. domestica*, *Chrysomya putoria*, *C. megacephala* and *S. calcitrans*. MONTEIRO; PRADO (2000), working in layer poultry farms in the state of São Paulo, found the diptera *C. putoria*, *M. stabulans*, *M. domestica*, *F. pusio* and flies of the family Sepsidae. BORGES (2006), in a study carried out in a poultry farm in the municipality of Igarapé, Minas Gerais, found the species *Drosophila repleta* (Diptera: Drosophilidae), *M. domestica* and *C. putoria* as the most abundant. In poultry establishments in the United States, the most frequently reported adult species are *M. domestica*, *M. stabulans* and *S. calcitrans* (LEGNER; OLTON, 1967). LOPES et al. (2008) reported the presence of only adult stages of *D. repleta* on posture farms and no larval stages were found in manure. FERNANDES et al. (1995) also found diptera of the family Drosophilidae in a poultry farm in Uberlândia, Minas Gerais.

Biology and epidemiology

Knowledge regarding the biology of the diptera species existent in the poultry environment is essential for the establishment of control strategies. These insects present holometabolism and their larval stages differ completely from the adult ones. Moreover, diptera can be ectoparasites in the larval or adult phases, turning the behavior as a parasite in both stages difficult (GUIMARÃES et al., 2001; TRIPLEHORN; JOHNSON, 2011; TAYLOR et al., 2010). They are mostly oviparous; some muscoid species deposit their eggs in plant and animal organic matter (D'ALMEIDA, 1989). In addition, diptera have preference for fresh feces, since they are considered an excellent means of larval development (PUTMAN, 1983; D'ALMEIDA, 1989). Factors such as temperature, humidity and precipitation are determinant in egg development. Hatching larvae usually require adequate water or moisture content to survive. Before reaching the pupal stage, the larvae pass through three to five stages, called L1, L2, L3, L4 and L5 (GUIMARÃES et al., 2001; PRADO, 2003). The biological cycle can last 30 days or less to even years in some rarer species (RAFAEL et al., 2012).

Some authors, such as BICHO et al. (2004), report that the problem of pathogens being carried by flies tends to increase significantly as the diptera population often moves to the cities adjacent to the poultry farms, increasing the transmission of pathogens. In general, it is observed that infestation by diptera in layer poultry farming generally increases in the summer, being associated with climatic variations such as precipitation and temperature, as suggested by research about the seasonality and population dynamics (MENDES; LINHARES, 2002; BORGES, 2006; LOPES et al., 2008). In the research by MACEDO et al. (2011), the highest number of dipterous collected occurred at temperatures between 21 and 25ºC in the months of January to April, representing 50% of the 705 captured specimens.

Several studies have stated that the occurrence of dipterans is directly related to the humidity of the manure of aviaries. The growth of Diptera populations is significantly influenced by the quality, humidity and temperature of manure (AXTELL, 1999). PECK; ANDERSON (1969) reported that larvae of *M. domestica* predominate in chicken manure with humidity above 70%. However, STAFFORD; BAY (1987) have described that the range of 70–79% moisture is the best for the development of *M. domestica*. BRUNO et al. (1993), when visiting several poultry establishments, verified that *M. domestica* reproduces in manure with relative humidity of 45 to 64%. In a study conducted by LOPES et al. (2008) in poultry farms in the state of São Paulo, the average manure moisture was estimated to be 61.21%, and significant dipteran abundance was found. Figure 1 shows the manure of an aviary with excess moisture, which favors the development of synanthropic diptera.

In addition to the mentioned factors, other aspects connected to the occurrence of synanthropes in facilities used in the poultry industry are also still important from an epidemiological perspective. Other elements may influence the seasonality of arthropods too, such as food availability, space, predation, genetic components, social interaction and dispersal capacity of each species (PINTO-COELHO, 2000).

Impact on poultry systems

The transmission of pathogens and discomfort to the animals are among the main problems posed by the flies, which may reflect on the decrease in production rates of eggs (GREENBERG,

Figure 1. Poultry houses containing manure with excess moisture and presence of diptera larvae (indicated by the arrows).

1971; BORGES, 2006; LOPES et al., 2008; BARREIRO et al., 2013; BLAAK et al., 2014). There are reports of diptera such as *M. domestica* and *C. megacephala* carrying helminth eggs of the genus *Ascaris* (Ascaridida: Ascarididae), *Toxascaris* (Ascaridida: Toxocaridae), *Toxocara* (Ascaridida: Toxocaridae), *Trichuris* (Trichocephalida: Trichuridae) and *Capillaria* (Trichocephalida: Trichuridae) (OLIVEIRA et al., 2002; HADI, 2013). In addition, some viruses and bacteria of importance in the poultry industry can be transmitted and carried by some species of diptera, as some authors emphasize. OLIVEIRA et al. (2006) have identified, in adults of *M. domestica* and *C. megacephala*, some species of Enterobacteria such as *Escherichia coli*, *Citrobacter* sp., *Proteus mirabilis*, *Morganella* sp., *Klebsiella* sp., *Pseudomonas* sp., *Enterobacter* sp. and *Salmonella agona*. FÖRSTER et al. (2007) performed a pilot study in which synanthropic flies belonging to 12 species of 12 genera were caught for the isolation and identification of microorganisms, that might have been possibly transmitted by these flies. Among them, a series of pathogenic *E. coli* strains (EAEC, EPEC, ETEC) was identified. CÁRDENAS; MARTÍNEZ (2004) observed that some protozoan species, such as *Blastocystis hominis* (Blastocystida: Blastocystidae), *Giardia lamblia* (Diplomonadida: Hexamitidae) and *Cryptosporidium* spp. (Eucoccidiorida: Cryptosporidiidae) were transported by *M. domestica* in Lima, Peru.

There are also reports of losses in poultry establishments due to the stress caused by the painful stings of *S. calcitrans*, especially in the months most favorable to infestation (ANDERSON; TEMPELIS, 1970). BICHO et al. (2004) state that diptera populations in poultry flocks, above the level of economic damage, cause some problems due to the habits of defecating and regurgitating on the surfaces, leaving stains on the farm equipment.

Diptera also represent obstacles to full compliance with quality management and self-control programs, in which their presence is considered inappropriate because they eliminate excreta and regurgitate on structures, equipment, lamps and eggs. Due to the porous characteristic of eggshell, the eliminate excreta above them can contaminate it by bacteria of the genus *Salmonella*, which causes commercial devaluation of the eggs (BORGES, 2006).

Control

The control of diptera population is highly recommended due to the damage caused by the flies (BORGES, 2006). Several strategies can be used to control infestations by synanthropic diptera associated with the layer poultry environment. Such strategies can basically be grouped into chemical, mechanical or biological methods. In Brazil, the chemical methods, which involve the use of insecticides, are those of more widespread use. Thus, adulticidal products are applied to places where the presence of adult diptera is undesirable

(PAIVA, 2000). However, one should avoid applying these products directly on the manure, because some substances may also act on insect predators of flies, which act as a form of biological control and are considered of beneficial effect (AXTELL, 1999). Aerosol applications of adulticide products should be avoided and may sometimes be necessary in crisis situations (AXTELL, 1999). Moreover, there are larvicidal products that are included in the feed in order to promote larval combat (PAIVA, 2000). Among these larvicidal substances, cyromazine, an insect growth regulator, has low effect on predatory beetles and predatory mites in manure (AXTELL; EDWARDS, 1983).

The use of pesticides should ideally be performed strategically at times when manure takes more time to dry, such as in rainy seasons, in new batch occasions and in phase changes (PAIVA, 2000). Table 1 shows the main pesticides registered by the Ministry of Agriculture, Livestock and Supply, used in the control of diptera in the Brazilian poultry industry. These data were obtained from the Compendium of Veterinary Products (Compêndio de Produtos Veterinários — CPVS), of the National Union of Animal Health Products Industry (Sindicato Nacional da Indústria de Produtos para Saúde Animal — SINDAN, 2016), which is available on the website of the SINDAN. Such products have expressly indicated their pharmaceutical specialties for use in combating Diptera associated with poultry environment. It is noted that most of these products are indicated for the control of *M. domestica* and *S. calcitrans*, while none of them mention the diptera of the Calliphoridae family, which are of great occurrence in poultry farms. However, several other chemical bases indicated for the management of other species such as cattle, pigs and equines are erroneously and empirically used by farmers and veterinarians in poultry farms.

In a study conducted in Punjab, Pakistan, to evaluate the resistance of *M. domestica* to insecticides, very low levels of resistance to deltamethrin were observed compared to pyrethroids. For the group of organophosphates, very low levels of resistance to profenofos were found (ABBAS et al., 2015).

The indiscriminate and non-strategic use of pesticides causes several species, such as *M. domestica*, to develop resistance (SCOTT; GEORGHIOU, 1984). The emergence of resistance causes the need of development of new classes of pesticides, which increases the final price of chemical control (KEIDING, 1999). Regular monitoring of insecticide resistance and integrated management plans on poultry farms is necessary to prevent the development of resistance (ABBAS et al., 2015). In addition to the development of resistance in target insects, the non-strategic use of insecticides can cause mortality of beneficial insects, such as the natural enemies of pest-insects (BORGES, 2006).

The search for chemical-free alternative control methods has been a global trend in the agricultural and veterinary areas, with the aim of producing better quality food (MORRONE et al., 2001; REZENDE et al., 2013). Mechanical methods

Table 1. Pesticides available in the Brazilian market for control of flies in poultry farms.

Active principle	Commercial name	Target	Manufacturer recommendations
Propoxur[1]	Bolfo® Pik Pulga®	*Musca domestica*, *Stomoxys calcitrans* (adulticidal)	Pour on the premises, avoiding contamination of drinking fountains and feeders. Topical and environmental use
Carbaryl[1]	Farmaril®	*Musca domestica*, *Stomoxys calcitrans* e other flies (adulticidal)	Pour on the manure, around the dunghill. Dose of 1 kg for every 200 chicken
Carbaryl[1] and Cipermetrina[2]	Talfon Top®	*Musca domestica*, *Stomoxys calcitrans* (adulticidal)	Apply on bedding and animal housing (50 to 100 g per m^2)
Metomil[1]	Vetomil®	Flies in general (adulticidal)	Pulverization. Dose of 1 L of product for every 10 L of water
Metrifonato[5]	Tira-Berne®	Flies (larvicidal)	Spray the facilities weekly. It is also recommended for the treatment of lateral lands of the sheds. Beware of chicks
Ciromazina[4]	Ciromazin 1%®	Flies (larvicidal)	500 g of product per ton of feed in continuous use for five weeks and suspend for five weeks. Grace period: poultry may be slaughtered three days after the last application. Do not administer to poultry producing eggs for human consumption
Diflubenzuron[3]	Difly®	*Musca domestica* (larvicidal)	Provide the treated feed (20 g / ton of feed) for three consecutive weeks and rest one week each month. Prior to the start of treatment remove existing manure and apply adulticides to the shed

Chemical class: [1]carbamate; [2]pyrethroid; [3]benzamide; [4]triazine; [5]organophosphorus.

have the goal of maintaining manure driest possible and free of waste. Thus, animal carcasses and broken eggs can also attract or encourage the development of diptera (AXTELL; ARENDS, 1990). These strategies are related to the global management and structure of the hen breeding activities. Manure moisture should be monitored daily concurrently with the verification of leakage points from drinking fountains and pipes. If high humidity is detected, corrective measures should be taken to prevent the formation of adult diptera population that will only be eliminated through the use of chemicals or after the lifetime of these insects (20 to 45 days) (PAIVA, 2000). Drying of the manure can be accomplished by spreading the wet part over the dry part or by using calcium oxide. In addition, the vegetation around the sheds should be kept low to facilitate ventilation. Large vegetation can only be used as a barrier between groups of sheds. Regarding the management of manure, there is also the possibility of implementing automated removal of this residue by collecting conveyors, which prevents the development of flies in the absence of substrate and result in more efficient poultry property per m^2 (Fig. 2) (FRANÇA; TINÔCO, 2014).

Carcasses must be properly managed through appropriate burial pits, incineration or composting. Egg debris may also be destined for pits or composting. The awareness of the farm employees is also of great importance and is obtained by imparting knowledge on insect control. This education should be continuous due to labor turnover in poultry establishments (PAIVA, 2000).

Figure 2. Poultry houses with manure removal through mechanical treadmills.

Biological control in Brazil has been increasing due to problems generated by the indiscriminate use of chemical insecticides (FERNANDES et al., 2010). Biological control refers to the control of diptera populations through their predation by other invertebrates in poultry manure. These invertebrates predate larval stages of the flies, keeping the population of these insects at a lower level (AXTELL, 1999). Keeping the manure as dry as possible contributes to the development of a heterogeneous fauna in manure, resulting in low populations of diptera such as *M. domestica*. Therefore, the ecological interaction of diptera, especially the larval and pupal stages, with mites from the genus *Macrocheles* (Acari: Macrochelidae) and *Fuscoropoda* (Acari: Uropodidae); with Coleoptera of the family Tenebrionidae *Alphitobius diaperinus* (Fig. 3); and microhymenoptera parasitoids may influence their occurrence in poultry farms, according to preliminary studies (DESPINS et al., 1988; AXTELL; ARENDS, 1990; BORGES, 2006; MONTEIRO; PRADO, 2006; LOPES et al., 2007).

Biological control can be stimulated by leaving part of the manure removed during the production period or by placing a layer of old manure (with predatory arthropods) at the start of a new batch (PAIVA, 2000). Recently, several studies have reported the possible use of entomopathogenic fungi in fly control, as in the case of *Metarhizium anisopliae* (FERNANDES et al., 2010). The release of parasitoids from poultry farms to control flies has also been reported, such as *Muscidifurax raptor* (Hymenoptera: Pteromalidae) (RUTZ; AXTELL, 1979). Encouraging the use of biological control through manure management is essential in fly control programs in poultry systems (AXTELL, 1999).

One of the major concerns in fly population management is at monitoring the potential of re-invasion and dispersion. Practical methods of surveillance are focused on adults and include direct observations (grids and fly-attraction techniques),

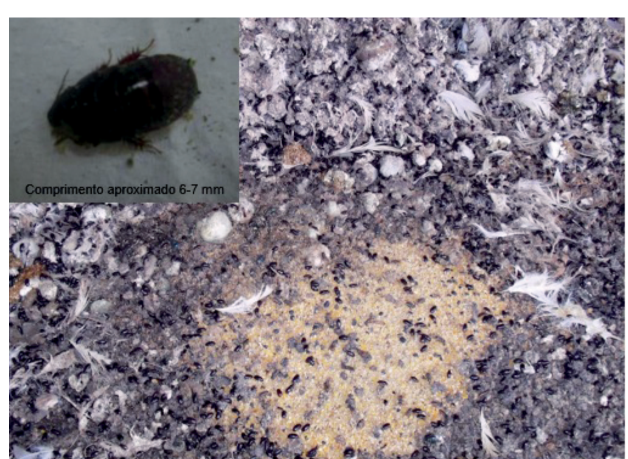

Figure 3. Poultry houses with presence of lesser mealworm (Coleoptera: Tenebrionidae), *Alphitobius diaperinus*.

traps, sticky traps, light traps, bait traps, vacuum scans, and fly spots counted on paper. Many different techniques and baits for fly sampling have been reported with considerable variation in results (BURG; AXTELL, 1984; AXTELL; ARENDS, 1990).

In order to obtain a better result, chemical, mechanical and biological control measures should be used in a coordinated manner, comprising what many authors designate as integrated management. This form of control aims to keep insect populations below the threshold of economic damage and causing the least possible damage to the agro-ecosystem. Therefore, pest insects will not be eradicated, but kept at an acceptable level of presence and below the cost of control actions (BORGES, 2006). Since the mid-1960s, the United Nations Food and Agriculture Organization (FAO) has recommended integrated management as a strategy of choice for pest control, as this is an integration of the 15 available control techniques with a minor disturbance to the agro-ecosystem, thus encouraging natural control mechanisms (FAO, 2017).

CONCLUSION

The presence of synanthropic diptera in poultry farms and surrounding areas causes significant sanitary and economic impact on poultry farming. The implementation of an effective control program requires knowledge of biological and epidemiological aspects of the species of flies found in the poultry environment, which raises the need to develop additional studies on the factors related to the occurrence of infestations. In addition, in the control programs, chemical, biological and mechanical methods must be used concomitantly, which is what is called integrated control.

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