



Integrated fly management for control of house fly (Diptera: *Musca domestica*) in layer chicken farms: A review

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ABSTRACT

The house fly, a major arthropod pest, causes great annoyance to birds, farm labourers and public residing in the vicinity of farms. The problem of house menace at times reaches beyond threshold level in poultry farms, particularly, in caged layer farms, leading to public health issue. Control of this challenging pest largely relies on various classes of insecticides. Realizing the inherent limitations with insecticide application over the years, much emphasize is being given for fly control through integrated fly management in the recent times. Hence, social and public health problems associated with house fly population, and various modules of integrated fly management such as biology of flies, factors responsible for fly problem, fly monitoring, litter management; farm sanitations, insect growth regulators, insecticide application, plant derivatives, entomopathogenic fungi and entomopathogenic nematode, bacterial pathogens, parasitoids and predators are discussed in this review.

Key words: Fly management, House fly, *Musca domestica*, Poultry farms

Poultry industry has witnessed a remarkable growth in the last two decades worldwide. This can be attributed to technological advancement in feeding, disease prevention and management. However, in the recent years, a problem confronting the poultry industries is house fly menace, especially in tropical countries like India. House flies feed on food stuff as well as decaying organic waste. Since they lack biting mouth parts, they cannot ingest solid food materials and hence, they regurgitate their crop fluid onto the material to liquefy. The liquefied material will then be imbibed, this activity enabling them to act as potential mechanical vector for many pathogens (Howard 1911). At Namakkal district, a poultry layer belt of Tamil Nadu, India, the fly menace has become a perennial problem. This situation prompted to work on fly control since 2000. This review is written with an aim to disseminate the knowledge we gained to the scientific community who are facing similar problems in other parts of India, tropical region as a whole.

Social and health problems associated with house flies

House flies are known to transmit more than hundred pathogens to man and animals. They are responsible for outbreak of amoebiasis, salmonellosis and helminthic infections (pin worm) in man. As for animal diseases, it acts as intermediate host for chicken tapeworm

Choanotaenia infundibulum (Ponnudurai *et al.* 2003), eye worm *Thelazia* spp. and *Stephanofilaria assamensis* in cattle, and Habronemiasis in horse (Shono *et al.* 2003 and Sasaki *et al.* 2000). *Musca* spp. is also considered as an important wound myiasis producer in sheep and cattle. Accidental ingestion of larvae with food material may cause pseudomyiasis in man (Hill 2005). Apart from disease transmission, high population of house flies in poultry farms causes irritation and great annoyance to the birds and farm workers. They have a tendency to regurgitate the crop fluid and defaecate on the surface where they rest. These vomit drops and faecal material of the flies cause erosion of cages, reduced illumination and dirty eggs.

House flies are capable of flying 6 km from the breeding site. They often enter human dwellings located in the vicinity of the poultry farms and produce discomfort to the people in many ways. During fly seasons, they do not allow the people to eat and sleep as they are found everywhere in the house. As a result, in many places the people have approached the authorities to resolve the fly problem. There are instances in which the people, who are unable to bear the fly menace, have blocked the highways if owners have failed to take measures for fly control.

At present, the house fly control in poultry farms is accomplished through insecticidal spray and insect growth regulators. The annual cost of insecticide for house fly control in poultry farms in USA has been estimated to be over 1.6 million US dollar (Crespo *et al.* 1998). As continuous use of chemical insecticides is likely to cause adverse effect on environment and mankind, it would be

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appropriate to practice integrated fly management for fly control.

Integrated fly management

Biology of house flies: Biology of the target insect is essential for sustainable control. A single female lays about 1,000 eggs in 5–6 batches, which hatch in 24 h. The larvae undergo 3 moultings in 3–5 days and then become pupae. Adult flies emerge in 4–5 days and begin to lay eggs in a few days of emergence. Under ideal condition (temperature 30° C and relative humidity 80%), the whole life cycle is completed in 10–12 days, whereas in winter the life cycle is prolonged. The adult flies live a few weeks in summer, but they live 3 months in cool weather (Soulsby 1982).

Factors responsible for fly problem in poultry farms: The climatic conditions that prevail in tropical countries like India is one of the main reasons for high fly population. Together, the droppings accumulated under the cages attract the flies for oviposition and provide suitable substrate for larval development. If the litter materials are in dry condition, there will be no fly menace. Because dry litter will not only discourage fly breeding but also create suitable condition for proliferation of natural enemies of house flies. Fly abundance in caged layer facilities is determined mainly by manure water content through direct positive effect on fly oviposition and larval survival, while negative effect on fly predators and parasitoids (Fatchurochim *et al.* 1989). Leakage of water through worn nipples causes wet litter problems and which serve as good medium for fly breeding. Similarly, improper disposal of broken eggs, dead birds and spillage of feed stuff will favour the fly breeding.

Monitoring of fly population: Monitoring of fly population is corner stone in the house fly control programme. Spot card method is a standard technique for monitoring fly population in poultry farms (Axtell 1970). The spot card is a 5" × 3" size white paper pinned onto the thermocole. Approximately 5–10 cards are placed inside the shed at different locations, depending upon the size of the shed and kept undisturbed for 24 h. After 24 h, all the cards are collected and counted the spots that are made by the flies (Ponnudurai and Harikrishnan 2011). As per literature, in temperate countries the spot cards are placed for 7 days in the farm, but in tropical countries the same methodology could not be adopted owing to high fly population. Therefore, the exposure time of card has been reduced to 24 h; lest it would have been difficult to count the spots. Burg and Axtell (1984) used baited jugs for monitoring of fly population and in this method, fly intensity is monitored by number of dead flies in the jug.

In Tamil Nadu, Ponnudurai and Harikrishnan (2011) recorded high fly population from March to June, and August and October, while during winter (November to February) the fly intensity was very low. Temperature and relative humidity are the main abiotic factors that usually influence intensity of fly population (Barth 1986). Fly population tend to be lower during winter (Stafford and Collison 1987). During winter when the temperature is very

low, the developmental process in house fly may be slowed and as a result length of the life cycle is extended than time taken during the summer. Consequently, the fly population appears to be below the nuisance level.

The fly intensity is always high in narrow caged houses than high rise caged layer house due to poor ventilation. Because of high moisture content of manure due to poor cross ventilation, more numbers of flies are attracted to lay eggs, whereas the dry manure in high rise system does not attract flies, thus resulting in low fly intensity (Tamilam *et al.* 2008).

Manure management

Moisture content of manure: Litter management plays an important role to keep the fly population below the threshold level in poultry farms. The moisture content of manure must be below 50% and if moisture level goes above 60%, the fly population will reach the nuisance level, but the moisture level above 80%, will have negative impact on fly oviposition (Stafford and Bay 1987). Therefore, it is necessary to keep the manure in dry conditions by maintaining good cross ventilation. This can be ensured through removal of unnecessary vegetations grown around the shed and cleaning of cobwebs on the mesh.

Nipple leakage in the waterline and watery droppings in birds are often attributed to increase in moisture content of the manure. The high moisture content of the manure favours fly breeding, resulting in fly menace in poultry farms. When the birds fed with high salt containing feed, the water intake of the bird will be more and thus leading to watery droppings. In addition, feed ingredients like molasses, soya and wheat also cause watery droppings. So the moisture content of the manure can be controlled by replacement of worn out nipples and minimizing the inclusion of diarrhoea inducing feed ingredients in the feed formulation. The salt content of feed must be optimum. If wet areas occur due to above said reasons, the fly ash or lime powder can be sprinkled over that to absorb moisture. The watery droppings were frequently observed in grower birds due to increased intestinal motility in growing birds. As a result of which, high fly intensity was recorded in grower shed. Hence, necessary steps must be undertaken to minimize moisture content of the droppings in grower farms (Ponnudurai and Harikrishnan 2011).

Removal of manure: Frequent removal of manure in poultry farms is practically not feasible as it involves high labour cost. However, it can be removed at least twice a year. According to the study carried out in Tamil Nadu, India, the fly population begins to rise from middle of the March following advent of summer with mild rainfall. This may be due to high rate of fly emergence from the over wintered pupae on returning of suitable conditions. Given the seasonal influence on fly population, it would be better to remove manure during February as first removal and second removal can be done, in August, before onset of monsoon in southern part of India (Ponnudurai and Harikrishnan 2011). Similarly, a single removal of manure

prior to the earliest date of fly activity was found to be the most effective means of controlling fly populations and also favours beneficial manure breeding species (Legner and Dietrick 1974).

It is important to note that the manure should not be removed completely; instead 15 cm height of manure must be left in the pit. This old manure facilitates absorption of moisture in the fresh droppings and thereby fly oviposition is prevented. In addition, old manure provides suitable condition for breeding and survival of natural enemies of house flies like predators and pupal parasitoids (Legner *et al.* 1973, Meyer *et al.* 1987). The manure does not accumulate evenly, but rather builds into peaks and valleys. Hence, the elevated manure gets dried better in most situations. While the pad does not actually absorb significant moisture, it elevates manure and improves drying, probably decreasing the manure's suitability for fly development (Mullens *et al.* 1996b). Manure should not be removed during high fly season. Because high moisture content of fresh droppings may favour the fly breeding. The removed manure should be heaped some distance away from the farm premises and if possible heap can be covered with tarpaulin. While doing so, the fly larvae and eggs would be destroyed by the heat generated from the manure heap.

Farm sanitations: Farm sanitations like proper disposal of broken eggs and dead birds, and absence of feed spillage will have telling effect on fly population. Quisenberry and Foster (1984) stated that sanitation had a direct effect on fly numbers. To maintain high sanitation in poultry farms, a concrete pit can be constructed to dispose of dead birds and other degradable wastes generated in poultry industry.

Chemical control

Insect growth regulator (IGR): In house fly control programme, preventive measure against larval stage is the best and early approach to find a tangible solution for the fly problem. As larvae of house fly is negatively phototropic, they are usually found in 4" deep from the surface of the manure. Therefore, spraying of any insecticide will be a futile exercise because the insecticide cannot percolate to reach out the larvae which lie in 4" deep. Hence, larval control using insect growth regulators like cyromazine 1% and diflubenzuron 25% are being commonly adopted in poultry farms. The advantage of using IGR is the genesis of resistance is slower than insecticides. In the *in vitro* trials, the highest concentration of Cyromazine 0.25% had caused 90% mortality of larvae, while lower concentrations of 0.05 and 0.1% were able to produce 40 – 78% mortality (Ponnudurai *et al.* 2009).

It was observed that when adult flies are found in more numbers in the farms, within a week time one can expect high numbers of maggots in the manure. As adult flies begin to lay eggs in 4 – 5 days of emergence, control measures should be initiated against adult flies and developing larval stages in the manure as well. The larval density in the manure can be determined by counting number of larvae in the manure sampling (each 100g) obtained from different

locations. For control of larvae, birds must be fed with cyromazine 1% incorporated feed @ 0.5 kg / tonne of feed (0.05%) for 6 weeks continuously. Cyromazine can also be sprayed on the manure. Another insect growth regulator namely diflubenzuron, which is commonly used against agricultural pest, can be sprayed over the litter material in poultry farms. But when it was used as feed through like cyromazine, its metabolites were observed in eggs (Harikrishnan *et al.* 2004)

Insecticides: Poultry farmers rely heavily on insecticides for control of adult flies. Organophosphate compounds were used frequently because they are readily available and relatively inexpensive. Short residual activity, necessitating frequent reapplication, is the disadvantage. Treatment with synthetic pyrethrins tend to increase the time interval between applications, but the products are more expensive (Townsend 1977).

Various classes of insecticides are used for control of adult flies, particularly if they are found in large numbers. Insecticides are usually sprayed on the surface where the flies rest, viz. floor, cage, pillar, wall and wire mesh, but should never be sprayed on the manure because they will destroy beneficial predators and parasitoids (Morgan *et al.* 1966). The major disadvantage of insecticide based fly control programme is environmental pollution, development of resistant strains and residues in the egg and meat (Haris *et al.* 1982). To tide over above limitations, insecticides must be used judiciously and in rotational manner, instead of using the same class of insecticide for a prolonged period.

Insecticides such as dimethoate, fenthion, permethrin were found to be cost effective and provided the best level of control, while dichlorvos was not cost effective and produced only marginally acceptable level of control (Quisenberry and Foster 1984). In addition, insecticides like cypermethrin, deltamethrin, fenvalerate, chlorpyrifos and carbamates were also widely used for control of flies in poultry farms.

Nowadays, insecticide impregnated baits are being frequently used rather than direct spraying of insecticides for control of adult flies. Insecticides like methomyl 40%, cartap 50% and spinosad were mixed at the rate of 1.6% (0.4 g) with fly attractants jaggery (12 g), rice bran (12.6 g) and to which small quantity of water was added (Burg and Axtell 1984). The mixture was kneaded until get a consistency enough to sprinkle it on the wet gunny bags. The bait laden gunny bags were then placed in different locations. Immediately flies were attracted and killed. The dead flies and left over bait should be disposed of carefully (Tamilam 2008).

Biological control

Botanical insecticide: Plant extracts and essential oils are being widely used as insecticides for control of animal and crop pests. Ponnudurai *et al.* (2007) reported that herbal formulation containing ingredients such as *Azadirachata indica* (neem), *Cedrus deodara* (lemon grass oil), *Brassica compestris* (mustard), *Ocimum sanctum* (tulsi) and palm

rose oil showed 90 – 96% fly repellency for 5 – 6 h. Suba *et al.* (2001) observed 70 – 80% mortality of *Musca domestica* treated with ethanolic extracts of neem kernel, while Desai (1997) observed variable effects when 10% aqueous solution of *Annona squamosa* seed was used against adult flies under laboratory condition.

Suba *et al.* (2001) observed 4.4 and 12% larval mortality when they were seeded into the dropping collected from the birds fed with 0.0156 and 0.1% ethanolic extracts of neem incorporated feed. In contrast, ethanolic extracts of neem leaves 0.1 and 0.2% had caused above 90% larval mortality in contact method. Azadirachtin extracted from neem seed acted as insect growth regulators against larvae of *Musca domestica* and the LC₅₀ and LC₉₀ were 10.5 and 20.2 ppm respectively (Millar and Chamberlin 1989). The lectin extracted from *Ricinus communis* (castor oil plant) had caused higher mortality in house fly with LC₅₀ value of 353.4 ppm. The extract also caused significant reduction in the pupal development (Alvarez Montes de Oca *et al.* 1996). Herbal fly repellent (keetguard-liquid) at the dilution 1:20 and 1: 40 produced a significant fly repellent effect for 2–6 h, besides it also showed larvicidal effect against third stage larvae (Gopal *et al.* 2014).

Plant essential oils can be used as green pesticide for control of house flies. Essential oils obtained from various plants possess larvicidal, pupicidal and adulticidal properties while some of them may be repellents, antifeedants, ovipositional deterrents and insect growth regulators for house flies. Lipophilic nature of the plant essential oils facilitates them to interfere with basic metabolic, biochemical, physiological and behavioural function of insects. Green pesticides are benign to the environment as they are more specific and do not affect non target organisms.

The emergence of adult flies was low when the larvae of house fly were dipped in eucalyptol with LC₅₀ value of 101 µg/ µl. Further, Sukonstan *et al.* (2004) suggested that the insecticidal property of eucalyptol could be further enhanced by more effective application modes such as fumigation as it is volatile in nature.

Shouky (1997) investigated the effect of essential oils of *Matricaria chamimilla* and *Clerodendron inerme* on biology and biotic potential of *Musca domestica*. The LD₅₀ values were calculated as 76µg and 84µg/ fly for *Matricaria chamimilla* and *Clerodendron inerme* respectively.

Rani (2013) observed promising insecticidal properties of essential oils obtained from leaves of eucalyptus, mint, lemon, lemon grass and peels of orange against various developmental stages of house fly *in vitro* and *in vivo* method. The LD₅₀ values of mint, lemon grass, orange, lemon and eucalyptus against larvae and pupae were 5.89 and 48.27 µl, 29.58 and 18.26 µl, 33.28 and 48.27 µl, 37.42 and 17.8µl and 48.2 and 15.69 µl respectively. While fumigant toxicity against adult flies revealed that at the highest concentration of (200 µl) of essential oil of lemon, lemon grass, mint, eucalyptus and orange took 4.0 ± 0.6, 4.3 ± 0.11, 5.5 ± 0.17, 6.5 ± 0.24 and 10.5 ± 0.22 min to

cause 100% mortality. Author also evaluated the essential oils of the above plants against house flies under field condition in quail farm and reported that there was a significant (P< 0.01) reduction in adult fly and larval count in quail shed of size 12 m² sprayed with diluted oils–1 ml of oil in 10 ml of acetone mixed with 100 ml of water.

Entomopathogenic fungi: Entomopathogenic fungi are pathogens of house flies and are widely distributed in nature (Mwangi *et al.* 1995). Entomopathogenic fungi such as *Metarhizium anisopliae*, *Beauveria bassiana* and *Entomophthora muscae* are pathogenic, causing mortality in adult flies (Watson *et al.* 1993). The spores of fungi attach to, germinate and penetrate the cuticle of the host. Once within the host they proliferate as a progression of single or multi cell structures exploiting the nutritional resources of their hosts, ultimately killing (Inglis *et al.* 2001).

Biopesticides containing *Metarhizium anisopliae* and *Beauveria bassiana* are widely used for control of flies in poultry farms in temperate regions of the world. But in tropical countries, the prevailing climatic condition appears to be unfavourable for survivability of spores for longer period and hence using of fungal under field condition may not yield desirable results, although, baits incorporated with spores of *M.anisopliae* and *B.bassiana* under laboratory condition caused 90 – 95% mortality adult flies (Tamilam *et al.* 2010).

Temperature and relative humidity are the main abiotic factors that usually influence infection rates by entomopathogenic fungi. The optimum temperature for germination of conidia was 21°C (Caruthers and Haynes 1986), whereas high temperature had negative effect on conidia viability, vegetative growth and virulence (Alexander *et al.* 2006). Keeping this in view a suitable delivery system has to be designed, which can provide ideal condition for fungal growth and viability under field condition in tropical countries.

Entomopathogenic fungi *Metarhizium anisopliae* and *Beauveria bassiana* were found virulent against *Musca domestica* and *Chrysomya bezziana*. Oil suspension of fungal spores was more effective than aqueous suspensions (Mythili 2003). Similarly Kannagi (2006) reported that *Metarhizium anisopliae* spores suspended in soya oil caused 85% mortality among adult house flies. Introduction of flies infected with *Entomophthora muscae* reduced house fly intensity in dairy and poultry houses. The success of using entomopathogenic fungi for biological control was low when average weekly temperature was above 17–20°C (Six and Mullens 1996).

Entomopathogenic nematode: Nematode parasites of insects have been known since the 17th century (Nickle 1984). Recent research revealed that entomopathogenic nematodes carry symbiotic bacteria and utilized them as food. The infective juvenile nematodes enter the insect host through the mouth, anus, spiracles, or by direct penetration through the cuticle. Once the nematode reaches the haemocoel cavity of the insect, the bacteria would be released, which multiply rapidly in the haemolymph. The

infected insect usually dies within 24 – 72 h due to toxins produced by the nematodes. In addition, the bacteria are also responsible for the mortality in most of the insects (Smart 1995). Nematodes are nonpolluting and environmentally safe. Although nematodes target various growth stages, larvae are highly susceptible resulting in death.

The efficacy of *Steinernema feltiae* and *Heterorhabditis megidis* incorporated bait formulation was compared with commercial bait formulation of methomyl for control of *Musca domestica* on a pig farm. Significantly fewer flies were counted in the houses baited with either *Steinernema feltiae* or *Heterorhabditis megidis* than those baited with methomyl (Renn 1998).

Bacterial pathogens: It was believed that β -exotoxins produced by *Bacillus thuringiensis* during sporulation is toxic to the pest, but Hodgman *et al.* (1993) identified three kinds of toxic protein, viz. Cry I Aa (b), Cry IB and Cry II A in *Bti*, which are toxic to larvae of *Musca domestica*. A high mortality was recorded among the larvae of *Musca domestica* that were seeded into the medium containing 20 and 25% toxic protein of VCRCB426, while mortality of pupae was higher than larvae at all concentration except 20%. The LC₅₀ and LC₉₀ values for larvae and pupae were 8.25 and 51.79 μ g/g of fly rearing medium (Padmanaban *et al.* 2005).

In vitro evaluation of *Bti* spores against larvae of *Musca domestica* revealed that 50–66% mortality of larvae that were seeded into the 0.5 cm depth medium incorporated with 1–2 g of spores. But, the percentage of larval mortality declined to 50 when the depth of the medium increased to 1 cm. The results suggesting that *Bti* may not produce larval mortality under field condition. Because, the solid dropping may not be suitable for multiplication of *Bti* as it does in water (Ponnudurai and Harikrishnan 2008). Chirco (1998) reported that no lethal effect was observed when larvae and adult house flies were exposed experimentally to toxins from 2 strains of *Bacillus thuringiensis* (H – 14 and var. *israeliensis*).

Parasitoids and predators: Natural enemies of house flies play a significant role in the control of fly menace in livestock and poultry farms. Hence, farm management should provide a suitable environment for survival and proliferation of natural enemies. The beetles belonging to the family Histeridae (e.g. *Carcinops pumilio*) and Staphylinidae and mite *Macrocheles muscae domesticae* devour eggs / first instar of *Musca domestica*. Predation of the house fly is one of the effective biological ways to reduce house fly density. The per day predation of beetle *C. pumilio* adults was 21 – 49 egg /larvae, while their larvae devoured 13 – 21 egg /larvae (Geden *et al.* 1988).

Parasitic wasp of Pteromalidae and Encyridae family parasitize the pupae of house fly. In addition, soldier and mucoid flies compete with house flies for breeding. The common pupal parasitoids, found in the poultry farm, include *Dirhinus himalayanus*, *Pachycrepoideus vindemiae* and *Spalangia endius* (Karunamoorthy 1987) in Tamil

Nadu. Hymenopteran wasp such as *Spalangia cameroni*, *S. nigroae* and *D. himalayanus* was recorded in high number in November in Puducherry (Srinivasan and Balakrishnan 1989).

Rutz and Axtell (1986b) reported that *Muscidifurax raptor* was the most abundant parasitoid species found in poultry farms. Sumathi *et al.* (2011) reported that *S. endius*, *D. himalayanus* and *P. vindemiae* were the common pupal parasitoids found in the poultry farms in Namakkal, Tamil Nadu. In the experimental trials, the weekly release of pupal parasitoids *S. endius* and *D. himalayanus* in a layer farm had increased the number of parasitized pupae than unreleased farm. Further, authors concluded that mass release of laboratory reared *S. endius* and *D. himalayanus* simultaneously in adequate number at weekly intervals during the fly season may be an effective biological measure for suppression of house fly population in small poultry farms.

It was observed that 88% of the pupae were found parasitized with *Muscidifurax raptorellus* when it was released in poultry houses. Further the authors noted that parasitoids were limited from parasitizing pupae buried 2.5 cm under the poultry manure (Kaufman *et al.* 2001a). A weekly release of *S. cameroni* and *M. raptorellus* for 12 weeks after the first week of manure accumulation in poultry houses had caused 40.2% pupal mortality. The pupal mortality during autumn was 3 to 4 times higher in the released house than control houses (Geden and Hogsette 2006).

Conclusion and future developments

Although the prevailing environmental conditions in the tropical countries are said to be the main reasons for fly problems, these can be managed effectively through farm sanitations and litter management. Farm sanitations lie in proper disposal of dead birds, broken eggs and other wastes generated in poultry houses. Whereas, in the litter management, litter must be kept in dry condition through good ventilation, replacement of faulty nipple and exclusion of wet-litter causing feed ingredients. Above all these, strategic removal of litter is very important for fly control programme. Removal of manure prior to the onset of fly activity, combined with insect growth regulators and selective insecticide spray or bait use would be the most appropriate management strategy for control of fly menace in commercial layer farms in tropical countries. Biopesticides using fungal spores can be developed, and used under field condition provided suitable delivery system is developed.

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