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Musca Domestica: A Vector of Pathogenic Microorganisms and Biocontrol Approaches

By Abir S. Al-Nasser, Dina E. El-Ghwas & Aisha A. Al-Sheikhy
University of Jeddah

Abstract- House fly *"Musca domestica"* Linnaeus is a common insect widely distributed all over the world and is one of the domestic insect pests found associated with human and animal. Due to their habits and habitats, house flies are able to transmit several pathogenic microorganisms to man such as: bacteria, fungi and virus. House flies are not just annoying human and animal, but they also have been known as vectors of infectious microorganisms either mechanically or biologically. Chemical insecticides have been used for many years and have been known as the most effective approach in house fly management but due to their side effects on the environment and the increasing development of pest resistance to each new chemical, studies tended to explore new alternative methods in pest control. Biological methods including different predators, parasites, entomopathogenic micro-organisms and botanical extracts showed in the last years a practical and effective ecofriendly method to control insect pests including house fly and at the same time safe on human and animal.

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Musca Domestica: A Vector of Pathogenic Microorganisms and Biocontrol Approaches

Abir S. Al-Nasser [α], Dina E. El-Ghwas [σ] & Aisha A. Al-Sheikhy [ρ]

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I. Introduction

Because house fly lives close with human, it finalizes its entire life cycle in human houses and their domestic animals. *Musca domestica* Linnaeus can be found in human residences, hospitals, food processing factories, food markets, butchery, food centers or restaurants, poultry and livestock farms, and different domestic areas or buildings. House flies can be a cause of decreasing the production of milk in dairies. Therefore, recently significant emphasis has been given to fly control measures (Crespo *et al*., 1998).

Repeated interaction of the fly with different animals and wastes provides an occasion forthe mechanical transmission of diseases to both human and animal (Davari *et al*., 2010; Fisher *et al*., 2017). Places with vast quantities of dung or manure, such as animal raising houses and sites without human cleanliness practices, represent favorable conditions for the dissemination of house flies and simultaneous procurement of bacteria (Meerburg *et al.*, 2007). Though, the concentration, possibility, and species dissemination of bacteria in animal excrement or compost differ broadly among places and within hosts (Himathongkham *et al.*, 1999). Therefore, flies might confront and eat highly varying quantities of bacteria throughout their connotations with animal trashes (Ahmad *et al.*, 2011).The feeding habits of house fly are one of the most harmful characteristics because it is exposed to decaying plant and animal matter, this put fly in contact with pathogenic organisms found in various environments, garbage, and animal waste (Park *et al.*, 2019).

Flies carrying pathogens are usually found with human and animal wastes and waste management then propagates to human dwelling and activity (Sulaiman *et al*., 2000; Mian *et al*., 2002). House fly, *Musca domestica*, and stable fly, *Stomoxys calcitrans* can transmit injurious pathogens to humans and animals in urban and rural regions. These species can cause irritation to farmers and affect animal health causing a decline in the production of cattle and rooster. They breed in organic matter causing problems in places where organic waste is stored such as waste management facilities (Malik *et al.*, 2007; Taylor *et al.*, 2012 and Weeks *et al.*, 2017). As a result of its life and conduct, flies have been involved as a vector of pathogenic microbes by mechanical and biological route (Graczyk *et al.*, 2001; Zurek and Ghosh, 2014).

Park *et al*.(2019), investigated the inner and outer microbial fauna in 400 samples of house flies from three different environments (cow farm, homes, and clinics) in Belgium and Rwanda. They reported that whatever was the nation or territory, house flies ported a high potential of various bacterial microbiota and that bacterial communities on the external body were much more various than the internal populations from the intestinal gut. Various researches reported the effect of house fly in transmitting different pathogens including bacterial, viral, rickettsial, and helminthic diseases(Sanchez-Arroyo and Capinera, 2014;Shah *et al*., 2015), which causes infections such as enteric infections (dysentery, diarrhea, typhoid, cholera, and certain helminth infections), eye infections (trachoma and epidemic conjunctivitis, poliomyelitis), skin infections (yaws, cutaneous diphtheria, some mycoses, and leprosy) (Bahrndorff*et al*., 2017; Baharet*het al*., 2018).

Hulten *et al*.(1996), indicated that there are three different possible modes of bacterial transmission by flies. A confirming study by Thomas *et al.* (1992) and Kelly *et al*. (1994), reported the isolation of viable

Author α ρ: Department of Biology, Faculty of Science, University of Jeddah, Jeddah, Saudi Arabia.
Author σ: Chemistry of Natural and Microbial products Department, National Research Centre, Dokki, Egypt.
e-mails: aalnasser@uj.edu.sa, al-nasser.abir@hotmail.com

bacteria from feces. Thus, suggesting that transmission through the fecal-oral route seems possible. In Malaysia, Tan *et al*.(1997), performed their study on how house fly could transmit rotavirus on their different body parts.

When flies feed on bacteria, they can keep these bacteria in their guts for several days, then propagate them in the ecosystem. Kobayashi *et al.* (1999), observed many bacteria in the foregut of the flies (crop) until four days after feeding it on *E. coli* O157:H7. Zurek *et al.* (2001), mentioned that the bacteria persisted in the house fly digestive system for 36 hours after feeding it on *Yersinia tuberculosis. Aeromonas caviae* was replicated in house flies for about 2 days and endured for up to 8 days post digestion, and a large number of viable bacteria were shed in vomitus and feces (Nayduch *et al.*, 2002). Similarly, *Pseudomonas aeruginosa* proliferated and persisted in house flies, and has been discarded in excreta for at least 24 hours post-ingestion (Joyner *et al.*, 2013).

Control procedures are normally established on the use of chemicals, insect pesticides have been widely utilized for house fly control (van Emden and Peakall, 1996). These chemical pesticides hold prospective dangers for both the environment as well as human health and continuously lead to the development of resistance to most used insecticides (Asaeedi *et al.*, 2017).Various pesticides used to control flies showed harmful effects on non-objective organisms, involving those that are natural control agents, such as predators and parasitoids (Scott *et al.*, 1991). To diminish harmful effects on health, environment and to prevent pollution of the ecosystem, research for new highly efficient alternative strategies for pest control such as biopesticides has increased (Rodrigues *et al.*, 1988; Zimmer *et al.,* 2013). Besides, insecticides and insect growth regulators, attention has been given to biological control of flies especially in livestock units where predators and parasites may be used to control fly populations (Noorman, 2001). Among bioinsecticides, efforts focused on pathogenic organisms such as nematodes, fungi, bacteria, and viruses (Geden, 2012; Ruiu *et al.,* 2013). The application of different procedures in house fly control is necessary to limit and suppress this pest and to prevent the transmission of infectious diseases to humans and animals. For that, health education, appropriate environmental cleanliness, and personal sanitation are reassured (Issa, 2019). Because of their high dispersion in the ecosystem, bacteria could develop different interactions with insects such as symbiosis (Feldhaar, 2011).

While several bacterial species occupy insect bodies and create various degrees of reciprocal relationships, only a small number of them act as insect diseases, developing several strategies to enter the host, conquer, influence, and destroy its immune responses (Vilcinskas, 2010).

II. Biology of House Fly

House fly *M. domestica* has a full metamorphosis including clear egg, larval, pupal, and adult stages (Cossé and Baker 1996). House flies can live from 15-30 days, females become sexually mature within 2-3 days post-emergence and mate once, while males usually mate several times from the day of their emergence (Saccà, 1964). Oviposition takes place four days after copulation and the female lays several batches of 100 to 155 eggs for 3-4 days, during its lifetime. Females deposit eggs in a humid medium such as cracks and crevices to protect them from dryness, their main breeding areas are usually manure and spilled food (Kelling, 2001; Weeks *et al.*, 2017). Usually, warm summer conditions are ideal for their development as they can complete their life cycle within 7-10 days. While under undesirable conditions life cycle may need two months. In temperate regions, around 10 generations may occur annually, while more than 20 generations may occur in subtropical and tropical regions (Weeks *et al.*, 2017).

Whitish 1 mm long eggs hatch after 8-20 hours post oviposition. Saprophytic larvae, white and legless grow through three instars for 4-13 days (Sarwar, 2016). Each of the first and second larval stages lasts around 1-3 days, the third in star larva develops in 3-4 days to a creamy white 8-11 mm long maggot, tapering from the front and thicker behind to a shortened back end, where two apparent black spiracles are placed through which the tracheal system is attached with the exterior air (Kelling, 2001). At optimum temperature (32-37°C), pupae could finalize their growth for 2-6 days. Thus, the entire life cycle from egg to adult laying eggs ranges from 14-18 days under ideal conditions (25°C). Numerous generations could grow up during the warm season, but in unfavorable conditions, it could be slow down to nearly six weeks giving emergence to abnormally low size offlies (Kelling, 2001).

III. Pathogens Transmitted by House Fly

The most known way for house fly to transmit pathogens is mechanically (Fisher *et al*., 2017). Hence, some reports have shown that house fly is a disruptive pest and an important pathogenic micro-organism vector such as bacteria, viruses, fungi, and protozoa among human and animal (Sanchez-Arroyo and Capinera, 2014). Adults houseflies consume human foodstuff, various excretions, animal compost, moisture, meat potage, milk, trash, and damp or decomposing material of pet litter because of their strong odor. They usually suck up their food through their proboscis because they cannot grind or chew.

If a fly sucks up food from any infectious source, some of the germs attach to the fly's mouth/body part, and when the fly comes in contact with human food, pathogens move on it (Malik *et al.*, 2007). Szalanski *et al.* (2004) reported that flies breeding in feces and other organic waste could become inhabited with pathogenic bacteria such as *Escherichia coli* O157:H7, which affects humans with hemorrhagic colitis and *Campylobacter.* Moreover, Rosef and Kapperud (1983) separated 161 strains of *Campylobacter fetus subsp. Jejuni* from house flies. They noticed that their carrier rates were 50.7% and 43.2% in farms of chicken and pig, respectively. They assumed that flies play a connecting function in the epidemiology of *Campylobacter* contamination in humans by spreading these bacteria from animals to human nutrition. Sukontason *et al*. (2000), in North Thailand and urban areas of Chiang Mai province, evaluated the number of bacteria on house flies and found that about 60 percent of the *M. domestica* flies transported around 1 to 5 strains of bacteria and that *Staphylococci* were the most excessive. Various studies isolated highly infectious bacteria from house flies, comprising enteropathogenic strains such as enterotoxigenic *E. coli* (ETEC), enteroaggregative *E. coli* (EAEC), enterohaemorrhagic *E. coli* (EHEC), and enteropathogenic E. coli (EPEC) (Fleming *et al.*, 2014; Solà-Ginés *et al.*, 2015; Songe *et al.*, 2017).

The areas of flies' collection are related to the micro-organisms transmitted by these insects. Places such as hospitals and animal farms where antibiotic and growth stimulators are applied extensively had flies carrying antimicrobial-resistant micro-organisms (Davari*et al.*, 2010; Nazari *et al.*, 2017). Previously, Rady *et al.* (1992) isolated 21 bacterial species of house flies collected from four general hospitals in Cairo (Egypt). Nine species of *Enterobacteriaceae,* two species of *Brucellaceae, one species of Acromobacteriaceae,* and *Pseudomonodaceae*. Boulesteix *et al.* (2005) also explored how the house fly is spreading multi-resistant microbes at the intensive care units of hospitals in sub-Saharan Africa. They revealed that 99 flies from 120 carried human pathogenic micro-organisms, and alarmingly, 17 flies carried antibiotic-resistant bacterial strains (including methicillin-resistant *Staphylococcus* and ticarcillin resistant *Pseudomonas*). Furthermore, Khamesipour *et al.* (2018), were able to isolate 130 pathogenic organisms from the house fly were bacteria was the most frequent.

In their study, Macovei and Zurek (2006) mentioned that houseflies in food-handling and supply amenities houseflies can transport and may be able to deliver antibiotic-resistant and potentially virulent bacteria. Moreover, several studies registered multiple antibiotic bacterial species isolated from house flies: *E. coli*; *Klebsiella pneumoniae* (Davari *et al.*, 2010; Fotedar *et al.*, 1992) and *Pseudomonas aeruginosa* (Davari *et al.*, 2010; Hemmatinezhad *et al.*, 2015). On the other hand, Olsen and Hammack (2000) isolated *Salmonella enteritidis, S. infantis,* and *S. Heidelberg* from house flies around poultry houses. Also, Nazni *et al.* (2005) isolated *Bacillus sp., Staphylococcus sp.* and *Micrococcus sp*. from feces and spews of houseflies extra than from their outer body. In India, during a craze, Fotedar (2001) showed the ability of house flies as a vector in transmitting *Vibrio cholerae*.

Reports indicated that antimicrobial-resistant strains responsible for 10% of in-hospital nosocomial infections such as *Klebsiella* species were transmitted by pests, including house flies and cockroaches (Fotedar *et al*., 1991; Davari *et al.,* 2010; Tajbakhsh *et al.*, 2015).In Japan, Sasaki *et al.* (2000) mentioned that house flies transmitted a toxic strain of *Escherichia coli*. Moreover, the World Health Organization (2004) reported that just trachoma transmitted by fly can cause six million cases of childhood blindness yearly. Because of their high activity, house flies are involved in transmitting many severe and widespread diseases. Flies come into contact with excreta, cadavers, garbage, and different infected matter, and at the same time, flies are closely associated with human's food and tools (Keiding 1986; Nichols, 2005). The kind and quantity of micro-organisms transported by flies are closely related to the presence of these organisms in the excreta and other wastes where flies grow and feed (Nichols, 2005). Usually, most antibiotic species have been secluded from insects collected from hospital and farms (Solà-Ginés*et al.*, 2015; Hemmatinezhad *et al.*, 2015; Nazari *et al.*, 2017), signifying that house fly shows a part in propagation of antibiotic-resistant species in the ecosystem (Zurek and Ghosh, 2014). A growing problem in hospitals and other health care facilities is house flies' involvement in transmitting life-frightening antibiotic-resistant bacteria (Boulesteix *et al.* 2005; Macovei and Zurek, 2006). A recent study, mentioned the contribution of house flyin the spread of avian influenza (Graham *et al.,* 2009).

Because *M. domestica* can bear a variety of bacteria, viruses, fungi, and parasites diseases over their appendages, several significant steps should be accomplished to combat these micro-organisms. One of these actions is to recognize pathogenic agents that enhance health civilization's status and monitor and reduce the population of house flies in human and animal activities (Service, 2000).

IV. Different Approaches used for House Fly Control

a) Mechanical control

Some self-protection behaviors prevent house flies by frequent cleanliness of indoor and the correct way of removing recycling rubbish (Urban and Broce, 2000). It is of importance to enhance ecological purification and hygiene to control house flies (Keiding, 1986).Effective control method for house flies producing in domestic and animal wastes is by removing properly compost or any other organic matter causing propagation of house fly eggs. Around 50% of houseflies in metropolitan areas occur due to poor management in arranging waste materials from houses, hospitals, and markets.

b) Physical control

Numerous pests are susceptible to ultraviolet light with a frequency of roughly 350 nm. The adults of houseflies are phototactic positively and are captivated to light blue-green (450-550 nm) and ultraviolet (340-365 nm) (Bellingham and Anderson, 1993). Thus, electrocuting traps with fluorescent lamps emitting light in the ultraviolet range are usually used for indoor control of houseflies (Bellingham and Anderson, 1993; Sanchez-Arroyo and Capinera, 2014). It is challenging to preserve a hygienic ambiance and avoid house flies from transmitting diseases. As a substitute, through different physical methods such as light traps, adhesive tapes, fly swats, and electrocuting grids, monitoring the house fly population can be achieved. These techniques are used to precisely kill, repel, or capture the flies without creating any resistance in the flies' body, as observed in the case of chemical insecticides. Methods for physical control are simple and very secure to use. They often do not influence the surroundings but are not very effective in controlling a high density of house flies (Urban and Broce, 2000).

c) Chemical control

Numerous chemical compounds affect different insect systems, including the nervous system, energy production, cuticle production; endocrine system, or water stability that can also be used through various application modes such as topical application, baits, and fumigants to effectively manage house fly population (Shen and Plapp, 1990; Oi *et al*., 1992).For many years, house fly control has been performed by treating the surfaces where the flies usually rest with different chemical compounds such as chlorinated hydrocarbons Dichlorodiphenyltrichloroethane known as DDT and methoxychlor, as well as other (lindane, and chlordane), organophosphates (malathion, diazinon, and dimethoate), carbamates (methomyl), pyrethrins (usually with piperonyl butoxide), pyrethroids (permethrin, fenvalerate, and cyfluthrin), and most recently spinosad (limited use) and neonicotinoid baits (imidacloprid) (Noorman, 2001).

Although chemical insecticides were toxic against a large selection of pests, they also affected non-target organisms. These substances cannot be decayed by organisms and their residues sustained in the environment, get into the food chains, and stored in the body tissue of non-target organisms, as well as humans (Pimental & Perkins, 1980).In addition to the increase of tolerance and resistance of flies to insecticides, the high costs of using insecticides and their toxicity to other organisms make them less desirable for fly control.

Over the years, new pesticides were produced but flies reacted by producing resistance to organophosphate, carbamate, and pyrethroid pesticides (Kozaki *et al.*, 2009; Memmi, 2010). The continual introduction of flies to chemicals has encouraged the development of pesticide resistance (Sanchez-Arroyo and Capinera, 2014). Further pesticides that are safe for mammals were synthetic pyrethroids, although they could affect crustaceans and fish. But, at the same time some of these products are biologically broken down (Hill, 1985).

d) Botanical control

Basic oils insecticides, have been well-known for their fumigant properties, and their method of activity might include components that inhibit the acetylchol inesterase and octopaminergic impacts (Isman, 2000). More impacts could be found in the behavior variation (attraction/repellency) and contact harmfulness for several life stages (Koul *et al*., 2008). Normal oils are composed of numerous biological active constituents, including terpenes, acyclic monoterpene alcohols, monocyclic alcohols, aliphatic aldehydes, sweet-smelling phenols, monocyclic ketones, bicyclic monoterpene ketones, acids, and esters (Koul *et al.*, 2008). For this purpose, a massive effort was performed to investigate different components similar to the established essential oils effective as insecticides (Isman, 2000; Koul *et al*., 2008).

Terpenoids showed different effects on house flies. Some compounds had an attractant effect, others acted as a repellent of females, and both inhibited the larval development (Sharma and Saxena, 1974). Furthermore, Neem extracts and Azadirachtin had been somewhat effective against larvae of the horn fly (*Haematobiairritans*), however, doses required to kill house fly larvae were not useful because they were too high to be manipulated (Miller and Chamberlain, 1989).

The effect of essential oils as insecticide and repellent in flies' control has been reported in several research such as essential oils from orange peel and eucalyptus (Palacios *et al*., 2009 a, b); essential oils of pennyroyal mint (*Mentha pulegium*) and rosemary (*Rosemarinus officinalis*) Pavela (2008). Ezeonu *et al.* (2001), also reported that sweet orange peel extracts (Citrus sinensis) showed a positive effect on adult house flies when used as fumigants. Moreover, Kumar *et al*. (2011), reported that between 6 plant extracts that have been investigated against house fly (*Mentha piperita*) and blue gum (*Eucalyptus globulus*) were the most efficient as insecticidal and repellents. Also, Urzua*et al*. (2010), reported that essential oils from *Haplopappus foliosus* (Asteraceae) were effective on adult house flies.Hence, plant extracts can be used as larvicidal, pupicidal, and adulticidal. Others act as repellents, feeding inhibitors, oviposition reducing, and insect growth managers for house fly as well as for some other

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pests (Tsao *et al.*, 1995). Botanical pesticides could be economically and ecologically beneficial as these are more specific than chemical pesticides and do not affect the non-target organism (Willikins and Metcalfe, 1993). Plant oils effect of on flies varies with the sex and the developmental stage of the house fly and the mode of application (Malik *et al.*, 2007).

e) Hormonal control

Searches for alternatives other than insecticides have increased in the last years. Insect growth regulators are called third-generation pesticides. They do not usually kill the target pest immediately, these substances show some selectivity and take a longer time to reduce insect populations than with nerve insecticides (Myamoto *et al.,* 1993). Lindquist *et al.* (1992), mentioned that discharging sterilized male flies could destroy flies population as it was effective against the screwworm fly *Cochliomyia homonivora*in Libya. Also, Howard and Wall (1996 b, c), used triflumuron in sugar -baited targets to sterilize house flies, and they reported that this chemical could decrease the population of house flies in combination with the discharge of predators and parasites. Anyhow, usage of sterile insect technique (SIT) has been constrained by its high cost and logistic complication. Otherwise, discharging a large number of sterilized males around human residency could increase the frustration problem at least for a brief time. Anyhow insect growth regulators IGRs, have no dangerous influences on humans, animals or the environment when applied as listed on the product labels (Oberlander *et al.* 1997). Though widespread resistance against IGRs, also has developed (Pap and Farkas, 1994).

f) Biological control

There are various substitutes to chemical insecticides for house fly control (Achiano and Giliomee, 2005). Entomopathogenic bacteria are additional alternatives to chemical compounds. In addition to their effectiveness, such as safety for humans and other non-target species, elimination of pesticides left in food, defense of natural enemies, and improved biodiversity in the environment, various benefits can be seen in using entomopathogens. Although there are several natural enemies of house flies such as entomopathogenic bacteria, fungi, nematodes, predatory beetles, parasitic wasps, mites, flies, and birds, few cases showed successful results of control by natural enemies, mainly when mixed with other control strategies (integrated fly control) (Urzua *et al.*, 2010).Because pathogenic fungi could be found on animal supplies, their activity varies on temperature and moisture. Besides, contamination of flies in summer is not very high, while it is most needed in summer (Hung and Gerry, 2013). Hence, natural enemies are thought to successfully suppressing the fly, if the right genus and strains are employed in the right region (Pawson & Petersen, 1988).

V. Parasites and Predators

King (1997), explored the efficacy of the parasitoid wasps *Spalangia cameroni* and *Muscidifurax raptor* in controlling fly populations and reported that *S. cameroni* alone seemed to be reliably more efficient in destroying flies' pupae than *M. raptor.* Greene *et al.* (1998), reported that the parasitoid *Spalangianigroaenea* induced mortality in pupae of *M. domestica* by 23 to 58 %, depending on the parasitoid to host ratio. Moreover, *Spalangia cameroni* Perkins and *Muscidifurax raptor* Girault and Sanders (Hymenoptera: Pteromalidae) are ectoparasites of filth fly and they are widely distributed (Taylor *et al*., 2006). These two pupal parasitoid species are commercially available to control house fly*Musca domestica* L. and stable flies *Stomoxys calcitrans* (L.), two pests of medical and veterinary importance. Some researchers pronounced that parasitoids wasps (Pteromalid) that attack pupae were used for fly management as they are the best biocontrol agents (Skovgaard and Nachman, 2004; Geden and Hogsette, 2006), Tsankova and Luvchiev (1993), mentioned that the second and third instar larvae of *Ophyra capensis* can execute as much as 17 housefly larvae varying on the larval instar and the population density. Some studies reported the effect of Histerid beetles and macrochelidae mites as predators on egg and larvae of house flies (Kaufman *et al.,* 2002; Achiano and Giliomee, 2005).

VI. Entomopathogenic Nematodes

Entomopathogenic Nematodes are small roundworms (much less than 1-3mm), parasites of soil-inhabiting insects. These parasites are stated as insecticidal nematodes, such as some species within the genus *Steinernema*(family: Steinernematidae) and *Heterorhabditis* (family: Heterorhabditidae) of the Phylum Nematoda (Mwamburi,2008). Steinernematid and heterrhabditid nematodes when used in the control of filth flies, the larval stage was very sensitive to these entomopathogenic nematodes (Mullens *et al*., 1987; Taylor *et al*., 1998). There is a mutualistic association between Nematodes and micro-organism inhabiting their digestive tracts, these bacteria execute the insect after the nematode conquers its body, some of these bacteria species are *Xenorhabdis nematophilisis* associated with *Steinernematid Steinernema carpocapsae* while *Photorhabdis luminescensis* associated with *Heterorhabditis bacteriophora* (Kaya and Gaugler, 1993; Mwamburi, 2008).Penetration of nematodes into the insect body depends on the host and nematode species, although there are many methods of penetrations such as the mouth or the anus the infection of house fly larvae and leaf miners is through the anus mainly (Renn, 1998), some studies mentioned that the mouth is the most successful way (Cui *et al.*, 1993). *Steinernema feltiae* can go into the body insect via the cuticle or the inter segmental membranes, penetration through the integument was shown to be their main route of entry (Peters and Ehlers, 1994). An Additional way of entry to the adult insect is the genital openings (Samish and Glazer, 1992). After entering the hemocoel, nematodes feed on the blood, and at the same time, they evacuate the excretions, discharging the symbiotic bacteria (Martens *et al.*, 2004). Bacteria rapidly inhabits the insect and kill it for 1 to 3 days. The nematodes consume the bacteria and tissues of the larval body, it develops and undergo 2-3 generations in a period ranging from one to 2 weeks. The last generation leaves the cadaver searching for a new host (Ciche *et al.*, 2006). Bacteria from nematode destroy the insect as soon as it enters its body, so it cannot form a host-parasite relation. This allows the nematode to visit many hosts and cover most insects' orders (Grewal and Georgis, 1999). The tough behavioral barrier in some insect hosts could limit the efficacy of nematode (Gaugler, 1988).

VII. Entomopathogenic Fungi

Some studies have evaluated the effect of infective fungi for house fly management in the field such as *Entomophthora muscae* (Cohn) Fresenius, and they mentioned that sometimes the pathogenic *E. muscae* could destroy fly populations (Geden *et al.*, 1993; Steinkraus *et al.*, 1993; Watson and Petersen, 1993).Kuramoto and Shimazu (1997), used house flies infected with *Entomophthora muscae* in experimental poultry houses, these flies were able to kill 90% of the originally existing flies after 33 days of their introduction. Normally, the effect of *Beauveria bassiana* and *Metarhizium anisopliae* against house flies and stable flies are low in the field (Skovgaard and Steenberg, 2002). Nevertheless, they showed a high effect in the laboratory trials against larval and adult flies, their virulency depends on the strain and the formulations (Lecuona *et al*., 2005). It is important to use a mixture of pathogenic fungi with chemical insecticides to improve their effectiveness as biological control (Ericsson *et al.,* 2007). Fungi enter the body of the insect through the cuticle (Charnley, 1989) or the trachea (Feng *et al.*, 1994). The conidia attach to the cuticle (Boucias and Pendland, 1991), then germination begins and the insect becomes infected. The hyphae penetrate the cuticle and proliferate into the hemocoel, which causes the insect's death due to toxemia (Khachatourians, 1991).

VIII. Entomopathogenic Virus

One of the Hytrosaviridae family is the salivary gland hypertrophy virus that contaminates house flies, tsetse flies (*Glossina* spp.), and the narcissus bulb fly (*Merodon equestris* Fabr.) (Lietze *et al*., 2011). Contaminated flies do not show any external disease signs. The most visible infection characteristic is the incidence of significantly enlarged (hypertrophied) salivary glands with a blue-whitish presence that often dominates the abdominal cavity of the fly after dissection. Viral duplication and morphogenesis are confined to salivary gland cells, although complete virions are also found in asymptomatic tissues such as the midgut, ovaries, fat body, and brain (Lietze *et al*., 2010). The virus in both sexes of infected flies causes a decrease in mating achievement and shorten life periods. Sustainable virus particles pass by the digestive system of infested flies and are evacuated with feces, even if at low rates (Lietze *et al*., 2007; Lietze *et al*., 2009).

IX. Entomopathogenic Bacteria

To reduce the effect of chemicals on health and the ecosystem, other selected approaches have been applied for insect control. Many different genera of micro-organisms have been utilized as biological insecticides (Rodrigues *et al.*, 1988), and there is a tremendous review on the insecticidal impacts of *Bacillus thuringiensis(Bt)* beside the different isolates that are effective against house fly(Ruiu *et al.*, 2006). *B. thuringiensis,* has many advantages over conventional pesticides, itis specific to certain pest species, eco-friendly, and safe to non-target organisms, mosquitoes did not develop significant resistance to it in the field so far (Bravo *et al.,* 2007).Johnson *et al.* (1998), described the utilization of *Bacillus thuringiensis* as a protected and successful method for controlling rural pest and particularly houseflies. The active factor in the bacteria is a member of Cry IB class of protoxins, and it is created in some strains of *B. thuringiensis.*

Carramaschi *et al.* (2015), reported that *Brevibacillus laterosporus* (Laubach) is a biological control agent. It showed broad entomopathogenic activity against various insects such as blowflies (Pessanha *et al.,* 2015) and house flies (Ruiu *et al.*, 2006; Ruiu *et al.*, 2008; Ruiu *et al.*, 2011; Zimmer *et al.,* 2013). Innovative bacterial species with advanced methods of action have been found and prepared as new biological insecticide products (Ruiu *et al.,* 2013). *Bacillus thuringiensis* has proven an enormous potential factor in the control of livestock pests. Investigation and improvement of the toxins and their method of activity against pests are progressing in several countries (Pinnock, 1994).The impact of *Bacillus thuringiensis* against filth flies was encouraging, the control against larvae was achieved by feeding cattle and chickens with a spore formulation of *Bt* bacteria in that way animals can deliver these bacteria in the manure known as house flies rearing places (Miller *et al.*, 1971), also by blending *Bt* straight forwardly with fly reproducing substrates (Rupes *et al.*, 1987). Some studies used the exotoxin delivering *Bt* strains where flies showed higher sensitivity than most other pests to the exotoxin (Carlberg, 1986). Indrasith *et al*. (1992), and Johnson *et al*. (1998), detected numerous strains to be effective against adult house flies, and they mentioned that all the *Musca domestica*-active strains had in them the endotoxin Cry1B which might be the key entry of these strains effect against house flies (Lysyk *et al.*, 2010). *Bacillus thuringiensis* was found to be more efficient against house fly when mixed with poultry food rather than added directly to the manure (Labib and Rady, 2001). Additional to the crystal-related poisonous proteins related to sporulation, some *Bt* isolates can produce proteins during their development such as vegetative insecticidal proteins. These vegetative proteins were effective against a big range of Lepidoptera (Estruch *et al.*, 1996; Schnepf *et al.*, 1998).

Most researches have focused on the validity of *Bt*on pest insects that are routes of human infections (Kellar and Langenfruch, 1993; Rajakulendran, 1993; Teakle, 1994). *B. thuringiensis israelensis* were applied as a pesticide compound to control medical dipteran pests such as mosquitoes and blackflies (MullaBecker and Margalit, 1993; Becker, 1997), Btisraelensis showed toxicity to the house fly (Zhong *et al.,* 2000).

The oral effect of bacterial toxins crystalogenic proteins (Cry) and cytolytic (Cyt) affect the larval stage by stimulating the formation of cell membrane lytic pore in the lining epithelia of the midgut, which causes an increase in the permeability of the membrane, paralysis of the intestine, stop digestion and finally kills the larva (Kongsuwan *et al.*, 2005). The recognition of insecticidal bacterial strains against the synanthropic housefly is of great importance. Zimmer *et al.*(2013), evaluated (in artificial medium) the entomopathogenic effects of *B. laterosporus* (Bl), *B. thuringiensis* var. *israelensis* (Bti), *B. thuringiensis* var. *kurstaki* (Btk), against immature and adult life stages of *M. domestica*. There is a convincing opportunity for using microbial control agents against flies as they are reasonably selective, active, and there are many options for implementations. *Bacillus thuringiensis* (Berliner) (Bt) is a naturally occurring bacterium creating proteins that are active as insecticides against many species.

House fly and antimicrobial resistance strains

Regrettably, restricting the human diseases transferred by house flies has not been successful due to the shortage of knowledge of this species' basic molecular process (Scott *et al.,* 2009). Adjustment to distinct ecological environments might result in the progression of specific immunity of house flies. Therefore, comparing the instinctive immune systems of *Musca domestica* with those of the species that face different ecological pressures and pathogens such as *Drosophila* and *Anopheles* can be very informative and thus offer clues on how house flies can flourish in close contact with many pathogens (Scott *et al.,* 2009).

There are some public health concerns regarding the global use of agricultural antibiotic and the increasing of drug-resistant bacteria(Levy & Marshall 2004; Erb *et al.*, 2007). A significant quantity of antibiotic-resistant bacteria with resistant genes have been found in poultry litter, where antibiotics are used to produce poultry (Nandi *et al.,* 2004).The house fly could take part in in disseminating these antibiotic-resistant bacteria from the poultry or hospital areas to the ecosystem (Winpisinger *et al.*, 2005; Akter *et al.*, 2020). The antibiotic-resistant *enterococci* and *staphylococci* have been isolated from poultry litter (Hayes *et al.,* 2004; Simjee *et al.,* 2007).

X. Conclusion

Several studies confirmed the competence of house flies in dispersing numerous species of micro-organisms. Hence, the flies transport these micro-organisms, including bacterial species on their body surface or through their internal digestive tract and transmit them to human and animal food while their feeding mechanism. Previous studies indicated that among the bacteria transmitted by house fly, some antibiotic-resistant species worsen the problem. Recently, different species of bacteria proved their efficiency in reducing the population density of house fly. Therefore, it is of importance that researchers focus on biological pest control to avoid the damage inflicted by chemical insecticides.

Abbreviations

Bt: Bacillus thuringiensis

E. coli: Escherichia coli

M. domestica L.: *Musca domestica* Linnaeus

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