Controlling risks of pathogen transmission by flies on organic pig farms

A review

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Abstract: *Fly prevention and control on animal production units is necessary to prevent the transmission of pathogens that could affect animal and human health and the maintenance of good hygiene. Organic farmers are often hesitant to apply insecticides for this purpose because of their farming philosophy. Organic production systems are relatively open as pigs generally have access to the outdoors. Here, we investigate the need for fly control and analyse various possibilities that organic farmers have to reduce the number of flies on their farms. We conclude that although biological control looks promising, more research should be done concerning its side effects. Currently, optimal monitoring and prevention seem to offer the best solution.*

Keywords: *organic farming; pigs; flies; pest control; animal health; Musca domestica*

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Flies can be a serious pest in animal production. They irritate livestock and workers, cause financial loss by decreasing the production of farm animals (Campell *et al*, 1977; Catangui *et al*, 1997), give a bad impression to visitors, and can even transmit contagious diseases to livestock and humans (eg Graczyk *et al*, 2001). Because of the availability of vast quantities of manure, pig units provide a perfect environment for the breeding, feeding and settling of various types of flies: for example, stable flies (*Stomoxis calcitrans*), the common housefly (*Musca domestica*) and the lesser housefly (*Fannia canicularis*). Of these species, the housefly is most frequently encountered around pig houses, and can be considered illustrative. Adult female houseflies live for between 15 and 25 days. They produce about five batches of 75–150 eggs. The increase in the fly population in spring results from a combination of increasing temperatures and rain. As a result, the fly eggs develop faster and remain for only a few days instead of months. Their rapid development, combined with the high number of eggs deposited, can result in a dramatic increase in numbers. Although fly numbers fluctuate throughout summer, there can be 10–12 generations in temperate climates. Numbers decline again in October, but the decline is less drastic than the increase during springtime.

From a biosecurity perspective, the presence of flies on farms should be prevented as much as possible, as they can transfer a large number of pathogens. However, this is rather difficult on organic pig farms within the European Union (EU) since organic farmers raise their pigs according to the regulation set up by the EU (EU regulation 2092/91), which requires the provision of organic pig feed (ingredients grown without artificial fertilizer or pesticides) and straw bedding. Also, unlike in conventional indoor housing, pigs in organic production systems are allowed outdoors and therefore the pig facilities are more open. Moreover, the provision of straw beddings for pigs can result in hygiene problems and at the least, thorough cleaning is required between batches. The consequent presence of liquid manure and especially straw manure is known to attract flies. Use of conventional insecticides is often not in line with organic farming principles. As a consequence, it is difficult for organic farmers to acquire the same biosecurity level as in conventional pig production systems. In this review, we specifically analyse the transmission risks of pathogens by flies to pigs and offer some suggestions to deter these pests.

Table 1. Means of transmission of various pathogens by flies present on-farm.

Means of transmission	Pathogen
Mechanical (exoskeleton)	*T. gondii*, *C. parvum*, *C. jejuni*, Shigella spp. PRRS virus, TGEV
Faecal	PRRS virus, *E. coli* O157
Digestion	*Y. enterocolitica*, *E. coli* O157

Pathogen transmission

Flies have been shown to act as vectors for a number of pathogens. They are known to travel up to 20 miles (Murvosh and Taggard, 1966), although more commonly for no more than two miles. Transmission of pathogens by adult flies occurs by: (1) mechanical dislodgement from their exoskeleton (eg by hair and bristles on their legs or by cushion-like structures [pulvilli] that are used for adherence to vertical surfaces), (2) faecal deposition, and (3) the regurgitation of incompletely digested food.

They can carry protozoan parasites such as *Cryptosporidium parvum* (Graczyk *et al*, 1999), *Toxoplasma gondii* (Wallace, 1971; Graczyk *et al*, 2001) and *Sarcocystis* spp. (Markus, 1980) on their exoskeletons and pulvilli. Moreover, these animals have also been reported to transmit several types of viral pathogens to livestock, including hog cholera (Dorset *et al*, 1919), transmissible gastroenteritis virus – TGEV (Saif and Wesley, 1999) and porcine reproductive and respiratory syndrome virus – PRRSV (Otake *et al*, 2003a and b). Flies are also involved in the transmission of bacterial pathogens such as, for example, *Yersinia enterocolitica* (Fukushima *et al*, 1979), Salmonella spp. (Barber *et al*, 2002; Mian *et al*, 2002; Olsen and Hammack, 2000; Winfield and Groisman, 2003), Campylobacter spp. (Ekdahl *et al*, 2005; Szalanski *et al*, 2004), *E. coli* O157:H7 (Sasaki *et al*, 2000; Szalanski *et al*, 2004), Shigella spp. (Bidawid *et al*, 1978) and *Streptococcus suis* (Enright *et al*, 1987; Staats *et al*, 1997). *Streptococcus suis* is a pathogen that also poses a serious hazard to farmers, butchers and abattoir workers. It causes an infection characterized by septicaemia, meningitis, possibly arthritis, pharyngitis and diarrhoea (Snashall, 1996). Recently, there was a severe outbreak of *Streptococcus suis* in China: 206 cases were reported and 38 were fatal (Anonymous, 2005).

Another pathogen, *T. gondii,* can also have serious consequences in humans, such as encephalitis, mental retardation and blindness. In a previous study, Kijlstra *et al* (2004) conducted a risk analysis of infection with this protozoan parasite on organic pig production facilities. Even though it was shown that the chance of introduction of *T. gondii* by flies was estimated to be low, the authors consider fly control to be necessary to prevent transmission of *T. gondii* (Kijlstra *et al*, 2004).

Flies play a more important role with regard to Campylobacter spp. (one of the most important zoonotic bacteria). A study by Rosef and Kapperud (1983) has already postulated the hypothesis that flies might form a link between animals and human food in the transmission of Campylobacter. Moreover, flies have been shown to play a vital role in the epidemiology of avian campylobacteriosis (Hald *et al*, 2004; Shane *et al*, 1985; Szalanski *et al*, 2004). Nichols (2005) looked for possible seasonal drivers behind Campylobacter infections in humans. In this study, only vector transmission by flies appeared to provide a convincing explanation for the observed seasonal trends in human Campylobacter infections (Nichols, 2005).

The porcine reproductive and respiratory syndrome (PRRS) virus, a member of the Arterivirus group, is an economically significant pathogen leading to a drop in pig reproduction and increased perinatal mortality of piglets. Moreover, the virus causes increased susceptibility to secondary infections of the respiratory and reproductive systems. The studies of Otake *et al* (2003a and b) demonstrate that the PRRS virus can survive for up to six hours in houseflies on their exoskeleton, but 12 hours in their intestinal viscera, after they have fed on an infected pig. In a previous study, Golding *et al* (2001) had observed that the flight velocity of *Musca* sp. was 0.3 m s^{-1} (about 1 km/h). Thus, if we assumed that flies flew in a straight line during those 12 hours, they could theoretically contribute to horizontal transmission of PRRSV among pigs at a distance of 12 kilometres from an infected commercial pig farm. The means of transmission of various pathogens by flies are summarized in Table 1.

Flies can also be responsible for human–human transmission of diseases. *Musca sorbens* Wiedemann (Diptera: Muscidae) breeds on human faeces and can transmit *Chlamydia trachomatis* to cause human trachoma (Emerson *et al*, 2001). Moreover, *Musca domestica* can acquire *Helicobacter pylori* from human excrement and transmit it to human food by regurgitation or depositing faeces. Contaminated food, if swallowed by a susceptible individual, will be a source of *H. pylori* in the gastric mucosa, thus re-establishing human infection.

Control of houseflies on organic farms

Guaranteeing animal health and food safety industry-wide and at farm level thus requires the control of pathogens such as those transmitted by flies. In conventional pig production systems, efforts to control insect pests often focus on the use of insecticides. In organic pig farming, however, the use of chemical control of insect pests is generally not condoned – although it is allowed by the regulations – as it does not fit with organic farming philosophy and it is difficult to achieve in practice because premises usually have access to the outdoors.

Limited use of insecticides, however, may ultimately be advantageous, as it will prevent the development of resistance to insecticide among insect pests (Liu and Yue, 2000) and thus increase their long-term effectiveness. Insecticide resistance is a global problem: control failures with cyfluthrin, one of the relatively new chemicals used (Scott *et al*, 2000), have, for example, been reported from New York, and it is debatable whether we will be able to create an unending supply of new insecticides to replace current compounds (Scott *et al*, 2000).

The most important aspect of pest control is year-round farm hygiene, which will prevent fly infestations from happening. Rubbish should be removed regularly and stored in closed containers. Manure should be removed daily from pig pens and areas around feeding stations, and feed storage should be cleaned frequently. Manure piles should be covered: the rise in temperature will render them as breeding sites. Farmers should aim to keep solid manure as dry as possible to prevent hatching.

The use of electrocuting insect traps (EITs), popular devices that contain a visual attractant and a high-voltage metal grid, is not suitable for farm environments and ought not to be considered as an alternative to insecticides. A study by Urban and Broce (2000) has shown that when insects are disintegrated by high voltages, they can release a number of bacteria (including *E. coli*) and viruses. The spread of pathogens carried on the surface of the fly exoskeleton was the largest risk, but internally contaminated flies can also release some micro-organisms (Urban and Broce, 2000). Non-electrocuting glueboard flytraps would seem to provide a better option.

Another solution in managing pests is the exploitation of natural enemies of flies, ie biological control. This may be done by protecting or improving the habitat of these natural enemies. Several options exist. A previous study in the UK (Renn, 1998) demonstrated that entomopathogenic nematodes could be used successfully to control housefly infestations in intensive pig units. During a field trial, he compared the application of two species of nematodes, *Steinernema feltiae* and *Heterorhabditis megidis*, with the application of a water-soluble carbamate insecticide, methomyl, and concluded that there were significantly fewer houseflies in pig houses baited with the nematodes. These nematodes occur naturally in soil and possess a durable, motile infective stage that can actively seek out and infect a broad range of insects, but they do not infect birds or mammals. Within their bodies, they carry insect-pathogenic gram-negative bacteria – *Xenorhabdus* in the case of *Steinernematids*, and *Photorhabdus* in the case of *Heterorhabditids* (Forst *et al*, 1997). When a host (eg a maggot of the housefly) has been located, the nematodes penetrate the insect body cavity, usually via natural body openings (mouth, anus, spiracles) or areas of thin cuticle. When bacteria are released from the nematode gut, they multiply rapidly and kill the insect (Sicard *et al*, 2004). The nematodes feed upon the bacteria and liquefying host, and mature into adults (Forst *et al*, 1997). This is an obligate symbiotic relationship, as the bacterium needs the nematode to carry it into the body cavity of the insect, while the nematode needs the bacterium to create conditions in the insect suitable for its growth and reproduction, and as a food source (Sicard *et al*, 2004). The bacteria are safe to vertebrates and have never been detected living freely in the soil: they only occur together with these nematodes and infected insects. Their environmental persistence is limited (Morgan *et al*, 1997).

Another use of a natural enemy that might be used for biological control of houseflies on farms may be the release of parasitoid wasps such as *Spalangia cameroni* (Hymenoptera, Pteromalidae) and *Muscidifurax raptor* (Rondani) (Geden, 2001; King, 1997; Meyer *et al*, 1990; Skovgård and Jespersen, 1999; Skovgård and Nachman, 2004). These parasitoids attack pupae of houseflies and stable flies by laying single or multiple eggs. When the parasite eggs hatch, the maggot feeds on the host pupa, thereby killing it. The wasp then completes its development, emerges as an adult and continues the process by looking for more hosts. These small wasps only attack flies; they neither sting nor bite other insects, animals or humans. In Skovgård and Nachman's (2004) study, it was shown that weekly releases of adult *S. cameroni* on a dairy cattle farm and two pig facilities restricted the population of houseflies and stable flies to acceptable levels. However, there have also been studies in which attempts to control houseflies by releasing pupal parasitoids failed (Maini and Bellini, 1990; Mourier, 1972; Stage and Petersen, 1981; Skovgård, 2002).

A third option is the use of a microbial insecticide such as *Bacillus thuringiensis*. This bacterium grows in manure, and functions as a larvicide. It prolongs the larval stage, and affects the lifespan and fertility of adults emerging from treated larvae. High doses cause mortality among young larvae. According to a previous study, it is safe, effective and easy to produce (Carlberg, 1986). Furthermore, fly resistance to *B. thuringiensis* has been shown to develop very slowly, and it is, therefore, suitable for fly control.

Discussion and conclusion

There is no need to question the necessity for fly control as flies can cause financial losses and nuisance and can spread a number of hazardous pathogens. Although the risk of pathogen transmission by a single specimen is probably limited, this is compensated by the large populations commonly found due to the rapid reproduction of flies.

Whilst some chemical control methods are allowed by organic regulation, most organic farmers will be reluctant to use them, for reasons already discussed. Biological control looks promising as it has two advantages over chemical control: (1) it fits in with the organic farming philosophy, and (2) at the same time, it forms an option for reducing the resistance of flies to insecticides. However, there are also several constraints. The first constraint is that from a food safety perspective it is not known whether the application of biological methods such as parasitoid wasps, nematodes or microbes fit in with a Hazard Analysis on Critical Control Points (HACCP) approach. Although many studies have been performed into the mechanisms behind biological control and potential effects are often said to be minimal, it is still largely unknown whether these methods pose threats to farm animal health or food safety. Moreover, from experiences in greenhouses (Van Lenteren and Woets, 1988), we know that biological control can potentially disturb the ecological balance. The natural enemy should therefore not attack non-pest organisms of importance where it is introduced or have other non-target effects (Louda *et al*, 2003). As these knowledge gaps exist, more research into these aspects is required before all the effects of biological control can be assessed.

The second constraint is efficacy: effective natural enemies should have a pest kill rate equal to or greater than the potential maximum rate of population increase of houseflies. Ideally, they should be able to search out and destroy the flies before these have crossed economic threshold densities.

Another constraint of biological control is economic viability. Unlike in a relatively closed system such as a greenhouse, application of biological control in organic pig farming will have a lower efficiency, as adult wasps can easily migrate elsewhere or microbes will be removed when the pens are cleaned. Continuous application of new parasitoids or sprinkling of bacterial preparations will thus be essential and will have financial consequences. Application of conventional insecticides will probably be less expensive. Physical control methods such as use of non-electrocuting glueboard flytraps can be useful, but operating/labour costs are high as the glueboards need to be replaced regularly. Moreover, the attracting lamps need to be replaced approximately once a year, which is expensive.

Because of the constraints of chemical, biological and physical methods for fly control, prevention by reduction or elimination of fly breeding sites always seems to provide the best solution and requires a good farm hygiene policy. Furthermore, fly populations should be monitored by a standardized, quantitative method in order to make appropriate fly control management decisions. The spot card technique (Stafford, 1988) in which white file cards are placed near the livestock houses and/or near manure heaps is the easiest monitoring technique (Hogsette *et al*, 1993; Jacobs *et al*, 1992). These spot cards (3 × 5 inches) can be fastened to support posts, ceilings or other areas where flies tend to land. After placement, cards should be left for a period of seven days and then replaced with new cards. The number of 'fly specks' on the exposed side of each card should be counted and recorded. Generally, 100 or more spots per card indicates the need for fly control measures (Stafford, 1988). The use of spot cards is a simple, cost-effective and widely adopted method for assessing fly populations. With the outcome of this monitoring, a farmer can objectively visualize whether his or her prevention strategy is sufficient or whether fly control should be applied.

Good monitoring combined with prevention seems to offer the most viable solution for organic farmers to keep the transmission risks of pathogens by flies to their pigs at a minimum. If their prevention efforts are insufficient, use of non-electrocuting glueboard traps seem to be a good option. Although promising, more studies into the mechanisms behind biological control, its efficiency and side effects are necessary before farmers can truly make an informed choice between chemical control and biological control.

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