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Black soldier fly from pest to 'crown jewel' of the insects as feed industry: an historical perspective

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EDITORIAL

An historical overview of the black soldier fly is given and how the appreciation of the insect developed from being harmful to beneficial. The change occurred in 1980, initially for their role in forensic entomology and later when it was realised that the insects can be used both for recycling organic waste streams and for providing nutritious feed for production animals. Now the number of publications on the black soldier fly is increasing exponentially, while more companies focus on its commercial use.

1. Introduction

Hermetia illucens (L.) (Diptera: Stratiomyidae), also known as the black soldier fly, is currently recognised as the primary arthropod species produced for use as animal feed around the world. This recognition as the 'crown jewel' of the industry was on full display at the 2018 Insects to Feed the World Conference held in Wuhan, China, where 278 individuals representing 40 nations were in attendance (Tomberlin *et al.*, 2018). Of the 170 posters and platform presentations given, 40% were about this species (Tomberlin *et al.*, 2018). However, few today are aware of its historical categorisation outside the limelight as a beneficial arthropod.

The purpose of this article is to provide some historical perspective of the black soldier fly before its recognition as a model for recycling organic waste to produce feed for aquaculture (St. Hilaire *et al.*, 2007), poultry (Moula *et al.*, 2017), livestock (Biasato *et al.*, 2019; Gasco *et al.*, 2019), and pets (Bosch *et al.*, 2014), or use to produce bio-energy (Surendra *et al.*, 2016), while generating organic matter (i.e. frass) that can be used as fertiliser (Setti *et al.*, 2019; Xiao *et al.*, 2018). By providing the following 'review', potential hurdles encountered previously can be avoided as the industry continues to expand globally. In order to provide such a historical perspective, a CAB database search of the phrase, '*Hermetia illucens*' was conducted for publications prior to 1994. This year was chosen as the cut-off as it coincided with Sheppard and colleagues' seminal paper published in BioResource Technology (Sheppard *et al.*, 1994) that outlined the benefits of this species as known at the time.

A total of 79 publications were catalogued based on the following topics: (1) natural history; (2) pest; (3) beneficial; and (4) use as feed (Figure 1). Over time, publication numbers increased and diversified. However, studies prior to 1980 were predominantly focused on the black soldier fly as a pest species. After 1979, publications were more diverse with all four categories represented in the literature. Beneficial aspects of the species in combination with production of feed represented approximately 20% of the publications and natural history comprised slightly more than 30%; however, research still heavily focused on this species as a pest.

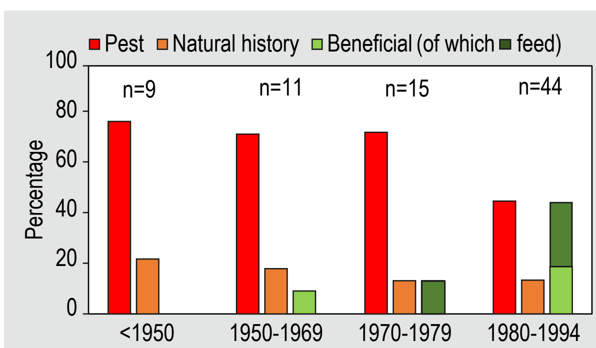

Figure 1. Historical breakdown of publications (%) on the black soldier prior located through the CAB database from <1950 to 1994.

2. From being considered a pest to a beneficial insect

Early publications indicate the black soldier fly was considered a pest. The black soldier fly was viewed as a health risk due to it producing myiasis in humans (Canavan, 1936; Meleney and Harwood, 1935; Nagakura *et al.,* 1991) and pets (Sartain and Sartain, 1978). Also, their pest status was apparent as control measures were proposed for fly larvae colonising garbage (Quarterman and Mathis, 1952) and food waste (Simmons and Dove, 1942), as well as human (Bradley, 1930; Dews and Morrill Jr, 1946; Fletcher Jr *et al.,* 1956; Kilpatrick and Schoof, 1956; Kilpatrick and Schof, 1959) and animal manure (Cunningham *et al.,* 1955; Tanada *et al.,* 1950). However, a paradigm shift was initiated at the conclusion of the 1950s. Researchers began validating early observations of the benefits of black soldier fly larvae in waste as related to interactions with other pest species, such as the house fly, *Musca domestica*, L. (Diptera: Muscidae). More specifically, the presence of black soldier fly larvae in waste negatively impacts development and survival of the house fly (Furman *et al.,* 1959).

By the 1960s and 1970s, research on the black soldier fly had diversified extensively. While a series of natural history studies were still being published (Iide and Mileti, 1976; May, 1961; Peris, 1962), confirmation of its global dispersal was being recognised (Callan, 1973; Leclercq, 1977; Toyama and Ikeda, 1976). Unfortunately, most still viewed the black soldier fly as a pest (Leclercq, 1962, 1966; Mathis *et al.,* 1969) and consequently such expansion as a negative. Thus, efforts were still predominantly focused on developing effective strategies for suppressing black soldier fly populations in animal facilities and privies (Axtell and Edwards, 1970; Christensen and Knapp, 1978; Christensen *et al.,* 1978; Mitchell *et al.,* 1974). However, the first studies demonstrating the potential of its larvae as feed for livestock, such as swine (Newton *et al.,* 1977) and poultry (Hale, 1973), were appearing in the literature.

In fact, appreciation for the black soldier fly as a coloniser of decomposing material had expanded to include the forensic sciences (Lord *et al.,* 1994). The presence of this species in association with human remains could be used to determine a time of colonisation as related to the postmortem interval (i.e. time of death) (Sinniah *et al.,* 1994) given certain assumptions. Such an appreciation resulted in several succession studies exploring the sequence of insect arrival and colonisation of vertebrate remains with special reference to the black soldier fly (Omar *et al.,* 1994).

The 1980s were truly the years where appreciation of the ability of the black soldier fly to recycle waste and produce animal feed was recognised. For example, black soldier fly larvae were found to be an appropriate feed for select fish species (Bondari and Sheppard, 1981, 1987). Suppression of house fly populations in wastes colonised by the black soldier fly was also again documented (Bradley and Sheppard, 1984). Unfortunately, these benefits could not be industrialised due to a lack of methods for colony maintenance for mass production.

As recognised by the research community today, appreciation for the black soldier fly was amplified after the publication of the Sheppard publication demonstrating industrialised application (Sheppard *et al.,* 1994). Once colony methods were published (Sheppard *et al.,* 2002) less than a decade later, a paradigm shift occurred, and the industrialisation process was viable. Today the black soldier fly is viewed as a beneficial arthropod for recycling organic waste into insect biomass for use a poultry, aquaculture, or livestock feed. As an illustration: in 2019 there were 185 publications listed in the Web of Science (using '*Hermetia illucens*' or 'black soldier fly' in Web of Science, consulted 11 January 2019), while in the 70-year period from 1947 to 2017, there were only 137 publications.

However, the issues initially discussed (e.g. myiasis; Meleney and Harwood, 1935, or bee (Hymenoptera: Apidae) hive infestations; Copello, 1926) are not simply historical as they are still occurring today (e.g. myiasis; Adler and Brancato, 1995; Calderón-Arguedas *et al.,* 2005; Fuentes González and Risco Oliva, 2009, and infestation of stingless bee, *Geniotrigona thoracica*, (Smith), and *Heterotrigona itama*, (Cockerell), (Hymenoptera: Apidae) colonies in Indo-Malaysia; Hashim *et al.,* 2017). However, taxonomic accuracy (i.e. misidentification) in each of these instances is potentially lacking due to limited morphological keys available for identifying early instar stratiomyids, or in some instances, mis-identification of adults (Hashim *et al.,* 2017). Furthermore, instances of myiasis are most often associated with public health practices. Washing, or avoiding rotten/overly ripe fruits and vegetables prior to consumption could eliminate the potential for intestinal myiasis. And, maintaining healthy stingless beehives will reduce risks of soldier fly colonisation.

3. Conclusions

It is interesting to note the black soldier fly was considered a pest due to its ability to colonise organic waste and manure, while currently for the same reason, this feature of the fly is considered a key asset in its transition for use as a tool used as part of a circular economy. The realisation of its potential in recycling organic matter and use as a feed source started about 20 to 30 years ago, first in identifying its uses and second in showing that mass-rearing it is possible. In fact, the worldwide focus of academia and private enterprise took off only about five years ago. This is an exponential increase and we expect a lot of progress in the five years ahead. However, it should be emphasised: the black soldier fly can be a pest if not properly managed.

With regards to this review, the relationship between industrialisation of the black soldier fly and the occurrence of these issues should in no way be interpreted as cause and effect. It should be noted, from a historical context, mass production practices had not been developed and implemented when such accounts (i.e. myiasis and colonisation of bee hives) were published in the early twentieth century. During this period, these events were due to the surrounding circumstances. Naturally occurring black soldier fly populations in regions where societal (i.e. lack of sanitation) and industrial (i.e. maintenance of unhealthy stingless bee colonies) practices created opportunities for colonisation events to take place. Regardless, they should serve as a warning to the industry as it continues to grow and expand. Maintaining proper industrial management practices of associated black soldier fly colonies are essential to avoid the resurrection of the ghost of reputation past as a pest.

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