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(REVIEW ARTICLE)

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Biological aspects of the Stratiomyiidae Family

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Abstract

Distinctions found between the studied environments were used as clues to which resources are more abundant in each type of environment. However, soldier flies have many morphological differences and diverse habits. The objective of this mini review is to determine the bioecology of the Stratiomyiidae Family. The research was carried out in studies related to quantitative aspects of the Family, Subfamily and Species (taxonomic groups) and conceptual aspects such as: biology, geographical distribution, species, life cycle, damage, laboratory creation, economic importance, medicinal importance, biological aspects, and reproduction. A literature search was carried out containing articles published from 1975 to 2021. The mini-review was prepared in Goiânia, Goiás, from September to October 2021, through the Online Scientific Library (Scielo), internet, ResearchGate, Academia.edu, Frontiers, Publons, Qeios, Portal of Scientific Journals in Health Sciences, Pubmed, Online Scientific Library (Scielo), internet, ResearchGate, Academia.edu, Frontiers, Biological Abstract, Publons, Qeios, Portal of Scientific Journals in Health Sciences, and Pubmed, Dialnet, World, Wide Science, Springer, RefSeek, Microsoft Academic, Science, ERIC, Science Research.com, SEEK education, Periódicos CAPES, Google Academic, Bioline International and VADLO.

Keywords: Insecta; Taxonomy; Nomenclature; Life Cycle; Larvae; Behavior

1. Introduction

Figure 1 Specimen of Stratiomyidae; (Source: https://www.resource-online.nl/index.php/2021/06/02/soldier-fly-is-what-it-eats-too/?lang=en)

The order Diptera is mainly rich in decomposers (54%) and predators (28%) but several other eating habits are found. The separation of Diptera into trophic guilds can provide additional information about important communities, especially for comparison between environments. The first time that the distribution in trophic guilds was used for Diptera, it was done in urban forest fragments. Distinctions found between the studied environments were used as clues

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to which resources are more abundant in each type of environment. In this study, soldier fly larvae (Stratiomyidae) were described only as detritivores, and adults as floral visitors. However, soldier flies have many morphological differences and diverse habits (Figure 1) [1,2].

The Stratiomyidae family is composed of 12 subfamilies, all of which occur in the Neotropical region and there is considerable food diversification among these different subfamilies (Figure 2) [4,5].

Figure 2 *Hedriodiscus pulcher* (Wiedemann, 1824); (Source: https://www.ecoregistros.org/site_br/familia.php?id=220)

Larvae of the Stratiomyidae family can be terrestrial, mainly associated with decomposition of plant or animal organic matter; or aquatic associated with vegetation. In adults of European species, they are usually found in undergrowth, shrub leaves, trees in gardens and forest edges. In some adults of this family, they can also be found near larvae that they normally use as a food source (Figure 3) [5,6,7].

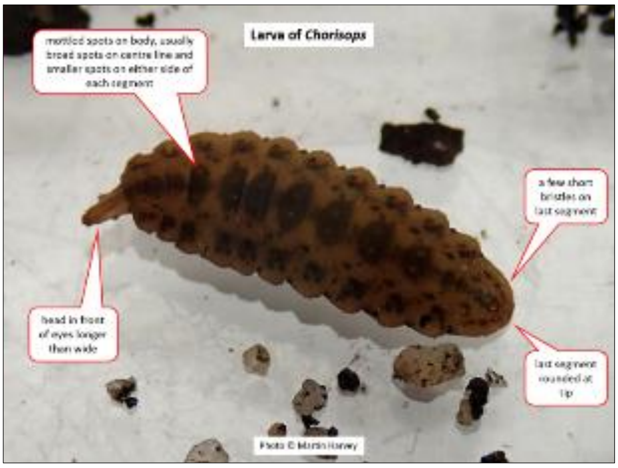

Figure 3 Larvae of Stratiomyidae

Aquatic larvae of the subfamilies Hermetiinae and Stratiomyinae are found in practically all types of inland water collections and are mainly associated with aquatic vegetation or unconsolidated substrate on the bottom of rivers and lakes. Larvae of some species of the subfamily Raphiocarinae were found on decaying trunks within a remnant forest of the Atlantic Forest. Sarginae larvae are little known in the Neotropical region, due to the difficulty of obtaining larval stage flies and the lack of knowledge of their specific habitats. Among the Sarginae are coprophagous and sarconecrophytophagous larvae, which participate in the recycling process of plant organic matter (Figure 4) [6,7].

Figure 4 Habitus of Stratiomyidae: (28) *Chloromyia tuberculata* James, dorsal view ♀; (29) *Chrysochlora amethystina* (F.), lateral view ♂; (30) same, *Chrysochromioides micropunctata* Brunetti ♀; (31) same, *Crocutasis abyssinica* Lindner ♂; (32) same, *Cyphoprosopa lindneri* James, ♂; (33) same, *Dactylotinda saegeri* Lindner ♂; Source: https://www.researchgate.net/figure/33-Habitus-of-Stratiomyidae-28-Chloromyia-tuberculata-James-dorsal-view-29_fig5_321966562

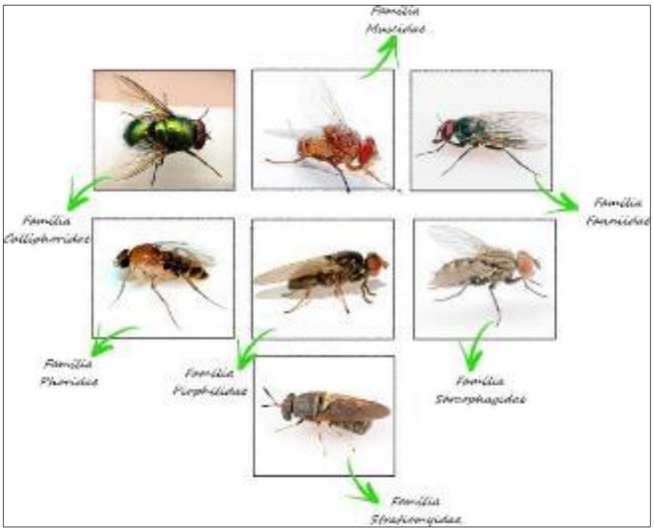

Figure 5a Forensic Entomology (Stratiomyidae Family) (Strais) an important ally in the resolution of cases, insects have their life cycle, and through the analysis of the collected insects it will be possible to determine or approximate the post-mortem interval. The corpse becomes a perfect environment for the proliferation of various insects. It is possible that each species is related to a certain phase. Diptera insects (flies) are very important in Forensic Entomology, as they are the first to reach the body. They are attracted by the odors of decomposition. The colonization of carcasses is done mainly by flies that belong to the families: Calliphoridae, Sarcophagidae, Muscidae, Fanniidae, Stratiomyidae, Phoridae and Piophilidae. Families are represented in the figure below; (Source: Available at: http://pontobiologia.com.br/csi-da-vida-real-entomologia-forense/)

There are reports of association of the larvae of some species with mango *Mangifera indica* L. (Anacardiaceae), associating their life cycle with the fruit cycle and the bamboo shoot. In Brazil Sarginae larvae have been found in different types of plant resources such as branches, inflorescences, and plant fruits [5,6,7].

Family adults are generally floral visitors and use resources such as nectar to feed themselves, acting as pollinators. Little is known about the biology of the larvae of each Stratiomyidae subfamily, but through the studies already completed we can see that the vast majority have the trophic guild mainly linked to the recycling of organic matter (Figure 5 a and b) [7].

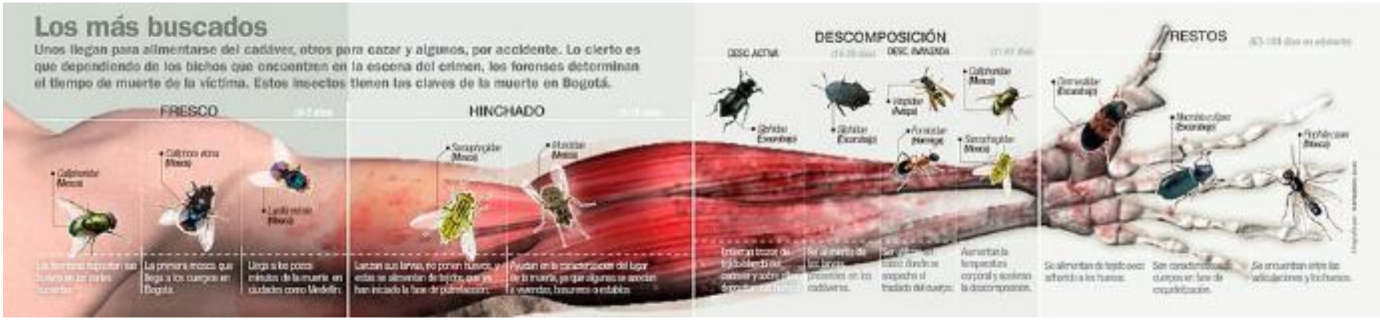

Figure 5b According to some authors, the corpse becomes a perfect environment for the proliferation of various insects. It is possible that each species is related to a certain phase. The phases are: Chromatic: blowflies (Calliphoridae), oviposition, hatching the larvae. Adult beetles of the Silphidae family may appear. Gaseous: Calliphoridae, Sarcophagidae and Muscidae larvae. There is also the presence of adults and larvae of the Silphidae and Histeridae beetles. Coliquative: Coleoptera of the Staphylinidae and Histeridae families, appear and feed on other insects. Skeletonization: predominance of Staphylinidae, Histeridae and Dermestidae coleoptera. Diptera insects (flies) are very important in Forensic Entomology, as they are the first to reach the body. They are attracted by the odor of decomposition; (Source: Available at: http://pontobiologia.com.br/csi-da-vida-real-entomologia-forense/)

The flies of the Stratiomyidae family are known as "soldier flies". The name is derived from the Greek: stratiotes mean soldier (or warrior), because the marks on the abdomen resemble the distinguishing marks of hierarchy on the military uniform (Figure 6) [8,9].

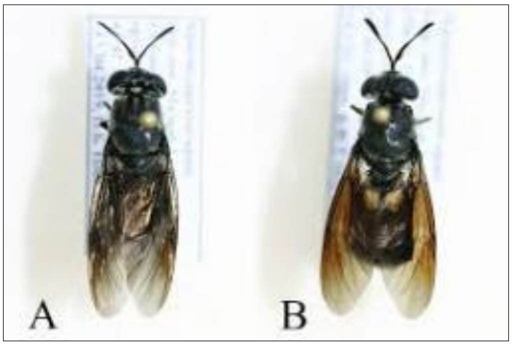

Figure 6 *Hermetia illucens* (Linnaeus, 1758): A -female, B –male; (Source: Photo: Vladimir V. Gladun)

The species of the Stratiomyidae family range in size from 3 to 28 mm in length. Some species are slender, shaped like wasps (mimicry), while others may be vigorous or conspicuously flat. The coloration also varies, from black to yellow to white to green patterns, with metallic reflections being frequent. Adults are often found resting on vegetation or feeding on flowers. Usually close to larval habitat. Adults' mouthparts, capable of grinding, indicate a preference for granular foods. Thus, some stratiomyids can feed on nectar, while others probably feed on pollen grains (Figure 7) [8,9,10].

Stratiomyidae larvae can develop in aquatic or terrestrial environments. They feed on decaying organic matter such as dung, mushrooms, and decaying animal meat. They live in fallen leaves or in upper soil layers (Beridinae, *Chloromyia,* *Microchrysa*), sometimes in manure (Sarginae). Pachygasterinae larvae are usually found in decaying tree bark *Clitellaria ephippium* (Fabricius, 1775) larvae develop in ant nests (Figure 8) [10].

Figure 7 Diptera-Stratiomyidae-*Cyphomyia pilosissima* Gerstaecker, 1857 soldier flies Male (A)

Figure 8 *Oplodontha viridula* (Fabricius, 1775);

(Source: https://commons.wikimedia.org/wiki/File:Oplodontha_viridula_(Stratiomyidae)_-_(male_imago),_Arnhem,_the_Netherlands_-_2.jpg)

Aquatic species can occur in both rapids and standing water, and some species can inhabit the semi-aquatic environment. Some Stratiomyidae larvae are halophilic and can be found in brackish water *Oplodontha viridula* (Fabricius, 1775), some *Stratiomys* and *Nemotelus* ssp.). Aquatic species can occur in both rapids and standing water, and some species can inhabit the semi-aquatic environment. Some Stratiomyidae larvae are halophilic and can be found in brackish wate *O. viridula* some *Stratiomys* and *Nemotelus* ssp. [11].

Stratiomyidae is a family of Diptera (flies), historically placed in the obsolete group called Orthorrhapha. The family contains more than 2000 species in about 400 genera. They are widely distributed across all zoogeographic regions. They are small to medium-sized animals, their larvae are associated with decomposition of plant organic matter, both in natural and urban areas. A few species have become specialized in man-made organic waste [11,12].

Subfamilies: Anti-sign, Beridinae, Chiromyzae, Chrysochlorininae, Clitellariinae, Hermetiinae, Nemothelinae, Pachygastrinae, Parhadrestiinae, Raphiocerinae, Sarginae and Stratiomyinae [12].

Stratiomyidae are recognized by the following characters (1 to 4 = Stratiomyomorpha; 5 to 8 = Stratiomyidae autapomorphies): (1) a puparia formed from the integument of the last larval stage, (2) cuticle calcium carbonate impregnated larval, (3) loss of anterior leg spur, (4) abbreviated costal vein, (5) loss of middle tibial spur, (6) female enclosures separated by 10 tergite, (7) radial veins grouped forward from the costal margin of the wing and (8) reduced-size disc cell (Figure 9) [12].

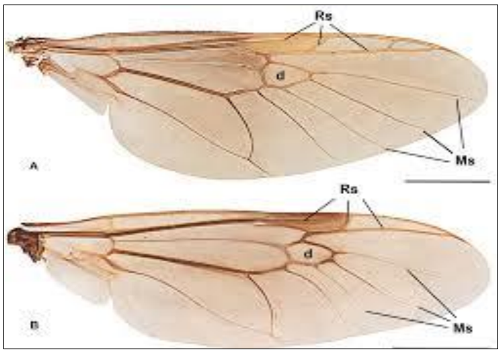

Figure 9 Radial veins grouped forward from the costal margin of the wing and (8) reduced-size disc cell; (Source: https://www.brc.ac.uk/soldierflies-and-allies/early-stages/stratiomyidae)

1.1.1 Genus Chloromyia

Just one species in this specie, *Cephalopholis formosa* (Shaw, 1812) (Serranidae) serranidaes, that has a distinctive striped appearance with a notched 'tail' (Figure 10, 11 and 12).

Figure 10 *Cephalopholis formosa* (Shaw, 1812) (Serranidae) serranidaes; (Source: https://fishesofaustralia.net.au/home/species/4411)

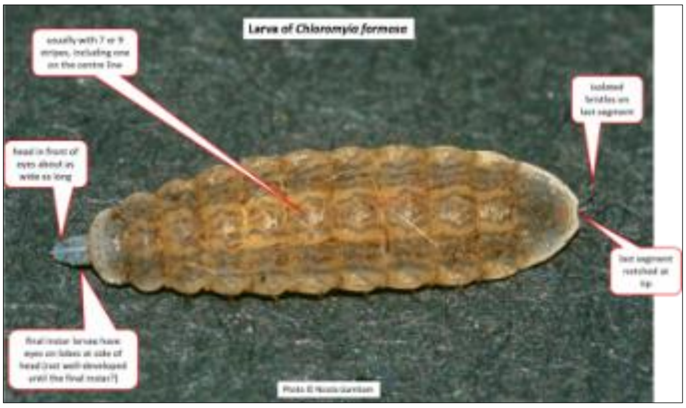

Figure 11 Genus *Chorisops*; (Source: https://www.brc.ac.uk/soldierflies-and-allies/early-stages/stratiomyidae)

Two species in this genus (*C. nagatomii* and *C. tibialis*), and there are no known features for distinguishing the larvae. The larvae can be readily found among leaf litter and under stones (Figures 13. 14, 15, 16, 17, 18, 19 and 20).

Figure 12 Subfamily Pachygastrinae; (Source: https://www.brc.ac.uk/soldierflies-and-allies/early-stages/stratiomyidae/pachygastrinae)

Figure 13 Genus *Sargus* four species. *Sargus bipunctatus* (Scooli, 1763) has distinctive stripes, but the others are darker. *Microchrysa* larvae are similar but smaller; (Source: Source: https://www.brc.ac.uk/soldierflies-and-allies/early-stages/stratiomyidae)

Figure 14 Genus *Chorisops; (*Source: https://www.brc.ac.uk/soldierflies-and-allies/early-stages/stratiomyidae)

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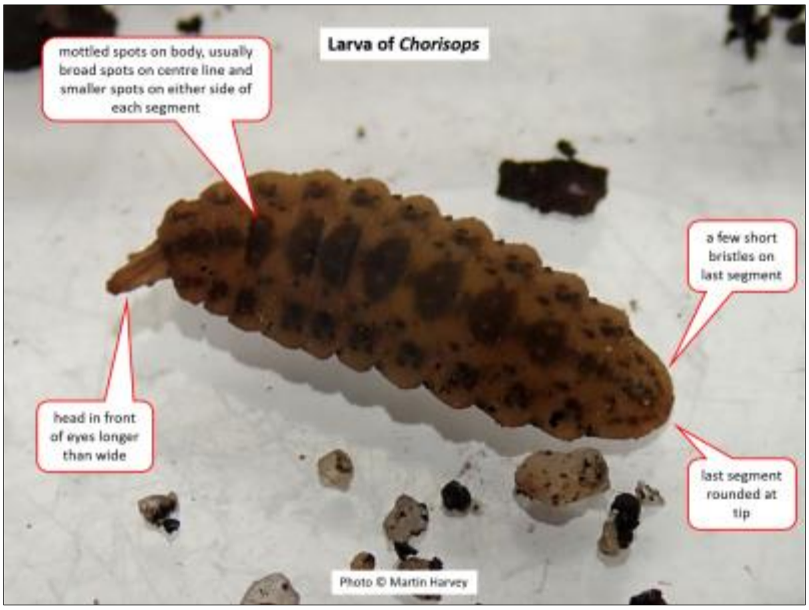

Figure 15 Subfamily Pachygastrinae

Figure 16 Genus *Sargus* four species. *S. bipunctatus* has distinctive stripes, but the others are darker. *Microchrysa* larvae are similar but smaller; (Source: Source: https://www.brc.ac.uk/soldierflies-and-allies/early-stages/stratiomyidae)

Figure 17 Recognising the genera - aquatic species *Odontomyia ornata* Macquart, 1826. (Ornate Brigadier) From Oulton Marshes in Suffolk. They show the larva of *O. ornata.* Both adult and larval *O. ornata* are rather like species in genus *Stratiomys*, but as Adrian's photos clearly show, the larva has characteristic hooks on the underside of segments 9 and 10 (these hooks are absent in *Stratiomys*). Larvae of *O. ornata* can be easier to find than the adults and are most often found in grazing marsh ditches with aquatic, floating vegetation [13]; (Source: https://www.brc.ac.uk/soldierflies-and-allies/early-stages/stratiomyidae)

Figure 18 *Stratiomys* genus; (Source: https://www.brc.ac.uk/soldierflies-and-allies/early-stages/stratiomyidae)

During the treatment of organic wastes, the growth of BSFL can be monitored by analyzing aspects of larval development. Larval development time, final larval weight, growth rate, and larval survival rate is reported to be 15–36.7 days, 154–271 mg, 2.3–37 mg/d, and 85.6–97.1%, respectively. The growth of BSFL can vary depending on the types of substrates and rearing conditions. For example, the survival rate of BSFL were 87%, 90%, and 93% when fed with food waste, fruits & vegetables, and poultry feed, respectively. However, when fed with digested sludge, the survival rate was as low as 39% [14,15].

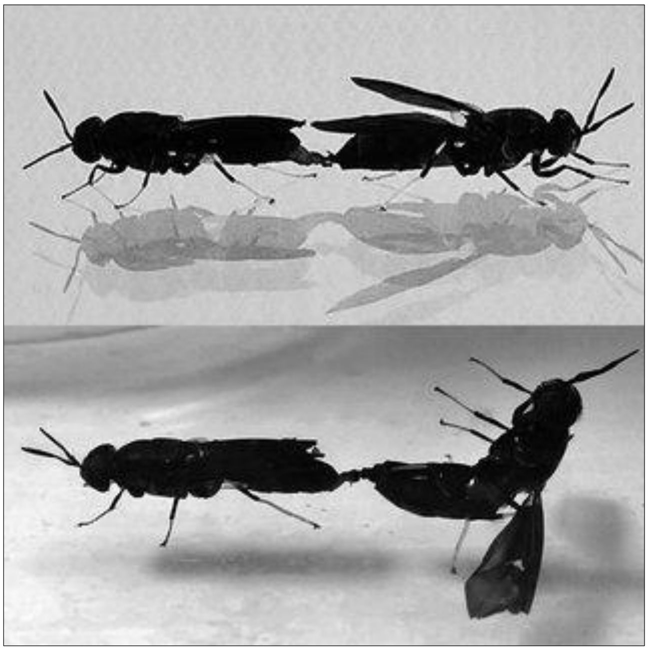

Figure 19 Successful copulation of *Hermetia illucens* (Linnaeus, 1758) according to female landing type: A) dorsal and B) ventral; (Source: https://www.researchgate.net/figure/Successful-copulation-of-Hermetia-illucens-according-to-female-landing-type-A-dorsal_fig3_327935981)

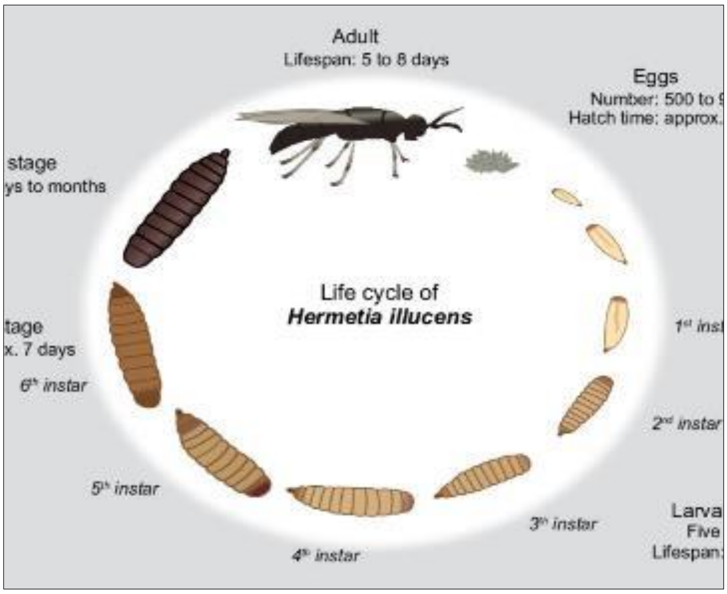

Figure 20 The life cycle of the black soldier fly *Hermetia illucens* (Linnaeus, 1758); (Source: (modified from De Smet et al., 2018).)

Throughout the process of food waste treatment using BSF (Food Waste Treatment Using BSFL), the volume of waste is reduced as it is utilized as a substrate. When BSFL ingest substrates for their growth, the substrates are converted into nutritional compositions of BSFL. Such bioconversion process leads to the production of larval biomass, and this can be utilized for further applications in the field of waste valorization. Since the production of well-grown BSFL biomass is the requisite for high-quality animal feed and biodiesel, feeding and the resulting growth of BSFL is very important. The waste reduction efficiencies are strongly related to the amount of biomass production and are also related to the protein conversion. As summarized in previous studies have analyzed the substrate reduction ratio, biomass conversion ratio, and protein conversion ratio. Generally, the substrate reduction ratio and biomass conversion ratio are shown to be approximately 50% and 13%, respectively; however, the protein conversion ratio varies between studies likely due to the difference in substrate (Figures 21 and 22) [16,17,18,19,20,21].

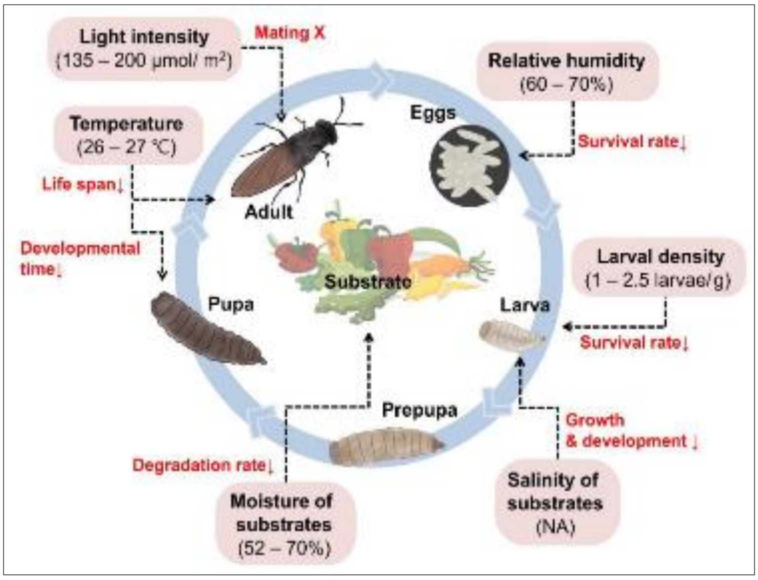

Figure 21 Factors that directly affect black soldier fly *Hermetia illucens* (Linnaeus, 1758) larvae (BSFL) growth. Optimal ranges are indicated below the factors. The consequences that follow when each factor is not properly controlled are shown in red. (i) Relative humidity: survival rate decreases when relative humidity is lower than the optimal range; (ii) larval density: indicates the ratio between substrate weight (g) and number of larvae, and survival rate decreases when larval density is higher than the optimal range; (iii) light intensity: mating does not occur depending on the light source; (iv) temperature: adult life span and pupal development time decrease when temperature is higher than the optimal range; (v) salinity of substrate: growth rate and development of larvae decrease when salinity of substrate increases ; (vi) moisture of substrates: degradation rate decreases when moisture is higher than the optimal range

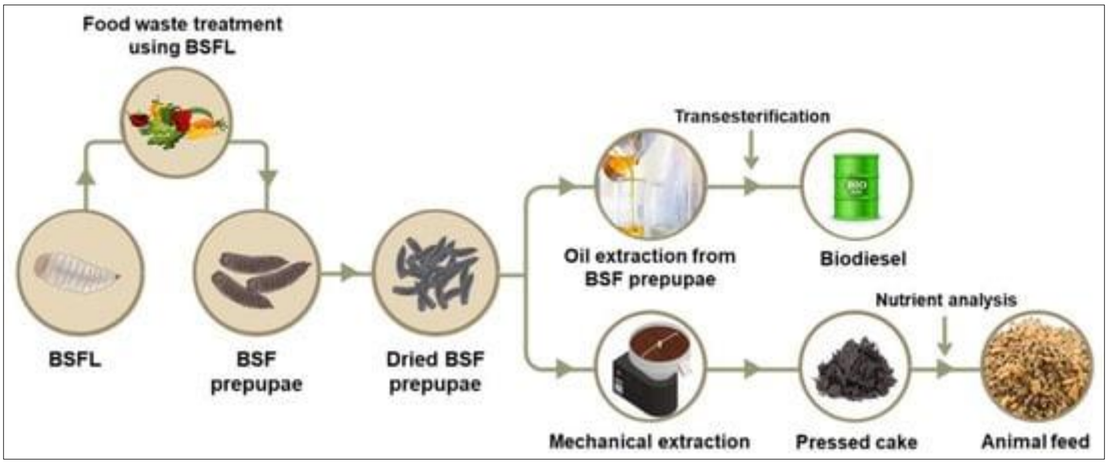

Figure 22 Process of food waste treatment using BSFL and production of biodiesel and animal feed from BSF (modified from). The aim of this work was to investigate the influence of the fatty acid properties of Hermetia illucens on the quality of biodiesel through a transesterification reaction. *Hermetia illucens* (L., 1758) larvae were cultivated on fruit residues and food residues. Harvested prepupae were processed into dry biomass and stored in a container for later use. *H. illucens* prepupae were transesterified with methanol in the presence of sulfuric acid as a catalyst. The reaction was conducted using methanol to sample 6:1 mass, reaction time (255 min), reaction temperature (50°C) and catalyst charge (20v/v%). The degree of unsaturation, long-chain saturated factor and methyl ester composition of each biodiesel also influence the properties of the biofuel. The fatty acid extracted from the biomass of *H. illucens* showed a high content of saturated fatty acids derived from both diets. Lauric acids were the predominant SFA; (Source: https://www.mdpi.com/2227-9717/9/1/161/htm)

Objective

The objective of this mini review is to determine the bioecology of the Stratiomyiidae Family.

2. Methods

The research was carried out in studies related to quantitative aspects of the Family, Subfamily and Species (taxonomic groups) and conceptual aspects such as: biology, geographical distribution, species, life cycle, damage, laboratory creation, economic importance, medicinal importance, biological aspects, and reproduction. A literature search was carried out containing articles published from 1975 to 2021. The mini-review was prepared in Goiânia, Goiás, from September to October 2021, through the Online Scientific Library (Scielo), internet, ResearchGate, Academia.edu, Frontiers, Publons, Qeios, Portal of Scientific Journals in Health Sciences, Pubmed, Online Scientific Library (Scielo), internet, ResearchGate, Academia.edu, Frontiers, Biological Abstract, Publons, Qeios, Portal of Scientific Journals in Health Sciences, and Pubmed, Dialnet, World, Wide Science, Springer, RefSeek, Microsoft Academic, Science, ERIC, Science Research.com, SEEK education, Periódicos CAPES, Google Academic, Bioline International and VADLO.

3. Studies performed

3.1. Study 1

Hermetia illucens (L., 1758) is a species of Brachyceran Diptera of the Stratiomyidae family originating in North America, which thrives in temperate, subtropical and warm areas of North America, and is currently also widely distributed throughout Europe, with higher incidence in the South, occupying territories in the Iberian Peninsula, the South of France, Italy, Malta, Croatia and even Switzerland. It has also been present in Africa, Asia (Figure 23].

Figure 23 *Hermetia illucens* (L., 1758); (Source: Fly breeding **-** illucens.com)

Particularly India, and some islands in the Pacific. The black soldier fly, when it reaches the adult stage, is black in color with metallic reflections, which alternate between blue and green hues. As a Diptera, it has two membranous wings, which fluttered when flying, and has two transparent windows in the abdomen to protect them (Figure 24).

It has a broad head with large eyes and long antennae, composed of 3 segments, when they reach adults. The ends of the legs are whitish in color. It does not come with a stinger at the tip of the abdomen, so it is not a dangerous species. They can luff between fifteen and 25 millimeters in length. This species reproduces 3 times a year, between the months of April and November. Lay eggs during the day, for two days after fertilization. Each female lays an average of five hundred eggs, each of which is yellowish in color and one millimeter long. After 1 week, these eggs hatch (Figure 25).

The white-colored larvae reach up to twenty-seven millimeters in length and six millimeters in width, weighing around 220 milligrams, in the last larval stage. They are characterized by a prominent head and mouth. The larvae feed daily and can consume between 25 to 500 milligrams of fresh organic matter, such as manure, food scraps or rotting vegetables, which they convert into high quality proteins and lipids. If there are temperatures between 29 and 31 degrees Celsius and relative humidity in the order of 50 to 70%, the ideal conditions are met for the black soldier fly larvae to reach maturity within two months (Figure 26).

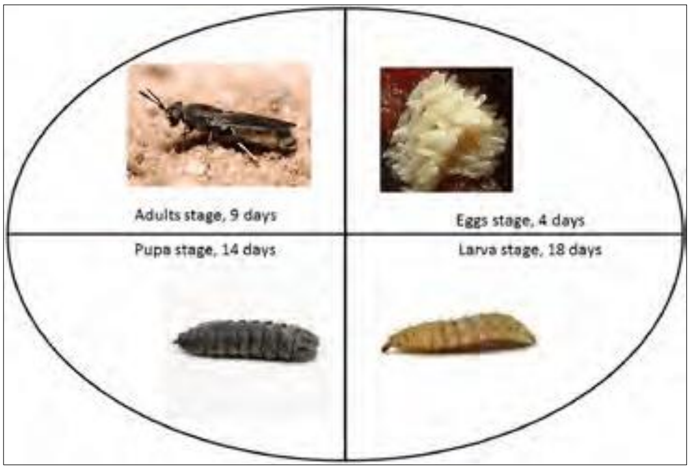

Figure 24 Black soldier fly *(Hermetia illucens* L. 1758) life cycle (45 days total). They spend two stages of their life in the growing media as eggs (4 days) and larva stage (18 days). Only when they are transforming from pre-pupa (14 days) to adults (9 days) do they move away from the media to find a dry place to complete the metamorphosis (source eggs stage: www.justbajan.com, source larva stage: pre-pupa stage adult stage; (Source: www.aquaponics.wikia.com.)

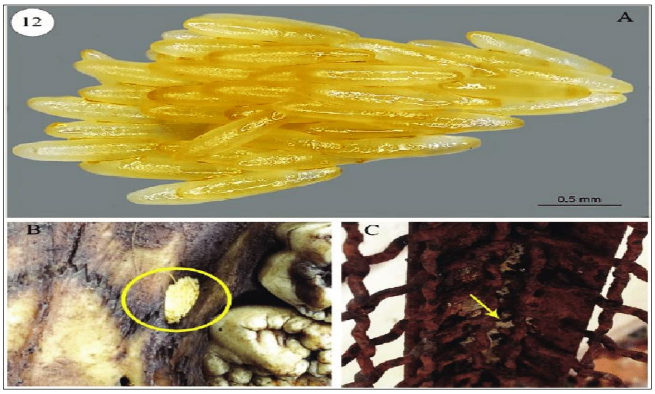

Figure 25 Egg posture of *Hermetia illucens* (Linnaeus, 1758). (A) Egg cluster under stereomicroscope. (B) Eggs cluster on the swine cranium (greater palatine foramen). (C) Egg cluster inside open slots in the metal cage; (Source: esearchgate.net/figure/Egg-posture-of-Hermetia-illucens-Linnaeus-1758-A-Egg-cluster-under_fig7_331073068)

Figure 26 Illustration of black soldier fly (BSF) *Hermetia illucens* (Linnaeus, 1758) (Diptera: Stratiomyidae) and high-quality nutrient larval biomass; (Source: https://www.researchgate.net/figure/Illustration-of-black-soldier-fly-BSF-Hermetia-illucens-Diptera-Stratiomyidae-and_fig1_328679995)

At the end of the larval stage, before transforming into pupae, the larva empties the digestive tract and stops feeding and moving. Only after transforming into pupa does the exoskeleton darken. Black soldier fly larvae have a protein content in the order of 35-46% and an essential amino acid profile like fishmeal (Figure 27).

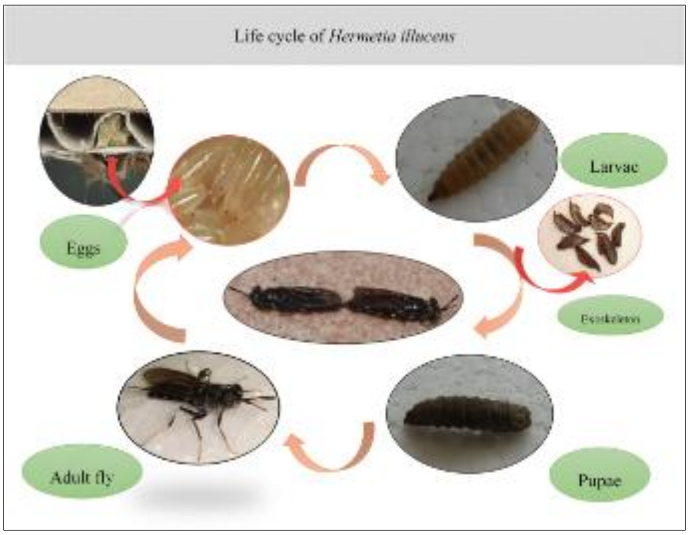

Figure 27 Characteristic of *Hermetia illucens* (Linnaeus, 1758) (Diptera: Stratiomyidae) fatty acid and that of the fatty acid methyl ester synthesize based on the aim of this work was to investigate the influence of the fatty acid properties of Hermetia illucens on the quality of biodiesel through a transesterification reaction. *H. illucens* larvae were cultivated on fruit residues and food residues. Harvested prepupae were processed into dry biomass and stored in a container for later use. *H. illucens* prepupae were trans esterified with methanol in the presence of sulfuric acid as a catalyst. The reaction was conducted using methanol to sample 6:1 mass, reaction time (255 min), reaction temperature (50°C) and catalyst charge (20v/v%). The degree of unsaturation, long-chain saturated factor and methyl ester composition of each biodiesel also influence the properties of the biofuel. The fatty acid extracted from the biomass of H. illucens showed a high content of saturated fatty acids derived from both diets. Lauric acids were the predominant SFA**.**

On the other hand, the lipid content varies between 15 and 49%, and the variation depends exclusively on the larvae's diet. This lipid percentage can, in any case, be reduced to up to 9%, by means of degreasing processes, which, by drag, will result in a corresponding increase in the protein content from 35% to 60%. Likewise, the fatty acid levels of these larvae mirror the fatty acid profile of their diet, meaning they can be manipulated. For example, the black soldier fly's n-3 fatty acid content is about 0.2% when fed on cow manure, however, this percentage rises to 3% if the larva is fed 50% of cow manure and 50% fish waste (Figure 28 and 29).

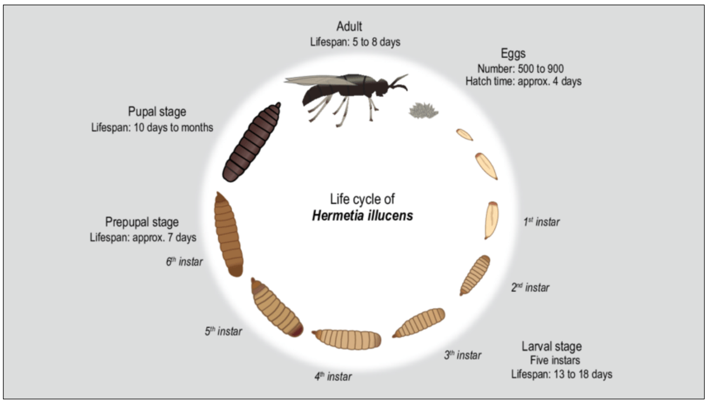

Figure 28 The life cycle of the black soldier fly *Hermetia illucens* (Linnaeus, 1758) (Diptera: Stratiomyidae); (Source: Modified from De Smet et al., 2018)

Figure 29 *Hermetia illucens* (Linnaeus, 1758) (Diptera: Stratiomyidae) larvae (left) and adult (right); (Source: esearchgate.net/figure/Hermetia-illucens-larvae-left-and-adult-right_fig3_342529688)

This species is commonly used for pest control and bioconversion of organic waste. The larvae can also be used for animal consumption, once converted into flour, bran, and other feeds, which in turn are used in aquaculture. From the pupae, once processed and pressed, fat can be extracted, which makes biodiesel.

Black soldier fly meal has been weighed as a base ingredient for aquaculture fish rations, mainly aimed at freshwater species. Thus, the replacement of fish meal by black soldier fly meal was tested in yellow catfish *Pylodictis olivaris* (Rafinesque, 1818) fish, rainbow trout and common carp cultures. From these tests, it was concluded that the black soldier fly meal can be used as a substitute for fish meal and feed, without prejudice to the growth or digestibility of the fish species and even for other fish species.

Aquaculture, such as European sea bass, Japanese sea bass *Lateolabrax japonicus* (Cuvier, 1828) fish and Atlantic salmon (*Salmo salar* Linnaeus, 1758) However, the same did not happen in the tests with sea bream, in which there were losses in growth and digestibility. This time, it is concluded that there are significant differences between species regarding the potential use of black soldier fly meal as a substitute for conventional fish meal [22,23,24,25].

3.2. Study 2

It all starts with the laying of the eggs of the adult *Hermetia illucens* (Linnaeus, 1758) (Diptera: Stratiomyidae). Our flies are kept under ideal, digitally controlled, biosafe conditions that do not only replicate nature's conditions, but goes beyond and enhances them. By recreating and improving the tropical living conditions, we succeed in maximizing the number of eggs deposited over and over again. While in a natural habitat a survival rate of only 1-5% is quite sufficient to maintain the species, we are getting closer to 100% survival through continuous improvements and advancements (Figure 30).

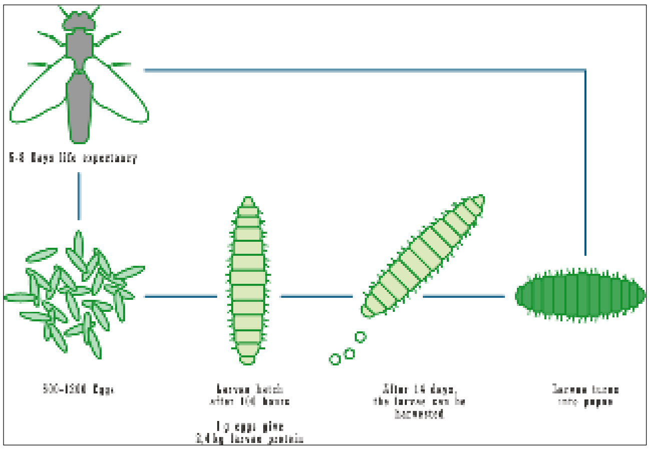

Figure 30 Life cycle of *Hermetia illucens* (Linnaeus, 1758) (Diptera: Stratiomyidae). Aquatic and terrestrial environment

Only when the larvae in our nursery have reached a reasonable size, they are ready to be relocated to the fully automated growth stations, the computer-controlled fattening, and bioreactors. By applying technology, the perfect conditions are created to achieve the ideal mast size in the shortest possible time. But all the technology is ineffective without the experience of the employees (these have been part of the operation since inception)! We have also optimized the process behind the horizontal agriculture. In this process, the larvae are not exposed to the stress and undue pressure created by farming the larvae in vertical stacks. Using this combination of a flat bed and an ideal amount of feed and low toxins we achieve optimized yields [26,27, 28,29,30].

3.3. Study 3

The larvae of the black soldier fly (BSF) *Hermetia illucens* (L. 1758) (Diptera: Stratiomyidae) are promising organisms to be used in the bioconversion of organic waste. Creating BSF indoors has been suggested as an economical approach for countries with long winters or low levels of sunlight throughout the year. As BSF mating is visually mediated, artificial lighting conditions are critical to a successful indoor breeding system ((Figure 31) [31,32,33,34,35,36].

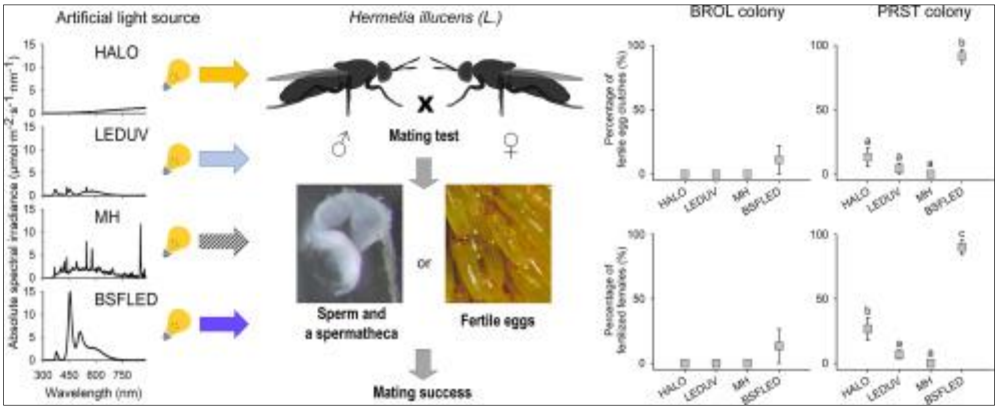

Figure 31 Mating success of the black soldier fly, *Hermetia illucens* (L. 1758) (Diptera: Stratiomyidae), under four artificial lights; (Sources: https://www.sciencedirect.com/science/article/abs/pii/S1011134419307808)

We determined the spectra of four artificial light sources, compared their spectral composition against the visible spectrum of BSF, and compared their effects on the mating success of two different BSF colonies. BSFLED was the most energy efficient light source in spectral composition and led to the highest mating success in terms of percentage of inseminated females and fertile litters. Thus, BSFLED is the most suitable light source tested in our experiment for reproducing BSF indoors. The colony effect and possible light flicker effect on BSF mating success were also detected [36].

3.4. Study 4

Large volumes of manure are produced by concentrated animal facilities around the world that must be properly managed (Figures 32 and 33).

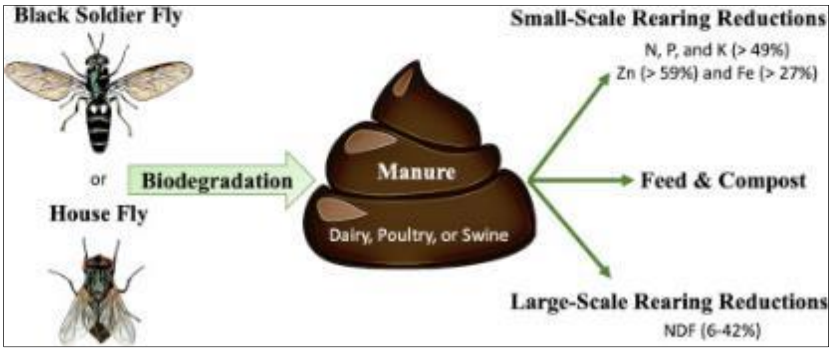

Figure 32 Black soldier fly, *Hermetia illucens* (L., 1758) (Diptera: Stratiomyidae), and house fly, *Musca domestica* L. 1758 (Diptera: Muscidae), larvae reduce livestock manure and possibly associated nutrients: An assessment at two scales; (Source: V3.boldsystems.org)

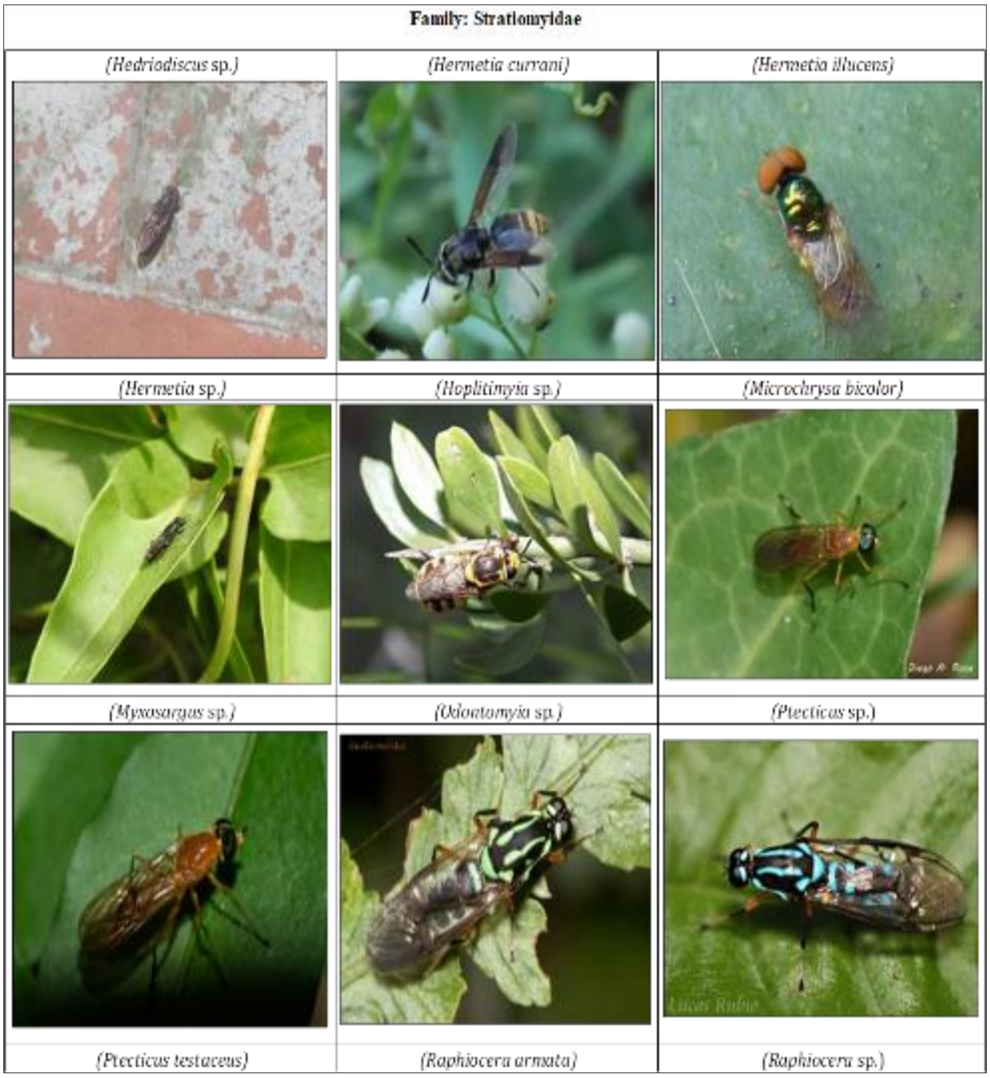

Figure 33 Species of the Stratiomyidae Family; (Source: Source: V3.boldsystems.org)

Flies offer a partial solution with their ability to reduce these residues and heavy metal pollutants. Meat and crop proteins are being supplemented by insect proteins for many foods around the world. The results indicate that nitrogen is a key nutrient impacted by larval manure digestion by both species, regardless of scale. However, the scale significantly affected the reductions in other nutrients as well as the type of manure in which the insects were reared. Ultimately, this study demonstrated that manure type and rearing scale affect the ability of BSF and HF larvae to reduce nutrients and heavy metals in manure and therefore insect management procedures need to be congruent. [36,37,38,39].

4. Conclusion

In this study, soldier fly larvae (Stratiomyidae) were described only as detritivores, and adults as floral visitors. However, soldier flies have many morphological differences and diverse habits.

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