

AFRO**B**eyondist**C**ivilization



BEYONDIST
BSF
FARMING

Researched
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ABSTRACT

BEYONDISM aims to publish required key information for domestication and production of the insect *Hermetia illucens*. Also known as « Black Soldier Fly » (BSF), this cosmopolitan dipteran, belonging to the family of Stratiomyidae, is considered as non-pest. Being saprophagous at the larval stage, it is able to biodegrade various organic wastes. Agriculture is Africa's most important sector. Particularly, in 2017, 34% of Kenya's GDP and 65% of the total export of Kenya were because of agriculture (The World Bank, 2018). In total, 63% of all food produced in Kenya originates from smallholder farmers. Smallholders produce the majority of Kenya's agricultural products, but their yields are low. To reduce hunger, it is important to increase the productivity of the smallholders in this country. A big problem in the current agricultural sector of Kenya are the high prices for animal feed due to high protein prices. For chicken, feed is around 60-70% of the total production costs (FAO, 2007). For pigs, feed is around 80% of the production costs (FAO, 2012). Of these percentages, around 60% of the total feed costs are because of protein. These high protein prices lead to low-quality and very expensive animal feed. We realize that the current situation is unfair towards farmers and want farmers to receive a fairer income. The production of the BSF on the waste products of smallholder farmers gives farmers an opportunity to produce protein rich animal feed without having to buy expensive animal feed with foreign protein sources as soybean - and fishmeal. The usage of the black soldier fly larvae as feed would decrease the costs of animal feed for farmers and can lead to a more food secure economy.

INTRODUCTION

Demographic evolution, impact of climate change on natural resources and necessity of their sustainable management, require increasing the global food production by about 70% before year 2050 in order to feed the 9 billion inhabitants the planet will count by then. The necessity to feed such a growing population generates a constant pressure on both plant and animal productions. This is especially true in Africa, which is the most densely populated region in the world. Industrial rearing of chickens, pigs and fish is in continuous expansion due to increased consumption by humans. This growth is intimately dependent on the availability of protein sources for sustaining animal productions.

The production of vegetal protein-rich soybean meal supports this demand to a great extent with a worldwide production of about 124 million tons (United States Department of Agriculture, 2012). However, soybean intensive cultivation has a strong impact on

environment (deforestation, pollution, GMO) and the sustainability of this production remains widely debated. Fishmeal, with over 4.7 million tons produced yearly, is the main source of animal protein. Animal proteins generally display higher biological value than plant proteins and they are much more used to feed fishes in aquaculture.

Fishmeal essentially originates from the fisheries of small pelagic fishes, mainly Peruvian anchovies. 68% of this fishmeal was intended to aquaculture food. The use of this resource is rightfully questionable. Moreover, the stagnation of wild fish captures, linked to an increasing and endless demand for animal rearing purposes, makes this resource increasingly expensive and limited.

The availability of food in aquaculture is restrained, more particularly as regards the sources of protein. Therefore, the use of agricultural byproducts and unconventional animals as bioconverters becomes a true necessity. Although rather anecdotal until now, insect rearing opens heuristic perspectives well beyond the field of animal feeding.

According to FAO (2012), no less than 527 species of insects are currently consumed by humans in 78 countries. Most of them are collected in the wild, whereas their rearing in controlled conditions could be much more advantageous for many purposes, including their use as protein sources for other animal productions.

The Black Soldier Fly is often found in the vicinity of poultry and pig rearing units where their larvae feed on manure or compost. BSF Larvae are able to utilize massive amounts of organic waste and reduce their unpleasant smells. They reduce efficiently the accumulation of polluting compounds (nitrogen, phosphorus) from manures and composts. They also modify the bacterial microflora by reducing the occurrence or abundance of undesirable bacteria.

Therefore, BSF larvae increasingly emerge as a sustainable alternative method for organic waste treatment. Moreover, they are efficient converters as they produce a protein and lipid-rich biomass from substrates that can be poorly used by monogastric animals. These characteristics, linked to a short production cycle, make BSF larvae very good candidates for intensive production, as far as the domestication and the production of the insects are controlled.

ANALYSIS

Classification and Distribution

Hermetia illucens known as the Black Soldier Fly (BSF) is an insect belonging to the order of Dipterans, family of Stratiomyidae, sub-family of Hermetiinae.

Native of tropical, subtropical and temperate regions of the American continent, BSF is nowadays present in the rest of the world, between latitude 40° south and 45° north, and has been found in many countries across Europe, Africa, Oceania (Australia and New Zealand) and Asia (Indonesia, Japan, Philippines and Sri Lanka).

Human migrations and trade of goods have contributed to its dispersion. This insect, considered as non-pest, does not appear in the list of disease carrying organisms or vectors for pathogens. Some cases of myiasis caused by larvae of *H. illucens* have been reported, but are just exceptional.

Anatomy

Hermetia illucens is a holometabolous insect: the transition from the larval stage to the adult stage happens following a passage through a nymphal stage. Transformation is complete, and larvae and adults have contrasting morphologies and life habits. Larvae are saprophagous (feed on decaying matter) and photophobic (grow well in reduced light): they live and feed on organic matter (animal or plant) in decomposition.

Their cephalic (head) capsule is separate from their body; their strong mouthparts serve eating purposes but also contribute to their locomotion. The larval body comprises 11 segments covered by hairs and bristles. Its colour is beige or light brown until pupation, thereafter it turns to dark brown. Larvae can reach up to 20 mm in length and about 6 mm in width.

Adults measure from 13 to 20 mm in length, they possess two long antennae, a single pair of well-developed wings (when at rest wings are folded up to one on the other), as hind wings are tiny (halteres, as in all dipterans), and three pairs of legs with a white/yellow tarsus. Males are smaller than females and an anatomic difference on the last abdominal segment enables to discriminate between genders. Females possess a retractile tubular

oviduct whereas males exhibit an aedeagus (male insect reproductive organ) and a pair of hooks which enable him to grasp the female genital organ during copulation.

Life Cycle

The BSF life cycle varies between populations (wild or domesticated) and environments (temperature, humidity, light intensity, quality and quantity of available food). During the breeding phase, also referred to as the “hatchery” phase, the females lay between 320 and 1000 eggs, on a dry substrate in a humid environment (to limit the water losses of their eggs) using their ovipositor.

Eggs are laid into tight rows, generally in an interstice to hide them from predation and close to a potential food source. BSF females lay their eggs close to those of other individuals, and they die soon after oviposition. Eggs have an ovoid shape, and are about 1 mm long. They change from beige to yellow/beige colour during the incubation period, which lasts from a little bit more than 4 days, at 27-29°C to about 3.5 days at 30°C.

As soon as larvae have hatched (0.66 mm long), they use surrounding organic matter as a food source. The duration of the larval stage lasts from 4 weeks to 5 months, depending on food availability. Temperature is also a key parameter for larval development and survival rates, the optimum temperature being in the 20-30°C range. The growing larvae perform successive moults (shedding covering periodically) that separate five larval stages. They reach successively the pupa then the imago stage following the imaginal moult.

Morphologically, the first four larval stages are difficult to differentiate (except for body size) but the prepupal stage (5th larval stage) is characterized by a marked colour change from beige to dark brown, a migration out of substrate (made easier by a modification of mouth organs in hooks), as old larvae cease feeding prior to pupation. The last stage refers to pupae, which are 12 to 25 mm long. They lie motionless; their cuticle (covering) is rigidified and rich in salts of calcium forming a dark envelope.

Generally, the metamorphosis is completed within 2 weeks and males often emerge earlier than females. After emergence, young adults take off after few minutes, after they have unfolded their wings. BSF is an eurygamous insect, as a consequence, it needs broad areas for its nuptial (mating) flight. Mating takes place about 2 days after the emergence of the imago, and another 2 days are needed before egg laying. An imago lives only 5 to 14 days,

its life expectancy being unquestionably dependent on body size (and associated energy reserves) and on access to water.

Physiology and Feeding

BSF adults do not need feeding as they largely live on the “energy reserves” built during the larval development, but these supplies can be supplemented by nectar. However, the environmental factor that intimately governs their life expectancy is the access to water: adults having access to water may live up to 14 days, whereas those deprived of water hardly survive more than 8 days.

BSF larvae are voracious (consumes food in great quantity) until 21-24 days after hatching. The substrate in which they live is saturated with water, so dehydration is reduced and the access to food is straightforward. However, if the substrate becomes excessively humid, larvae tend to go away. Their feeding activity reduces the volume of organic matter by 40 to 80% and strongly impacts the substrate’s content in nitrogen and phosphorus. BSF larvae are not cannibalistic.

Digestion – Enzymatic and Bacterial System

BSF larvae are polyphagous (have an insatiable appetite for food). This polyphagia, which enables them to make the most of many food sources, largely owes to their powerful mouthparts and efficient enzymatic activity of their digestive system (gut and salivary glands). It is especially in the intestine that enzymes such as amylases, proteases and lipases are most active. Other enzymes such as leucine arylamidase, α -galactosidase, β -galactosidase and α -mannosidase, not present or poorly active in domestic fly *Musca domestica*, are strongly effective in BSF larvae.

Besides, BSF larvae host an intestinal flora that takes an active part in the digestion of food. The identification by pyro-sequencing of bacterial communities of BSF larvae’s intestine has provided evidence for a specific intestinal flora, which largely differs from those documented in other insects. This flora comprises four phyla (Bacteroidetes, Firmicutes, Proteobacteria and Gammaproteobacteria) in variable proportions, depending on food sources. Among these bacterial communities, some strains or species have a substantial enzymatic activity (protease, amylase, cellulase, lipase), such as *Bacillus amyloliquefaciens*, *B. stratosphericus* and *Proteus mirabilis*.

Behavior

Usually, adults BSF are found near places where manure, decaying food or dead animals are abundant. Smells from decaying organic matter attract females that are ready to lay eggs, whereas males prefer sunny places where vegetation prevails. Also, males are “strongly territorial” in that they defend their area against other males until mature females in search of a mate pass nearby.

The life of a BSF imago being very short, mating takes place no more than 2-3 days after emergence. Mating is exclusively diurnal and comprises several steps: first the male grabs a female flying over its resting area with its legs and hooks of the aedeagus, then male and female will perform a “courtship flight” which can lead them up to 1.5 m above ground level where copulation starts. Thereafter, they return to ground level, for 20 to 30 minutes, and continue forming a pair, but here male and female look in opposite directions.

Reproduction steps are governed by environmental conditions and by time of the day; in particular, illumination and space availability are crucial during mating. The oviposition depends mainly on the temperature (optimum from 27.5°C to 37.5°C) and on humidity (30 to 90%).

Current knowledge of the biology of BSF provides a framework for starting their rearing in captivity.

HOW TO PRODUCE THEM?

Prepare yourself

Before you can start with the production of BSF, several products need to be available on the farm. Firstly, for hygiene aspect several pieces of protective clothing are recommended. These are; a pair of overalls, non-dispatchable rubber gloves and a pair of gumboots. This will protect your clothes and shoes from getting dirty and will protect your hands from bacteria. Besides, the protective clothes protect the BSFL from bacteria and mites. Make sure the gloves and boots are cleaned regularly, and the overalls are washed on at least a monthly basis. For visitors, dispatchable rubber gloves can be bought.

Basins are needed to grow the larvae in. depending on the size of your farm, the amount of crates needed can be calculated. For example; a farmer with 30 chicken needs only 2

crates, and a pig farmer with 10 pigs needs 8 crates to replace the recommended protein content with BSFL.

Tape and markers are needed to mark the crates with the date of the start of the production, this keeps everything structured. A kitchen scale is needed to measure the amount of kitchen waste and manure. Besides, a scale can be used to measure the harvest. Lastly, a sieve is needed to separate the BSF manure and skins from the harvesting-ready larvae.

Preparing feed substrate

The feed substrate can be a mixture of animal manure and different kinds of kitchen waste. The recommended amount is 60% animal manure and 40% kitchen waste. Research has shown that the larvae fed on a percentage with this substrate had the highest harvest outcome.

It is recommended to cut the kitchen waste into smaller pieces before mixing, the larvae are then able to consume the substrate better and faster. It is also recommended to first create a substrate out of kitchen waste before mixing it with the animal manure.

When the kitchen waste substrate is mixed through correctly, animal manure can be added into the BSFL crates. Afterwards, the kitchen waste substrate can be mixed with the manure to create the final feeding substrate.

When the feed substrate is ready, a bag of larvae needs to be added in each crate. One bag of larvae with substrate weighing 100 grams, can lead to a harvest between 1.8 kg and 2.5 kg of end product. The amount of harvest depends on several factors; feed substrate, temperature and relative humidity. When the feed substrate does not contain enough nutrients, the larvae tend to be smaller and have a longer development time.

When the larvae are active, the temperature in the crates increases. The recommended outside temperature is between 25°C and 35°C. This leads to a higher productivity and development rate of the larvae. For humidity, the feed substrate needs to have a high water content. When the feed substrate is pressed together in one hand, it needs to stick together, but only a little bit so no water has to come out of the substrate.

Risks

The production of the larvae has a few risks which are not severe. These risks are; mites, birds and houseflies.

- Birds are attracted towards the larvae and are likely to consume them when possible. To decrease this risk, a net can be placed on top of the crates.
- Mites can be recognized because of their red colour. They feed themselves on the blood of the larvae. Mites are attracted towards chicken manure. When the larvae are contaminated with mites, the time before the larvae reach harvesting stage can be extended. After harvesting crates with chicken mites, the crates need to be cleaned and dried properly.
- The pupae of houseflies can be recognized because of its colour and shape. Houseflies are no threat for the larvae, but they are in competition because of the feed substrate. The developing time of the housefly larvae is shorter and therefore they do not form a big risk.

Harvesting

The harvesting of the BSFL needs to happen when the protein content of the larvae is the highest. This can be recognized by their beige colour. Before harvesting stage, the larvae have a white colour.

When the larvae are past their harvesting stage, they turn into a black/grey colour and are most likely to escape the crates.

The harvesting can be done by sieving. A sieve will be part of the smallholder starter kit. The manure/frass received from the sieving process can be used as fertilizer on land.

Processing

After the harvesting of the larvae, they need to be processed. For chicken, the larvae can also be fed alive (this does not count for pigs). The cleaning of the larvae needs to be done via blanching. The larvae need to be boiled for 3 minutes in water. This to kill and clean the

larvae and kill bacteria. After this process, the larvae need to dry in the sun. Let them dry for two weeks. Then the final product is ready, which can be fed to pigs and chicken.

When the product is ready it can be fed to pigs and chicken. As stated before; pigs have a replacement rate of 75% for protein. The replacement rate of protein for chicken is 50%.

Cleaning

When the processing of the larvae is done, the crates can be cleaned. This needs to be done properly to reduce any risks and create a hygienic environment. The crates need to be washed with warm water and soap. Disinfectant can be used afterwards to kill present bacteria. Let the crates dry at least one day before using them again.

FEEDING BSFL TO...

Feeding Black Soldier Fly Larvae to chickens

Chickens enjoy Black Soldier Fly Larvae as a treat or as a reward for training purposes. They will eat them straight from your hand or from a dish. BSFL can also be used to attract your chickens to a new feeder or to encourage them to eat a new food. Just scatter a few BSFL on top of the new feed, or lay a path of BSFL to the feeder, with more on top of the food inside.

Scattering a handful of BSFL on the ground encourages your chickens to show natural foraging behaviours and provides amusement while they find the treat. Black Soldier Fly Larvae are a great treat to use in chicken toys. There are lots of toy designs available online.

A cheap, DIY (Do It Yourself) option is to cut small holes in a plastic bottle and fill it with a handful of BSFL. Your chickens will go nuts playing soccer and trying to get the BSFL out! Just make sure the holes are the right size so that the treats do not fall out too quickly!

Remember that BSFL are not suitable as a main source of food for chickens. They should be used as a treat or supplement in addition to a complete feed. 8-10 BSFL for each bird, per day, is plenty.

Feeding Black Soldier Fly Larvae to other pets

For birds, reptiles, fish, amphibians, spiders and small mammals, Black Soldier Fly Larvae can be used as a treat or training reward.

Depending on the species, BSFL can be fed from your hand or from a dish. They may also be suitable for scattering on or mixing with other foods to encourage consumption. For some species, such as reptiles and fish, Black Soldier Fly Larvae may be suitable as a main source of food. Please consult your veterinarian.

Feeding Black Soldier Fly Larvae to native animals

Wild birds and lizards also love Black Soldier Fly Larvae. And because insects are a natural food source for wildlife, it is safe to give them BSFL. Black Soldier Fly Larvae are a much better option than feeding wildlife unsuitable foods like bread or other human food.

Black Soldier Fly Larvae can be used to attract more native animals to your back yard. You can scatter BSFL on a bird feeder, or on the ground for lizards. You will have to be patient and wait for your local animals to discover the treat. But once they do, they will quickly become regular visitors to your yard!

Do's

- Provide clean, fresh water e.g. a bird bath, or a shallow dish on the ground for lizards
- Feed somewhere safe from cats and dogs
- Remove any uneaten food
- Clean dishes and water sources regularly

Don'ts

- Give more food than they will eat in 10 minutes
- Feed wildlife every day
- Feed wildlife unsuitable food

How to rehydrate Dried Black Soldier Fly Larvae

Dried Black Soldier Fly Larvae can be rehydrated. This makes the larvae look more lifelike for fussy eaters or shy wild birds.

Rehydration may be recommended in hot weather. It will help digestion and prevent dehydration. Depending on the liquid used, rehydrating BSFL can also add additional vitamins and minerals. Rehydrating liquids include water, Apple Cider Vinegar (ACV) or an oil such as seed oil or a cold-pressed vegetable oil. If you are using ACV, use 1.5-3 ml mixed with enough water to cover the BSFL.

Rehydrate the Black Soldier Fly Larvae by covering completely in liquid and allowing to soak until soft and flexible, usually 15-30 minutes. Drain and use within 1-2 hours, removing any uneaten BSFL after 20-30 minutes.

Left-over soaking liquid can be mixed with grain or another feed for an extra treat!

SUSTAINABILITY

Insect farming is, in principle, much more efficient and sustainable than the farming of cattle, pigs, and poultry. Insects are 4 to 10 times more efficient in converting nutrients into body mass. In addition, insect larvae feed on a wider range of residual waste streams that are efficiently converted into protein-rich body mass.

Finally, insect farming requires much less space and water, and the emission of greenhouse gases also appears to be lower. In short, an insect farming business offers a sustainable solution for the growing global demand for protein.