# Insect Rearing for Processing Protein in Animal Feed

## A scalable technology

**Winnie Nyakerario Akara**
Nairobi, Kenya

**Heinrich Katz**
Berlin, Germany

**Key messages**

- Due to a rising global population, there is a corresponding rise in demand for food, including sources of protein, for both humans and animals.
- Using fishmeal for traditionally farmed animals and growing soya are both extremely resource-heavy approaches, and intensification is not sustainable.
- Nutrition scientists are instead turning toward alternate sources of protein, whether as animal feed or as a source for human nutrition.
- A German biotech company, Hermetia Baruth, advocates using large bioreactors as incubation hubs for harvesting the protein and fats from insects.

### Introduction to the world of insects

Insects are by far the class of animals with the most species. About one million insect species have been named and classified, but it is estimated that between two and five million insect species are yet to be discovered. The weight of all insects on the planet is four times the combined weight of all other animals, including mankind. To date, the most dangerous member of the animal kingdom is an insect, the mosquito – transmitter of malaria, and a parasitic vector responsible for more than 400,000 casualties per year.[1] The diversity in the insect group ranges from typically beautiful species such as butterflies, through uglier ones such as cockroaches and useful ones such as bees, to pathogenic ones like the deadly mosquito.

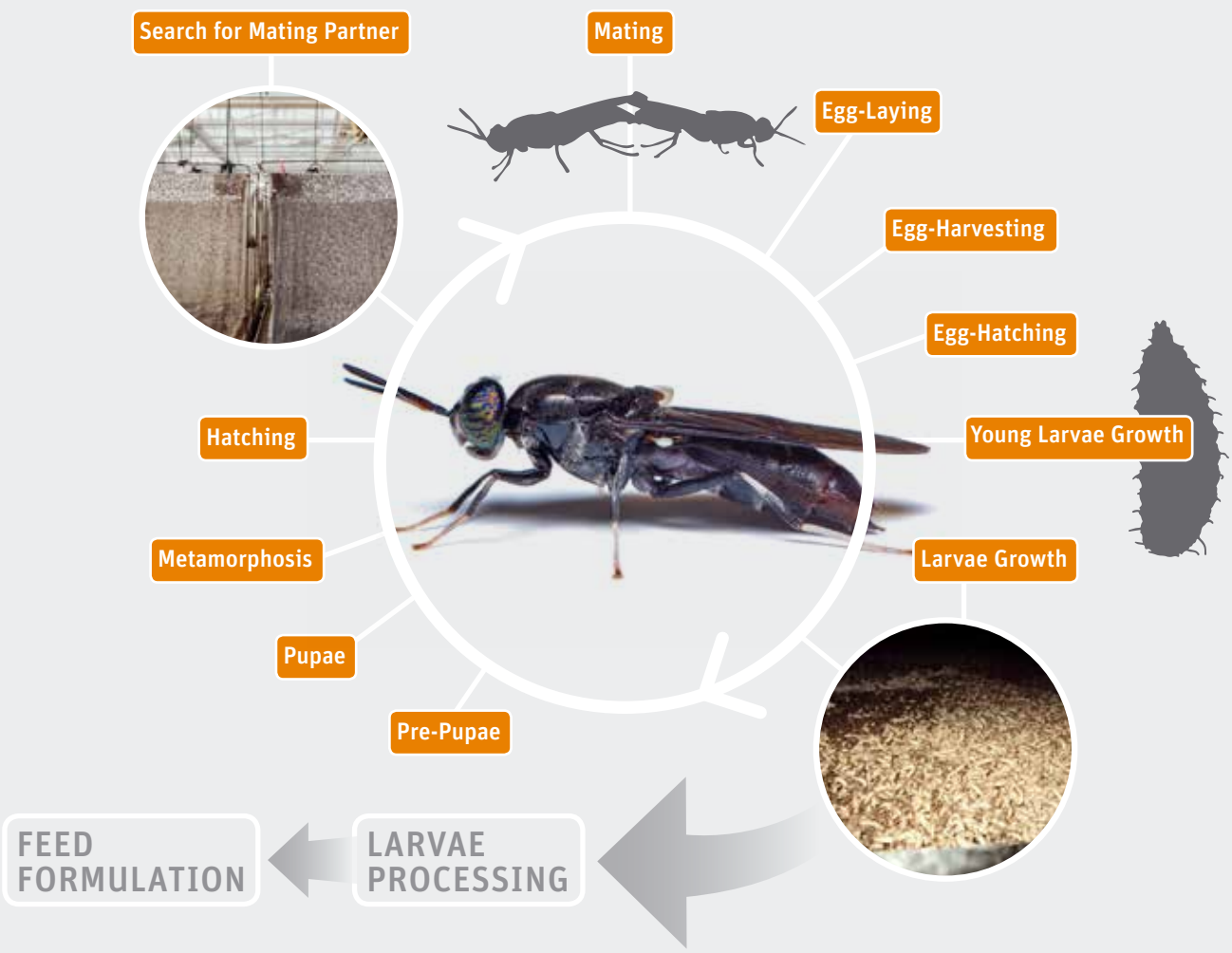
> "Nature is a perfectly circular economy and does not know waste – something we should all aspire to"

For centuries now, mankind has been known to benefit from insects. For example, the silkworm, larvae of the butterfly *Bombyx mori,* is used to produce silk fabric. This practice originated in China, but is a common tradition and economic practice in Western Africa. One major beneficial role of insects, specifically the larvae of some fly species, is their innate ability to convert rotting material into valuable protein for other members of the animal kingdom as feed. The enzymatic processes used to convert organic matter (dead bodies, plant material, feces, manure, catering waste, biological waste, etc.) into something valuable are amazing. Nature is a perfectly circular economy and does not know waste – something we should all aspire to – and a large portion of decomposition happening on the planet is due to insects.

### Insects as a source of valuable proteins for food and feed

One of the major nutritional requirements of all animals is protein. Proteins consist of amino acids, but the essential amino acids tryptophan, isoleucine, leucine, valine, methionine, threonine, histidine, phenylalanine, and lysine cannot be produced by our bodies, or by the bodies of other species with single-chambered stomachs (monogastric species), such as pigs, poultry and fish. Instead, these must be acquired through the diet. Globally, the major protein sources for farmed animals are soya and fishmeal. Due to the increase in the world's population,

**FIGURE 1:** The holometabolic life cycle




there is a corresponding demand for dietary meat sources, and therefore the demand for protein supplies to feed these animals is also increasing. The surface area of the planet used to grow soy beans is extended every year, while over-fishing continues to be a major issue. One third of all the fish caught in the world's oceans is processed into fishmeal. Neither procedure is healthy for our planet, and they are not sustainable for the future.

Larvae of flies are able to produce essential amino acids and store them in their bodies. All known carnivorous animals that naturally come into contact with insects eat insects, and for some, insects are even a significant part of their diet. Wolves eat insects of all stages (eggs, larvae, pupae, and adults) whenever they can. Fish such as salmon or trout jump out of the water to catch flies in the air, while the archerfish spits a high-pressure burst of water over four meters above the surface to hit insects – they fall in the water and can be easily swallowed. Boars plough the soil in search of larvae, which sometimes leads to significant damage to agricultural areas – this nutritional protein is a real treat for them, and they invest a lot of effort to make this food source available.

Various feeding trials with fish, chicken, turkey, pigs, and dogs from universities in Germany (Berlin, Göttingen, Kiel) and other European countries (Torino, Italy; Aarhus, Denmark), from private research institutes (feedtest, Dr Scharch), and from several feed-producing companies show the absolute eligibility of insect meal as a replacement for soya and fishmeal. In some areas, the nutritional value of insects is considered superior to soybean protein, e.g., in the feeding of young poultry, piglets and dogs.

## Insect rearing vs. wild catches

Migratory locusts are known as the eighth biblical plague. A locust swarm consists of more than a billion insects and weighs more than 1,500 tons. A swarm has to eat its bodyweight each day, and the damage it causes to agriculture can be tremendous – there are no means of protecting against such a swarm. Some tribes in

Africa – for example, those in Madagascar – catch as many as they can, which they then fry or roast for people to eat. At least here the devastating swarms are used to supplement nutrition and can act as a replacement for losses or for lack of agricultural products. In Central Africa, techniques such as concrete traps are used to catch insects, with the insects then processed through sun-drying, and light nets are used to deter mosquitoes.

However, there are significant disadvantages to wild catches. This approach often involves a large amount of effort to collect a decent yield of biomass, and the supply chain is not consistent. The volatility is high, whereas the feed production industry needs a constant supply. From a swarm of locusts, you get a lot of biomass, but then questions arise concerning processing capacity (e.g. drying), storing, and transportation, etc. Further, you don't know what the insects fed on before capture; and a lot of toxic chemical pesticides and fungicides are used in agriculture. These toxic substances may accumulate in the bodies of the insects and bring subsequent harm to the consumers.

> "The ability to rear the larvae of the black soldier fly is the basis for producing high-value insect protein in large quantities"

Insect rearing can be done just like animal farming: on a small scale with boxes and manual work, or on an industrial scale through highly automated processes. The major advantage is the control over the entire process from the input of substrate to the final product.

## Bioreactors as a technology to rear insects

The process to get insect protein and fat is threefold:

- control of the holometabolic life cycle;
- mass rearing of larvae; and
- larvae processing.

### *Control of the holometabolic life cycle*

The holometabolic life cycle is common throughout various species of insects, and refers to the life cycle of the insect, which consists of four stages: egg – larva – pupa – adult. Total control of the holometabolic life cycle is critical for insect farming, as you need to ensure that you always have enough adult flies to keep the population going. The objective is to allow 10% of an egg harvest to complete the total life cycle and to process 90% of the larvae into protein and fat.

### *Mass rearing of larvae*

The ability to rear the larvae of the fly *Hermetia illucens* (black soldier fly) is the basis for producing high-value insect protein in large quantities. The challenge is to bring the freshly hatched larvae of the "Queen of waste transformation" together with the feed substrate and to cultivate the optimal habitat in terms of temperature, humidity and oxygen supply. The solution designed by Hermetia Baruth GmbH, a biotech company from Berlin, Germany, is a bioreactor. These bioreactors are around the

**FIGURE 2:** The mating of two adult black soldier flies

same size as a 20-foot shipping container, with a production area inside of at least 75 m², over ten levels with two trays on each level. They take up about 12 m² on the ground.

The scalability is obvious. If enough ground space is available, you can line up the bioreactors, and it is even possible to stack them if necessary. The young larvae remain in the bioreactor for about 10 days until they are harvested. Some agricultural skills are required to run a bioreactor, but this is not difficult and can be learned with training. Some farming background in terms of rearing pigs or poultry is helpful, but not a prerequisite.

The ethics and sustainability of the mass rearing of farmed animals is the subject of intense discussion in developed countries, but the mass rearing of insects does not have the same problems, either from a biological or an animal welfare point of view. The larvae always seek each other out and congregate together, even when they are actively separated. Hermetia Baruth now has over 10 years' experience in the mass rearing of black soldier fly larvae, with no problems encountered.

Black soldier flies are used to living in rough environments – they are robust and able to deal with high and low pH values, and can deal with both microbes and mold. However, it is necessary to clean the trays with hot water after each cycle, and the input substrate should be treated with heat to kill any bacteria. The source of the substrate should also be known, and if there is reasonable suspicion of heavy metals or dioxin-polluted material, the substrate should be declined.

The advantages of the bioreactor technology are that the containers are easy to transport, either locally via trucks or internationally via cargo ships. They are also very easy to run and to maintain, very robust in their operation, and their life span should exceed 20 years.

> "Scientists are now studying the nutritional value of insects and their potential for mass production"

*Larvae processing*

The processing starts with the separation of the food substrate, the insect frass, from the larvae. Frass is a good fertilizer. The larvae are killed via heat and dried. Next, the fat is mechanically separated from the protein of the larvae – the fat consists of a high proportion of lauric acid (C12) and palmitic acid (C16). C12 comprises around half the fatty acid content in coconut milk, and C16 is a major component of palm oil. By means of high pressure, the cells are cracked and the protein (along with its essential amino acids) is extracted. In the whole process there is no waste, as all the products can be used, and none need to be disposed of.

## Outlook

In the year 2016, the international trade in animal feed had an estimated turnover of almost US$1,000 billion.[2] Africa currently produces less than one percent of global animal feed, despite having a large demand for the product itself – making the production of insect-based protein for the animal feed industry a huge business opportunity for African entrepreneurs. Scientists across the continent and abroad have therefore dedicated time and effort to studying the possibilities behind their nutritional value and their potential for mass production. Insects could help address the global challenges of food security and sustainability. This creates room for entrepreneurship, and business opportunities can be incubated in the food and feed systems and the pharmaceutical sectors,[2] which in turn can lead to job creation. The possibilities are endless.

This potential however, remains largely untapped. Many countries on the European mainland are eagerly searching for an alternative protein source for animal feed. This is particularly notable in the fish and poultry sector, where there is growing scarcity of the resources needed to produce healthy and nutritious feed. This has created a rise in feed prices, yet the solution is simple: the evidence clearly supports the fact that insects can provide a viable and sustainable solution.

The elephant in the room, however, is perception. In order for us to uncover the real value of insects, powerful education programs are needed. This can be done through structured frameworks covering invention, technology, upscaling, safety, processing, and legislation – similar to what Hermetia Baruth and their specialization in the breeding of the black soldier fly has established in Europe. If it were possible to replicate their model in Africa, it would most certainly create an impact in the animal feed sector and quite possibly, on the human population as well.

**Correspondence:** ***Heinrich Katz,***
*Managing Director, Hermetia Baruth GmbH,*
*An der Birkenpfuhlheide 10, 15837 Baruth/Mark, Germany*
***Email:*** *h.katz@hermetia.de and winnieakara@gmail.com*

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