The PRIMA programme is supported under Horizon 2020 the European Union's Framework Programme for Research and Innovation

Technical Guide to Produce Black Soldier Fly Larvae (Hermetia illucens) Using Agricultural Waste

Key Exploitation Result 7: Low and medium tech insects' production schemes

Capacity: 200 kg/day of fresh larvae

Low and Medium technological level

1. Introduction

The black soldier fly (Hermetia illucens, known by its acronym BSF) is a dipteran insect native to America, although it is now widely distributed in tropical, subtropical, and temperate zones around the world. In the last two decades, it has gained great relevance due to its ability to transform low-value organic waste into high-value protein and lipid biomass in an efficient and environmentally sustainable process. BSF larvae are responsible for this transformation. They have a crude protein content of between 40–45% and a fat content of between 25–35%, making them a viable alternative to fishmeal and soy in the formulation of feed for aquaculture, poultry farming, pig farming, and pet nutrition. In addition, their production requires fewer water resources and generates a much lower carbon footprint than conventional protein sources.

The BSF breeding process generates two main products are: a) fresh or processed larvae: these can be marketed as whole larvae, dried larvae, insect meal, or extracted oil and; b) Frass: a by-product resulting from the digestion of waste, rich in nitrogen, phosphorus, and potassium, which is used as an organic fertilizer in agriculture.

From an environmental point of view, the use of BSF contributes to waste reduction such as fruit, vegetables, and agricultural by-products that would otherwise end up in landfills to be recovered. The use of BSF align with the circular economy principles by transforming local waste into high-value inputs, closing the production cycle. And last but not least decreased negative impacts by reducing odors and emissions from uncontrolled waste decomposition.

The objective of this guide is to describe, in a detailed and replicable manner, the design and operation of a medium-scale plant capable of producing 200 kg of fresh larvae per day, using exclusively agricultural waste as substrate and with a medium level of technology. This means that practical and viable solutions are proposed (such as mechanical shredding, basic temperature and humidity control, and manual or semi-automatic harvesting systems), avoiding both high technological complexity and inefficient artisanal management. Suporting in that way the principles of the SustavianFeed project. Thes, this guide is intended as a reference document for agricultural producers, entrepreneurs, or technicians interested in implementing a system for utilizing agricultural waste through BSF breeding, with the aim of obtaining alternative protein, organic fertilizer, and a production model aligned with environmental sustainability.

2. Facility requirements

The success of a Hermetia illucens breeding and production system depends largely on the design and suitability of the infrastructure. A properly planned facility ensures stable environmental conditions, facilitates the management of each stage of the production cycle, and enables compliance with the biosafety and hygiene standards necessary to guarantee a quality product.

2.1 Required surface area

For a plant with a capacity of 200 kg/day of fresh larvae, a total area of 800–1,000 m² is estimated, distributed as follows:

1. Adult rearing area (fly house): 10–15% of the total space. Includes mesh cages to maintain stable breeding populations and egg-laying areas.
2. Egg incubation area: approximately 5%. A temperature- and humidity-controlled environment is required to ensure a high hatching rate.
3. Larval rearing or fattening area: 60–70%. This is the largest area, where trays, containers, or modules are arranged for the development of larvae on the agricultural substrate.
4. Separation and processing area: 10–15%. This is where harvesting, separation of larvae and frass, washing (if applicable), and preliminary drying take place.
5. Storage and auxiliary services area: 5–10%. This includes storage for pretreated agricultural waste, storage for larvae and frass, changing rooms, an office, and an equipment area.

2.2 Minimum infrastructure

The infrastructure must be functional, easy to maintain, and of average cost, avoiding highly sophisticated systems but ensuring sufficient control of environmental conditions:

- Closed buildings or sheds, with metal or block structures and sheet metal or polycarbonate roofs. If climate control is used, insulated walls are highly recommended (see figure 1)
- Waterproof floors (cement or epoxy resins) that allow for frequent cleaning and leachate collection. It helps disinfection to decrease the risk of biological hazards(see figure 1).
- Insect screens on all openings to prevent cross-contamination with other insects (houseflies, mosquitoes, etc.) and to prevent BSF adults scape.
- Basic ventilation and air conditioning using extractors, fans, misters, and, in extreme climates, auxiliary heating or cooling equipment.
- Washing and disinfection areas for trays, equipment, and utensils.

Figure 1. Insect rearing facillity, with laminated insulated walls, resin floors and drainage for easy cleaning

<u>2.3 Recommended environmental conditions</u>

The life cycle of the SFB is highly influenced by temperature, humidity, and light. Considering the original distribution area (wet tropical) mimic those tropical conditions will ensure success, although at each production step, thos parameters could be changed to optimize cost. Basic control of these parameters ensures productivity and bearing in mind:

- Temperature: 26–30 °C in all breeding areas. Lower temperatures slow growth, and excessive temperatures (≥35 °C) increase mortality.
- Relative humidity: 60–75%. An environment that is too dry hinders hatching and larval development; excess humidity promotes the proliferation of fungi.
- Photoperiod (fly house): 12–14 hours of light per day. Adult reproduction requires intense light, preferably natural light supplemented with solar spectrum LED lamps.

2.4 Biosecurity and workflow

The facility design must ensure a unidirectional mass flow from the agricultural waste inlet to the product outlet (larvae and frass). And inlet area should be spatialy separated from the outlet. This reduces the risk of cross-contamination and facilitates sanitary control. Thus, raw material (waste) entrance should be located at one end of the plant, and the area should have place to dump the waste, containers able to hold liquids (fruit and vegetables are mainly water and tent to drain liquid) and if dry components are also used to feed the larvae it should be stored in a dry area.

Processing and cleaning areas should be at the opposite end of the farm and physically separated. Even better, if after the cleaning area another compartment for processing is created where end product could be considered clean and ready to be stored.

For the transition areas it is recommended that personnel wear clothing and footwear exclusively for the plant, with footbaths or disinfection stations at the entrances or if it necessary, have dedicated personnel to each area, which is highly recommended if the production scale increases.

3. Biological cycle and production management

The life cycle of the black soldier fly (Hermetia illucens) comprises several well-defined stages (egg → larva → prepupa → pupa → adult). The larval stage is the most important in terms of production, as this is where the biomass destined for harvest accumulates. Normally for the production point of view, the larva stage is considered in two steps, step one (nursery) where just born larvae are endured and grown in a defined diet and, step two (fattening) where larvae are fed with the waste and biomass accumulate. The larvae grows so fast than there are big changes in just days and to differentiate development the term Days Old Larvae (DOL) is used preceded by a number indicating the day after hatching. A 5DOL larvae is a larva with 5 days of life after hatching. Normally step one goes from 1 to 6DOL and step two goes from 6-14DOL. To achieve stable production of 200 kg/day of fresh larvae, it is essential to properly manage each stage of the cycle, ensuring continuity, population balance, and optimal environmental conditions.

3.1 Adult breeding (fly farm)

It is the place where the adults are kept for reproduction proposals, the place needs to have very good climate conditions considering several point

1. Humidity must be 75% or above or else adults will not release the eggs.

2. Adults will not mate if they do not have intense light with a good amount of UV light, UV ligh does not need to be on continuously but at least couple of hours in the start of the photocycle is recommended.
3. Temperature during matting should be above 23ºC and preferably 29ºC for a good matting
4. Adults need a spot with an attractant substance (normally a recipient with rotten products) to encourage eggs releasing.
5. The place should be well vented as high concentration of females' pheromones discourage females to release eggs

Structure:

For the cages, they should allow adults to fly, since the mating starts during flying. Cages of 1×1×1 m cages(see figure 2), covered with mosquito netting are sufficient to maintain populations of 5,000–10,000 adults.

Figure 2. Adult cages

Inside each cage, moisture sources are included, probably the easiest to use are damp sponges. In addition, a sugar solution (10% sugar or diluted honey) could be used instead of just water to give to the adults longer life span.

Reproduction:

Adults do not feed on solid substrates but require moisture and carbohydrates to maximize fertility. if adults lack water large mortality could be expected, especially if humidity is low.

For the female to release the eggs, normally an oviposition device with crevices, dry and porous is provided. There are many different ways to provide this kind of elements but normally either cardboard or wood pieces are used. Those elements are normally set on top of an attractant (rotten organic products) to induce the adult to release the eggs (see figure 3). Eggs will be released in this egg collecting elements as far as it doesn't get wet. Since the adult cages can produce eggs during several days, new oviposition devices should be replenished after removing the device with eggs.

Figure 3. Oviposition device set on top of the attractant

A female can lay between 500–900 eggs during her life cycle (5–8 days).

Eggs are collected manually and transferred to the incubation room. It is recommended to collect the oviposition devices (see figure 4) daily so the larvae size/age difference will be little. Or else larvae growth will be less even during fattening

3.2 Egg incubation

The process itself is not laborious but optimal conditions should be kept, or else low hatchability can be expected.

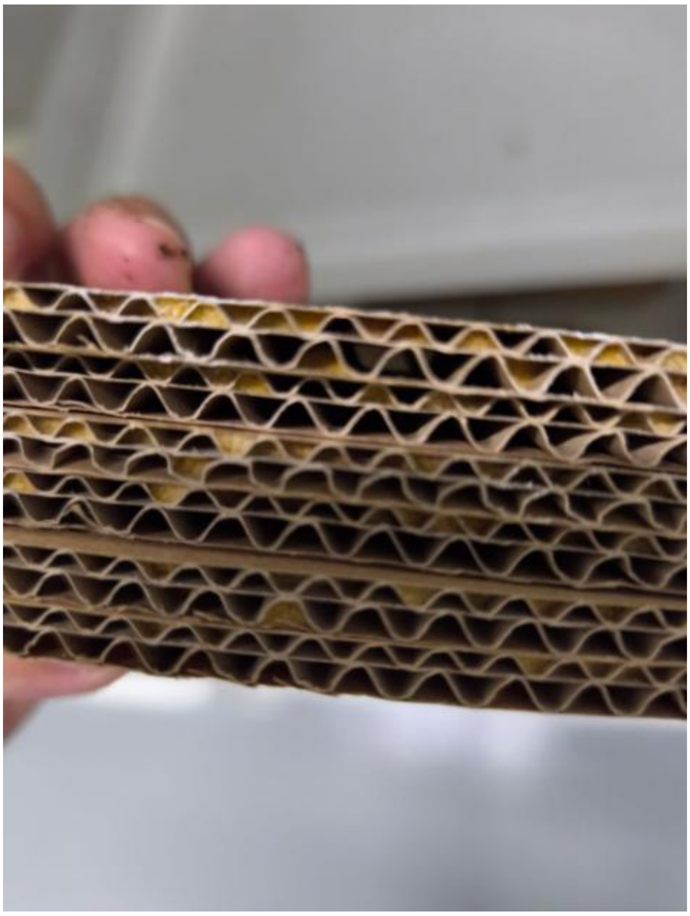

Figure 4. Oviposition device with eggs clutch inserted in the cardboard flutes

Environmental conditions:

- Temperature: 27–29 °C.
- Relative humidity: 85–95%.

The incubation normally takes 2.5 days although changes in temperature can change it

Handling:

The eggs are placed on trays with a thin layer of pre-moistened substrate (bran + grains+ water mixture). Eggs should be kept slightly separated from the wet diet or else hatchability will be compromised. Another option is to let the eggs hatch in an empty box (see figure 5) and transfer the small larvae to fresh diet. When the conditions are appropriated an average hatching rate of 85–95% can be expected.

Figure 5. oviposition device with eggs ready to hatsh in an empty box

3.3 Larval fattening

This stage is key to the system, as the larvae consumes agricultural waste and generates biomass. However, to properly carry out better is to divide the process in nursery from 1 to 5DOL, and fattening from 5DOL to 12 DOL.

Nursery: small larvae from the hatching room are fed daily with a mix of grains and water (25% grains 75% water). It is necessary to refill food when needed, taking care not to overfeed. Normally the average weigh of the larvae at 5DOL is from 5-9mg and is ready to go to the fattening process (see figure 6).

Figure 6. 5DOL ready for fattening

Fattening: is the process where the production of larvae takes real place. And where biomass is accumulated, normally, 5 DOL of 5mg start the process and in a period of 9–14 days achieve a weigh of 250mg.

The process takes places using rearing units, which normally use plastic trays or boxes measuring 60×40×15 cm (see figure 7), the stocking density is about 0,5-2 larvae per gram of food depending on nutrient density, but considering vegetables as main input, a stocking density of 5–8 g of eggs (~35,000 larvae) per tray is an standard.

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Figure 7. 5DOL seeding on fattening plastic boxes

To feed the larvae there are two main strategies, either add all the feed(5-7kg) in day one, add the seeding larvae and harvest at the end (one feeding strategy) or to feed daily with a proportion of diet (continuous feeding strategy) and to achieve about 7-8 kg by the end of the cycle. When vegetables with large amounts of water are used 15-20kg of waste per tray during the whole cycle can be expected, but also the whole fattening cycle gets extended. The optimum temperature is 27–30 °C. although the main concern is to prevent the feeding core of the larvae (where larvae eat during feeding frensy) stays bellow 36ºC.

Figure 8. fattening boxes in stainless steel larger capacity than plastic boxes

Humidity control is not relevant while moist in the diet is enough (60%) to allow the larvae to eat. Constant ventilation to prevent gas (mainly CO_2) and heat accumulation.

If the process is adequate, 1 kg of fresh larvae per box can be collected and from 5 to 20 kg of waste have to be used (depending on nutrition density). The larval weight at the end of the cycle: 0.2–0.25 g per larva.

<u>3.4 Larvae harvest</u>

Optimal time for harvest is when the larvae have reached 18–22 mm and are whitish yellow in color. If larvae are not collected at this stage, they will start pupation with a lost of production. The time depends on feed quality, but for a good diet 9 days are commonly achieved. 12–14 days can be expected for average diet quality.

Collection method:

The most common method for collection is by vibrating screens or manual sieves to separate larvae from frass. Obviously vibrating screens are needed at a certain production scale.

It is recommended to keep 5% of the production to replenish the parent colony of adults (ensuring the sustainability of the system). Those larvae are refeed and let to pupate and keep at 80% humidity and 28ºC during 8 days to produce adults.

3.5 Balance for production of 200 kg/day

If the target production is to harvest 200kg/day or 1400kg/week, it is necessary to use about 1000-1500kg of waste a day, and needs to have about 2000 boxes in rotation with staggered sowing to ensure continuity.

4. Agricultural substrates and pretreatment

The substrate is the fundamental input for the production of Hermetia illucens larvae. Its quality, composition, and preparation largely determine the growth rate, biomass yield, and nutritional quality of the larvae obtained. To achieve stable production of 200 kg of fresh larvae per day, it is necessary to ensure a constant supply of suitable agricultural waste and proper pretreatment.

4.1 Recommended types of agricultural waste

Agricultural waste is abundant and low-cost, but it must be selected based on its availability and nutritional value:

Discarded or unmarketable fruit: bananas, mangoes, papayas, melons, citrus fruits, apples, pears. These are easily degradable and have high moisture content, promoting rapid larval growth.

Discarded vegetables: tomatoes, zucchini, cucumbers, peppers, lettuce, cabbage. They provide moisture and carbohydrates, but in excess they can acidify the substrate (see figure 9)

Figure 9. smash vegetables with righ structure, granulometry and moist to feed the larvae

Cereal by-products: wheat bran, corn residues, partially ground rice husks. They improve the structure of the substrate and provide protein and fiber.

Pulp and bagasse: by-products of the juice and vegetable processing industry, which increase the volume and digestibility of the substrate.

From the nutritional point of view, fiber is not nutritious for the larvae and main nutrients are simple sugars (fructose, sucrose, lactose) or starch rich products.

In the mediterranean basin olive pomace is very abundant and it could easily represent 30% of the total formula. Furthermore, olive pomace, when still humid can be preserved as silage and used year round although it is abundant just during a short season

Animal waste and manure are not allowed as substrates to feed the larvae if they are intended for animal feed.

4.2 Substrate quality criteria

To maintain optimal larval growth, the substrate must meet certain physical and chemical parameters:

Initial moisture content: 65–70%. Lower moisture content dries out the medium, while higher moisture content promotes unwanted fermentation and mold growth.

pH: between 6 and 7.5. Values that are too acidic (<5.5) or alkaline (>8) reduce the consumption rate.

Absence of chemical contaminants: pesticides, herbicides, heavy metals, or plastics must be completely excluded.

Uniformity: the more homogeneous the substrate is, the easier it is to handle and the more efficient larval consumption. Although, uniformity is normally difficult if large amounts of waste is needed year round

4.3 Substrate pretreatment

Pretreatment is essential to adapt the waste to the needs of the larvae and ensure the stability of the process:

1. Grinding: reduce the particle size to less than 20 mm using a mill, crusher, or grinder. This increases the contact surface and facilitates ingestion.
2. Homogenization: mix different types of waste (e.g., 60% fruit + 30% vegetables + 10% cereal) to balance nutrients and moisture.
3. Moisture adjustment: add water if the substrate is dry or incorporate fibrous by-products (such as bran) if it is too moist.
4. Light pre-fermentation (optional): let the material rest for 24–48 hours in close piles. This initiates sugar degradation, reduce pH and facilitates larval digestion but should not be prolonged to avoid nutrient loss.
5. Temporary storage: the prepared substrate should be used within 48 hours. It is recommended to store it in the shade and on impermeable surfaces to prevent leaching.

4.4 Balance for the production of 200 kg/day

• Required substrate: 1000-1200 kg/day of agricultural waste with a proportion of 50–60% discarded fruit, 10-30% olive pomace and 10-30 % of dry products like bran or spoiled grains. Expected results eating this mixture and with the pre-treatment conditions is a conversion rate of 6-8 kg of waste to produce 1 kg of fresh larvae is maintained, ensuring productive continuity and good quality in the biomass obtained.

5. Larvae management

The larval stage is the core of the Hermetia illucens production system, as this is where the biomass destined for harvest is generated. Proper management of the larvae ensures that the target of 200 kg of fresh larvae per day is achieved, with efficient substrate consumption and no significant losses due to mortality.

5.1 Breeding units

For the larvae production, the use of plastic trays or polypropylene boxes measuring 60×40×15 cm is recommended as standard. Each tray can hold between 35,000–40,000 larvae throughout their cycle. The boxes should be smooth, resistant, and washable, allowing for reuse after disinfection.

5.2 Larvae seeding

Incubated eggs are transferred to the initial substrate (pre-treated and moistened). Recommended seeding density: 5–8 g of eggs (~35,000 larvae) per tray. Sowing should be done on a thin layer of initial substrate (1-2 kg) to prevent clumping.

5.3 Feeding during the cycle

Day 1–3: light feeding, no more than 1-2 kg per tray, to facilitate start-up.

Day 4–10: add 2–3 kg of substrate every 2–3 days, depending on observed consumption.

Day 11–14: consumption intensifies, requiring an additional 3–4 kg per tray.

Total per cycle: each tray consumes 20 kg of substrate in 12–14 days.

5.4 Environmental conditions

The bes temperatures are 27–30 °C. Lower temperatures slow growth; temperatures above 35 °C cause stress and mortality. However, the main concern is to keep the feeding core below 36ºC. Relative humidity is not really relevan as far as the substrate humidity stays above 60%. Must be kept stable through misting or ventilation. Ventilation is essential to prevent the accumulation of ammonia and gases derived from decomposition. Substrate thickness should not be more than 8 cm; thicker layers promote anaerobic fermentation and mortality.

5.5 Monitoring and control

Daily monitoring is key to ensuring efficiency:

a. Substrate consumption: if undigested material remains, delay addition

b. Larval appearance: active, whitish, and mobile larvae indicate good health; premature dark tones indicate stress or the onset of pupation.
c. Health control: remove material with fungi or excessive fermentation.
d. Weight sampling: it is recommended to randomly weigh 100 larvae every 3 days to verify growth (target: 0.2–0.25 g at the end of the cycle).

5.6 Replenishment of the parent colony

To ensure continuity, it is recommended that 3-5% of the harvested larvae be allocated to the pupation and adult rearing phase. This allows for a constant flow of eggs and ensures the sustainability of the system without the need for frequent external purchases.

6. Harvesting and separation

Harvesting the larvae is the stage at which the main product of the system is obtained: fresh larvae for animal feed or industrial processing. Proper management of this phase ensures that biomass yield is maximized, and product quality is preserved, avoiding degradation due to pupation processes or contamination with frass.

6.1 Optimal harvest time

The ideal harvest time is between 12–14 days of age, when the larvae have reached their maximum size (18–22 mm in length and 0.2–0.25 g in weight) and still retain their whitish or cream color (see figure 10). If harvesting is delayed, some of the larvae enter the prepupal stage (darkened cuticle, reduced mobility), which reduces their value as direct food and alters their nutritional profile. It is recommended to schedule daily, staggered harvests to maintain continuous production of 200 kg/day.

Figure 10. 15DOL ready to be harvested

6.2 Larva–frass separation methods

There are several separation techniques with varying levels of technical sophistication:

1. Manual shaking or sieves:

The mix of larvae and frass are screened with 4–6 mm holes are used, which allow the frass to pass through and retain the larvae. This method is economical and simple, although it is labor intensive.

2. Mechanical vibrating screens:

Electrical equipment that speeds up separation. It is suitable for medium volumes, allowing up to 500 kg/h to be processed (see figure 11)

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Figure 11. mechanical sieving to separate larvae from frass

3. Separation by flotation (optional):

Fresh larvae float in water, while frass sinks. It is used when the larvae are intended for live feed or immediate consumption but requires subsequent drying. In some cases, it becomes more difficult and messier.

<u>6.3 Post-harvest handling of larvae</u>

Washing (if applicable): in clean water to remove frass debris. It serve as light disinfection if quick immersion in a diluted acetic acid solution (0.5–1%) to reduce microbial load. After that, draining and partial drying using screens, ventilation, or centrifuges. When larvae have been cleaned and dried immediate cooling or processing is recommended to stop deterioration and If used as fresh food refrigeration at 4 °C (maximum 48 h) or If processed into meal drying at 60–70 °C for 4–6 h and subsequent grinding.

<u>6.4 Quality considerations</u>

To maintain hygienic conditions during harvesting to avoid bacterial contamination avoid prolonged exposure of larvae to ambient heat after collection and process or store harvested larvae within a maximum of 2 hours to preserve freshness and nutritional value.

7. Processing and preservation

The processing of Hermetia illucens larvae aims to preserve their nutritional value, adapt them to market needs, and extend their shelf life. Depending on the final destination (direct animal feed, meal production, oil extraction, or use in pet food), different treatments are applied (see figure 12).

7.1 Initial processing

Once harvested, the larvae must undergo rapid post-harvest handling to prevent fermentation and loss of quality:

1. Cleaning: larvae intended for direct animal consumption must be washed in clean water to remove frass residues.
2. Draining: screens or manual centrifuges are used to remove excess water after washing.
3. Sorting: Separate larvae by size, allocating the largest for sale/processing and the smallest for internal recycling as future breeders.
4. Mechanical pressing or solvent extraction to separate the lipid fraction.
5. Oil with a high lauric acid content, useful for animal nutrition and industrial applications.
6. By-product: defatted cake, which can be reincorporated as protein meal.

Figure 12. Different products extrected from larvae, up left, Insect fat, up right insect meal rich in proteins and down insect chitin

7.2 Processing options according to final destination

1. Fresh larvae

It could be used direct as feed for birds, fish, and reptiles. It can be stored under refrigeration at 4°C for up to 48 hours. It requires cold transport to prevent premature mortality.

2. Scalded and refrigerated larvae

As treatment the larvae are immersed in hot water (80–90 °C for 2–3 min) to inactivate enzymes and bacteria. After that, the slaughtered larvae are storage under refrigerated conditions at 4 °C for 5–7 days. The main advantage is a greater hygienic safety.

3. Dried larvae / Insect meal

It consists in drying in ovens or dryers (see figure 13) at 60–70 °C for 4–6 hours, until reaching 8–10% moisture content. Although 3% moisture is preferred for longer preservation. After that, the dried larvae are ground to obtain flour with 40–45% protein and 25–30% fat. To prevent rancidity the insect meal is storage in airtight bags.

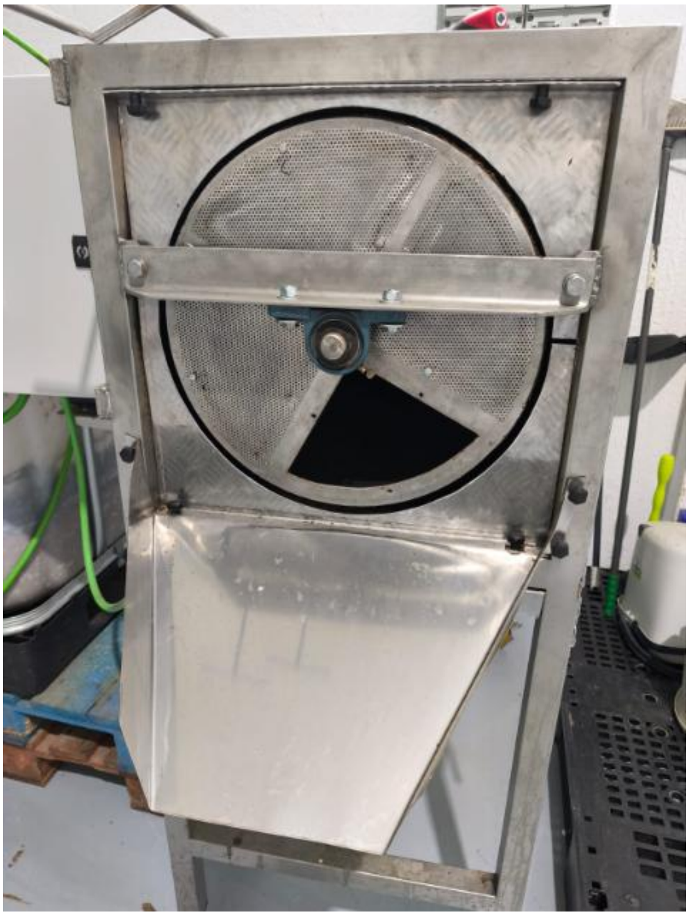

Figure 13. Drum dryer for larvae dehydratation

7.3 Preservation of frass

Frass is the remaining nondigested food after treating the waste with the larvae. It is obtained when the substrate is sieved, frass is one of the fractions along with the larvae. The frass can be dried actively with a dryer or more under the sun until the moist content is below 15%. To be commercialized a treatment of 70ºC during several hours is necessary to kill insects.

It can be stored in sacks or big bags in a ventilated, dry area or pelletized for better market acceptance. Shelf life is up to 12 months, maintaining its value as an organic fertilizer.

7.4 Hygiene and biosafety recommendations

For hygiene and safety the following recommendations should be followed:

1. Perform all processes in a clean area separate from the breeding area.
2. Wear gloves, masks, and protective clothing during processing.
3. Implement a traceability system (batches, harvest dates, destination).
4. Avoid mixing batches with different harvest times to ensure uniformity.

8. Frass as by-product

Frass is the solid by-product resulting from the consumption of substrate by Hermetia illucens larvae. It consists of partially digested food remains, larval excrement, and exuviae (skins shed during growth). Far from being waste, frass is a high-quality organic fertilizer with growing agronomic value in the market (see figure 14)

Figure 14. frass after sieving

<u>8.1 Typical composition of frass</u>

Values may vary depending on the substrate used, but in general terms it contains:

- Organic matter: 60–70%.
- Main nutrients (dry basis):
- Nitrogen (N): 2–3%.
- Phosphorus (P_2O_5): 1–2%.
- Potassium (K_2O): 1–2%.
- pH: 6.5–7.5 (slightly neutral).

Other components: chitin, beneficial microorganisms, and enzymes.

These values make frass comparable to traditional organic fertilizers (manure, compost), but with the advantage of a shorter and traceable production cycle.

8.2 Agronomic benefits

As main product frass can be used as organic fertilizer which provides essential nutrients for agricultural crops. In farms, it can be used as soil improver increasing water retention capacity and soil structure. It also acts as biological stimulation because its chitin content promotes the activity of beneficial microorganisms and can induce natural resistance in plants against pests and pathogens. It is a sustainable alternative which reduces dependence on synthetic chemical fertilizers.

8.3 Management and processing of frass

1. Initial separation: occurs during harvest, when the larvae are sifted.

2. Drying:

Sun drying is done by spreading in thin layers (2-3cm) for 1–2 days or mechanically under hot air dryers until humidity reaches <15%.

3. Sieving and homogenization: to obtain a product with uniform particle size.

4. Packaging: in 25–50 kg bags or big bags for commercialization.

8.4 Storage and preservation

Best option is to store in a dry, ventilated place protected from rain. It should be avoided to store under prolonged accumulation of moisture to prevent fermentation. Under the right conditions the shelf life is up to 12 months without significant loss of quality.

8.5 Estimated production volume

In a system that generates 200 kg of fresh larvae per day, the frass produced is equivalent to approximately 600–800 kg/day. This represents a volume three to four times greater than that of the larvae, which gives it considerable economic importance in the plant's final balance.

8.6 Market and practical application

Main market is local agriculture where its most direct use is in vegetable gardens, fruit crops, and organic farming. Another option is the specialized market as certified organic fertilizer (subject to compliance with local regulations). And Of ourse agricultural self-consumption which allows the BSF production plant to close the circular economy cycle if the agricultural waste comes from its own crops, returning recovered nutrients to the soil.

9. Biosafety and hygiene

The production of Hermetia illucens larvae on a medium scale involves the handling of large volumes of decomposing organic waste. Although the larvae have a high capacity to control pathogenic microorganisms by competing for the substrate, the production plant must operate under strict biosafety and hygiene measures to protect the health of personnel, ensure the quality of the final product, and prevent the proliferation of pests or diseases.

9.1 General principles of biosecurity

1. Prevention over correction: preventing contaminants from entering is more efficient than dealing with problems once they have arisen.

2. Unidirectional flow: from the entry of agricultural waste to the exit of final products, without any backflow that could contaminate clean areas.

3. Separation of areas: clearly differentiate between “dirty” areas (waste reception) and “clean” areas (larvae processing, meal or frass storage).

4. Traceability: record substrate batches, sowings, and harvests to quickly identify the source of any incident.

9.2 Measures at waste reception

Main measures to apply:

Inspect agricultural waste to ensure it is free of plastics, glass, metals, or chemical residues.

Keep waste in a covered area separate from the rest of the facility.

Establish an exclusive, waterproof unloading area with leachate drainage.

9.3 Measures during larval rearing

1. Control stocking density to avoid overcrowding that causes excessive fermentation.
2. Remove uneaten remains that show signs of mold or bad odors on a daily basis.
3. Maintain adequate ventilation levels to reduce ammonia accumulation.
4. Use clean and disinfected equipment for each tray rotation.

9.4 Measures during harvesting and processing

1. Harvest in areas that are separate from the breeding area, clean, and disinfected.
2. Staff must wear gloves, masks, boots, and protective clothing exclusively for use in the plant.
3. Clean surfaces and equipment daily with safe disinfectants (1–2% diluted bleach or quaternary ammonium compounds).
4. Avoid direct contact between freshly harvested batches and already processed products.

9.5 Staff hygiene

1. Access control with footbaths or disinfectant mats.
2. Exclusive work clothing within the facility.
3. Training in hygiene practices and safe handling of biomass.
4. Prohibition of food consumption within breeding and processing areas.

9.6 Pest and external fauna control

1. Install insect screens on all openings in buildings and sheds.
2. Avoid accumulation of waste outside designated areas.
3. Regular inspections to detect houseflies, rodents, or birds that may act as vectors of pathogens.

9.7 Cleaning and disinfection protocols

1. Daily: cleaning of floors, equipment, and trays in use.
2. Weekly: disinfection of empty trays, tools, and common areas.

3. Monthly: deep cleaning of sheds, ventilation, and drains.

10. Daily operational summary

To ensure continuous and stable production of 200 kg of fresh larvae per day, the plant must operate under an organized, standardized, and repeatable work schedule. The following operational summary outlines the essential activities that must be performed daily in each area of the facility.

10.1 Receipt and preparation of substrate

a. Receipt: arrival of1000–1,200 kg of agricultural waste.

b. Sorting and removal of contaminants: manual removal of plastics, stones, metals, or non-biodegradable materials.

c. Shredding and mixing: reduction of particle size to <20 mm and homogenization of components (fruit, vegetables, dry by-products).

d. Adjustment of moisture and pH: achieve 65–70% moisture and pH 6–7.5.

e. Temporary storage: store the pretreated substrate for a maximum of 24–48 hours, in the shade and on an impermeable surface.

10.2 Incubation management

a. Checking egg trays (3–4 days of incubation).

b. Control temperature (27–30 °C) and humidity (70–80%).

c. Transfer hatchlings to rearing trays with freshly prepared substrate.

10.3 Feeding and monitoring of larval trays

a. Feeding: add substrate to the trays based on observed consumption (2–3 kg every 2–3 days).

b. Monitoring: Check the activity and health of the larvae, check for mold or fermentation, check substrate thickness (<8 cm) and check environmental conditions: maintain temperature at 27–30 °C and RH at 65–70%.

10.4 Larvae harvesting

a. Select 12–14-day-old trays for harvesting.

b. Separate larvae from frass by shaking or mechanical systems.

c. Sorting 90–95% for processing or sale (200 kg/day). And 3-5% for pupation and maintenance of the parent colony.

10.5 Post-harvest processing

Options:

a. Refrigeration of fresh larvae (48 hours max.).
b. Scalding and refrigeration (up to 7 days).
c. Drying and grinding into meal (40–50 kg/day).

Optionallly oil extraction could be an option to create insect melas. And in this case an oil expeller machine has to be used to extract the oils from the dry larvae

For the frass drying and storage (600–800 kg/day).

10.6 Cleaning and hygiene

a. Cleaning of trays, utensils, and work surfaces.

b. Disposal of unusable waste.

c. Checking footbaths, protective clothing, and tidiness of areas.

10.7 Records and traceability

a. Recording substrate entries (origin, quantity, date).

b. Recording incubation, fattening, and harvest batches.

c. Recording daily production (kg of fresh larvae, dry larvae, frass).

d. Recording incidents (temperature, mortality, contamination).