**REPUBLIC OF RWANDA**

**RWANDA AGRICULTURE AND ANIMAL**

**RESOURCES DEVELOPMENT BOARD (RAB)**

# STANDARD OPERATING PROCEDURES FOR BLACK SOLDIER FLY (BSF) FARMING IN RWANDA

Consortium Partners:

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Project Coordinator

NESTLER

oNe hEalth SusTainabiLity partnership between EU-AFRICA for food sEcuRity

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This document contains information on the Standard Operating Procedures (SOPs) for Black Soldier Fly (BSF) Farming in Rwanda. This document was developed by Rwanda Agriculture and Animal Resources Development Board in collaboration with different stakeholders (see List in Annex) as part of the work supported by the NESTLER Project [(https://nestler-project.eu/index.php/about/)](https://nestler-project.eu/index.php/about/). It is expected that these SOPs will be useful guides for people involved in BSF larvae farming and use and other people directly or indirectly involved in the implementation of food security program/project.

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## 1. General Introduction

BSF farmers should note that the economic viability of black soldier fly (BSF)/ *Hermetia Illicucens* farm will depend on a range of environmental conditions:

- Scale and respective capital and operating costs of the farm
- Climate (season, temperature, and humidity)
- Potential revenue from frass sales
- Sales revenue from fly derived products (e.g. Eggs, 5'day old larvae, Protein meal, Pupa, Larval oil, etc.)

These standard operating procedures (SOPs) do not fully explain the financial aspects of such BSF production system, but rather focuses on what researchers and experienced farmers suggested as minimum number of operating steps required to optimize BSF farming. Besides the list of activities that must be conducted at every specific time intervals, SOPs provide a list of equipment, which is based on practical experience.

## 2. Problem

In many parts of the world including East African countries, the increasing demand for fishmeal and soybean meal as major protein sources in animal feeds has led to their scarcity and increasing market prices (Onsongo et al., 2018). Furthermore, feed costs represent about 70% of total aquaculture and livestock production (Ssepuuya et al., 2017; Daniel, N. 2018). The issue is especially severe in rural East Africa, particularly in Rwanda where feed compounds, in specific proteins, are scarce or unaffordable for smallholder farmers and fish producers. According to Niyonshuti (2021), the scarcity of animal feed is one of the main challenges that impair the development of the animal sector in Rwanda. Even though the animals like pig and poultry farming have been growing rapidly for the past 5 years in East African (EA) countries including Rwanda were driven by rapid urbanization; the growth of the middle class in EA; rise in the number of quick services restaurants in urban areas in EA; and growing need for animal protein (Vernooij, et al.,2018). However, the issue of feed affects the productivity from these animals reared by a big number of peoples and the reason is the limited availability of common source protein ingredients (fish meal and soybean) that have become particularly expensive, scavenging poultry farming of poor households particularly suffers from quantitative and qualitative food shortages and, consequently, the productivity becomes low (Ossebi et al., 2023).

## 3. Justification

✦ The consumption of meat and fish is growing, and it is becoming increasingly difficult to meet the growing demand for protein by farming on land and in water, causing serious repercussions for the planet's resources, socio-economic development, and environmental sustainability. In sub-Saharan African countries including Rwanda, poultry, pig and fish are fastest and most rapidly growing agricultural sectors. But these sectors are unable to realize their full potential due to the high cost of feed. This high cost of feed is attributed to the rising cost of major protein sources (fishmeal, soya bean, cotton seed cake, sunflower seed cakes and others), which represents over 70% of total production costs. Therefore, Black Soldier Flies (BSF) larvae which are protein rich sources have been widely considered as alternative proteins for animal feeds.

- Traditionally, Rwandan farmers use fishmeal and soybean as protein sources for livestock. Fishmeal and soybean can be problematic for smallholder farmers. Rwanda does not produce high quantities of soybean, and the limited local supply translates to expensive import taxes, which often push the commodity out of the reach of small-scale operations. These high protein prices lead to low-quality and very expensive animal feed. Also, the current situation is unfair towards farmers and want farmers to receive a fairer income. Likewise, fishmeal is becoming a less reliable protein source due to greater market competition. Insects such as BSF larvae could provide a reliable, sustainable, safe, and cost-effective source of protein for small-scale livestock including fish farming enterprises. Also, insects are consumed naturally by many animals, including fish, wild birds, and free-range poultry, we can assume that these animals are evolutionarily adapted to eating them as a part of their regular diet.
- The production of the BSF on the waste products of smallholder farmers allows farmers 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.
- In Rwanda, BSF provides the opportunity for smallholder farmers to shift towards a more reliable, profitable, and ultimately more sustainable source of protein for their livestock towards sustainable food security. In particular, the use of insects in the bioconversion of waste materials constitutes a novel approach and a remarkable example of a sustainable circular economy.

## 4. Why Black Soldier Fly

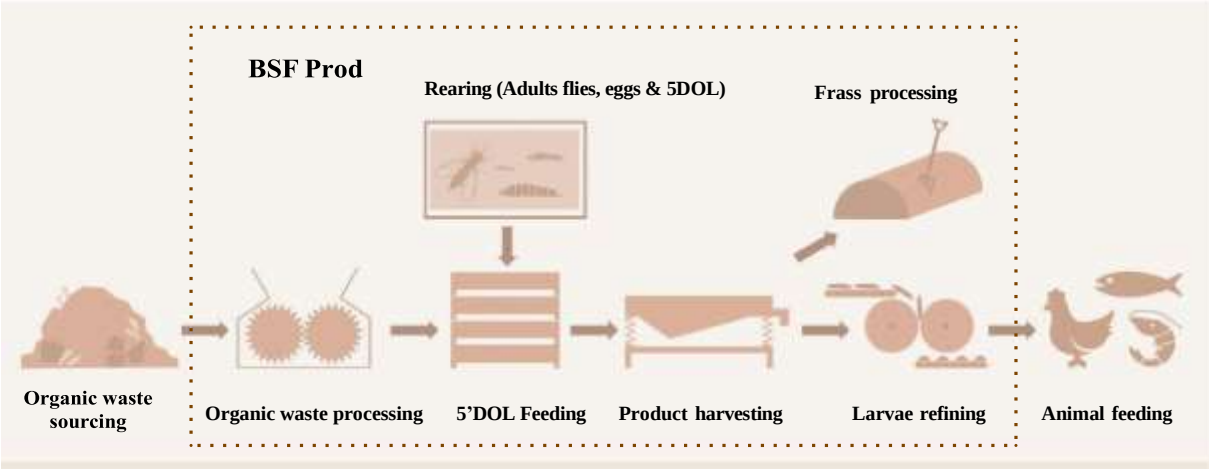
The BSF is a common and widespread fly in many tropical regions, but the BSF originates from South America. Because of human actions, the fly was able to spread to other tropical, sub-tropical and warmer regions. The BSF has the ability to adjust to different circumstances very quickly. But, in contrast to the housefly, the BSF is not a pest (de Baets, 2017). This, since they do not bite, sting and are not able to transfer zoonotic diseases. The larvae of the BSF are able to concert organic waste towards protein. The protein content of the dried BSFL is between 35 and 50 percent. The adult flies are between 15 to 20 millimeters long. Adults do not have a mouth; therefore, the larvae consume a lot of organic substrates during their larval stage. The larvae are able to feed quickly and can reach their harvesting stage in 10 to 14 days.

The dried larvae can be used as a substitute for soy and fishmeal in animal feed. The larvae can survive a lot of environmental differences and are therefore a suitable implementation for farmers to produce themselves. They are able to survive huge differences in temperature, humidity and feed substrate. They do prefer a warm temperature (around 27 degrees Celsius). When the temperature gets too high (above 30 degrees Celsius) or too low (under 25 degrees Celsius), the developing time of the larvae will increase, but the larvae are most likely to survive. This makes it easy for farmers to produce. Besides the low work load, the production of the BSFL leads to an eventual decrease in feed costs, since the buying and production of the larvae is cheaper than buying soy and fishmeal. Besides, the production of livestock on BSFL leads towards higher revenues since the pigs have a developing time of 4.5 months instead of 7 months, and the meat is of higher quality (Mulderij, 2019). For layer hens, their laying period extends which leads to an average increase of 62% more eggs. The eggs have thicker shells and the yolk is more yellow. And lastly, broilers fed on BSFL are on average 10% more heavy than broilers which are not fed on BSFL (ICIPE, 2017). According to Musoni et al. (2022), Mean weight gain recorded for the fish fed with diet containing 75%BSFLM and 50%BSFL were significantly higher ($p<0.05$) than that of the control diet while both diets contained 25%BSFLM and 100%BSFLM did not differ from that of the fish fed with the control diet ($p>0.05$). The specific growth rate (SGR) ranged from 1.7 (g% day-1) to 1.8 (g% day-1).

## 5. Concerting through this SOPs

These Standard Operating Procedures (SOPs) are structured according to the five main production units that are keys to a BSF Production process (Figure 1).

- ❖ BSF rearing unit
- ❖ Waste receiving and pre-processing unit
- ❖ BSF small larvae (Five Day Old Larvae: 5 DOL) rearing unit
- ❖ Product (mature larvae & frass) harvesting unit
- ❖ Post-treatment unit (larvae refining and frass processing)



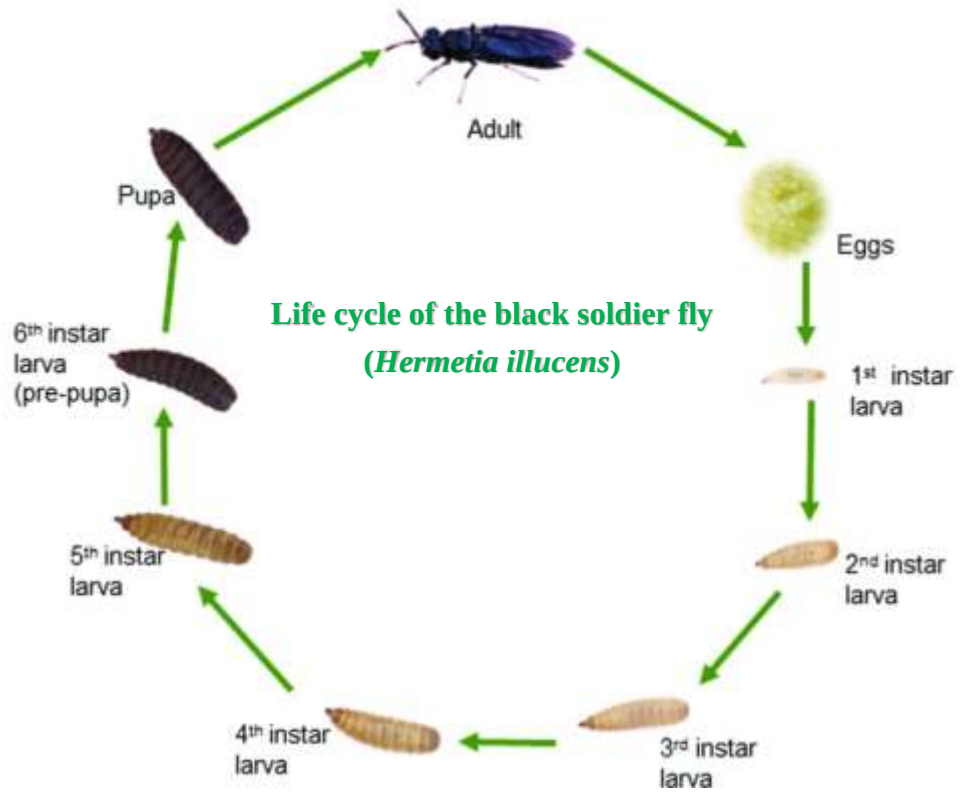

**The different units of BSF production System**

# CHAPTER ONE

# HOW TO PRODUCE BLACK SOLDIER FLY

## 1.1 Understanding the natural BSF life cycle

* Understanding the life cycle helps one to know why BSF is a suitable insect for the production of novel protein feed stuff and to know how this cycle can be "simulated" to enhance the benefits produced in terms of waste conversion efficiency and product harvest in quantity and quality.
* The BSF is of the dipteran family Stratiomyidae.
* It can be encountered in nature worldwide in the tropical and sub-tropical areas between the latitudes of 40°S and 45°N.
* The BSF has five stages in its lifecycle: ***egg, larvae, prepupae, pupae and adult***.




| Phase | Period (days) | | |
|---|---|---|---|
| | Average | Minimum | Maximum |
| Hatching | 5 | 5 | 7 |
| Larvae production after hatching up to prepupae stage | 13 | 10 | 15 |

| | | | |
|---|---|---|---|
| Prepupae to adult BSF | 18 | 14 | 21 |

## ▲ Eggs

- A fly laying a cluster of eggs (also called ovipositing). The female fly lays a package of 400 to 800 eggs close to decomposing organic matter, into small, dry and sheltered cavities.
- During the breeding phase, also referred to as the hatchery phase, the eggs deposited by adult Black Soldier Flies are placed in vertically racked containers filled with compost consisting of residual waste streams such as organic food waste. Under completely controlled climate conditions, the eggs hatch very quickly into tiny Black Soldier Fly larva.


- The egg starts a BSF life cycle and at the same time marks the end of the previous life stage.
- The sheltered cavities protect the eggs from predators and prevent dehydration of the egg packages by direct sunlight.
- Shortly after having laid eggs, the female dies.
- The closeness of the eggs to the decomposing organic matter (attractants) ensures that the larvae have their first food source nearby after hatching.

## ▲ Larvae

- On average, the eggs hatch after four days and the emerged larvae, which are barely a few millimetres in size, will search for food and start feeding on the organic waste nearby.

- The larvae feed voraciously on the decomposing organic matter and grow from a few millimetres size to around 2.5 cm length and 0.5 cm width, and are of cream-like colour.
- Under optimal conditions with ideal food quality and quantity, temperature and humidity, the growth of the larvae will require a period of 14-16 days. However, the BSF larva is a very resilient organism and has the ability to extend its life cycle under unfavourable conditions.
- The larval stage is the only stage during which the BSF feeds and, therefore, it is during this time of larval development that enough fat reserves and protein are stored that allow the larvae to undergo pupation, emerge as flies, find mates, copulate and (as a female) lay eggs before dying

▲ **Prepupae**

- After having gone through five larval stages, the larvae reach the final larval stage **(the prepupae**).
- When transforming into a prepupae, the larva replaces its mouthpart with a hook-shaped structure and **becomes dark brown to charcoal grey in colour**.

- It uses this hook to easily move out and away from the food source towards a nearby dry, humus-like, shaded and protected environment that it deems safe from predators and is where the imago emerge from the pupa and fly off without significant hindrance.

▲ Adult

- The process of pupation is the transformation from a pupa into a fly.
- The pupation stage is initiated when the prepupae finds a suitable location and become immobile and stiff.
- For a successful pupation it is best if the environment conditions do not change to much or in other words that they remain warn, dry and shaded.
- Pupation takes around one to two weeks and ends when the fly emerges from its pupa shell.

- The emerging process is a very short procedure.
- It usually takes less than five minutes for the fly to break open the part of the pupa that used to be the head section, crawl out, dry and then spread its wings and fly off.
- After emerging, the fly lives for about one week.
    - During this short life, it will search for a partner, copulate and (for the female) lay eggs.

    - As a fly, BSF do not feed. Only a source of sugar water or a humid surface is required to stay hydrated.
    - What is important in this life stage is an abundant amount of natural light and a warm temperature (25-32°C).
    - A humid environment may prolong the life span and, thus, enhance the chance for successful reproduction. It has been observed that the flies prefer to copulate in the light of the morning

## 1.2 Optimal environmental conditions and food sources for the larvae

### 1.2.1 Optimal environmental conditions

- ★ ***Warm climate***
  - The ideal temperature is between 25 and 30°C. If too hot (greater than 30°C, the larvae will crawl away from the food in search of a cooler location. If too cold (less than 25°C), the larvae will slow down their metabolism, eat less and develop slower.
  - The elevation is between 900 and 1800 m of altitude
- ★ ***Shaded environment***
  - Larvae avoid light and will always search for a shaded environment, away from sunlight.
  - If their food source is exposed to light, they will move deeper into the layer of food to escape the light.

### 1.2.2 Food sources for the BSF larvae

- ★ ***Nutrient requirements of the food***
  - Substrates rich in protein and easily available carbohydrates result in good larval growth.
  - Waste or substrates are more and easily consumed, if it has already undergone some bacterial or fungal decomposition process.
- ★ ***Particle size of the food***
  - as the larvae have no chewing mouthparts, access to nutrients is easier if the substrate comes in small pieces or even in a liquid or pasty form.
- ★ **Water content of the food**
  - The food source has to be quite moist with water content between 60% and 80% so that the larvae can ingest the substance.

## 1.3 Procedures for setting up a black soldier fly farm

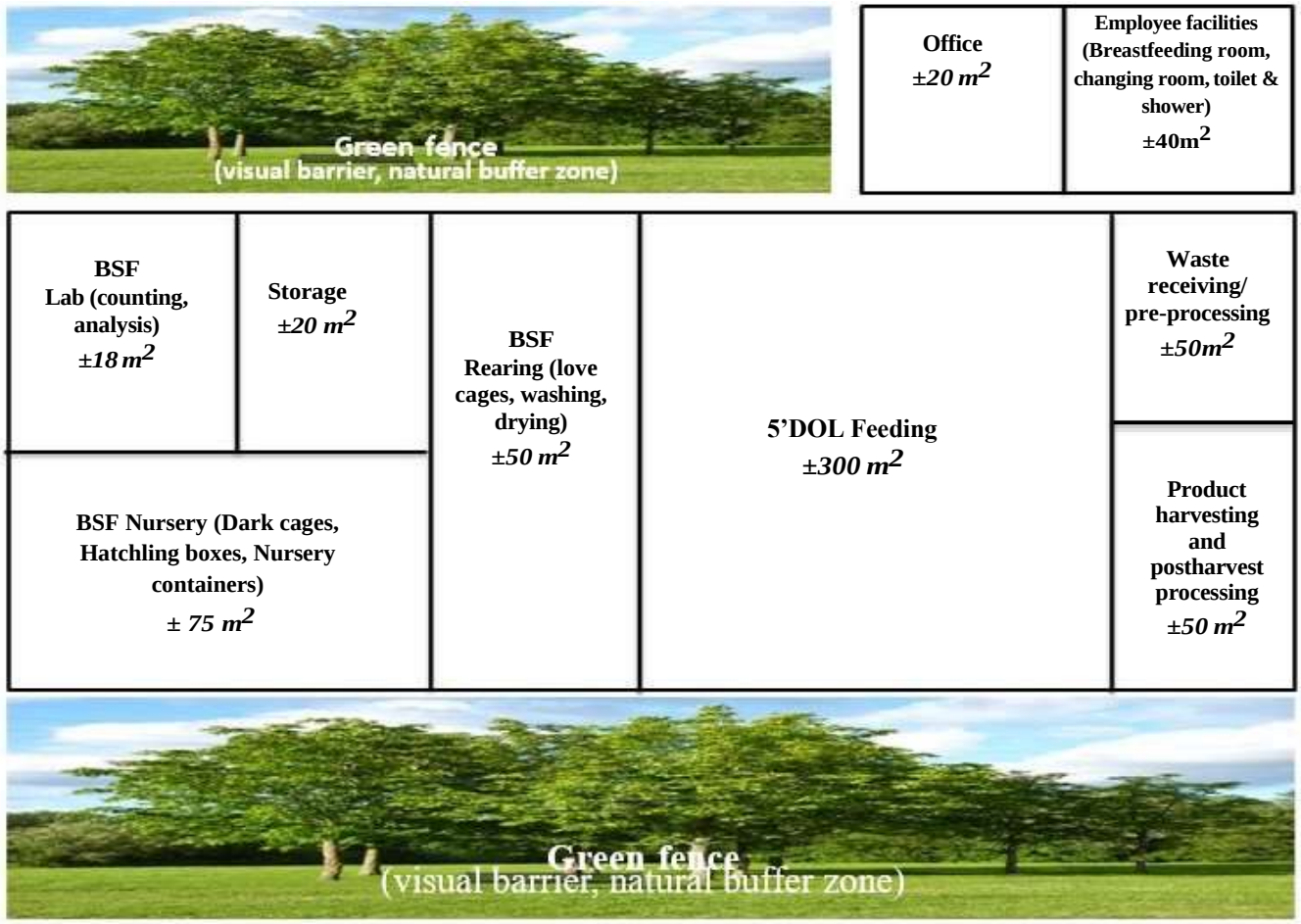
Setting up a black soldier fly (BSF) farm refers to a sustainable and efficient way to process organic waste, produce high-quality novel protein feed stuff, and contribute to the overall ecosystem. To provide an environment that best mimics the natural habitat of the BSF, while at the same time ensuring a continuous waste treatment and BSF larvae production, the following points should be taken into consideration when selecting an appropriate site for a BSF farm:

### 1.3.1 Site Selection

1. Not far from the source of substrates/organic wastes to reduce logistics for wastes from the collection point to the farm, and create a profitable and scalable business.
2. Accessible to the infrastructures (Water, Electricity, Roads etc).
3. Located far from urban/residential area, as densely populated neighbourhoods and areas where adjacent land users may find a BSF production farm inappropriate.
4. Availability of labour source.
5. The site elevation should be between 900 and 1800 m of altitude.
6. Adequate environmental buffers that separate the facility from the surroundings should be maintained (e.g. open areas, trees, fences, etc.).

### 1.3.2 Housing

1. Compartments of the BSF house: Dark room/dark cages, incubation and hatching room, love cage or insectarium, larvarium and processing unit, and wate pre-treatment unit
2. Annexes of BSF house: administrative block, stock/storage room, changing room, breastfeeding room, dining room, and waste treatment unit.
3. Facility should be downwind from the residential areas.
4. Closed and ventilated room for the rearing, but sunlight for the love cages.
5. Sheltered area without direct sunlight for the BSF larvae production units.
6. The minimum temperature in the house should be 25-degree centigrade.
7. The maximum temperature in the house should be 30-degree centigrade.
8. The relative humidity (RH) should be between 50 and 60%.
9. The BSF farm should be fenced and constructed in an East-West direction.
10. Facility should have laboratory space/counting and analysis.
11. Toilet and hygiene facilities.
12. Waste receiving/pre-processing
13. Product harvesting and postharvest processing
14. As a rule of thumb, one can calculate with 50m2 for the nursery and 100m2 per ton of incoming waste per day




**Possible layout of a BSF production facility for the use of two tons organic waste per day**

### 1.3.3 Description of BSF Housing compartments

Farmers should have to know the following important distinctive production units:

#### *1.3.3.1 BSF rearing Unit (Adult flies, eggs & 5'DOL)*

This unit enable (s) the farmer (s), to make sure that a reliable and consistent number of small larvae (called 5-DOL) is always available to every planned production cycle, but within this unit few larvae hatchlings are kept in the rearing unit to ensure a stable breeding population.

**a) Darkroom**

- Darkroom is a recommended place at BSF Farm to ensure proper and timely pupation of prepupa into pupa.
- Pupas at their 10 days old may be transferred to a love-cage for the easy flies emerging.
- When the farmer chooses to keep pupas in the darkroom, s/he may have a hole in the darkroom to enable the migration of flies from the darkroom to the love-cage.

**b) Incubation**

- The incubation room would provide optimal heat to enable BSF eggs to hatch into small larvae in a 2-day (hot region) to 5-day (cold region) period.
- It should be of medium size comparable to a dark room.

### c) Insectarium

- This room should be transparent i.e. the roof should be made with transparent iron sheets.
- The flies need to be farmed in a transparent room where solar radiation can easily penetrate inside to allow the reproduction cycle of the flies.

### d) 5'DOL growing unit

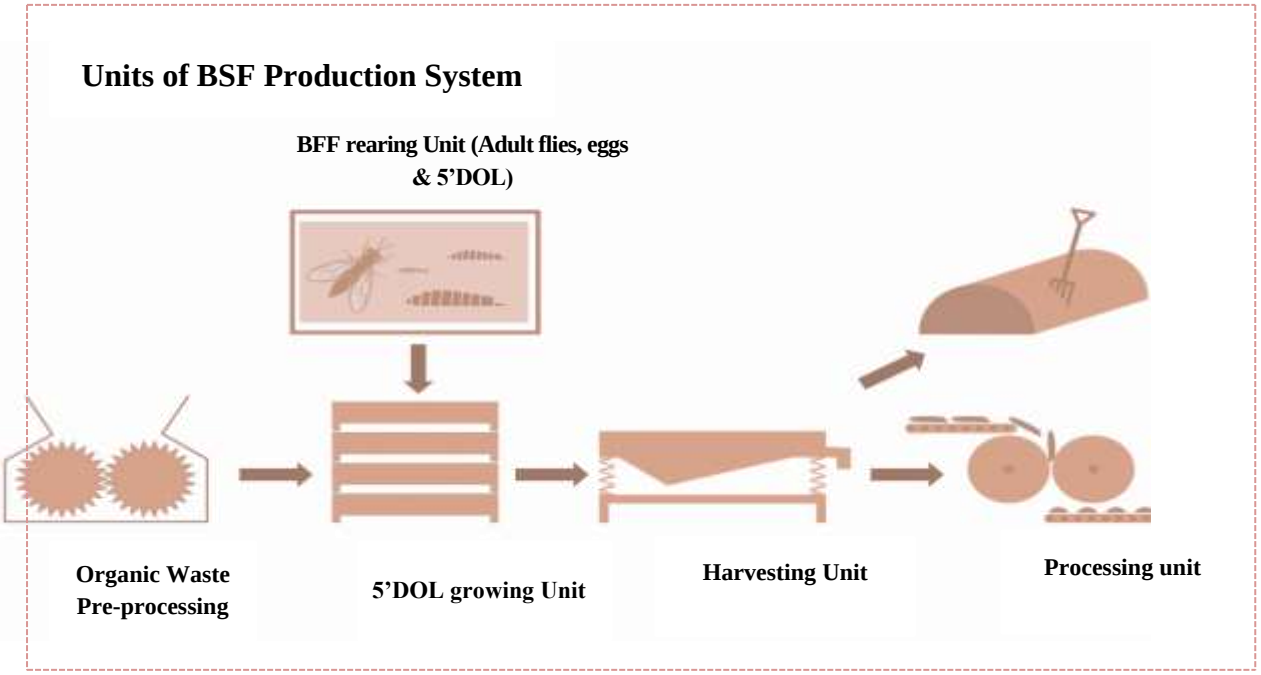
- This is where the 5-DOL from the rearing unit is fed with processed organic waste in containers called **"larveros"**.
- Here, the young larvae feed on processed organic waste and then grow into large larvae ready for harvesting and processing.

#### *1.3.3.2 Product Harvesting unit (Larvae & Frass)*

- The unit is used for sorting, separating, picking, milling, drying or boiling larvae. Here, farmers separated larvae from pre-pupae/pupae.
- The room should be much larger enough to facilitate black fly larvae processing activities.
- Before the growth of larvae into prepupae just from day 14 up to 16, larvae are harvested from the larveros, and the remaining frass is kept for its value.
- Products, larvae and frass are processed to meet quality requirements, larvae are killed, dried and their oil content extracted from protein meal, frass is sorted and packed.

#### *1.3.3.3 Organic waste sourcing, receiving and pre-processing Unit*

- It's not recommended to receive organic waste and directly feed them to 5'DOL,
- The waste should be screened for both hazardous materials and inorganic wastes, then crushed and mixed,
- Once processed waste contains high moisture content, they are dewatered up to a moisture content ranging between 70 and 80%,
- Then later left for fermentation as 5'DOL like to feed on decomposing substrates.




**Main BSF Larvae production units**

## 1.4 Attractant and eggs harvesting and transporting

### 1.4.1 Type of attractant substrate

Mostly used attractant are:

- Mashed maize grains
- Vegetables and fruit wastes from the market, and
- Kitchen wastes
- Animal manure (mixture of chicken and cow manures)

### 1.4.2 Eggs harvesting techniques

#### *1.4.2.1 Egg harvesting from the wild*

In the starting of BSF farming, it is not always advised to either purchase eggs or small larvae "5DOL" from BSF producers as BSF are naturally presented in the environment. Farmers should also try to correct BSF eggs from the surrounding environment. This is because the collection of eggs from the wild has an added advantage of producing BSF that are locally available and adapted in the production environment.

The main important steps involved in egg harvesting from the environment are clearly detailed as follows:

1. Prepare an attractant: options for an attractant include rotting fruit, kitchen scraps, fermented bran (outer layer of grains removed during milling), animal manure or rotten pineapples.
2. The natural instinct of BSF is to oviposit in dry cracks close to moist and decomposing organic materials or attractants.
3. Place the container with the attractant in an outdoor place where BSF are likely to be.
4. On top of the container, provide a surface for female BSFs to lay their eggs, surfaces with cracks and crevices work well. A good way to do this is by placing several stacks of wooden blocks over the container.
5. Create each stack by cutting pieces of wood to a length that exceeds the diameter of the container.
6. Stack several pieces of wood and then secure the stack with a rubber band around each end, create an empty space between used piece of wood by placing tooth picks between them. You can also place toothpicks between the pieces of wood for adult female flies to lay their eggs.




7. Monitor the stacks of wood for eggs. If you don't see eggs, it could mean that wild BSF populations around the attractant are non-existent or low.
   In that case, try placing the attractant where there are likely to be wilder BSFs:
   - Look for a place with a lot of organic waste, such as near waste dumps.
   - If you are in a location that is not sunny and warm all year, keep in mind that BSFs may not be active during cold period.
8. If you fail completely to correct any egg, leave the rotting material with provided stack of wood in the area for a while, to see if some small larvae can develop, raise those small larvae up to adult stage.
9. If some eggs are deposited on a provided stack of wood, harvest them daily and hatch them.

#### *1.4.2.2 Egg deposition and harvesting within the colony (love cage)*

- As in the wild an attractant is prepared with surface (Cracks, crevices and or stack of woods) for female BSFs to lay their eggs, placed on the top of prepared attractants.
- Place the already prepared attractant and its egg laying materials in the love cage with BSF ready to lay their eggs.
- Weight egg laying materials before and after egg deposition, the difference will be the weight of laid eggs, one egg weight up to 25µg, simple to calculate the number of laid eggs per every love cage on dairy basis.
- Monitor eggs deposition process and remove provided laying material every 24 hours interval, directly harvest laid eggs, just before any small larvae hatch.

### 1.4.3 Transportation of BSF eggs and Neonates

#### *1.4.3.1 Eggs transportation in short distance*

1. Hatching facilities are prepared before the egg supply.
2. Plastic boxes of 500 ml are used with a mesh separating them from the bottom.
3. A maximum of 3 grams of eggs (24h old) per box are deposited within the box to prevent them from forming clusters and dying.
4. Transportation time should not go beyond 5 hours maximum.
5. Temperature should be above 25°C, as they are sensitive to low temperatures, with a relative humidity of 60%.
6. Eggs are directly incubated upon arrival.

#### *1.4.3.2 Eggs transportation in long distance*

1. Hatching facilities are prepared 2 to 3 hours before the egg supply.
2. A considerable number of stacks of wooden sheets with small gaps in between, containing (24h old) eggs are deposited within the container with a descant.
3. Plastic containers of 1000 ml are used, where the stack of wooden sheets with small gaps in between, are weighed before and after egg laying.
4. Transportation time should not go beyond 5 days at maximum.
5. Temperature should be above 25°C, as they are sensitive to low temperatures, with a relative humidity of 60%.
6. Eggs are directly incubated upon arrival

#### *1.4.3.3 Transporting the neonates (small larvae: 2 days old)*

1. Plastic boxes of 500 ml with filter paper to facilitate aeration could be used
2. These boxes are placed in a larger cork box without a lid and perforation.
3. One gram of neonates per box, 20 grams of feed (consisting of 70% poultry feed and 30% wheat bran) and 18 grams of water are added.
4. The temperature should be 25°C with a relative humidity of 60%.
5. If possible, a data logger could be added for monitoring the process, and in cold weather a heat pack
6. Neonates are directly transferred in the larvae-rearing house upon arrival

▲ **What to avoid during transportation of eggs and neonates**


1. Avoid agglomeration of eggs during transport and low temperatures
2. Avoid high densities in the transport of neonates and favour aeration
3. Avoid pleasant smells in the hatching facilities (working personnel, smelling objects and environment) .

## 1.5 Egg hatching Process

1. Hatching trays preparation are always performed on table
2. Hatching trays are properly cleaned and dried over the sun
3. Incubation shelves should be either made of wood or steel, with a room of 120 cm in length, 80 cm in width and 30 cm in Height (120 x 80 x 30 cm), shelve supports should be 40 cm in height (20 cm emerged in water).
4. Incubation shelves are covered by nets on all four sides, but one side is left with flapping nets for easy insertion of hatching trays.
5. Feed preparation is performed upon the arrival of eggs at the hatchery.
6. Hatching feeds should be one of the mixtures in the following:
    * 100 % Maize germ with water
    * 100 % Maize bran with water
    * Boiled monogastric and poultry offals
    * Broiler starter, fish starter, or pig starter are the most used feeds as they are rich in nutrient content.
7. Substrate feed for egg incubation is prepared as the following
    * 1-5 g of eggs per 0.5 kg of feed mixed with water to produce a thick, soft, moist paste.
    * Mix 5 - 10 g of eggs per 1 kg of feed with water to produce a thick, soft, moist paste.
    * Feeds are evenly distributed to hatching trays of 200 cm Height, 380 cm Width and 500 cm Length (200 x 360 x 500 cm).
    * 20 cm square stainless-steel mesh, with 3 cm folds for every side, is directly applied on the top of feeds, leaving 1 cm from feed level.
    * Upon insertion of the stainless-steel mesh, eggs intended for incubation are evenly deposited on top of the mesh with the use of a sheet of paper, directly hatching trays are covered by nets, to prevent external contamination (like Insects, other fly eggs, rodents, etc)
    * Completely prepared hatching trays are inserted in the hatching shelve room:
        - From day 6 of incubation, the covering net and mesh are removed, then 250 ml of clean water with 5 g of sugar are sprayed in each tray and the substrates are gently mixed up, by use of a small spatula to prevent injury to small recently hatched larvae.

- Once the target growth size is not reached at day 6, additional nutritious substrates are added according to the farmer's observation, generally 0.5 kg is added to every tray.
- From day 5-8 small larvae are transferred to growing trays

* Hatching period is ranging from 5 to 7 days
* Well mixed substrates should contain 40% of market/kitchen wastes and 60% animal manure (40:60 ratio).

### Risks related to the production of BSF larvae

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.

## 1.6 Pupation

1. Small larvae left in the nursery trays, are continuously feed up to prepupae stage.
2. The period from larvae production to prepupae stage is a period ranging from 10 to 15 days after hatching.
3. The substrate commonly used for larvae production are maize bran, kitchen and market waste, and animal manure.
4. Prepupae once they refuse eating and then crowd from the feeding trays, they are harvested and transferred into a pupation container.
5. As prepupae are disturbed by big masses of other prepupae, the containers should contain a moist soil-like substrate (compost) into which the prepupae can bury.
6. BSF farmers are advised to used saw dust mixed with few amounts of water to allow pupation process.
7. To facilitate the pupation process, the pupation containers are placed inside a pupation cage, which is completely dark inside, they are also called “Dark Cages”.

8. In addition to the dark environment, this cage also provides the pupae with sufficient protection from the changing outside environmental conditions (i.e. moisture, temperature, movement of air, etc.).
9. After a period of one to three weeks, the pupation material is slightly dried out, making it easier for the flies to crawl out of the pupal skin to the top of the material and fly out of the pupation containers but remain contained in the dark cage.
10. Due to the darkness inside the cage, the emerged flies will not mate, but will remain motionless.
11. The BSF in the dark cage, thus, are a constant source of fresh adult BSF which, as soon as released into the light, will start to reproduce.
12. Emergence of the adults BSF (pupation) starts on average 14 days but not exceeding 21 after they were put into the pupation box and continue emerging up to time the last BSF emerges.

## 1.7 Mating

1. Emerged BSF are collected from the dark cage; this is done by connecting this dark cage with a tunnel to a cage that is not darkened and is hanging it to any type of supporting frame.
2. Because this is the place where mating will take place, we call it the **"love cage"**
3. Light opened in the love cage will attract the BSF to fly from the dark cage into the love cage.
4. BSF farmers should make sure same-aged-BSF in the love cage which has an important benefit, the BSF will copulate and lay eggs around the same time and are, thus, predictable, and allow for a more efficient nursery operation.
5. Love cages are equipped with a wet box containing cloth tissues embedded in sugar added water, some grown vegetation and a smelly attractant to simulate the natural habitant of BSF.

**Love cage**

6. In the love cage enough light and heat ranging from 25 up to 30°C are provided to stimulate easy egg ovipositing process.

7. After egg ovipositing, BSF dies, then one rearing cycle closes and other one start by hatching laid BSF eggs.


To ensure a sustainable BSF larvae production cycle, BSF farm should provide a defined number of five days old larvae so called 5'DOL every day. It's against this background that every single production step is controlled and monitored. Therefore, BSF farmer should know the number of larvae left for pupation and the corresponding amount of emerged lie.

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## 1.8 Waste receiving and pre-processing unit

BSF Larvae are generally very tolerant when it comes to feeding substrates. Yet, it is important that inorganic waste received at the production facility is suitable as larva feed by fulfilling the following:

- A first step upon arrival of the waste involves a waste quality control to ensure that it contains no hazardous materials and no inorganic substances are contained.
- Water content should range between 60 and 80%
- Particle size should be reduced by shredders.
  - ✓ Shredded inorganic waste are left for fermentation in a period ranging from 4 to 6 days.
  - ✓ Whatever type of technology is used, the equipment should shred the waste to particles of smaller than 1-2 cm in diameter.
  - ✓ If the shredded waste has water content above 80% (waste at this moisture will have a slurry like texture, similar to a fruit mix when grinded with a kitchen blender), then the waste will need to be dewatered or mixed with another, more dry waste source to obtain a moisture content below 80%.
  - ✓ If the water content is below 70%, then water needs to be added. This can be determined by squeezing a handful of waste, and if less than a few drops of water emerge between your fingers, then the substrates are too dry.
  - ✓ If dry waste is moistened using water, the water has to be safe to use, meaning that it does not contain pathogens, heavy metals or other anti-nutritional elements.


**Moisture content of feed**

## 1.9 5'DOL Feeding

- Every day, a specific amount of 5-DOL is transferred from the BSF rearing unit to the BSF 5-DOL larvae feeding units, that contains feeding trays also known as "**Larveros**".
- The number of 5-DOL added will depend on the amount of processed inorganic waste that is contained in a specified volume and surface area of the larveros.

★ **Types of waste used in larvae feeding are**

Chicken shit, cow dung, pig dung, restaurant, hotel, high school leftover, food industry west, kitchen west, vegetable market west, brewery west, west abattoir, slaughterhouses and butcher, hatchery west, and concentrates

★ **Larvae feed processing**

- ✓ Well-selected feedstuffs are mixed and grinded to fine particles and the excess water content is reduced by gravity and the removed water is kept for future use.
- ✓ Obtained mixed feeds are left for fermentation within a period of 2 days.
- ✓ Obtained mixed feeds are left for fermentation within 2 - 6 days
- ✓ By the end of complete fermentation, 15 kg of feeds are distributed to rearing trays, every tray of 120 lengths, 80 cm width and 15 cm height

★ **Small larvae inoculation and feeding**

- ✓ For every rearing tray, 1-2 g of small larvae are added and left for 4 days
- ✓ After 4 days 15 kg wet feeds are added to every rearing tray
- ✓ From day 4 water spray is performed
- ✓ From the day of batching, harvesting is performed at day 9 up to 10

# CHAPTER TWO

# BLACK SOLDIER FLY LARVAE HARVESTING PROCESS

- Harvesting is the process in which the larvae are separated from its frass. From day 9 up to 10 days of small larvae feeding, each larveros is harvested.
- At this stage, the larvae have reached their maximum weight, but have not yet transformed into prepupae.
- Their nutritional value is, therefore, at its maximum. 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.


**Figure 1.** When to harvest

- Harvesting is carried on by sieving or by using their behaviours to let them collect themselves, also called auto-collecting.
- The choice of the method used will depend on the BSF stage (i.e., larvae and prepupae) at harvest and the feeding substrate humidity and particle size.
- The first method, and the most used in industry, consists to sieve the substrate while keeping the larvae or prepupae into the sieve

## 2.1. Natural harvesting techniques

- **Oiled Soup Bowl:** For this process the oiled bowl (saucepan) is placed in the middle of the container full of mature larvae to attract larvae to come inside the saucepan. Then the larvae move from the old substrate toward the bowl for their attachment as attached by the oiled soup in the bowl.

- **Self-harvesting sieved box:** For this process, the mature larvae are poured into a box with small holes at the base that can allow the mature larvae to pass through. Then the holed container is placed over the clean and dry basin/ bucket. Then, the larvae move by themselves toward the bucket.

**Figure 2. Sieving BSFL**

Farmers should note that, trays intended for future BSF cycle are not harvested at this time; they are left in larvae rearing units and harvested once larvae reaches prepupae stage.

## 2.2. Manual harvesting

- Using sharpened equipment like a bistoury or knife to remove eggs on the hatching facility

- Manual harvesting (using hand) is done by removing the large particles/manure from the top of the container containing mature larvae ready to be harvested.

- The remaining larvae will be sieved by using a small holed sieve that allows the remaining waste to pass through therefore maximally removing waste material and other impurities.
- Then the fine larvae/ maggots are stored in a clean and dry bucket/ basin that does not allow the larvae to escape.

The end products are then the larvae in harvesting stage and the manure of the larvae.

BSF larvae in harvesting stage

Frass/manure of larvae

# CHAPTER THREE

# BSF LARVAE POST-HARVESTING 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).

## 3.1. Killing

The killing of harvested larvae/ maggots can be done by using hot water and roasting

- The harvested larvae are immersed in hot water above 100$^{o}$C for a period ranging between 2 to five 5 minutes (blanching). This to kill and clean the larvae and kill bacteria.


- While roasting, the harvested larvae are cooked in the fire by using a big cooking pan for a time between 2 to 3 minutes.

## 3.2. Drying

- Directly after a successful killing of harvested BSF Larvae, they are dried by use of several drying methods
- Several drying methods can be applied to BSF Larvae: **sun-drying, oven-drying, freeze-drying and or on fire**.

Sun-drying method

- Drying insect products has many advantages since it improves preservation by reducing microbial growth and spoilage-enzyme activity.

## 3.3. Crush and grinding of the dried larvae

The fully dried larvae/maggot are crushed by using a grinding machine millers or mortar/to maggot meal powder or protein meal, for better packaging and used in feeding and feed manufacturing

### 3.4. Packing and storage

The maggot meal powder can be stored in fibre sacs/ normal sacs in a clean and dry place at room temperature that is free from birds, rodents/rats and pets.

### 3.5. 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.

# CHAPTER FOUR

# FEEDING WITH BSF PROTEIN SOURCE

## 4.1. Methods

When the product is ready it can be fed to pigs, chicken, and fish.

- ❖ Protein substitution: < 100%
- ❖ Protein replacement: = 100%
- ❖ Protein supplementation: > 100%

## 4.2. BSF Feed forms

BSF protein meal is either fed as Fresh (Not defatted), defatted or not defatted dry

## 4.3. BSF Larvae inclusion levels in poultry feeds (Broilers)

a) Feed forms and replacement levels:
   - ★ **Powder** after extraction of fats: 25%, 50%.
   - ★ **Dry** without fats extraction: 10%-12%
   - ★ **Fresh** without fats extraction: 50%

b) Replacement: 5-10 % of other protein sources by BSFL in broilers

c) Replacement: less than 5 % of other protein sources by BSFL in layer

## 4.4. BSF Larvae inclusion levels in pig feed

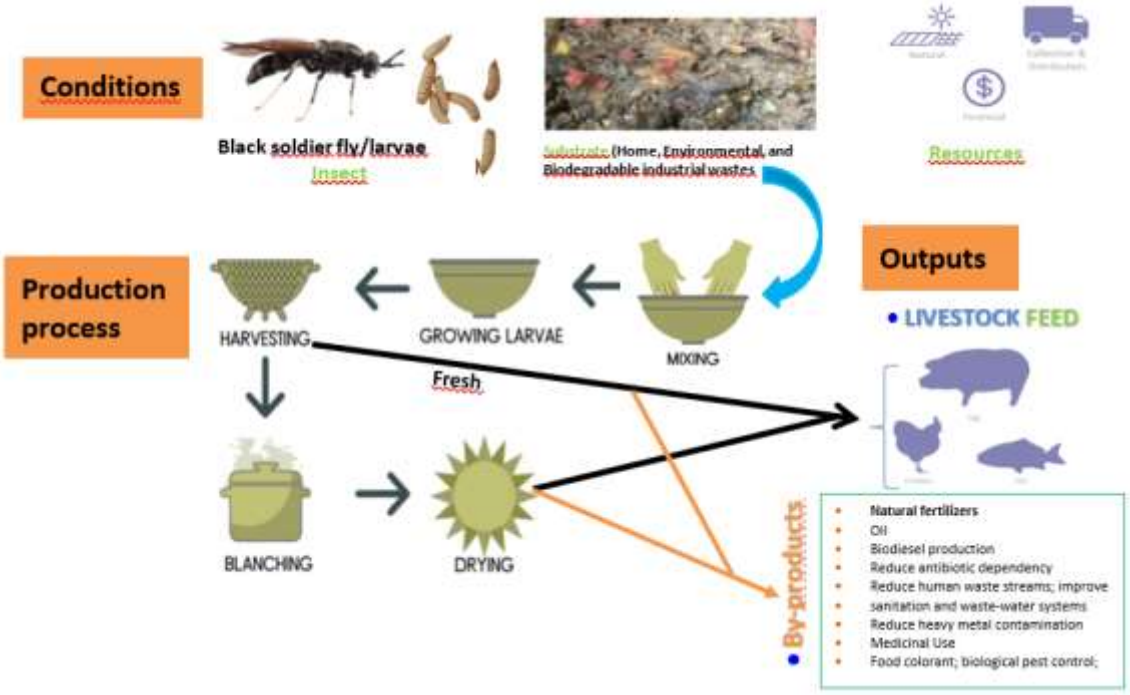
- ❖ Feed forms and replacement levels
  - ★ **Dry** 10% without extraction
  - ★ **Powder** after extraction (replacement of fish meal with BSF 50%,75,100%, piglets)

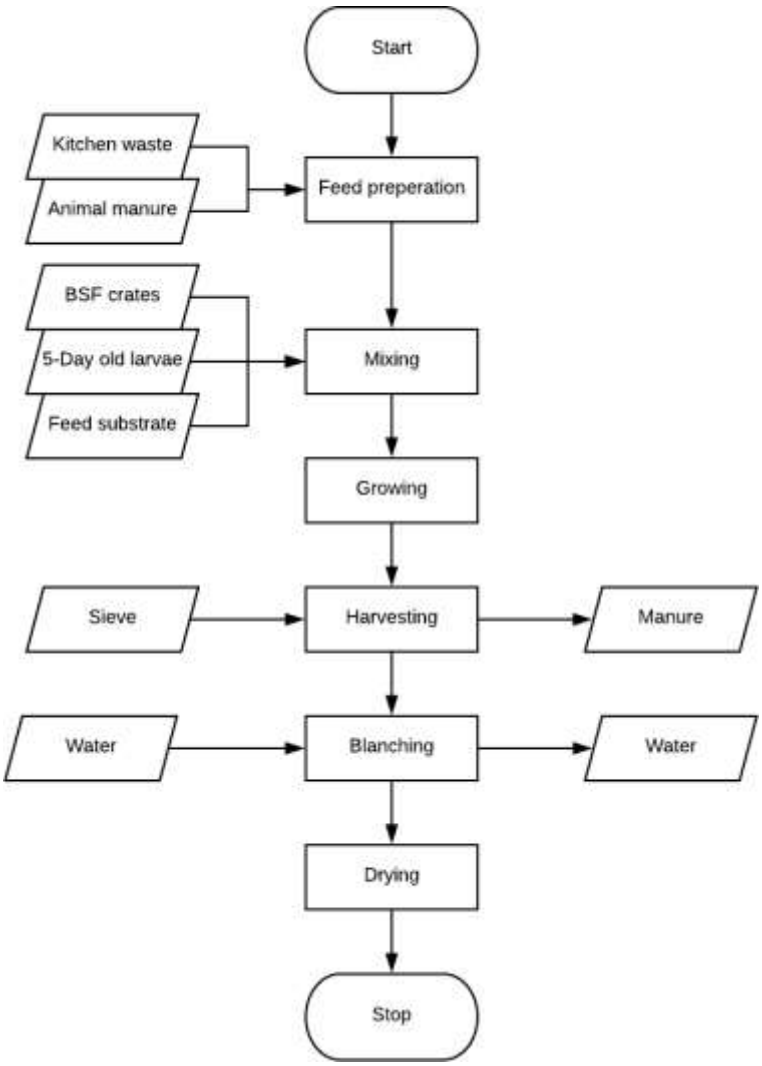
## 4.5. BSF Larvae inclusion levels in fish feeds

- ❖ Feed forms and replacement levels:
  - ★ Powder 50% replacement of fish meal with BSF
  - ★ Powder 50% substitution of soybean with BSF
  - ★ Powder 100% replacement of soybean with BSF
  - ★ 50% substitution of soybean has been the best compared to 100% replacement.

# CHAPTER FIVE

## SUMMARY PRODUCTION PROCESS



# CHAPTER SIX

# DATA RECORDING AND KEEPING

Most of the important records should be kept for every BSF production Unit.

- BSF rearing Unit
- Organic waste pre-Processing Unit
- 5’DOL Feeding Unit
- Product Harvesting Unit
- Post-Harvest Processing Unit

# CHAPTER SEVEN

# BASIC MATERIALS AND EQUIPMENT FOR BSF FARM

**(STARTER-KIT)**

| SN | Materials/equipment | Quantity |
|---|---|---|
| **Love cage management** | | |
| **1.** | Net | 1 |
| **2.** | Laying trays/crates | 1 |
| **3.** | Waste receiving and pre-processing unit equipment | 6 |
| **4.** | Stack of woods | 24 |
| **5.** | Attractant container | 1 |
| **6.** | Attracting light | 1 |
| **7.** | Attractant | 1 kg |
| **8.** | Four ant traps per love cage table (The love cage table legs are placed into these containers) | 4 |
| **9.** | Source of sugar water (water bowl) | 2 plastic food boxes with pc of cotton clothe |
| **10.** | Substrates/organic waste rich in protein | 200 kg |
| **11.** | Iron rack | 1 pc |
| **12.** | Goblets containing water to prevent predators like rat, mites, …. | 4 |
| **Dark cage and prepupae management** | | |
| **13.** | Dark cage | 1 |
| **14.** | Dark cage frame | 1 |
| **15.** | Pupation container | 1 |
| **16.** | Pupation substrate | 1 |
| **Egg and 5-DOL management** | | |
| **17.** | Shelve and hatchling shower | 1 |
| **18.** | Eggs or small larvae 5-DOL | 0.25 kg |
| **19.** | Hatchling container | 1 |
| **20.** | Sieve (mesh size 1 mm) for separating BSF larvae and frass | 1 |
| **21.** | Cup for 5-DOL portions | 1 |
| **General equipment and tools** | | |
| **22.** | Thermometer | 1 |
| **23.** | Hydrometer | 1 |

| | | |
|---|---|---|
| **24.** | Sheeting for sun drying | 1 |
| **25.** | Bag for BSF Larvae storing | 2 |
| **26.** | Overall | 1 |
| **27.** | Gumboot | 1 pair |
| **28.** | A pair of non-dispatchable rubber gloves | 2 |
| **29.** | Kitchen scale | 1 |
| **30.** | Cleansing agent | 1L |
| **31.** | 95% alcohol solution | 1 L |
| **32.** | Marker pen | 1 |
| **33.** | Calculator | 1 |
| **BSF waste processing unit** | | |
| **34.** | Bucket or other waste holding container | 1 |
| **35.** | Cotton cloth | 1 |
| **36.** | Plastic frame for dewatering | 1 |
| **37.** | Harvesting container | 1 |
| **38.** | Drying container | 1 |
| **39.** | Shaking sieve (mesh size 3-5 mm) | 1 |
| **40.** | Drying table | 1 |
| **41.** | Drying oven | 1 |
| **42.** | Sheeting | 1 |
| **43.** | Dustbin | 1 |
| **44.** | Protective clothes (gloves, mask, coat) | 1 each |

The number of crates needed depends to animal species and replacement rate**:**

- **Pigs**

| Amount animals | Replacement rate | Crate needed |
|---|---|---|
| **10** | **75%** | **8** |
| **15** | | **12** |
| **20** | | **14** |
| **25** | | **16** |
| **30** | | **18** |

- **Chicken**

| Amount animals | Replacement rate | Crate needed |
|---|---|---|
| **10** | **50%** | **1** |
| **25** | | **1** |
| **50** | | **3** |
| **75** | | **4** |

| | | |
|---|---|---|
| **100** | | **5** |

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