Simplified Black Soldier Fly Approach (SIMBA)

GROW-OUT UNIT

STANDARD OPERATIONS PROCEDURE

ECLOSE WE HELP YOU FLY

eawag aquatic research

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SCOPE

Standard operating procedures (SOPs) in BSF farming play a critical role in ensuring the success, safety, and scalability which connects to effective reproduction in the BSF life cycle, as well as consistent output and quality of larvae, frass, and by-products. SOPs help standardize tasks (and their timing at different stages of the process). This SOP focuses on the grow-out unit.

The larvae of the Black Soldier Fly (BSF), can be used for the treatment of the organic fraction of solid wastes. The larvae convert the nutrients contained in the waste into marketable products such as the grown larvae themselves for use as animal feed and the leftover of the process (called frass) for use as soil amendment.

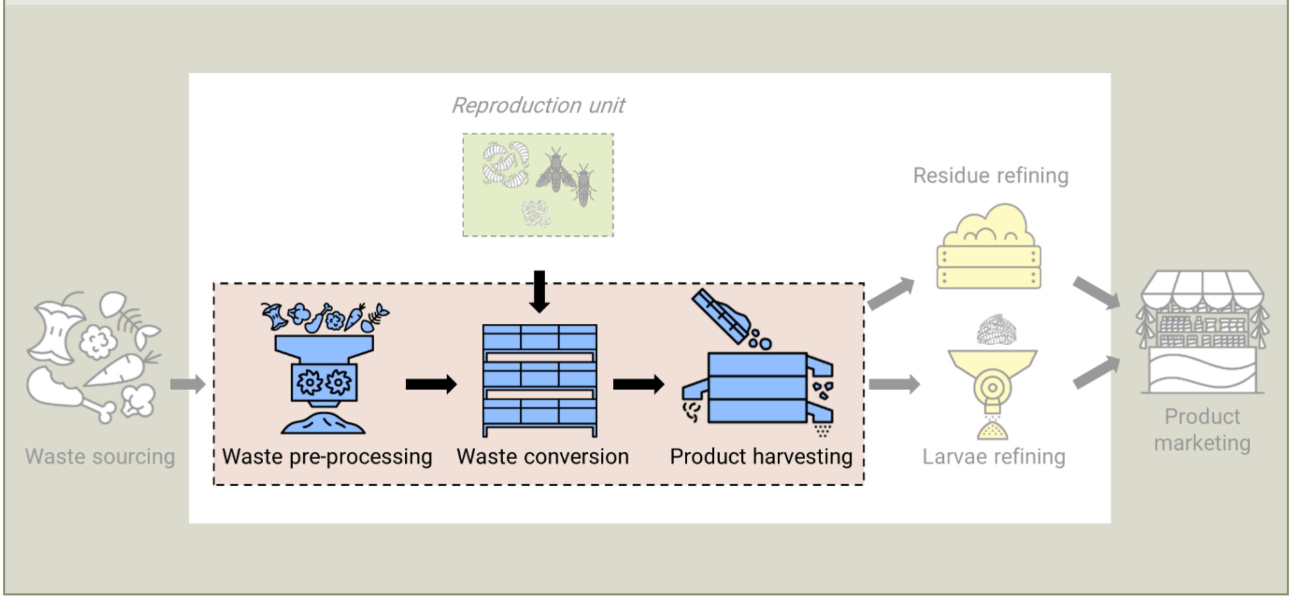
Running a professional BSF waste processing farm at medium to large scale requires a large number of tasks at different stages of the process, carried out on daily basis. However, such a farm can also be **operated part-time at smaller scale**, requiring just a few hours per week on selected days. We call this SIMBA: a **SIM**plified **B**SF **A**pproach.

A simplified BSF approach (SIMBA) can be suitable for:

- A first step entry into BSF waste processing, conducted as a part time side activity to explore and learn more about the practical aspects of BSF reproduction or use this as demonstration of BSF waste processing
- An established small farm that wants to produce BSF larvae as feed for their chicken, pigs and/or fish but has limited human resources and can allocate only a few hours per week to BSF activities.
- A research center that would like to operate a small-scale reproduction unit to then use flies, larvae or frass for research, or for training and demonstration purposes.

In this manual we focus only on the grow-out unit of such a simplified approach. The grow-out unit has the purpose to find a balance between optimal growth of the larvae for harvesting, production of frass for use as soil amendment and organic waste reduction. This all, while keeping the labour effort as low as possible. The grow-out unit will include the waste pre-processing, treatment of waste and product harvesting step (Figure 1).

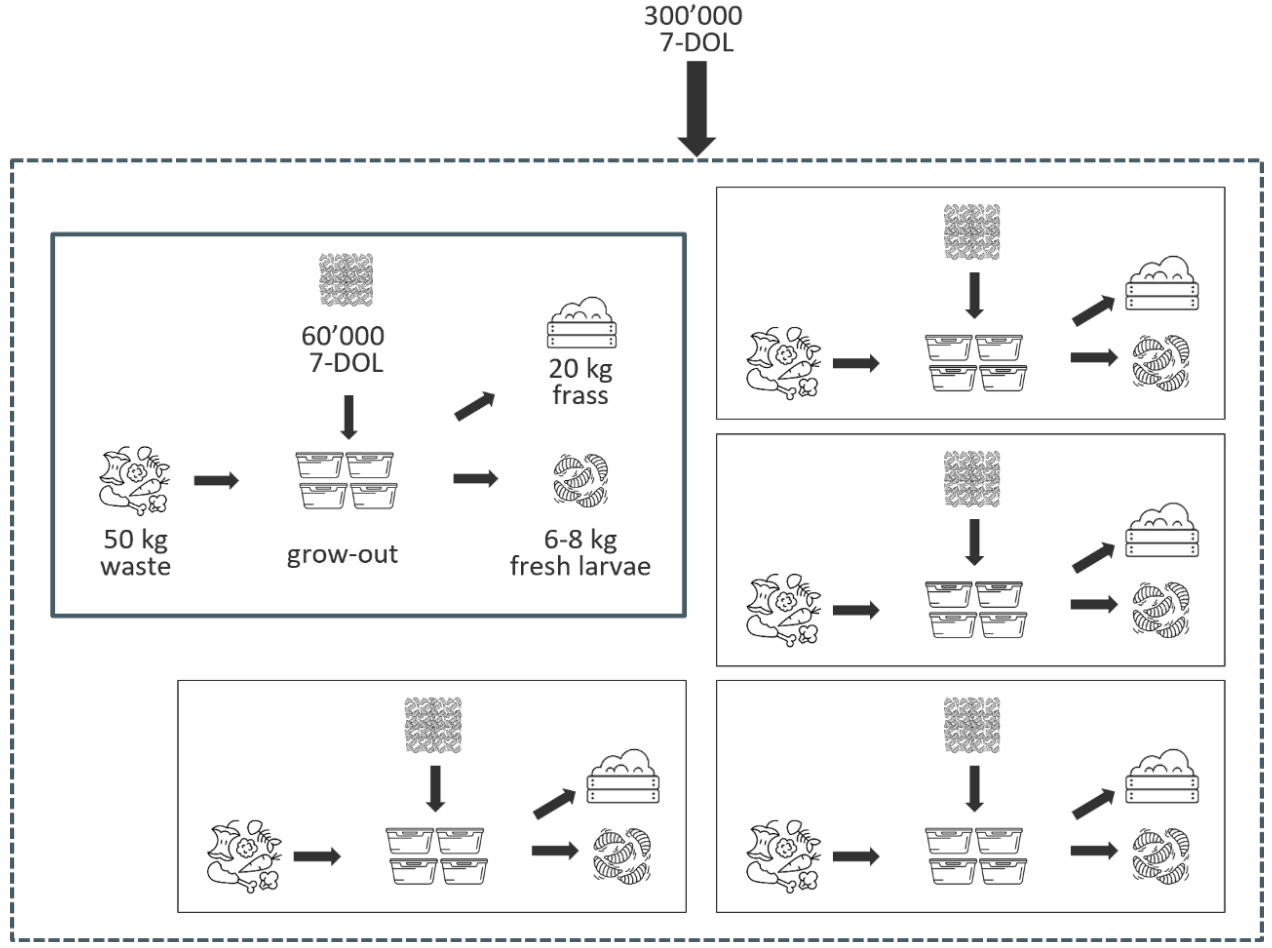
Figure 1: Overview of units in a BSF facility and the unit covered (shaded area) by this SIMBA document



This standard operations procedure (SOP) is a description of tasks conducted at the grow-out unit of a SIMBA BSF farm, operated with a labour input of only a few hours on two days per week (Monday and Thursday or Tuesday and Friday). In this manual we focus only on the grow out unit of such a simplified approach, treating 50 kg of waste weekly. A reproduction unit based on the "Simplified Black Soldier Fly Approach (SIMBA) – Reproduction Unit: Standard Operating Procedure" (by Eawag, published in 2025) will produce around 300'000 larvae, enough to treat approximately 250 kg of organic waste per week. The suggested approach however considers that the SIMBA reproduction unit would supply various grow-out units (decentralised grow-out).

With a workload of a few hours by one person on two days per week at each grow-out unit, this guide estimates that one reproduction unit can supply 5 grow-out facilities (Figure 2),each processing around 50 kg of waste weekly with each with 4 incubation and 4 grow-out containers and each producing 6-8 kg of fresh larvae weekly.

Figure 2: *Operation of SIMBA with one reproduction unit serving five grow-out units each processing around 50 kg of waste weekly, with four containers each containing 15,000 7-DOL, for a total of 60,000 larvae.*



To process larger quantities of waste at each grow-out unit, either the number of containers can be increased, or the containers sizes can be increased (see Table 2). However, this will then require more working hours per week.

If you are considering an even larger scale approach than proposed in this guide, we suggest to consult the "Black Soldier Fly Biowaste Processing - A Step-by-Step Guide, 2nd Edition" published by Eawag in 2021. It is freely available on www.sandec.ch/bsf-knowhow.

ESSENTIAL OPERATION REQUIREMENTS

Operating a BSF grow-out unit serves the purpose to generate the highest quantity and quality of larvae and frass with the optimal use of the biowaste streams available.

Preconditions for operating a simplified reproduction unit are:

- **Dedicated space:** A dedicated area is needed to accommodate the different steps in the treatment process:
    - It is preferable to have separate physical spaces (buildings, rooms, greenhouse, or outside area with tent) for the area where; a) waste is prepared for consumption by the larvae, b) the larvae feed on the waste substrate and c) where the grown larvae are harvested and separated from the frass. Main requirements of such physical spaces is a roof to protect from sun and rain.
    - The space for the pre-treatment requires about 6 m2 for storage and handling of the waste substrate.
    - For the grow-out itself (where larvae feed on the waste substrate), around 20 m2 is required.
    - A small area of 20 m2 is needed for where the grown larvae are harvested and separated from the frass.
    - So, in total you will require about 150 m2 of roofed space.
- **Suitable climate:** Ideally, the average daily temperature should vary within the range of 25 to 32°C. Between 20 and 25°C, the operation may be slowed down but larvae will still survive. If temperatures stay above 32°C for a longer period, more frequent turning of the substrate will be needed to prevent the larvae from overheating. A maximum relative air humidity of 50% in all physical spaces is ideal. However, a relative air humidity of 50-70% is acceptable. With higher humidity level, the larvae will have difficulty to evaporate the moisture in the waste substrate and it might take longer time to obtain dry frass. Dry frass is required to separate the larvae from the frass in the harvest step.
- **Seasonal changes:** There will be changes in environmental conditions throughout the year. The water content of the waste substrate and other climate adjusting measures will have to be adapted to maintain good conditions.
- **Responsible manager:** A person must be assigned as in charge of the grow-out unit, overseeing that tasks are completed by the worker, and ensuring that the equipment is well-maintained, and the necessary consumable materials are available. This person must have a good overall understanding of BSF larvae behaviour, and act as the point of contact for the worker (or student) responsible for the day-to-day tasks.

- **Committed worker:** A worker needs to allocate around 2 hours twice a week (total 4-5 hours per week) to operate the grow-out unit. The worker follows a strict standard operations protocol. The worker needs to be attentive and provide feedback on own observations to the person in charge (responsible manager). On small farms the worker may be the same person as the responsible manager.

- **Established monitoring system:** Implementing a basic monitoring system is crucial to track key performance indicators such as the waste substrate amount fed to the larvae per container (kg), harvested amount of larvae and frass per container (kg) and biomass conversion rate (%). The responsible manager of the grow-out unit should diligently analyse these numbers to evaluate the performance of the grow-out unit. In case of any significant deviations, the manager should investigate the cause and take appropriate action.

The operation at the grow-out unit can be divided into three parts:

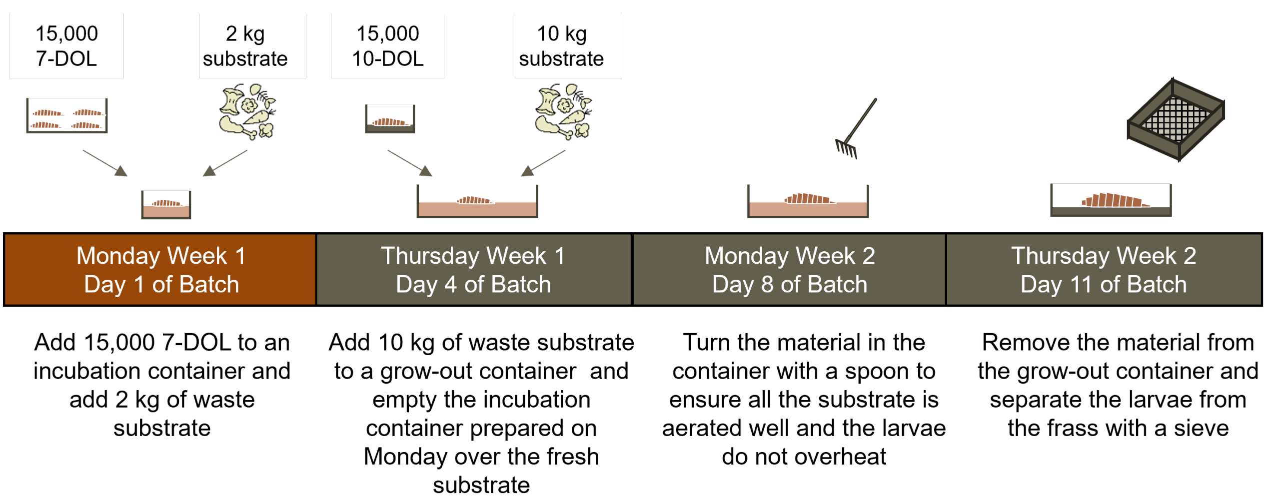
- **Waste pre-processing:** waste receiving, waste shredding (if needed), storage, mixing and dosing of waste substrate into containers.

- **Grow-out:** adding the 7-DOL to the containers, managing the containers and refeeding.

- **Harvesting:** selecting containers ready for harvesting, managing the containers not ready yet and separating the fresh larvae and the frass

The whole feeding process takes about 10 days (7-DOL are added and 17-DOL are harvested). As shown in Figure 3, the 7-DOL are initially placed into a container (~30x20 cm or a round basin of 25-30 cm diameter) - which we call "incubation container" - for 3 days and fed a small amount of waste substrate. After this, the larvae can be transferred into a larger container (~40x60 cm or 50-60 cm diameter) - which we call a grow-out container - where they then feed on a larger amount of the waste substrate until they are harvested.

Figure 3: Larval feeding schedule 2 days per week. This can be Monday & Thursday as shown in the figure, or else Tuesday & Friday or Wednesday & Saturday.



In the following section of this manual, we describe the principles of each process step and the associated tasks and activities to be carried out.

ACTIVITIES IN A BSF TREATMENT UNIT

WASTE PRE-PROCESSING

The term waste is used very broadly to refer to discarded goods. The organic fraction of waste (biowaste) can be utilised as feed if it does not harm the larvae. Larvae are generally very tolerant when it comes to the types of biowaste they feed on. With a water content between 60% to 90% and a specific particle size, most biowaste streams can be used as waste substrates and will be treated by the larvae. A list of biowastes known to result in satisfactory growth is shown in Table 1.

Table 1: Different types of biowaste considered suitable as waste substrates for BSF treatment.

Municipal organic waste	Agro-industrial waste	Manure and faeces
• Yard and garden waste • Food and restaurant waste • Market waste • Source separated household organic waste	• Food processing waste • Brewery spent grain • Slaughterhouse waste	• Poultry manure • Pig manure • Fresh human faeces

This SOP assumes that "waste sourcing" for the facility has been arranged and secured. The biowaste should be purely organic and biodegradable, and it should meet the criteria of appropriate biowaste types and suitable waste substrate as mentioned above.

A first step upon arrival of the waste involves quality control to ensure that it contains no hazardous materials and no inorganic substances. A few plastic bags in the waste may not pose a significant problem and can be sorted and removed manually. However, it is critical to keep hazardous contaminants out of the waste as these may affect all living organisms: the larvae, associated bacteria and, of course, the workers. Acids, solvents, pesticides, detergents, and heavy metals fall into this hazardous category, and it is especially critical to keep them out of the waste especially when they are in a liquid or dissolved form, as this can easily contaminate the whole waste batch.

With the waste quality ensured, the next required step then involves a reduction of the waste particle size. This can be achieved by using a shovel, rake, garden hoe, machete, or a hammer with a large surface. Whatever tool is used, its purpose is to break up and or smash the waste to particles of smaller size than 5 cm in diameter. Working with organic waste is messy and if the area is not kept clean it will attract vermin (flies, rats, ants, …). Therefore, a dedicated area for this task of waste quality control and particle size reduction is important, so that this area can be maintained clean after the work has been completed.

The next step is to provide good storage for the waste. As shown in Figure 3, only a small amount of waste substrate is fed on Mondays and then later a larger amount on Thursdays. This means that waste received must be stored until it is fed to the larvae on one of these days. Storage needs to prevent any animal and vermin from accessing the material while it is in storage. The ideal option is using a bucket with a lid which seals well enough to keep vermin out but allows fermentation gasses to escape. These fermentation gases could cause the lid to blow off if no ventilation is provided. There is no downside to the BSF conversion process if waste is stored for up to three weeks in a sealed but ventilated bucket as the BSF larvae feed on biowaste in any stage of decomposition. Figure 4 shows three options for buckets which can hold various quantities of biowaste and protect the content from vermin access.

*Figure 4: Options for biowaste storage buckets: left (20-25 L), **right** (50-70 L)*

Before adding the waste substrate into the containers with the larvae, conditions of a suitable waste substrate needs to be created which follows two essential principles:

1. The water content of the waste substrate needs to be around 70-80%. This allows the larvae to easily consume the feed and the frass to dry out quick enough for the time period of 10 days to be able to separate the larvae from the frass in the harvesting step.

2. The waste substrate should have a good protein, fat, and carbohydrate balance. A good balance of nutrients will allow the larvae to grow fast to their optimal size which positively impacts the harvest and biomass conversion rate. A good ratio of protein, fat and carbohydrates is 7%, 3% and 13% respectively. The remaining is typically made up of fibres (3%), ash (4%) and water (70%)

To assess how much water is in the waste, a scale and a bucket with a defined volume is required to first measure density of the waste. The bucket is weighed to know the empty mass of the bucket. The waste with small particle size (< 5cm) – after particle size reduction - is placed in the bucket. Apply pressure on top of the waste material to ensure there are no pockets of air left in the bucket. Also ensure that the amount of material has reached exactly the limit of the bucket volume so that the measured maximum volume of the bucket is filled with the waste. Then weigh the bucket again. From this weight then subtract the weight of the empty bucket to obtain the weight of the waste mixture of this specific volume.

The formula below can be used to calculate the density of the waste.

Density	$D\ (kg/L) = \dfrac{Mass\ of\ waste\ mixture\ (kg)}{Volume\ of\ waste\ mixture\ (L)}$

Ideally, the density of the waste mixture should be 0.8-0.9 kg/L. If the waste mixture density is close to or at 1kg/L, then the water content is very high. If this is the case, it is necessary to add some dry and fibrous material into the mixture which helps reduce water content of the mixture and also create better structure in the waste mixture. Dry and fibrous materials which can be considered are sawdust of untreated wood, cocopeat, wheat-/maize-/rice-bran, dry wheat/maize/rice milled products, dry bagasse dust and many other similar materials. Add dry material and conduct the measurement of density again – as described above - until a density value of 0.8-0.9 kg/L is reached. Should the density be lower than 0.8 kg/L, then add a more watery waste source or just some plain water and conduct the measurement again until you reach the ideal density of between of 0.8-0.9 kg/L.

Typically, regarding the requirements for the nutritional balance, the waste received will vary from the ideal nutritional composition. Animal waste (meat, dairy and slaughterhouse) might have a higher protein content whereas food processing waste and spent grains have a higher carbohydrate content. In general, waste collected from restaurants will come very close to the ideal nutritional composition as well as water content.

To prepare the small amount of waste substrate, which is fed on Mondays, one can simply manually mix the different waste substrates inside the container where the larvae will feed.

On Thursdays, when you feed a larger amount, use a shovel and/or rake to mix the different waste substrates well and create a homogeneous waste substrate with the total required weight and suitable density.

TREATMENT

The waste substrate is now ready to be fed to the larvae. The suitable amount of 7-day old larvae (7-DOL) are obtained from a reproduction unit. All aspects concerning reproduction is covered in another SOP document entitled “Simplified Black Soldier Fly Approach (SIMBA) – Reproduction Unit: Standard Operations Procedure”. For this guide we assume a grow-out unit that receives 60’000 7-DOL weekly to process around 50 kg of waste weekly with 4 incubation and 4 grow-out containers. Each week on Monday, you start a new feeding on waste substrate.

First feeding (7-DOL to 10-DOL): Larvae received from a reproduction unit are separated into the number of batches that you intend to start on this particular day. In case the number of larvae is unknown (as they might be delivered from another facility), check the document “Simplified Black Soldier Fly Approach (SIMBA) – Reproduction Unit” for more information on how to count larvae. The separation of the larvae can be done by weighing the total larval batch and dividing that weight by the number of required batches in the case of this guide this is 60’000 7-DOL divided into 4 units of 15’000 7-DOL. In absence of a precision balance, you can also divide the total larval batch volume.

Into each incubation container with a surface area of around 600 cm2 (~30x20 cm or a round basin of 25-30 cm diameter), add 2 kg (or about 2.5 litres) of the waste substrate. On top of this waste substrate 15’000 larvae are added to each incubation container. This is Day 1 of the batch. The layer thickness of waste substrate in each incubation container should not be thicker than 7-10 cm. If the waste substrate is bulkier and the layer is shows to be thicker than 10 cm, you will need to increase the size and surface area of your incubation containers.

The larvae will spend 3 days feeding on this waste substrate inside the incubation container. It is important that the waste substrate remains moist and does not dry out. The larvae will stop feeding when the moisture content is below 50% as they cannot ingest the feed when too dry and they will starve, not allowing them to grow to their optimal size.

Second feeding (10-DOL to 17-DOL): After 3 days of feeding (next working day) in the incubation container (or Day 4 of the batch), the larvae have reached their maximum tolerable size for the incubation container. If they stay in this restricted space for much longer, they will start to compete for space, resulting in higher mortality of the population. After 3 days of feeding, the larvae have consumed the nutrients contained in the provided waste substrate.

Figure 5: Treatment container with grown larvae and frass

Larger containers can now be prepared for the larvae in each of the incubation containers. This larger grow-out container can be designed in different ways. This guide describes the procedure for a 40 x 60 cm standard plastic crate. Other grow-out container types and sizes are described further below (Table 2). Place 10 kg of waste substrate in the centre of each grow-out container. Empty each incubator container, which contains 15’000 larvae, on top of the heap of waste substrate in each grow-out container. During the next few days, the larvae will start spreading out over the available waste substrate and feed on it.

The grow-out containers with the waste substrate containing the larvae can now be left alone until the next Monday (or Day 8 of the batch) when the content of each container should be stirred and turned over with a shovel or spoon. This allows the larvae to access the lower parts of the waste substrate, facilitates water evaporation from the waste substrate, and allows the waste substrate to cool to prevent the larvae from overheating.

After another 3 days in the grow-out container (Day 11 of the batch), the larvae should have grown to their full potential and are ready for harvesting.

The feeding schedule - 3 days incubator + 7 days in the treatment container – should be followed quite strictly to guarantee a well-structured process. Duration and scheduling of tasks should not be changed. If you feel something needs to be adapted, then consider changing the number of larvae or amount of waste substrate but refrain from changing the time scheduling. The main criteria for any change in number of larvae or amount of waste substrate should be based on the observed characteristics of the frass at the intended time of harvest (i.e. frass should be dry and crumbly) or on the observed characteristics of growth and development of the larvae. For instance, if after 10 days of being in the grow-out container, the frass is still soggy and wet, consider increasing the number of larvae for this container surface size or decrease the amount of waste substrate in your next batch.

Grow-out at larger scale:
The chapter above describes a grow-out facility processing around 50 kg of waste weekly with 4 incubation and 4 grow-out containers. If the grow-out unit has access to more than 150 kg of waste substrate per week, instead of using standard plastic crates (Table 2), you can use larger containers or structures, such as a biopond for the grow-out phase (Figure 6).

One example is building a simple rectangular structure consisting of a simple concrete floor with side barriers in a rectangular shape as shown in Figure 6, known as “pond” or “biopond”. The barriers do not need to be higher than 20 cm and can either be made of concrete or using wooden planks. Ideally one side of the barrier should be removable. This will make harvesting and cleaning of the (bio)pond easier. The bottom surface of the (bio)pond is typically concrete but can additionally be treated with a resin (e.g. food grade epoxy) so that the (bio)pond it is easier to clean after a feeding cycle has been completed.

Figure 6: Biopond on concrete floor with one removable side (left) and with all sides made of wood (right)

Other possible choices of grow-out containers are described in Table 2. Depending on the size of the container chosen, the number of larvae and the amount of waste that can be fed per container must be adjusted.

Table 2: Variations in combinations of number of larvae and substrate quantity depending on the choice of containers. We suggest a larval density of 6 larvae/cm^2.

	Type	Dimensions	Number of larvae	Total waste substrate	1st feeding	2nd feeding
	**Standard plastic crate**	**40x60 cm**	**15,000**	**12 kg**	**2 kg**	**11 kg**
	Round basin	Ø 50 cm	12,000	9.5 kg	1.5 kg	8 kg
	Half Jerrycan 20l	32x48 cm	9,000	7.5 kg	1 kg	6.5 kg
	Oval basin	32x45 cm	8,500	7.0 kg	1 kg	6.0 kg
	Concrete biopond	100x300 cm	300,000	240 kg	20 kg	220 kg

Based on the surface area of the treatment container of your choice, the number of larvae required and the amount of waste substrate can also be calculated (Table 3). Based on this number of larvae calculated you can also estimate the necessary size of the incubation container. This total area can be divided into several containers if needed.

Table 3: Calculation of: required number of larvae depending on size of container; amount of waste substrate depending on size of container; and surface area of incubation container. In the incubation container (between 7-DOL and 10-DOL) the larvae density is 30 per cm² while in the grow-out container (between 10-DOL and 17-DOL) the larvae density is 6 per cm². Larvae can treat 1kg of waste in an area of 200cm².

Number of larvae in a container	$Size\ of\ container\ (in\ cm^2) \times 6$
Total amount of waste substrate (kg)	$\frac{Size\ of\ container\ (in\ cm^2)}{200}$
Surface area of incubation container (cm²)	$\frac{Number\ of\ larvae}{30}$

Please note that with more weekly waste substrate and larger size (cm2) grow-out and incubation containers, the feeding schedule (3 days incubator + 7 days in the grow-out container) – should not change. The only thing that changes is amount of waste substrate and the number of larvae. In addition, what will also change is the time needed to conduct all the scheduled activities. Rather than working only a few hours twice per week you might have to consider working more hours twice a week or else consider a second person helping with the working tasks.

HARVESTING

After 3 days in the incubation containers and 7 days in the grow-out container, the 17-DOL (7-DOL+ 3 day + 7 days) are now ready to be separated from the frass. In general, visual indicators help detect whether the conditions are suitable to harvest the two materials, larvae, and frass from the treatment containers.

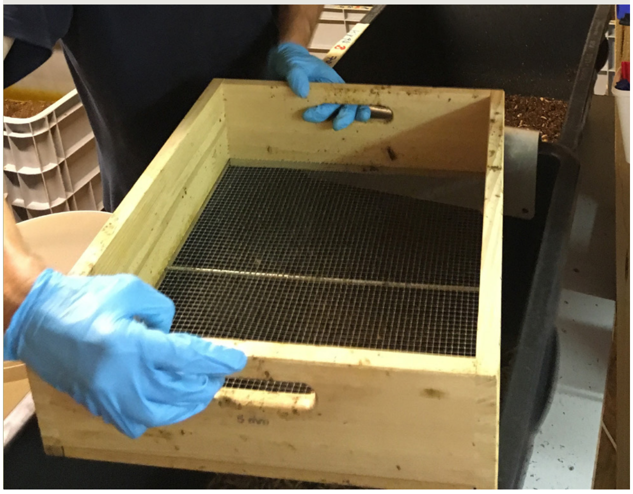
Larvae: A few larvae show a beige-brown colour instead of their normal light-beige colour (Figure 7). These beige-brown larvae are in the process of transforming into prepupae. Besides this visual aspect, weighing the larvae can also indicate whether they are suitable for harvest. Although their weight depends on what waste substrate they have fed on, a good larval weight is between 150 mg and 250 mg or more per fresh larva.

- To determine if the larvae have reached their maximum weight you can set up a small trial. Use a separate container where you take some larvae and feed them some more of the same waste substrate. If you observe them still feeding on this waste substrate then it seems the larvae could consume more during the grow-out phase. For the next batch you could therefore provide more waste substrate (e.g. 10% more) or keep the same amount but rather reduce the number of larvae per container.

Frass: The frass should have a dark, almost black, colour. The finer particles of this frass should have a round particle shape. This round shape is formed by the pressure from the friction between the larvae in the substrate (Figure 7). In the frass you might still notice larger pieces of woody and fibrous waste substrate (fruit peels, seeds, branches, etc.) as larvae generally do not feed on such woody and very fibrous substances. In terms of checking the appropriate moisture content, grab a handful of material (frass and larvae) and then release the material back into the treatment container. With suitable moisture content, ideally very little material should remain clinging to your hand. Lastly, when you hold some material close to your nose, you should not be able to detect any strong rotting smell. A very slight smell of ammonia (ammonia has a strong, pungent odor that is often described as being similar to urine or sweat) is acceptable.

Figure 7: Example of what the fraction should look like. From left to right: larvae, frass and residue

Figure 8: Example of a manual sieve



When the appropriate conditions of larvae and frass, as described above are achieved, it is time to harvest the two materials. When harvesting the material from a grow-out container that received 12 kg of waste substrate and 15,000 larvae, you can expect a total harvest of around 5-6 kg material (larvae, frass, and residue). For the separation of the fractions, you can use a sand sieve as shown in Figure 8 with a mesh size of about 4 mm. Such a sieve can either be handled by two people holding it on both sides or by one person holding one side and placing the other side on a solid surface. Add batches of around 10 kg onto the sieve and shake the sieve to separate the materials. The frass will fall through the sieve and the larvae together with larger frass or waste substrate particles will stay in the sieve. Once all frass has passed through the sieve, manually remove the larger frass or waste substrate particles from the sieve and then in a second step remove the clean batch of larvae as harvest. The separated fractions should look similar to the ones depicted in Figure 7. Once harvesting is complete, you should weigh each fraction, if a scale is available.

It is important to carefully look at the sieved materials as these materials and their conditions can provide information on how to improve the process. Figure 7 shows ideal conditions. Some troubleshooting is described below:

- If the larvae look dehydrated and the frass is dusty, the waste substrate in the treatment unit may have dried out too quickly thus not enabling the larvae to feed sufficiently before the day of harvest. It is therefore likely that the larvae were not able to consume all the nutrients in the substrate and thus the larvae probably did not grow to their optimal size.

- If the frass is still moist and sticky, it will be difficult to sieve the different fractions. Under such circumstances, for future batches, add some dry and fibrous material to the waste substrate at the start of the batch. This will help reducing the moisture by the end of the grow-out cycle to be able to successfully sieve the material.

SHORT-TERM STORAGE AND USE OF LARVAE

Assuming you are self-using the harvested larvae as animal feed, typically, not all the harvested larvae can be used as feed on the day of harvest. Therefore, you must provide storage of the harvested larvae for some days before you harvest a new batch. We recommend that you harvest on the day as scheduled and described above. Harvested larvae can be stored in a separate storage area in containers together with some damp sawdust, corn bran or wheat bran. The storage material should not be too damp, else the larvae might try to crawl out of the container. The storage area and container should be protected from ants, birds or other animals that might want to eat the live larvae. Place the container in a completely dark area.

When feeding the harvested larvae directly to the animals (chickens, pigs, fish), we recommend replacing up to maximum 20% in weight of the conventional feed with BSF larvae.
If larvae need to be stored for more than a week, you should consider killing and drying them. The larvae must first be killed by briefly dipping and blanching them for 10 seconds in boiling water. Once killed, batches of 250 g can be dried in a microwave oven using the highest power level (usually 1’000 watts) for 3-4 intervals of 5 minutes. The larvae should then have a crispy texture. In-between intervals the door of the microwave must be opened to allow the steam to escape. Once drying is completed, store the dried larvae in a dry place until use. Remember, after drying the larvae are lighter in weight. When using dried larvae, we now recommend replacing up to 5-8% in weight of the conventional feed with BSF larvae.

MONITORING

Monitoring and documenting performance of the grow-out is crucial to analyse and understand how the grow-out is functioning and what could be improved. Key data that needs to be monitored is:

- Number of 7-DOL used per incubation and grow-out container.
- Total weight of waste substrate per incubation and grow-out container (1st feeding and 2nd feeding
- Weight of material before harvest (mixture of for larvae, frass and residue)
- Weight of harvest for larvae, frass, and residue

With this information, you can now obtain an overview of the performance of the process.

- You can compare the weight of the frass harvested and compare this to the weight of the waste substrate added. Dividing these values and multiplying by 100 shows how much weight of the waste substrate was reduced. This is called the waste reduction rate in percent.

- You can compare the weight of harvested larvae to the mass of the waste substrate added. Dividing these two parameters and multiplying by 100 results in the Biomass Conversion Rate (or BCR) in percent. This is a value which indicates how efficient the larvae have been in converting the substrate into larval biomass. It is an important performance indicator which can be used to optimise the process.

The formula below can be used to calculate the waste reduction and the biomass conversion rate.

Waste reduction	$WR\ (\%) = \frac{Mass\ of\ substrate\ fed - Mass\ of\ frass}{Mass\ of\ substrate\ fed} * 100$
Biomass Conversion Rate	$BCR\ (\%) = \frac{Mass\ of\ larvae\ produced}{Mass\ of\ substrate\ fed} * 100$

The level of BCR is affected by the waste substrate and the processing efficiency at your facility. The goal is to achieve the highest possible BCR for the specific waste substrate you are using. What waste substrate you are using will obviously depend on what you can easily access in your local context. For example, when using pig manure as waste substrate the amount of harvested larvae will likely be lower than if they were to be fed with waste from a restaurant or the market. However, as pig manure may be much more available, easier to access and does not have to be shredded before it is fed to the larvae, this lower BCR (smaller harvest) may nevertheless be a good choice and the trade-off of lower harvest nevertheless acceptable.

Typical values of BCR when using different waste substrates are as follows:

- **Pig manure:** BCR 6-14%
- **Chicken manure:** BCR 6-10%
- **Cattle manure:** BCR 3-8%
- **Food waste:** BCR 12-20%

ANNEX

ANNEX A: Alphabetical list with a description of equipment items

Grow-out container

This is a medium size container (40 cm x 60 cm) which is used for the waste substrate treatment Such crates can either be cross-stacked, self-stackable or stacked using frames. All three options must ensure that enough ventilation over the surface of the crate is provided. Such crates are often made of sturdy plastic, are rectangular and can last for up to 10 years.

Basin

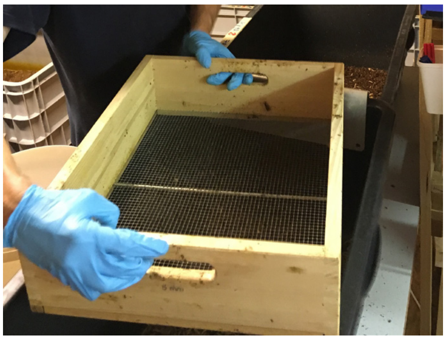
This is a plastic basin which can also be used for waste substrate treatment or as incubation container. They are available in most small-large hardware stores around the world. Stacking these require a rack, frame, or other supporting structure.

Biopond / Pond

Bioponds are large treatment containers (3-10 m2) where larvae feed on the waste substrate. The main difference to other containers is that bioponds are not mobile. Bioponds are often constructed directly on the concrete floor and have side barriers, preventing the larvae from leaving the waste substrate. The larger size and surface area allows treatment of larger amounts of waste substrate directly in one container. The downside of using bioponds is that it is more challenging to remove the material from the biopond for harvest, and that this system is not stackable, resulting in a large area requirement.

Storage bucket

A container which can be sealed (not airtight) and which is used to store waste substrate. It is important to have such storage buckets at the facility as it is likely that the waste will arrive on different days/times not necessarily at the same time when the waste substrate is pre-processed and added to the treatment container. It is thus important that the biowaste can be stored in a container where animals cannot reach the biowaste to prevent an unhygienic situation.

Shovel	A shovel as depicted on the right, can be used at various stages of the treatment process. A shovel is used to remove biowaste from the vehicle that brings the waste. It can also be used to mix the different ingredients and move certain materials into different areas/containers. The shovel can also be used to add or remove material to/from a treatment container	
Sieve	A sieve is used to separate frass, larvae, and residue from each other. At the SIMBA scale, a manual sieve can be used as the quantity of material to be separated is low. The type of sieve on the picture can be operated by a single person. Adding handles on the opposite side allows for two people to operate the sieve thereby increasing the speed of the harvesting process.	
Bulk scale	When receiving biowaste, preparing ingredients and dosing the substrate into the containers, it is important to weigh the material to be sure about the quantities which are handled. In addition, the scale is used for weighing the material before harvesting, as well as the sieved materials (frass, larvae, and residue).	

This document provides “Standard Operating Procedures (SOPs)” in BSF farming. SOPs play a critical role in ensuring the success, safety, and scalability which connects to effective reproduction in the BSF life cycle, as well as consistent output and quality of larvae, frass, and by-products. SOPs help standardize tasks (and their timing at different stages of the process). This SOP focuses on the reproduction unit.

Visit to learn more about the Black Soldier Fly (BSF) biowaste processing