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Black Soldier Fly Biowaste Processing

A Step-by-Step Guide



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Black Soldier Fly Biowaste Processing

A Step-by-Step Guide

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Glossary

5-DOL:	Abbreviation for Five-Day-Old-Larvae. Keeping the hatchlings in a controlled and protected environment for five days after hatching increases the survival rate and allows the larvae to be counted before they are added to the biowaste.
Adult:	The final development stage after pupation. With insects, this is usually called "imago".
Anaerobic digestion:	Degradation of organic compounds by microorganisms in the absence of oxygen, leading to the production of biogas.
Ant trap:	Protects from ant invasion. Each table leg is placed into a container filled with water and a drop of detergent. The detergent reduces the surface tension of the water.
Attractant:	Smelly liquid substance that attracts BSF females to lay eggs nearby. Usually, this contains different smelly substances like fermenting fruit, dead flies or residue. BSF eggs have also been found to act as an attractant. It is, therefore, advisable not to harvest eggs every day as the already laid eggs attract other females.
Batch operation:	In batch operation, a defined amount of waste and larvae are added to a container, which is harvested after a certain time. Batch operation is in contrast to continuous operation, where waste and larvae are added continuously to the same container. The container is only emptied once it is full.
Biowaste:	Generally, all biodegradable matter. In this particular context, it does not include waste high in cellulose (e.g. garden waste, wood, grass clippings, leaves, etc.) as this cannot be easily digested by the larvae.
BSF:	Black soldier fly, <i>Hermetia illucens</i>
Coco peat:	The powdery material resulting from processing coconut fibre. In this context, it is mostly used for its moisture absorbing properties. It can be replaced by other materials with similar moisture absorbing properties, such as wheat bran, for example.
Compost:	Organic matter that has been degraded and transformed by aerobic processes to a soil-like substance and can be used as a fertilizer and soil amendment.
Dark cage:	Adult flies emerge in the dark cage where they remain until transferred to the love cage. The darkness keeps the flies calm and prevents mating activity.
Date code:	The date code allows for calculating the duration of the ongoing process and is applied to cages and containers. It consists of the calendar week of the year and the day of the week (for example: Tuesday of week 8 is coded as 8.2).
Dry matter:	The mass of the matter after all water has been removed. It is usually determined by keeping a sample in an oven at 105°C for at least 12 hours.

Egg:	A female fly lays between 400 and 800 eggs from which young larvae will hatch within four days. One egg weighs about 25µg.
Eggie:	The media used in an engineered BSF-system to collect eggs. It provides sheltered cavities for egg deposition.
Emerging:	When adult flies emerge from a pupa after pupation.
Engineered biosystem:	A biological process that has been optimised for a practical use.
Faecal sludge:	A waste product from onsite sanitation systems, such as pit latrines or septic tanks. It is usually a combination of excreta and water, often mixed with sand and household trash.
Feeding station:	A designated area where waste is added to the larveros. It is advisable that it can be cleaned easily (tiled or sealed floor) as biowaste may be spilled during the feeding operation.
Fishmeal:	Fishmeal is a nutrient-rich feed ingredient used in the diets of farmed animals. It is manufactured from wild-caught small marine fish and is a powder obtained after grinding, cooking and defatting the fish. Fishmeal production is a significant contributor to over-fishing.
Food and restaurant waste:	Biowaste from restaurants consists of kitchen scraps and food waste. It typically has a higher nutritional value and a lower water content than market waste or food processing waste.
Food processing waste:	Biowaste from the food processing industry. It varies from fruit and vegetable bits to bread crumbs and/or dairy products. It is usually a homogenous and uniform waste source.
Hammer mill:	Crushes and shreds material into smaller pieces by repeated strikes of small hammers. It does not cut material. The particle size is defined by the diameter of the outlet screen.
Hatching:	The process of young larvae (hatchlings) emerging from the egg.
Hatching:	Larvae that have just hatched from the eggs. Sometimes also called "neonates".
Hatching container:	Hatchlings fall into the hatching container after hatching where they remain and feed for five days on nutritious feed (chicken feed) to become 5-DOL.
Hatching shower:	Harvested eggies are placed on a rack called a hatching shower, which is placed over a hatching container. When young larvae hatch, they fall into the hatching container, which is replaced regularly (every one to three days).
Human faeces:	Excrement that is not mixed with urine or water. A product from urine-diverting dry toilets.
Lab oven:	An oven which provides a uniform temperature. In BSF biowaste processing, it is mostly used to obtain dry matter samples from waste, residue and larvae, and operates at 105°C.

Larva:	The juvenile stadium of holometabolous insects. There are seven larval stages, so-called instars, in the life cycle of the black soldier fly before metamorphosis (transforming them into an adult fly).
Larvero:	The larvero is the container where larvae feed on biowaste. It can be of any form, from a standard crate (60x40x15cm) to a pallet sized bin, and up to large concrete basins.
Love cage:	The love cage is a netted enclosure with a cohort of same-aged flies received from the dark cages. In the love cage, adult flies mate and females lay their eggs into eggies. After a week, the love cage is removed and emptied.
Low- and middle-income setting:	Although BSF biowaste treatment can be applied all around the globe, the set-up and operation presented in this book focuses on low- and middle-income countries (GNI up to ±10,000 EUR). This context is characterized by low labour costs, and a high organic fraction of the municipal solid waste.
Market waste:	Consists mostly of fruits and vegetables. It has a high water content (up to 95%) and is subject to seasonal variation. The outer parts of leafy vegetables may have been exposed to pesticides.
Municipal organic waste:	Waste generated by settlements, which includes households, commercial and industrial premises, institutions (schools, health care centres, prisons, etc.) and public spaces (streets, bus stops, parks and gardens).
Nursery container:	In the nursery container, 5-DOL are fed a defined amount of nutritious feed (e.g. wet chicken feed) until they transform into prepupae. These are used to maintain the colony, which are transferred to the pupation containers where the prepupae pupate and eventually emerge as adults.
Pelletiser:	Equipment that molds larvae and other feed ingredients (soymeal, corn, rice husks, etc.) into feed pellets for fish or chicken.
Poultry manure:	Manure from broiler production or layer hens. BSF larvae grow well on this rather homogenous biowaste, but tend to remain quite small. This substance is rather dry and may, thus, be used in combination with fruit and vegetable waste.
Prepupa:	The last larval stage that crawls out of the waste to search a dry pupation site. In comparison to the larvae, prepupae have a higher chitin content and are, therefore, less easy for fish and chicken to digest.
Pupa:	During pupation, the metamorphosis from larva to adult fly happens. Black soldier fly larvae pupate within their last larval skin and pupation lasts around 20 days.
Pupation container:	The pupation container is filled with a moist pupation substrate (e.g. compost, moist coco peat, pot soil, etc.) which prepupae bury into and is where they pupate.

Rearing:	The rearing facility contains the whole life cycle of the black soldier fly and produces the 5-DOL sufficient to treat the incoming bio-waste.
Residue:	The leftovers after the treatment process. This substance can be a crumbly, soil-like substrate or a wet slurry.
Shaking sieve:	A sieve which vibrates or shakes, that is powered by an eccentric drive. It is used with a mesh 3 to 5 mm in size during harvest to separate grown larvae from the residue.
Slaughterhouse waste:	It includes bones, organs, hooves, blood and other inedible animal parts leftover after all the edible parts of the animal have been removed. It can also include the gut content of the slaughtered animals.
Spent grains:	The main waste product from beer production. The leftover malt and adjuncts after the mash has extracted most of the sugars, proteins, and nutrients.
Transfer container:	Collects the prepupae which crawl out of the nursery container. It contains coco peat or another dry substance to prevent the prepupae from escaping.
Ventilation frame:	Provides a space between the layers of larveros. It ensures the exchange of air and, thus, the removal of moisture from the larveros Waste reduction: The waste reduction is measured, either based on wet weight or dry weight, and compares the biowaste going into the treatment with the remaining biomass (residue). Depending on the type of biowaste, one can expect a waste reduction between 60% and 85% dry weight
Waste sourcing:	Proper waste sourcing is of crucial importance for a complete waste treatment chain. It relies on a well-organised collection scheme that takes into account efficient collection routes and adequate means of transport. When dealing with municipal solid waste, a special focus needs to be set on the segregation of the organic fraction.
Water content:	When a sample (waste, larvae, residue, etc.) is dried at 105°C in a lab oven, all the water that is evaporated is referred to as "water content". Together with the remaining solids ("total solids"), both are expressed as percentages of wet weight; it equals to 100%



Chapter 1:

Rationale

1.1 General Introduction

Urban solid waste management is considered one of the most immediate and serious environmental problems confronting urban governments in low- and middle-income countries. The severity of this challenge will increase in the future given the trends of rapid urbanisation and growth in urban population. Due to growing public pressure and environmental concerns, waste experts worldwide are being called upon to develop more sustainable methods of dealing with municipal waste that embrace the concept of a circular economy.

Recycling organic waste material (biowaste) is still fairly limited, especially in low- and middle-income settings, although this is by far the largest fraction of all generated municipal waste. This book deals with urban organic municipal waste from households, commercial activities, and institutions. It describes the fairly novel approach of biowaste conversion by insect larvae, using the example of the Black Soldier Fly (BSF), *Hermetia illucens*, an approach that has obtained much attention in the past decade. Its popularity links to the promising opportunities of using the harvested BSF larvae as a source of protein for animal feed, thus, providing a valuable alternative to conventional feed. Enterprises and small entrepreneurs are already investing significant amounts of money into this technology and are interested in keeping a competitive edge on the practical aspects of operating such a facility in a cost effective way. Although academic publications on BSF are on the increase, the business interest and perceived need to maintain a competitive edge has hindered open exchange about and discussion of the practical day-to-day working steps required to operate such a facility. Filling this gap is the main objective of this publication.

This document is based largely on the experience of a one ton of waste per day treatment facility in Indonesia that has been in operation for over two years and an experimental facility in Sweden in operation for one year. Waste processed at the facility in Indonesia was mostly fruit and vegetable waste from a wholesale market. Upscaling or transferring this information to a larger facility might require some adaptation or adjustment of equipment. It is, however, our opinion that the standard procedures described are valid for a large range of scaling-up.

Several key attributes make BSF technology an attractive treatment option for biowaste from the perspective of waste managers and businesses:

- Waste biomass is converted into larvae and residue. The larvae consist of ±35% protein and ±30% crude fat. This insect protein is of high quality and is an important feed resource for chicken and fish farmers. Feed trials have confirmed it as being a suitable alternative to fish meal.
- Feeding waste to larvae has been shown to inactivate disease transmitting bacteria, such as *Salmonella* spp. This implies that the risk of disease transmission between animals and between animals and humans is reduced when using this technology at farm level or when treating waste of animal origin in general (e.g. chicken manure or slaughterhouse waste). However, risk reduction is achieved mainly through material reduction (±80%) rather than through pathogen inactivation.
- Waste reduction of up to 80% on wet weight basis has been demonstrated. If treatment is applied at the source of biowaste generation, the costs for waste transport and space requirements for landfills can, thus, be reduced drastically. Such organic waste treatment could furthermore reduce open dumping, which is still an unfortunate reality in low- and middle-income settings.

- The residue, a substance similar to compost, contains nutrients and organic matter and, when used in agriculture, helps to reduce soil depletion.
- A high waste-to-biomass conversion rate of up to 25% on wet weight basis has been demonstrated, which is a satisfactory output quantity from a business perspective.
- There is no need for sophisticated high-end technology to operate such a facility. Therefore, it is suitable for low-income settings that rely mostly on simple technology and unskilled labour.

Two research projects provided the basis for the writing of these guidelines. FORWARD is a four-year applied research project, focusing on integrated strategies and technologies for the management of municipal organic solid waste in medium-sized cities of Indonesia. Among other activities, the project designed, implemented and operated a pilot-scale BSF waste treatment facility at a local wholesale market. The BSF facility was designed to act as a testing and showcase site at which “Standard Operating Procedures” could be determined for further dissemination. FORWARD is an independent non-profit R&D project, funded by SECO, the Swiss State Secretariat for Economic Affairs, under a framework agreement with the Indonesian Ministry of Public Works & Housing (PU-PeRa).

The SPROUT project is a three-year project geared towards developing waste-to-value treatment with the Black Soldier Fly (BSF) larvae. It focuses on hygienic aspects, design and operation of treatment units, quality of products (feed and fertilizer), post-harvest processing regarding feed quality and product safety, business models for BSF waste processing, and evaluation of the environmental impact of BSF waste processing compared to other biological treatment options. SPROUT is a multi-national project, and SLU (Swedish University of Agricultural Sciences) and Eawag (Swiss Federal Institute of Aquatic Science and Technology) are the main research partners and Pacovis AG from Switzerland is the partner from industry. It is funded by the EU-program ECO-INNOVERA, the Swedish Research Council Formas, the Swiss Federal Office for the Environment FOEN and Pacovis AG.

This manual was written as open source with the ambition that BSF treatment would obtain widespread notice, implementation and replication. In this spirit, the authors would like to acknowledge all those that helped to develop, document and discuss the practical aspects of BSF rearing and waste treatment by larvae. Particular thanks go to Sirajuddin Kurniawan, whose pictures of the equipment and work steps saved us many pages of explanatory text, Cecilia Lalander and Björn Vinnerås of the Swedish Agricultural University SLU (Sweden) for an excellent research partnership, Longyu Zheng and Jibin Zhang of the Huazhong Agricultural University (China) and Michael Wu of JM Green (China) for their openness and their fruitful input, and Puspa Agro for their hospitality.

1.2 Scope and target audience

An engineered BSF processing facility can be designed and operated to achieve certain target objectives based on the natural life cycle of BSF. These, for instance, can be to cost effectively augment larvae quality or maximize the larval mass quantity produced within a certain time frame or based on a particular feedstock, similar to a typical livestock rearing system (chicken, beef, etc.).

In this manual, however, we follow a waste management perspective. In other words, we start from the premise that biowaste is the substance of concern for which we suggest to use the BSF treatment technology as a suitable processing and recycling solution to produce larvae and waste residue.

The primary goal, therefore, is to process biowaste in an efficient way with regard to investment and operational costs, as well as space requirements. By processing biowaste, threats to public health and the environment can be reduced.

The technology solution consists of feeding segregated biowaste to BSF larvae, which have been reared in a nursery. Larvae grow on the waste feedstock and reduce the waste mass. At the end of the process, larvae are harvested and, if necessary, post-processed into a suitable animal feed product. The waste residue can also be further processed and potentially sold or used as soil amendment with fertilizing properties.

This guide has been prepared for practical use. It explains the required materials and equipment, as well as each working step, similar to a cookbook with its respective recipes. It includes all information required to develop and operate a Black Soldier Fly larvae waste processing facility. Where information is scarce or unavailable, it highlights these gaps and points to further research and development that are required.

It is worth mentioning that the approach presented in this handbook is one among many. It is based on locally available equipment and without automatization. The operations presented here have proven to work, but selected steps may individually be replaced with other procedures depending on the given context or experience.

Given the approach of this handbook, it targets readers with little or only some basic knowledge of waste management in general and black soldier fly technology in particular, who have the willingness to work with waste and to implement and operate such a facility. This guidance can also be helpful to someone who has already started with BSF treatment and is interested in obtaining other viewpoints on how things could be done.

1.3 Navigating through this guide

The manual is structured according to the five main processing units that are key to a BSF processing facility (Figure 1).

1. BSF rearing unit
2. Waste receiving and pre-processing unit
3. BSF waste treatment unit
4. Product harvesting unit
5. Post-treatment unit (larvae refining and residue processing)

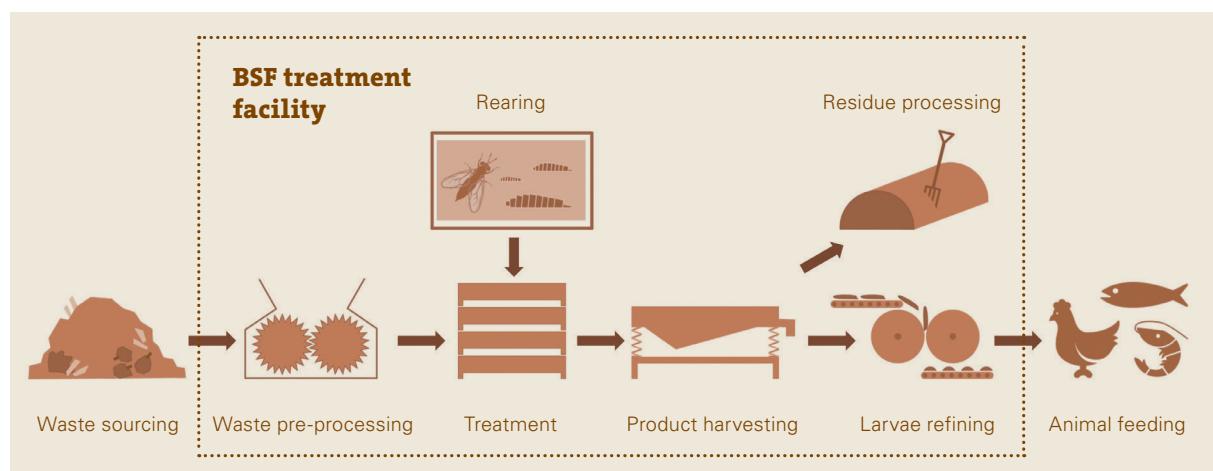


Figure 1: The different units of a BSF treatment system



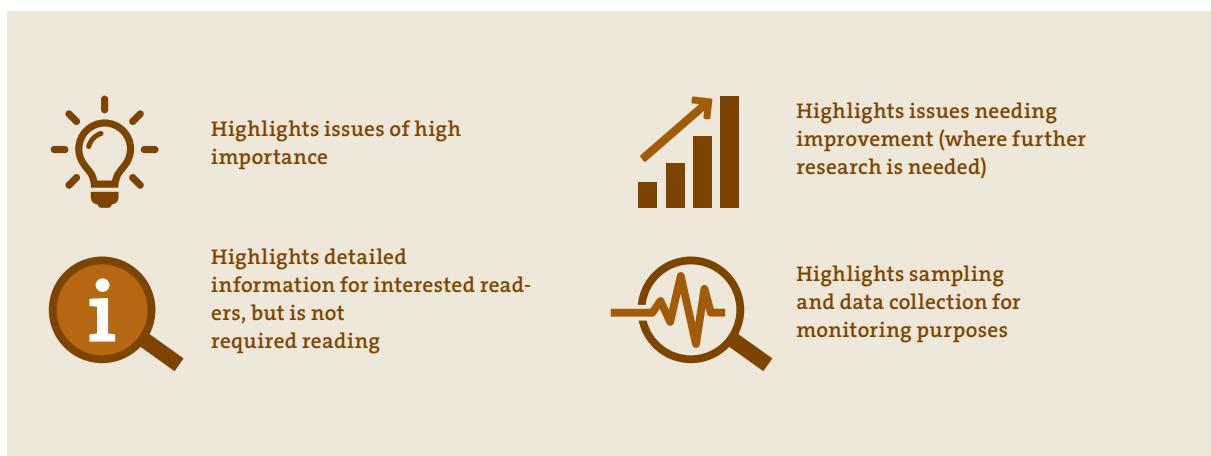
Although proper “waste sourcing” is of crucial importance to a well-functioning BSF facility, this unit is not discussed in detail in this manual.

The economic viability of a BSF processing facility will depend on a range of local conditions:

- Scale and respective capital and operating costs of the facility
- Climate (temperature, humidity)
- Potential revenue from waste processing (tipping fees)
- Sales revenue from larvae derived products (e.g. whole larvae, protein meal, larval oil, etc.)
- Sales of the waste residue as soil amendment or its use in a biogas plant.

This manual does not fully explain the financial aspects of such a facility, but rather focuses on what we suggest are the minimum number of operating steps required for a facility. Besides the list of activities that must be conducted at specific time intervals, this manual also provides an equipment list, which is based on practical experience. However, we highlight where we feel there is potential for improving the equipment.

Throughout the text, you will come across the following icons. They indicate issues of particular importance and background information or point to research gaps.



Chapter 2:

Waste Treatment by BSF

2.1 Understanding the natural BSF life cycle

This chapter takes a closer look at the life cycle of the Black Soldier Fly. Understanding the life cycle helps one to know why BSF is a suitable insect for organic waste management and to learn how this cycle can be “engineered” to enhance the benefits produced in terms of waste conversion efficiency and product harvest in quantity and quality.

The Black Soldier Fly, *Hermetia illucens*, 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 (Figure 2).



Figure 2: Distribution area of the black soldier fly, *Hermetia illucens*

The egg starts a BSF life cycle and at the same time marks the end of the previous life stage: 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, sheltered cavities. Shortly after having laid the eggs, the female dies. The closeness of the eggs to the decomposing organic matter ensures that the larvae have their first food source nearby after hatching. The sheltered cavities protect the eggs from predators and prevent dehydration of the egg packages by direct sunlight. 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. The different life stages are shown in Figure 3 and Figure 4.

Under optimal conditions with ideal food quality and quantity, 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.

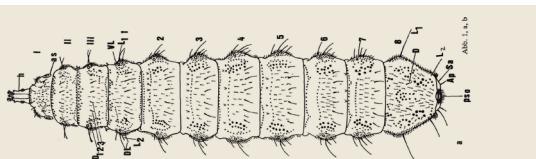


Figure 3: Drawing of a black soldier fly larva (Schremmer, 1986)

After having gone through five larval stages, the larvae reach the final larval stage: the prepupa. When transforming into a prepupa, 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.

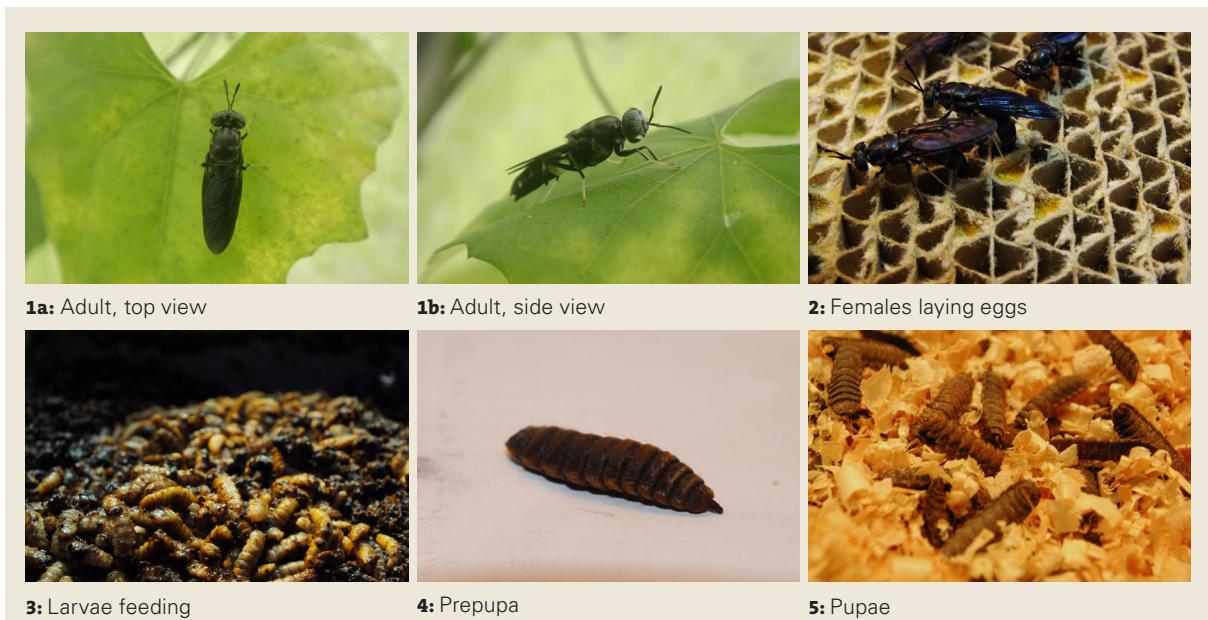


Figure 4: Life stages of the black soldier fly, *Hermetia illucens*, Photos: Nandayure Studt Solano (1a, 1b), Samuel Blyth (2, 3, 4), Sandec (5)

The process of pupation is the transformation from a pupa into a fly. The pupation stage is initiated when the prepupa finds a suitable location and becomes immobile and stiff. For a successful pupation, it is best if the environmental conditions do not change too much or, in other words, that they remain warm, dry and shaded. Pupation takes around two to three weeks and ends when the fly emerges from its pupa shell. The emerging process is a very short procedure. It 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 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. After copulation, the females then search for an ideal location to lay their eggs as explained above.

Optimal environmental conditions and food sources for the larvae can be summarized as:

- **Warm climate:** the ideal temperature is between 24 and 30°C. If too hot, the larvae will crawl away from the food in search of a cooler location. If too cold, the larvae will slow down their metabolism, eat less and develop slower.
- **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.

- **Water content of the food:** the food source has to be quite moist with a water content between 60% and 90% so that the larvae can ingest the substance.
- **Nutrient requirements of the food:** substrates rich in protein and easily available carbohydrates result in good larval growth. Ongoing research indicates that waste may be more easily consumed by the larvae 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.

2.2 Overall siting consideration for a BSF processing facility

The natural life-cycle explained above is the fundament for an efficient and reliable waste treatment facility using BSF larvae. However, to treat biowaste on a regular basis, the operator has to take control over the entire life cycle and, thus, create and operate an engineered biosystem. To provide an environment that best mimics the natural habitat of the BSF, while at the same time ensuring a continuous waste treatment, the following points should be taken into consideration when selecting an appropriate site for a BSF processing facility:

- Availability of sufficient fresh waste at low cost, in predictable amounts and on a regular basis.
- Routes for delivery of garbage and pickup of residue should be well maintained and easily accessible throughout the year
- Densely populated neighbourhoods and areas where adjacent land users may find a waste processing facility inappropriate should be avoided.
- Water and electricity supply and wastewater management options should be available.
- Adequate environmental buffers that separate the facility from the surroundings should be maintained (e.g. open areas, trees, fences, etc.)
- Facility should be downwind from the residential areas.
- As a rule of thumb, one can calculate with 50m² for the nursery and 100m² per ton of incoming waste per day (Figure 5)
- Closed and ventilated room for the rearing, but sunlight for the love cages
- Sheltered area without direct sunlight for the treatment containers
- Office and lab space
- Toilet and hygiene facilities

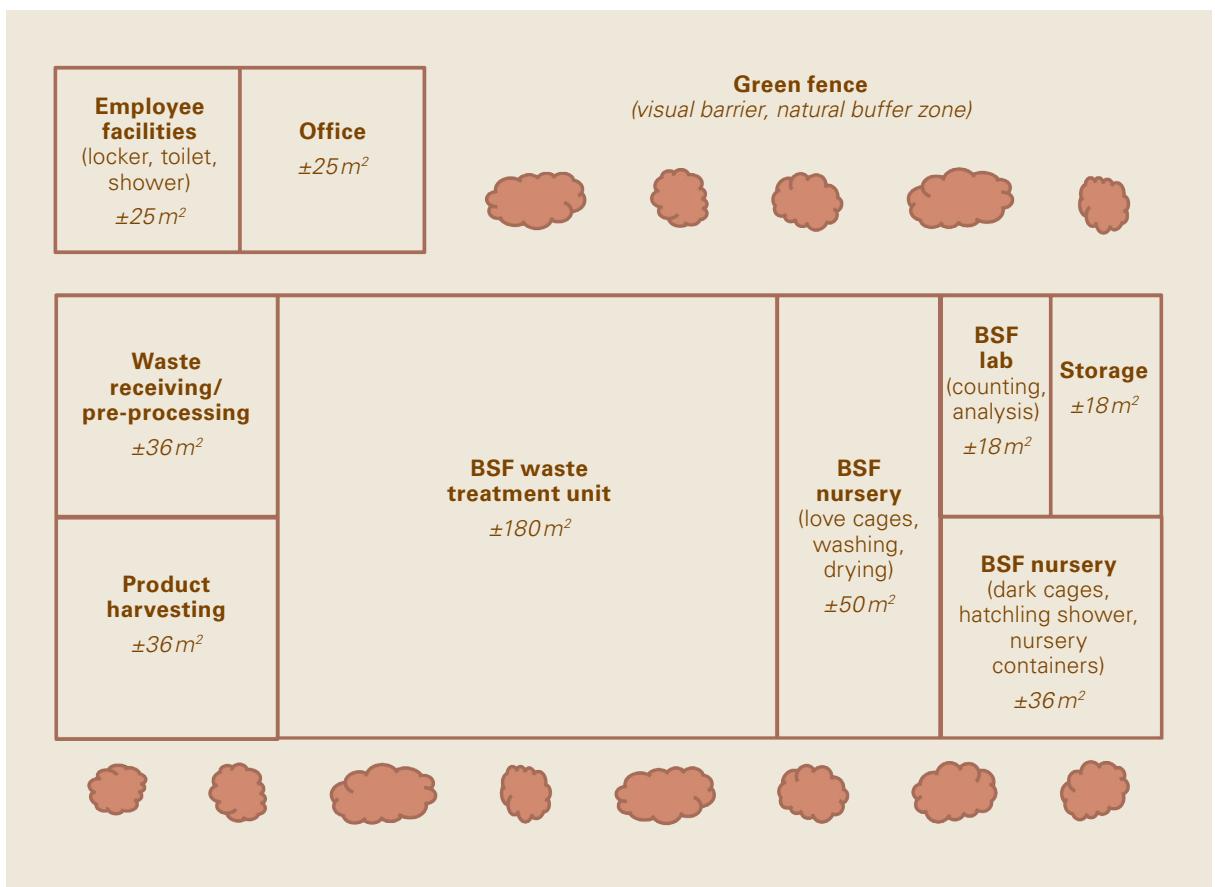
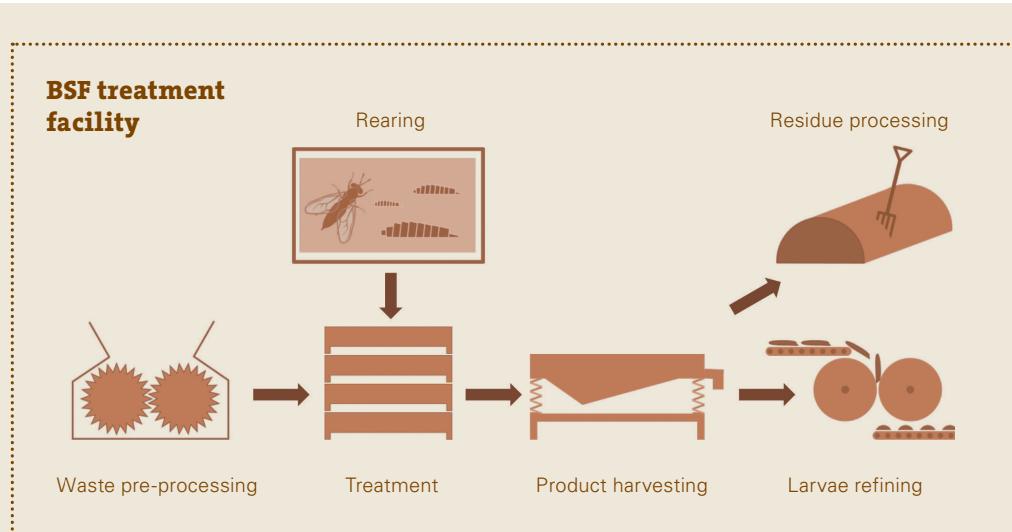


Figure 5: Possible layout of a BSF treatment facility for the treatment of two tons of biowaste per day

2.3 Engineering the BSF life cycle

In an engineered BSF processing facility, we can differentiate distinct processing units as shown in Figure 6.



BSF rearing unit

This ensures that a reliable and consistent amount of small larvae (called 5-DOL) is always available to inoculate the daily amount of biowaste that is received for processing at the treatment facility. A certain number of larvae hatchlings are, however, kept in the rearing unit to ensure a stable breeding population.

Waste receiving and pre-processing unit

It is critical that the waste received at the facility is suitable for feeding to the larvae. A first step involves a control of the waste to ensure it contains no hazardous materials and no inorganic substances. Further steps then involve a reduction of the waste particle size, a dewatering of the waste if it has too high moisture and/or a blending of different organic waste types to create a suitable balanced diet and moisture (70-80%) for the larvae.

BSF waste treatment unit

This is where the 5-DOL from the rearing unit are fed with biowaste in containers called "larveros". Here, the young larvae feed on the biowaste, grow into large larvae and, thus, process and reduce the waste.

Product harvesting unit

Shortly before turning into prepupae, the larvae are harvested from the larveros. The waste residue itself is also a product of value.

Post-treatment unit

Both products, larvae and residue, can be further processed if required by the local market demand. We call this "product refining". Typically, a first step will be to kill the larvae. Other steps of larvae refinement can be to freeze or dry the larvae, or to separate larvae oil from larvae protein. A typical step for residue refinement is composting or feeding the residue into a biogas digester for fuel production.

Figure 6: Units of a BSF treatment facility

2.3.1 BSF rearing unit

To ensure the treatment of a defined amount of waste on a regular basis, the rearing unit needs to provide a defined number of five day old larvae, so-called 5-DOL, every day. It is, therefore, important to control the single production steps during rearing and to monitor the performance of each step. In a well-engineered BSF nursery, it is possible and easy to control the number of prepupae that are allowed to pupate. This helps estimate the number of flies that shall emerge, which in turn provides an indication of how many egg packages will be deposited, how many larvae will hatch and how many of these larvae are available for biowaste treatment. Monitoring of the survival rates at every step in this cycle keeps track of the colony's overall performance and indicates problems at any particular step. Survival rates may differ from one nursery to another. Data provided here are based on a rearing unit in Indonesia (Figure 7) and serve as an example.

Egg deposition and egg harvest

From a management perspective, it is important that all egg packages are concentrated in one specific location. This will significantly facilitate harvesting of the eggs.

For this, we supply the cages with a suitable medium (called "eggies") that satisfies the flies' requirements regarding a safe location (i.e. sheltered cavities) for egg deposition, as well as an "attractant" which mimics decomposing organic matter that attracts the female to lay eggs close by. Once the egg packages are deposited into the eggies, they are harvested before any larvae hatch.

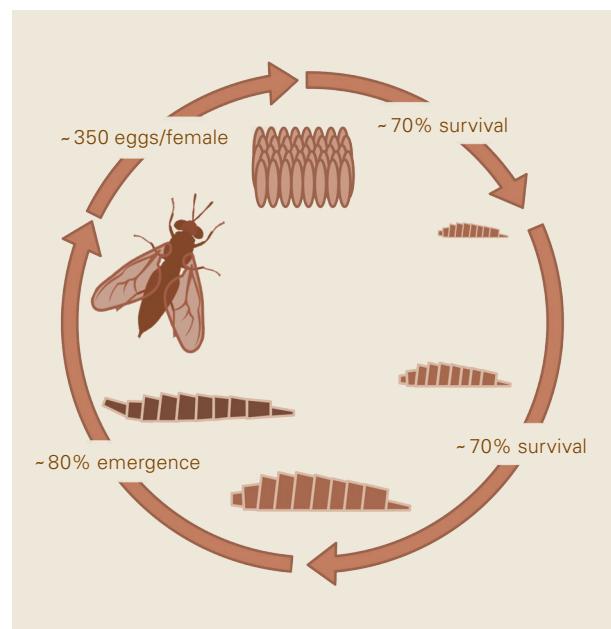


Figure 7: Performance indicators of a BSF rearing facility in Indonesia

Eggies may come in different shapes and materials (Figure 8). Since every move or touch of the egg packages or eggs decreases the survival rate of the eggs, it is important to limit handling the eggs to an absolute minimum. One aspect to minimize egg handling is to weigh the total egg mass together with the weight of the eggie.



Figure 8: Different variants of eggies: "Bioballs", usually used as filter media in aquariums and ponds (left), stack of wooden sheets with small gap in between (middle), and cardboard honeycomb (right)

Ideally, the empty eggie should be as light as possible to minimize error. Furthermore, the empty eggies should, if possible, be the same weight so that measuring the full eggie weight allows for easy calculation of the respective egg weight. Some eggie materials (wood and cardboard) may absorb ambient moisture, changing the weight of the eggie over time. Choosing plastic as a material prevents such error. Also, choosing a reusable eggie, which can be cleaned in a quick and easy way, or else a disposable one-use eggie is advisable.



Egg harvest is measured by the difference in weight between empty and full eggies. A standar-dized type (and weight) of the empty eggie is, therefore, advisable. The number of eggs is the total egg mass divided by the average weight of an individual egg, which is 25µg

Egg hatching and larvae feeding

The harvested eggies are placed together with eggies harvested on previous days over an open “hatching container” with a high quality food source. We call this the “hatching shower” (Figure 9). The larvae will hatch over a period of several days. Placing recently harvested eggies together with the older eggies guarantees a constant “shower” of hatchlings into the nursery container. After hatching, larvae fall from the eggies into the hatching container below where they will start feeding immediately. The high quality food source in the hatching container consists of chicken feed for starter chicks, mixed with water. This mixture has a water content of around 70%.



Figure 9: Hatchling shower: harvested eggies are placed above a feed source for the newly hatched larvae. Each cord colour represents a different day of the week when eggies were harvested

Waste management with BSF larvae is easiest with uniform larvae (same age and size). This allows for better planning of the waste input, conversion rate and harvesting time. By using the hatching shower, the number and age of young larvae in one hatching container can be controlled and determined. The frequency of replacing the hatching container determines the uniformity of the batch of larvae. The higher the frequency of replacement, the higher the uniformity of the young larvae. Larvae remain feeding in the same hatching container for five days after hatching. The 5-DOL are then harvested from the hatching containers, counted and a main share is then transferred to the BSF treatment unit where these 5-DOL are added to the waste.



The hatching container below the hatching shower is replaced with a new hatching container at regular intervals (every one to three days). The frequency determines the uniformity of the batch of larvae.

As counting all these small larvae is too much work, the number of 5-DOL is estimated by counting the number of larvae in a small sample (~2g), which then is extrapolated based on the total weight of all 5-DOL.

A small fraction of the 5-DOL (2-5%) is kept in the rearing unit depending on the amount of waste to be processed and the performance of the nursery. High survival rates and many eggs per female will require that less 5-DOL are kept in the rearing unit. These retained larvae are placed into a nursery container where they are continuously fed with a well-defined feed mixture until they transform into prepupae within about two weeks. All larvae in one nursery container will transform around the same time as they are of the same age. The prepupae will try to leave the food source in search for a more suitable dry location to pupate. To support this, the nursery container is placed into a transfer container with a dry, water absorbing material (Figure 10).

Pupation

Prepupae that have crawled into the transfer container are harvested and transferred into a pupation container. As prepupae are disturbed by big masses of other prepupae, the containers contain a moist soil-like substrate (compost) into which the prepupae can bury.

To facilitate the pupation process, the pupation containers are placed inside a pupation cage, which is completely dark inside (Figure 11). We call these “dark cages”. 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.).



Figure 10: Nursery containers standing in transfer containers



Figure 11: Dark cage with pupation containers stacked within



Figure 12: A love cage is being filled with freshly emerged adults



After two to three weeks, the pupation material has 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. Due to the darkness inside the cage, the emerged flies will not mate, but will remain motionless. The flies in the dark cage, thus, are a constant source of fresh adult flies which, as soon as released into the light, will start to reproduce.

Emergence of the adults starts ten days after they were put into the pupation box, then follows a bell-shaped curve and ends with a few latecomers after 25 days (Figure 13).

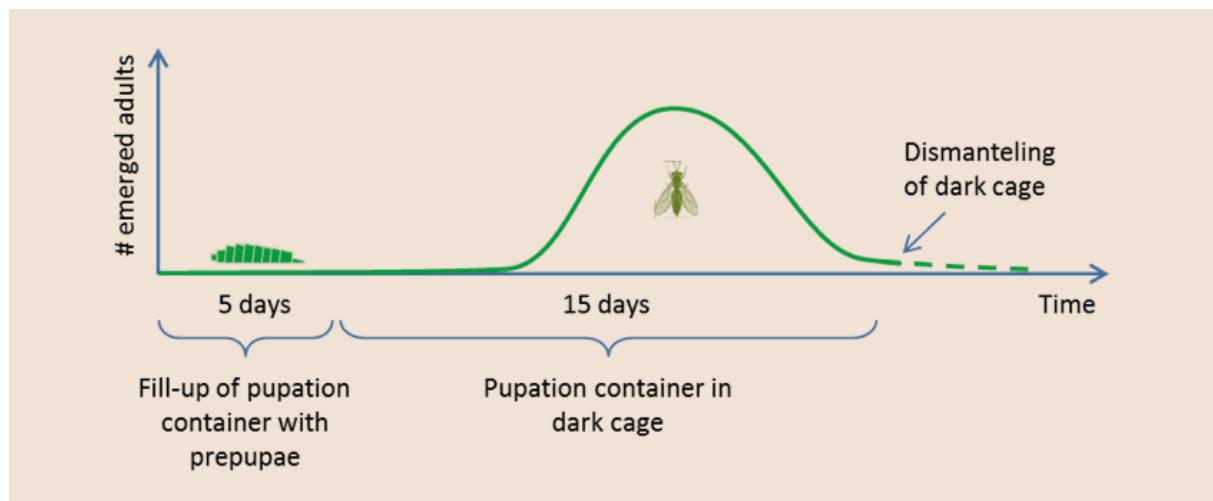


Figure 13: Dynamics of pupation and emergence of black soldier flies

Mating

Whenever required, emerged flies 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 in a mobile frame. Because this is the place where mating will take place, we call it the "love cage" (Figure 12). Light set at the end of the tunnel will attract the flies to fly from the dark cage into the love cage. A love cage is consecutively connected to three to four dark cages to collect the most recently emerged flies (Figure 14). This method allows for a constant and stable density of flies within the love cages. Moreover, the flies harvested are all of a very similar age. Same-aged-flies in the love cage has an important benefit: the flies will copulate and lay eggs around the same time and are, thus, predictable, and allow for a more efficient nursery operation. The love cages are equipped with a wet cloth to allow the flies to hydrate and with eggies and a box with a smelly attractant. The rearing cycle has, thus, been closed.

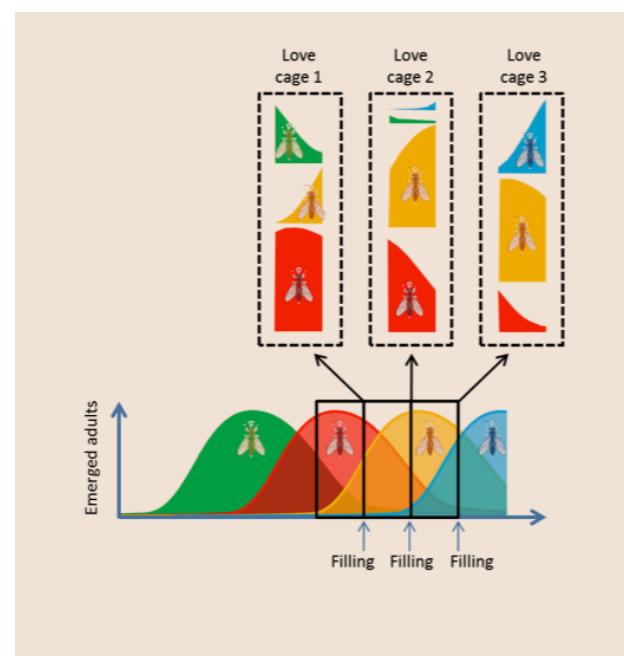


Figure 14: Composition of three love cages filled at intervals of two days from multiple dark cages

2.3.2 Waste receiving and pre-processing unit

Larvae are generally very tolerant when it comes to feeding substrates. Yet, it is important that the biowaste received at the facility is suitable as larva feed. With a water content between 60% to 90% and a specific particle size, most organic materials will be treated in one way or the other. A list of biowaste known to result in satisfactory growth and biomass conversion is shown in Table 1. The larvae strongly depend on symbiotic microorganisms which degrade cell structures and make nutrients available for the larvae to take up. With suboptimal feed, however, development time will be extended and the final larval weight will be lower. It is important to keep this in mind when looking at the BSF facility from an economic perspective.

Table 1: Different types of biowaste found suitable for BSF treatment

Municipal waste	Agro-industrial waste	Manure and faeces
<ul style="list-style-type: none">· Municipal organic waste· Food and restaurant waste· Market waste	<ul style="list-style-type: none">· Food processing waste· Spent grains· Slaughterhouse waste	<ul style="list-style-type: none">· Poultry manure· Pig manure· Human faeces· Faecal sludge

This guide assumes that “waste sourcing” for the facility has been arranged and secured. The biowaste should be purely organic and biodegradable, and meet the criteria of appropriate biowaste types as mentioned above.

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. A few plastic bags in the waste may not pose a significant problem and can be sorted out and removed manually. However, hazardous contaminants are critical to keep out as they may affect all the living organisms: the larvae, associated bacteria and, of course, the workers. Acids, solvents, pesticides, detergents and heavy metals fall into this category and it is especially critical to keep them out when they are in a liquid or dissolved form, as this can easily contaminate the whole batch of waste material. If such contamination is suspected, the waste should be refused.



Figure 15: Hammer mill for waste pre-processing

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 shredder or hammer mill (Figure 15). Whatever type of technology is used, the equipment should shred the waste to particles of smaller than 1-2 cm in diameter. This helps to speed-up BSF processing as BSF larvae do not have appropriate mouthparts to break apart large chunks of waste, and increasing the surface area fosters the growth of the associated bacteria.

If the shredded waste has a 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%.



There are different ways to dewater the waste. The simplest way is passive dewatering (by gravity), where the waste is filled into a cloth bag that acts as a filter and the water drains through the cloth into a bucket below. Other technologies to dewater might include a horizontal screw press or a cider press.

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 waste is 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.



At the moment the organic waste is accepted at the site, a measurement of weight should be performed to know the daily waste intake of the facility. The best time to measure the total incoming waste is after it has been shredded as then it will probably temporarily be stored in containers. If dewatering of waste is required, it is best to obtain a weight measurement before and after the dewatering process.

2.3.3 BSF treatment unit

A specific amount of 5-DOL are transferred daily from the BSF rearing unit to the BSF treatment units containing the waste (we call these "larveros"). The number of 5-DOL added will depend on the amount of biowaste that is contained in a specified volume and surface area.



Figure 16: Stack of larveros with ventilation frames in-between levels



As a rule of thumb we work with the following numbers: 10,000 5-DOL in a larvero (40x60x-17cm) feeding on 15 kg of wet waste (75% water) for 12 days

While the 5-DOL feed and grow, more waste is added to the same larvero on day five and again on day eight, until the larvae have developed large enough to be harvested after 12 days of feeding, i.e. on the 13th day. For the BSF treatment unit, we suggest the following operational parameters:

- 40,000 5-DOL per 1m² treatment area, which are fed 60kg of biowaste over a period of 12 days. As the larvae feed on the waste, they will break down the organic matter and metabolize the nutrients into larval biomass. If too much waste is used, an unprocessed waste layer can build up heat through bacterial activity and, thus, make the environment unfavourable for the larvae. The untouched feed will also attract other filth flies. Providing not enough waste will starve the larvae and, thus, reduce their development speed and the waste treatment capacity of the facility.
- Experience has shown that for each larvero, three feedings of equal amount over the development period of 12 days is suitable: on day one, day five and day eight.
- The amount of waste is also limited by the layer thickness of waste in the larvero. If the depth of the waste in the larvero is more than 5cm, larvae will have difficulties to process it entirely and the waste on the bottom will remain unprocessed.
- Larveros can be stacked upon each other to optimize surface area requirements. However, it is necessary that the larveros are well ventilated to allow the moisture-saturated air to be replaced. Also, provision of oxygen is crucial for the well-being of the larvae. For these purposes, we suggest to keep enough open space between the stacked larveros (Figure 16) to allow for free flowing aeration.
- It is further recommended to ventilate the stacks with fans during the last few days. This creates an active air flow over the surface of the larveros to increase evaporation. A crumbly waste residue will be the result, which can be easily sieved from the larvae. However, the intensity of active ventilation depends on the air humidity and the moisture content of the starting material and has, therefore, to be assessed individually in each context.



BSF research started in the mid-20th century in chicken barns. It was observed that the presence of BSF larvae in the manure underneath the chicken cages reduced housefly breeding and manure accumulation. Researchers, thus, started to put this new insight into practice by planning BSF friendly manure pits (ramps for prepupa self-harvesting, access for cleaning machinery and attached greenhouses for adults). Most of the attempts of taking BSF treatment to a professional level have been established around a continuously fed system based on prepupa self-harvesting.

Historically, continuously fed systems have been recommended for BSF treatment systems. A continuously fed system has certain advantages, especially when operating a backyard system at the household or neighbourhood level. All the organic waste accumulating in the household is fed to the system, which needs to be emptied from time to time. It relies on natural infestation by BSF and usually, the prepupae will crawl out on their own either into a collection container or into the environment where they would be picked up by roaming chickens or to a safe place where they have the chance to pupate. Upscaling a continuously fed system to operate a large waste management business, however, comes with definite down sides. For instance, system failure due to diseases, mycotoxins or environmental influences is a risk and is fatal to the whole treatment unit, which then has to be emptied, cleaned and restarted. Also, protein yield depends on self-harvesting. Admittedly, the prepupae crawling out on their own have the advantage of

being already separated from the residue. However, a great share of the prepupae always remain in the material, leading to unwanted fly populations and loss of harvest.

For waste management, we thus recommend to divide the risk in case of failure by using individual treatment containers, the larveros. We also take control over the life cycle by determining the number and age of the larvae, the amount of waste used and the duration of the treatment process.

2.3.4 Product Harvesting

After 12 days of waste treatment by BSF larvae, each larvero 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. Harvesting is the process in which the larvae are separated from the residue. This can be done by using a manual or automated shaking sieve by which the larvae are easily separated from the residue. With a higher shaking frequency, the mesh size of the sieve can be bigger. This is because the larvae have difficulties to position themselves and cannot crawl through the mesh when there is a high shaking frequency. Automated shaking sieves can achieve higher shaking frequencies than manual sieves and are, therefore, favoured (Figure 17).



Figure 17: Shaking sieve (left) and manual sieve (right) to separate larvae from dry residue

A sieve mesh size of around 3 mm for manual sieving and 5 mm for automated sieving is considered suitable. The sieve is placed at an angle and the content of the larvero is emptied onto the sieve. During the shaking, the larvae remain on the top of the sieve while the residue falls through the sieve into recipients. Given the angle of the sieve, the larvae are guided to the lower angle, which is connected to a bucket where the larvae drop into.



Figure 18: Harvesting of larvae from wet residue

Under certain circumstances, when the initial water content of the waste was higher than ideal (>80%), the larvero at the time of harvesting will contain larvae and a liquid slurry of processed waste with some undigested chunks (instead of a crumbly waste residue). In such a case, another harvesting method with non-shaking flat screens of 5 mm mesh size is recommended. A container is placed below the non-shaking flat screen. The content of the larvero is then spread out onto the flat screen. The liquid will flow through it as will the larvae because they want to avoid the sunlight, eventually falling into the container below. Larger residue chunks will remain on top of the screen and can be removed. In the container below the flat screen, the mostly floating larvae can be removed with a large strainer spoon, rinsed and then transferred into a drying container with coco peat or some other dry material (e.g. sawdust). The larvae remain in the drying container for around one day. Crawling around in this material helps to clean their skin and gives them time to empty their gut which adds to the quality of the end-product.



Each larvero is weighed when harvested. After separation of the larvae, they are weighed again to monitor the treatment performance (larval yield and waste reduction).

2.3.5 Post-treatment of the larvae and residue

After harvesting, larvae may be sold alive to customers (e.g. reptile farms or bird markets).

Another approach is to use them in the production of feed pellets. Freshly harvested larvae can be mixed with other ingredients (e.g. soy meal, sorghum, corn, etc.) to make a blend that meets the nutritive requirements of the targeted animal (broiler chickens, layer hens, different fish species, etc.). This mixture can be fed directly into a pelletizer which compresses it into feed pellets (Figure 19).

In most cases, larvae will need some form of post-processing to ensure that they can be sanitised, stored and transported easily to the respective customers.

Sanitising involves killing off any bacteria which might adhere to the larvae skin and ensures that the larvae empty their guts (which contain only partly digested residue). We recommend using boiling water for this. Dipping the larvae into a large pan of boiling water for about two minutes kills them instantly and also sanitises the product.



Figure 19: Pelletizer for animal feed

Other processing steps may require different measures and equipment depending on the market demand and customer groups. Freezing allows for easy storage, but is energy intensive. Drying (sun dried or in an oven) decreases the water content and also improves the storage potential (a moisture content below 10% should be achieved). As the larvae contain 30% oil, lengthy periods of storage of dead larvae might turn the oil rancid. To avoid this, the dried larvae can be defatted using an oil press or centrifuge. This process separates the larva oil from the larva protein, which can then be dried and stored more easily. The larva protein should have less than 10% oil content to ensure storage without spoiling. Defatted larva meal has a protein and fat content of $\pm 60\%$ protein and $\pm 10\%$ fat, respectively, and can, thus, be a substitute for fishmeal in animal feed. Formulation of the entire feed, however, has to take into account the amino acid requirements of the farmed species.

Post-processing of the crumbly residue is required to produce stable, mature compost. Different measures can be envisaged to do this. Composting the residue for a period of two months is the simplest approach. This will result in a stable mature material that can be marketed in the same way as compost. Another option is to feed the residue into a vermicomposting facility to grow (and market) worms, as well as to obtain a stable and mature vermicompost. Finally, the third option proposed here, which is suitable when the residue is high in moisture and slurry-like, is to feed it into an anaerobic digester (biogas reactor).

Chapter 3:

Activites in a BSF Processing Facility

This chapter explains the practical daily tasks of operating a BSF processing facility. There are separate sections according to the activities required in **each unit of the facility** (as shown in Figure 6). For each unit of the facility, subchapters explain the various **steps** required. Included is also the **equipment** needed to perform the work, the individual work **tasks, protective measures** for workers, and points of **monitoring** and data collection.

The day-to-day operation is summarized in the **handling schedules** and **log sheets** provided in Chapter 4.

3.1 Activities in the BSF rearing unit

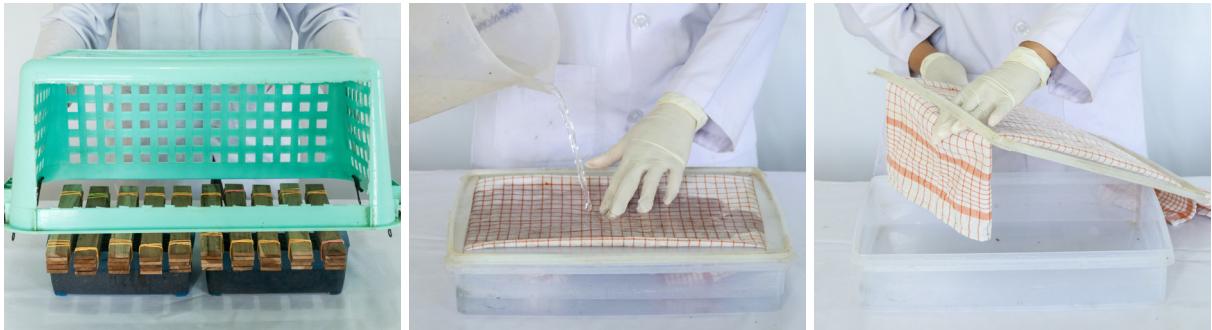
Step R1 - Setting-up the love cage to collect flies, let them mate and lay eggs

A love cage is filled with freshly emerged flies from the dark cages. In the love cage, the flies are provided water to drink and a place to lay their eggs.

Equipment needed:



- 1.** One **love cage** made of sturdy mosquito netting with loops at each corners, a long zipper opening and a central round tunnel opening (see Blue print 1). This is suitable for 6,000-10,000 flies
- 2.** One **hanger** per love cage
- 3.** Two **attractant containers** per love cage



4. One **shading basket** (slightly larger basket than attractant container) with four small pedestals. **5.** One **water bowl** with lid per love cage. Make two incision slits into the lid at both sides. The slits should be long and wide enough for a cotton cloth to pass through. **6.** One **cotton cloth** (towel) per love cage



7. Ten **egg media** units (eggies) per love cage. **8.** One **mobile frame** (with attached electrical light) (see Blue print 2). One can be used to serve several love cages **9.** A **stick** (approx. 2m) with a hook at the end



10. Four **ant traps** per love cage table. The containers should always contain water. The love cage table legs are placed into these containers. **11.** One **love cage table** with a frame which is large enough for three love cages. The frame should be as high as the love cage so that the bottom of the cage rests on the table (see Blue print 3). **12.** Eight **binder clips** to attach the dark cage's transfer tunnel to the love cage and to form the pedestals of the shading basket.



Attaching cage to hanger (R1-1)



Using the long stick to hang love cage into mobile frame (R1-3)

Tasks:

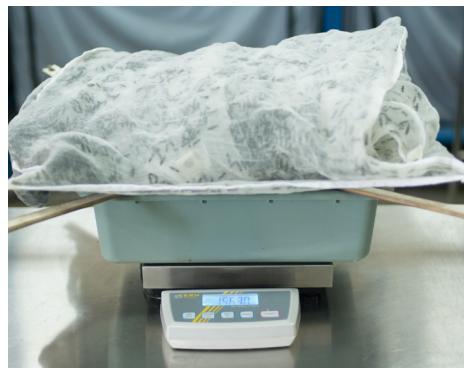
- R1-1:** Hang a clean love cage onto its hanger using the loops.
- R1-2:** Measure weight of the love cage with hanger.
- R1-3:** Attach the hanger onto the mobile frame using the long stick and fasten it at the bottom.
- R1-4:** Move the mobile frame with the attached love cage to the first dark cage and connect the two tunnels of the cages, using four binder clips. Turn on the light which is attached to the mobile frame as soon as the love cage is connected to the dark cage. Gently shake the cage to rouse the flies.
- R1-5:** After 30 minutes, disconnect and close the tunnel, measure weight of love cage and hanger and move the same love cage to the next dark cage. Repeat the same process of connecting, disconnecting and weighing after 30 minutes. Repeat this for all dark cages with emerged flies.
- R1-6:** Disconnect the love cage from the last dark cage and turn off the light. Close the tunnels with a rope.
- R1-7:** Now, the love cage contains all the freshly emerged flies from the dark cages. Measure the weight of the love cage with hanger again. The difference to the empty love cage measured at the beginning will correspond to the mass (grams) of flies in the love cage. If you collect 20 flies and measure their total weight and divide by 20, you will have an average weight of one fly. You can use the mass of flies and divide by the average weight of one fly to obtain the number of flies in the love cage.



Attaching dark cage to love cage from inside (R1-4)



Light lures flies from dark cage into love cage (R1-4)



Weighing of love cage after filling (R1-5)

R1-8: Move the love cage with its hanger to the love cage table using the long stick with a hook and hang it into the love cage table.

R1-9: Prepare attractant container: fill an empty attractant container with 100 grams of dead flies from an old love cage, 200 grams of residue from the nursery containers, 200 grams of residue from the old attractant container and one litre of fermenting fruit water (if no fermenting fruit water is available, use regular water). Mix thoroughly.

R1-10: Prepare 10 clean eggies: Take clean wooden sheets and separate them between the sheets with pushpins and sheets without pushpins (see also Step 5). The pushpins will create a small gap (1-2mm) between the wooden sheets. Build up the egg media alternating between a sheet with and without pushpins. The sheets are held together by two rubber bands on both ends of the bundle. Prepare 10 of these bundles (eggies) for each love cage.



Ingredients of the attractant container (R1-9)



Wooden sheets with pushpins to create a gap, allowing space for egg packages. The eggies are held together with two rubber bands (R1-10)

R1-11: Prepare water bowl: Fill a clean container with tap water until it is almost full. Take the lid and a clean cotton cloth and push the cloth on both side through the incision slits made into the lid. The towel should lie flat on top of the lid, while its ends pass through the incision slits and are immersed in the water in the container below the lid. Sprinkle the towel with water.



Eggs over attractant, covered with the shade box and the water bowl on top (R1-12)

The whole eggie-set-up in the filled love cage (R1-13)

R1-12: Open the love cage with the zipper. Pay attention to avoid flies escaping from the love cage. Place the attractant containers into the love cage and then place the 10 clean eggies over the attractant container. Cover the attractant container and the eggies with the shading basket placed upside down onto four small pedestals (e.g. binder clips which keep the shading basket away from the surface to avoid egg laying underneath). Finally, place the water bowl with towel onto the shading basket and close the love cage.

R1-13: After closing the love cage, add a sticker on the table next to the cage labelling the date of placement.



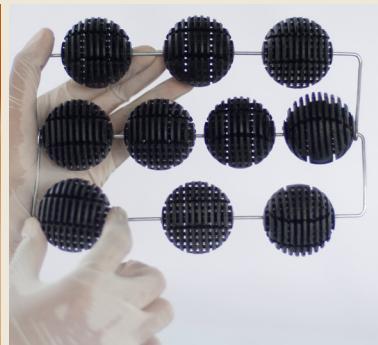
Love cage on the love cage table (**R1-12**)



Newly set-up love cage (**R1-12**)



The wooden eggies presented in this book have proven to result in good quantities of eggs in practice. However, as mentioned above, there are drawbacks associated with them (mixed weight and uptake of moisture). Another possibility is the use of so-called Bioballs or, in our case, "Oviballs", which are fabricated for biofilters of aquariums and fish ponds. They offer a large, lamellar surface for egg laying, can be bought in large quantities and all have the same weight.



PROTECTIVE MEASURES FOR WORKERS:

- Pay attention to the light attached to the mobile frame and avoid burns.
- Use lab coat and latex gloves when handling attractant.



POINTS OF MONITORING AND DATA COLLECTION:

- Weighing the love cage after every connection to a dark cage (R1-5) allows for the monitoring of the emergence rate from dark cages and yields the total number of flies in a love cage. A reference sample of 20 flies is taken from the filled cage with a cylindrical container. The flies in the cylindrical container are brought to the laboratory where the container is quickly turned upside down on a smaller cylindrical container with cork chips sprinkled with 10-15 drops of ethyl acetate. This is left for 30 seconds to paralyze the flies, so that they can then be easily weighed with a precision balance.
- Measure the weight of each empty eggie with a precision balance and document this before putting it into the love cage.

Step R2 - Dismantle old love cage

Love cages are removed after six days of use. No more eggs will be laid after one week because most females die within one week.

Equipment needed:



1. Dustpan, brush and dustbin **2.** Scrubbing brush



3. Cleaning utensils **4.** Drying rack



5. Pressure washer **6.** Washing machine **7.** 95% alcohol solution

Tasks:

- R2-1:** Remove the last eggies (proceed with these under Step R5).
- R2-2:** Remove the water container and the shading basket. Clean both with the pressure washer, a scrubbing brush and some detergent and let dry.
- R2-3:** Remove the old attractant containers. Use 200 grams of old attractant residue for filling a new attractant container (see R1-9). Empty the remainder of the residue into the dustbin. Clean the attractant containers with detergent and let dry.
- R2-4:** Sweep the dead flies from the love cage you have dismantled. Keep 200 grams of dead flies for filling new attractant containers (see R1-9) and dispose of the others into the dustbin.
- R2-5:** Disconnect the love cage from the hangers, turn it inside out and shake it to remove the last (dead) flies from the love cage. Then, place the love cage into the washing machine, add detergent and wash it on a 30°C program. Remove the love cage from the washing machine and let it dry.
- R2-6:** Clean the love cage table where the old cage was attached. Spray the same space with a 95% alcohol solution, spread it out with a cloth and let the alcohol dry. Remove the date label of this love cage from the table.



PROTECTIVE MEASURES FOR WORKERS:

- Use lab coat and latex gloves for handling eggies, attractant, dead flies and detergent.



POINTS OF MONITORING AND DATA COLLECTION:

- Measure weight of the last eggies removed. See R5 for details.

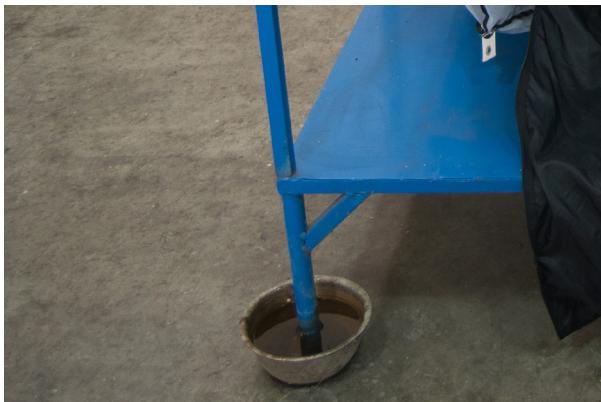
Step R3 - Set-up new dark cage

Pupation containers are placed into a dark cage where flies will emerge and eventually move to a love cage.

Equipment needed:



1. One **dark cage** (Blue print 4) is made of a double layer fabric: a dark soft fabric on the inside and a light blocking fabric (sturdy mosquito netting) on the outside, both fabrics let air pass through.
2. One **dark cage frame** (see Blue print 5) and pieces of rope to attach the dark cage to the frame.



3. 16 **pupation containers** of 60x40x12cm size for each dark cage
4. Four **ant traps** per dark cage frame. The containers should always contain water. The dark cage frame legs are placed into these containers.

Tasks:

- R3-1:** Hang a clean dark cage onto the dark cage frame using four ropes to tie it in the top corners to the frame. Open the zipper door in the front of the cage and close the round tunnel opening.
- R3-2:** Ensure that the bottom of the dark cage lies on the dark cage frame table which has its table legs placed in ant traps.
- R3-3:** Fill the new dark cage with 16 pupation containers as prepared following the step R8. Cross-stack the pupation containers. Make sure that enough open space remains between the containers so that the emerged flies can exit the containers.
- R3-4:** Label the dark cage on the frame with the date of its set-up.



PROTECTIVE MEASURES FOR WORKERS:

- Use lab coat and latex gloves for handling pupation containers



POINTS OF MONITORING AND DATA COLLECTION:

- None required.



Step R4 - Dismantle dark cage

A dark cage is dismantled after around two and a half weeks, after connecting it a last time to a love cage.

Equipment needed: Same as Step R2

Tasks:

- R4-1:** Remove the 16 pupation containers from the cage. Empty them into a dustbin. Use the pressure washer, a scrubbing brush and detergent to clean the 16 crates and store them to dry.
- R4-2:** If present, remove dead flies from the dark cage with a brush and dispose of them in a dustbin.
- R4-3:** Detach the dark cage from the frame and turn the dark cage inside out and wash with detergent in a washing machine using a 30°C program. Then, remove the love cage from the washing machine and let dry.
- R4-4:** Clean the dark cage frame. Spray the frame with a 95% alcohol solution, spread it out with a cloth and let the alcohol dry.
- R4-5:** Remove the date label from the frame.



PROTECTIVE MEASURES FOR WORKERS:

- Use lab coat and latex gloves for handling pupation containers, dirty dark cages and detergent.



POINTS OF MONITORING AND DATA COLLECTION:

- None required.

Step R5 - Egg handling

Eggies are placed onto the hatchling shower where newly hatched larvae fall into the hatchling container. The hatchling container is replaced regularly and the cohort of larvae feeds in the same container until it is used in the waste treatment.

Equipment needed:



1. Ten **egg media (eggies)** per love cage. Each eggie consists of five clean thin wooden sheets (25cm x 5cm x 0.3cm).
2. **Metal shelfe**, 6-Tier with shelve height of at least 15cm (a bit more than nursery container height) (see Blue print 6)



3. **Hatching shower** - a grate set above nursery container - and a set of strings in seven different colours to colour code by day
4. Three **hatching containers** (60x40x12cm), feed and coco peat

Tasks:

- R5-1:** Prepare new and clean eggies (± 10 units are required per love cage) according to equipment specification (see R1-10).
- R5-2:** From the hatching shower grate, remove all the eggies with the colour coded string of the current weekday. Eggies are marked with a string in a particular colour according to the day they were put onto the hatching shower (e.g. Monday = Yellow, Tuesday = Purple, Wednesday = Grey, etc.). Eggies with today's colour-code have been lying on the hatching shower for one week and all the eggs have already hatched. Clean the eggies (**No detergent!**) and let dry.
- R5-3:** Harvest the full eggies from the love cages and replace them with new empty eggies. Follow the instructions on the "Egg harvesting schedule" as shown in Appendix B to know which eggies in which love cages need to be replaced.

R5-4: Bring harvested eggies from all love cages together and make three even groups. Bind each group together with the colour coded rope assigned to the current day. Then, place the three groups of eggies on the grate over the three hatchling containers.

R5-5: Prepare 9 kg of fresh larvae feed: Produce a mixture of 30% dry chicken (broiler) feed and 70% water. Stir the mixture until it has become a homogeneous substance. Fill the three hatchling containers each with 3kg. Cover each hatchling container with dry and sieved coco peat (0.5-1.0 cm thickness) to avoid loss of moisture. Add labels to each hatchling container with the date code of the current day.

R5-6: Move all existing hatchling containers in the shelves down by one shelf. The lowest hatchling containers will have five day old larvae.

R5-7: In the now empty top-most shelfe, add the new hatchling containers.



Hatching shower with bundles of eggies (above) and hatching containers (below) (**R5-4**)



Hatching container is filled with 3kg of fresh larva feed (**R5-5**)



The nursery feed is covered with a thin layer of coco peat to avoid moisture loss (**R5-5**)



PROTECTIVE MEASURES FOR WORKERS:

- Use lab coat and latex gloves for handling eggies.



POINTS OF MONITORING AND DATA COLLECTION:

- Each **empty** eggie is weighed before inserting it into the love cage and its weight noted in the according monitoring sheet.
- each **full** eggie is weighed after removing it from the love cage. The net difference in weight is the weight of the egg packages.

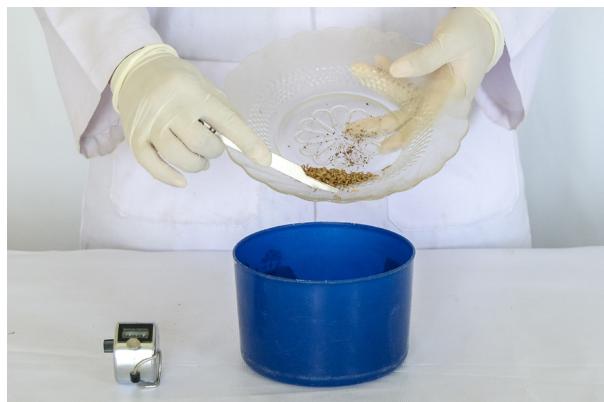
Step R6 - Handling of 5-DOL larvae

The 5-DOL are separated from the residue and their number determined.

Equipment needed:



1. Sieve (mesh size 1 mm) and **scoop** **2. Containers** for larvae and residue



3. Precision balance with plastic cup and measurement cup **4. Click counter**, plate and **soft tweezers**

Tasks:

R6-1: Remove the six days old hatching containers from the shelves. Use a manual sieve (mesh size 1mm) to sieve all the material in the hatching containers. The small residual particles together with the small larvae will fall through the sieve into a container, while larger residue particles and larvae stay on the sieve. The larger residue and larvae that stay on the sieve are placed in a plastic box. From this box, the larger residual particles are scooped off with a spoon as much as possible and stored elsewhere until lumps of 5-DOL are clearly visible (while some residue will still also remain). Tapping on the wall of the plastic box will help to separate larvae from residue as the vibrations make the larvae aggregate.



Scooping off residue from the 5-DOL to create a pure fraction (**R6-1**)

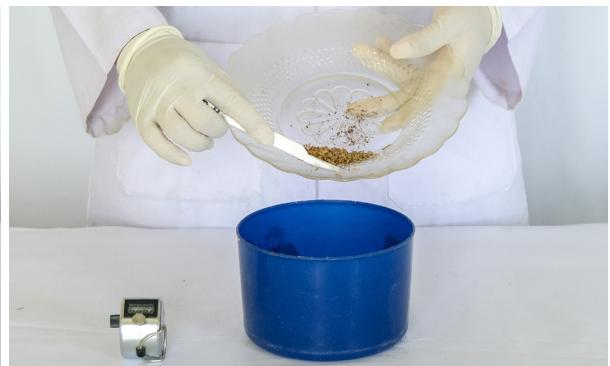
R6-2: Clean the hatching containers with the pressure washer, a scrubbing brush and detergent and let dry.

R6-3: Take a random scoop from the purified 5-DOL mixture and measure two grams each of the mixture into two cups.

R6-4: Place these two grams of 5-DOL mixture from the cup onto a plate. On the plate, manually count all the 5-DOL using tweezers and a click counter, by pushing them into a bowl. Repeat the process for the second cup as well. Document the result as number of 5-DOL per two grams.



After mixing to homogenize the purified section of 5-DOL, a random scoop is taken (**R6-3**)



The 5-DOL contained in the 2 gram samples (including the unavoidable remaining residue) are counted (**R6-4**)

R6-5: Weigh the total mass of all 5-DOL available in the box. Using the results of the count per two grams, calculate the total number of larvae in that box. See calculation below.

R6-6: Based on the number of larveros to be started (which depends on the waste amount), prepare cups and fill each cup with the weight of 5-DOL mixture from the box, as needed for each larvero. See calculation below.

R6-7: The remaining 5-DOL will then be used for rearing flies or discarded (see step 7).



Portioning of 5-DOL for the treatment larveros (**R6-6**)



PROTECTIVE MEASURES FOR WORKERS:

- Use lab coat and latex gloves for handling 5-DOL and residue.



POINTS OF MONITORING AND DATA COLLECTION:

Calculating the number of larvae in the box:

- Total number of larvae in box: L_{total} (number)
- Total mass of larvae in box: M_{total} (gram)
- Number of larvae in sample: L_{sample} (number)
- Mass of sample: M_{sample} (gram)

$$L_{total} = M_{total} * L_{sample} / M_{sample}$$

Calculating the mass of larvae needed for each larvero:

- Mass of larvae needed per larvero: $M_{larvero}$ (gram)
- Number of larvae required per larvero: $L_{larvero}$ (number)
(we calculate with 600-800 larvae per kg of wet waste fed during the whole treatment period)
- Total mass of larvae in box: M_{total} (gram)
- Total number of larvae in box: L_{total} (number)

$$M_{larvero} = L_{larvero} * M_{total} / L_{total}$$

Step R7 - Handling nursery containers

The nursery containers provide the prepupae, which go into the pupation containers to maintain the necessary adult population. The required number of 5-DOL are fed for approximately two and a half weeks until they turn into prepupae.

Equipment needed:



- 1. Chicken feed** according to Appendix C and **nursery container** (55x35x16cm)
- 2. Transfer container** (60x40x12cm) and coco peat
- 3. Nursery rack** to hold the transfer and nursery containers (see Blue print 7)

Tasks:

- R7-1:** Prepare 2 kg of food made up of 30% dry chicken feed and 70% water. Stir it until it is a homogeneous mixture.
- R7-2:** Add this food to a nursery container, cover it with coco peat (layer of 0.5-1.0 cm) and then add the required number of 5-DOL (see R6-7) on top of the coco peat (see Appendix A).
- R7-3:** Add coco peat into the corners and along the edges of a transfer container and place the nursery container into it. Since prepupae will eventually crawl out of the nursery container and fall into the transfer container, the nursery container needs to be slightly smaller than the transfer container. Put the two on the nursery shelf.



Put coco peat in the corners of the transfer box to hinder the prepupae from escaping (**R7-3**)



Place the nursery container with the 5-DOL into the transfer container (**R7-3**)

- R7-4:** Place a sticker with the date code and the amount of larvae that have been added on the nursery container.
- R7-5:** During the two and a half weeks of operation, the newly set-up nursery containers receive a mixture of chicken feed and water in different concentrations. This mixture is fed on specific days within the time period according to feeding schedules (see Appendix C).
- R7-6:** After two and a half weeks (see Appendix C), the nursery container is removed and the remaining prepupae in the transfer container harvested (see also Step 8)



PROTECTIVE MEASURES FOR WORKERS:

- Use lab coat and latex gloves for handling 5-DOL and residue.



POINTS OF MONITORING AND DATA COLLECTION:

- None.

Step R8 - Prepupae handling

The prepupae, which crawled out from the nursery containers, are placed into the pupation containers which later are put into the dark cage.

Equipment needed:



1. Cement mixer **2. Compost** or other soil-like material (left) and **pupation container** 60x40x12cm (right) **3. Precision balance** and counting containers



4. Prepupae-coco peat-mix from transfer containers and **sieve** (mesh size 3mm) **5. Click counter**, plate and soft tweezers

Tasks:

- R8-1:** Prepare pupation material: 50 kg of pupation material is made of mature compost ($\frac{3}{4}$) and water ($\frac{1}{4}$). Mix it thoroughly with a concrete mixer until no dry material is visible and the mixture is homogeneous.
- R8-2:** Take 16 clean pupation containers and fill them each with 3 kg of the prepared pupation material. Spread the mixture equally over each crate.

R8-3: Visually identify the transfer containers that have prepupae in them and are around two weeks old. Harvest the prepupae together with the coco peat from the transfer container and separate the prepupae from the coco peat with a sieve. The empty transfer container is then filled again with coco peat and the nursery container is placed again in it. This same process is repeated for each transfer container assigned to be harvested that day. Note the weight of the harvested prepupae for each individual container for monitoring purposes.



The prepupae are separated from the coco peat by sieving it with a 3mm sieve (**R8-3**)



Counting of 200 prepupae to assess the average weight for portioning them to the pupation containers (**R8-4**)

- R8-4:** After the prepupae are harvested from all relevant transfer containers, they are then weighed on the bulk balance. From these pooled prepupae, two samples of 200 prepupae are weighed and its average noted.
- R8-5:** Prepare 16 batches of 500 prepupae (for schedule 1), 400 prepupae (for schedule 2) or 800 prepupae (for schedule 3, see Appendix A).
- R8-6:** Transfer the 16 batches of prepupae into each of the 16 pupation boxes. The same pupation boxes are filled with the same number of prepupae over several days, according to the respective schedule (see Appendix A).



PROTECTIVE MEASURES FOR WORKERS:

- Use lab coat and latex gloves for handling larvae, prepupae, coco-peat and compost.



POINTS OF MONITORING AND DATA COLLECTION:

- The weight of prepupae harvest from each transfer container is measured.
- The weight of 200 prepupae is measured. This is repeated twice to obtain an average value.



3.2 Activities in the waste receiving and pre-processing unit

Upon arrival, the waste first undergoes a quality check. Accepting waste with hazardous contaminants must be avoided as this may affect the health of the larvae or compromise the end quality of the larvae and the residue. Liquid pollutants are especially critical to avoid as they may have soaked and contaminated the waste, and this can be difficult to detect. It is crucial that the waste collectors are aware of this potential hazard. With each delivery of waste, the collectors can be asked about the source of the waste batch and the potential risk of contamination. If there is strong reason to suspect hazardous contamination, the waste should be refused and not processed.

After an oral exchange with the collectors and after passing a first visual waste quality check, the activities of waste reception and pre-processing involve: (i) rough sorting, (ii) waste particle size reduction (iii) weighing, and if required (iv) a dewatering step.

Step W1 - Waste receiving and shredding

The goal of the shredding is to reduce particle size and homogenise the input material. The feed can then easily be distributed and the nutrients made easily accessible to the larvae and the associated bacteria.

Equipment needed:



1. One **shredder**: the type of shredder may vary and can be a hammer mill with an output screen or a single- or twin-shaft shredder. Ideally, waste is reduced to a particle size of 0.5-1 cm **2.** Various **buckets** or waste holding containers **3.** One **bulk scale**. Ideally up to ~150kg

Tasks:

- W1-1:** After a quality check and acceptance, remove the organic waste from the collection vehicle and place the waste near the shredder. While emptying the vehicle, remove non-organics contained in the waste (rough sorting).
- W1-2:** Place a labelled bucket under the shredder outlet and turn on the shredder.
- W1-3:** While filling the hopper to shred the waste, manually remove non-organic components in the waste. Use a wooden beam to push waste into the hopper and shredder if necessary. When the waste receiving bucket is full, exchange it with a labelled empty new bucket.
- W1-4:** Weigh and document each full bucket of shredded waste using a bulk scale.
- W1-5:** After all waste is shredded, use the high pressure washer to clean the inside, outside and around the shredder. All the wastewater needs to be discharged for treatment.



PROTECTIVE MEASURES FOR WORKERS:

- Use gloves, protective clothing, eye and ear protection when using the shredder.
- Make use of the protective measures available for the shredder/hammer mill, i.e. feeding hopper, flap and other safety features, to avoid any risk of direct contact between workers' hands and moving parts.



POINTS OF MONITORING AND DATA COLLECTION:

- The net weight of shredded waste is measured with a bulk scale.

Step W2 - Waste dewatering

The shredded waste is assessed manually to estimate the moisture content. If, when squeezing a handful of waste in your fist, less than a few drops of water emerge between your fingers, then the waste moisture content is lower than 60% and water needs to be added. If the shredded waste has a water content above 85% (waste with this moisture content will have a slurry like texture, similar to a fruit mix when grinded with a kitchen blender), it will need to be dewatered to obtain a moisture content below 85%. Alternatively, a dry bulk material that is abundantly available (e.g. rice husk/wheat bran) could be added to reach the critical limit for the moisture content in the waste.

It is, however, inevitable to determine the exact moisture content from the start in order to tune the feed material for the larvae, using defined pre-processing steps or additives (see Step T1 for methodology).

There are different ways to dewater the waste. The simplest way is a passive dewatering (by gravity), where the waste is filled into a cloth bag that acts as a filter, allowing the water to drain through the cloth into a bucket below. This method is described in this document. However, other, more sophisticated technologies to dewater might include a horizontal screw press or a cider press (Figure 20).



Figure 20: Different dewatering methods: passive dewatering by gravity (left), screw press (middle), cider press (right), (Photo screw press: Vincent Corporation)

In the task list below, a simple passive dewatering procedure is explained which can be skipped if the waste is below 80% in moisture.

Equipment needed:



1. Dewatering buckets for passive dewatering and plain **cotton cloth**. Any cloth material with a low thread count, such as a cheesecloth tofu-cloth or muslin, will serve the purpose. **2. Plastic frame** to be placed into the dewatering bucket under the cotton cloth. The frame will create a space in the bottom for the water seeping through. **3. One bulk scale**. Ideally up to ~150kg.

Tasks:

- W2-1:** Prepare a dewatering unit. Use an empty bucket. Place a plastic frame into the bucket and add the cotton cloth over the outer edges of the top of the bucket and fix it with a rope.
- W2-2:** Empty the shredded waste into the cloth. Document the weight of this full dewatering bucket. Then, put a lid on the bucket and leave it standing for 24 hours.
- W2-3:** Repeat the process of W2-1 and W2-2 for all the waste to be processed.
- W2-4:** After 24 hours merge the content of the two cloths, and leave for another 24 hours. Repeat this process for all dewatering buckets. The empty dewatering units (bucket, frame and cloth) are then cleaned using a high pressure washer and the washing machine, respectively.
- W2-5:** Open the 48 hour old dewatering units and remove the cotton cloth with the dewatered waste. Empty the dewatered waste into a bucket and weigh it. Empty the water into a holding tank for later use or discharge for treatment.



The plastic frame inside the bucket keeps the cloth and thus the waste away from the drained water (**W2-1**)



PROTECTIVE MEASURES FOR WORKERS:

- Use gloves and protective clothing during dewatering activities.



POINTS OF MONITORING AND DATA COLLECTION:

- The net weight of the dewatered waste is measured.
- The difference of the total shredded waste and total dewatered waste is the amount of water removed.

3.3 Activities in the BSF waste treatment unit

Waste treatment using larvae of the black soldier fly can be done in many different ways. In this document, we describe a batch operation with manual harvesting. This means, that same-aged young larvae (5-DOL) are put in a container with biowaste (Larveros). After a defined time, the resulting mixture of grown larvae and residue is then harvested and separated. In the facility described here, all the biowaste treatment units, as well as the feeding and harvesting tasks, are handled manually.

For its treatment, biowaste can either be brought to the larveros or the larveros are moved to a central feeding station. The installation of a centralized feeding station has the advantage of concentrating a potentially filthy area in one spot and avoids unnecessary displacement of the bulk scale. Furthermore, the stack of larveros are then easily accessible and their content can easily be checked for irregularities. The operation described here assumes, therefore, the existence of a central feeding station.

Step T1 - Set-up and feeding in the larvero

A new batch of larveros is initiated by filling a defined amount of shredded (and dewatered) waste into a crate and then adding a defined number of 5-DOL. Furthermore, larveros on their 5th and 8th day in operation also receive additional shredded (and dewatered) biowaste.

Equipment needed:



1. 36 conversion crates, so-called larveros 2. Six ventilation frames



3. Pallet and pallet trolley 4. Feeding station with bulk scale and scoop 5. 36 cups with 10,000 5-DOL each

Tasks:

T1-1: Get a pallet and a pallet trolley. Prepare 36 larveros and six open ventilation frames. Place these close to the feeding station.

T1-2: Place six larveros onto the pallet and feed them with 5 kg of biowaste each. Add one cup containing 10,000 5-DOL onto the waste in each crate (R6-6). Lastly, place an open ventilation frame over the six larveros. Now stack the next layer of six larveros onto the ventilation frame and repeat this process until a stack of six layers with a total of 36 larveros is complete. On the top ventilation frame, place six empty larveros (or any kind of cover) to protect the top larveros from direct light. Label the pallet with the date code. Then, use the pallet trolley to bring the pallet to its destination in the building.



Adding 5-DOL to a larvero (**T1-2**)



A stack of larveros. The metal frames allow ventilation and thus help water to evaporate from the waste (**T1-2**)



Feeding of the larveros using a bucket (**T1-2**)

T1-3: Wash the waste holding containers (or dewatering units and cloths) which have been emptied using a high pressure washer and leave to dry.

T1-4: Use the pallet trolley to move the pallet that was set-up five days ago (i.e. today minus five days) to the feeding station. Place an empty pallet next to the five day old pallet. Remove the top six empty crates and the ventilation frame. Move the top level of six larveros from the old pallet to the new empty pallet.

T1-5: Add 5 kg of waste to each larvero that was placed on the new pallet and move the ventilation frame from the top of the old pallet to the new pallet. Reassemble the larveros on the pallet level by level and place the six empty crates on top of the last ventilation frame. Take the opportunity to check each larvero for irregularities while moving them. Place the pallet back to its place.

T1-6: Do the same as in T1-5 for the pallet that was initiated eight days ago (i.e. today minus eight days).



PROTECTIVE MEASURES FOR WORKERS:

- Use gloves and protective clothing during feeding activities



POINTS OF MONITORING AND DATA COLLECTION:

- Before adding waste to the larveros, it is important to obtain waste samples to determine the moisture content. For this purpose, thoroughly mix the waste in each waste holding container and place one large scoop from each waste container into a bucket. Mix the content in the sampling container thoroughly and remove one sample of about 500g and place it onto a sample tray.
The tray with the sample is weighed and then dried in an oven at 105 °C for 24 hours before weighing the tray again. Calculate the water content of the sample by: Water content [%] = 100 * (Wet weight-Dry weight)/Wet weight

3.4 Activities in the product harvesting unit

In the harvesting step, the two products need to be separated: larvae and residue. Depending on the water content of the input material, the residue is a crumbly dry mass or a wet slurry. In the worst case, the residue is something in-between – a sticky mass, which would make harvesting almost impossible. In this case, either the input material has to be optimized or water needs to be added during the harvesting process. In case of dry fractions, separation can be done with a shaking sieve with a mesh width of 3-5 mm (depending on the size of the larvae). In this manual, we describe the harvesting and separation if your treatment results in a wet slurry.

Step H1 - Harvesting of the products

After 12 days in the larvero (with waste additions at day one, day five and day eight), the content of the larveros is harvested. The wet harvesting technique makes use of the larvae behaviour of crawling away from the light through a mesh. They can eventually easily be strained from the watery solution which also passes through the mesh.

Equipment needed:



1. Screens on which the content of the larveros are emptied onto **2. Tools** to spread the material and strain the larvae from the effluent



3. Harvesting containers to collect effluent and larvae **4. Buckets** to collect harvest **5. Sampling trays** for larvae and residue



6. Drying container filled with coco peat **7. Manual shaking sieve** (mesh size 3-5 mm)

Tasks:

- H1-1:** Prepare the harvesting station by placing screens onto two empty harvesting containers. These should be exposed to the sun or intense light. Prepare the tools required for spreading the residue and for scooping the larvae. Prepare two 80 litre collection buckets and place these next to the harvesting containers. Fill them with about 50 litres of water each. Prepare a drying container.
- H1-2:** Use the pallet trolley to move the 12 day old pallet with larveros from its position to the harvesting station.
- H1-3:** Weigh each larvero. Then, from a random selection of three larveros, take a scoop of each larvero content for a monitoring sample and combine these scoops into a sampling bowl. Further process the sample as described below in the section "monitoring" below.
- H1-4:** Empty the 36 larveros of the pallet onto the screens, and place the empty crates near the cleaning area.
- H1-5:** Spread the material (larvae and residue) out over the screens in a layer that is thin enough to ensure that the photophobic larvae are exposed to direct sunlight. Leave to settle. The larvae will try to avoid the light by crawling downwards through the screen and they fall into the harvesting container below. Turning the layer of material on the mesh might be required to achieve that all larvae crawl through the mesh. The harvesting container will also receive any liquid and smaller residue particles that drain through the screen.
- H1-6:** While the larvae crawl through the mesh, clean the empty larveros with the high pressure washer and leave these to dry.
- H1-7:** After all the larvae have crawled through the screens, remove the residual solid material from the screen into buckets. This material can be post-processed in a composting or a biogas facility.
- H1-8:** Remove the screens from the harvesting containers and clean them with the high pressure washer and leave them to dry.



Separation of larvae and wet residue on the screen (H1-5)



Straining the larvae from the runoff water (H1-9)



Larvae drain on a cloth after second rinsing before put into the drying container with coco peat (H1-10)

- H1-9:** Use a strainer spoon to remove the BSFL from the liquid in the harvesting container and put them into the first collection bucket for the first rinse. Rinse the larvae by submerging and stirring them in the water of the bucket with the strainer spoon. Move them to the second collection bucket for a second rinse.
- H1-10:** Use the strainer spoon to remove the rinsed larvae from the last rinsing bucket. Let the larvae drain on a cloth before placing them onto a bed of coco peat in the drying container.
- H1-11:** The liquid remaining in the collection buckets can be discharged and processed (i.e. waste water treatment or biogas facility).

H1-12: Discharge the dirty water from the buckets and clean the collection buckets with the high pressure washer.

H1-13: Remove the content of the drying container (larvae and coco peat) and place onto a manual shaking sieve with a container underneath. The larvae remain in the sieve while the coco peat passes through. Empty the sieved larvae into a second bin. Repeat this process until all drying containers are empty. The sieved coco peat can then be dried and reused for the next batch of drying containers.



A larvero is weighed with the bulk scale before its content is emptied onto the harvesting screen (**H1-3**)



Samples for determination of dry matter content are put into the oven



PROTECTIVE MEASURES FOR WORKERS:

- Use lab coat and latex gloves for handling 5-DOL and residue.



POINTS OF MONITORING AND DATA COLLECTION:

- It is critical to measure the weight of the “harvest” of all products: the solid residue, the liquid residue and the larvae. These data are used to calculate performance indicators that allow the operator to monitor the performance of the treatment facility, namely waste reduction, bioconversion ratio and larval yield. For this purpose, we measure the net weight of the larvero content as well as the larvae harvest. The difference between net larvero content and larvae harvest is the weight of the residue. Furthermore, we analyse the residue with regard to its water content.
- Document the weight of each larvero before emptying. Subtracting the weight of the empty larvero container will result in the net weight of the larvero content.
- Document the total weight of harvested larvae.
- Put the sampling bowl as described in H1-3 onto a plate and pick out all the larvae. Make sure to not spill the liquid as this is part of the wet weight measurement. Once you take out all the larvae, put the residue into a sampling tray. Take 50 of the larvae and dry them with a tissue before putting them onto a sampling tray. Put the rest of the larvae back to the harvested crates or directly on the harvesting screen. Weigh the samples (larvae and residue) and dry them in an oven at 105 °C for 24 hours before weighing each tray again. By doing this, you will obtain the water content of the larvae and the residue.

3.5 Activities in the post-treatment unit (larvae refining and residue processing)

Step P1 - Refining of the larvae

Post-treatment of the larvae is not explained in much detail in this guide as this will depend on customer demand. However, independent of customer demand, we recommend that the larvae be refined through the sanitizing step of immersion into boiling water, which is explained below. The immersion into boiling water will kill the larvae in a fast and effective way and also triggers the larvae to empty their guts.

Whether or not the dead larvae have to be dried afterwards depends on their further use. Whenever the larvae are not further processed directly after harvest, we recommend to dry them to a water content below 10%.

Equipment needed:



1. Large cooking pot and gas stove 2. Drying table

Tasks:

- P1-1:** Prepare the sanitizing step by placing a cooking pot with water onto the gas stove. Heat the water until boiling.
- P1-2:** In batches of about 5-10 kg of larvae (depending on pot size), submerge these into the boiling water for about one minute. Remove the larvae with the strainer spoon and place into a bucket
- P1-3:** Replace the water when very dirty and discharge for treatment.
- P1-4:** Repeat the processes described above until all larvae are sanitized.
- P1-5:** Spread the larvae onto the drying table and leave them to dry. Regular turning with a spatula quickens the process. Please note: sun drying will not make the larvae storable! It just reduces the “wetness” of the larvae and makes further processing easier.
- P1-6:** After a few hours in the sun, the larvae are ready for cold storage (freezer) or further processing (further drying, oil extraction, grinding, pelletizing, etc.)



PROTECTIVE MEASURES FOR WORKERS:

- Use gloves, eye protection and protective clothing during sanitizing activities.



POINTS OF MONITORING AND DATA COLLECTION:

- Measure the weight of harvested larvae before sanitizing and then after sun drying.

Step P2 - Processing of the residue

Processing of the residue is not explained in detail in this guide. For wet residue, we recommend two options, either compost the residue together with other garden waste or, if available, feed it into a biogas reactor. Preliminary results have shown that the expected biogas amounts from the residue compare to biogas from cow manure.

Dry residue needs to undergo a maturation process before it can be used as a soil amendment. Due to the short treatment of 12 days, the microbial activity in the material is still very high, and compete for oxygen and nitrogen with the soil in which it is applied. Application of immature residue, thus, might stunt, damage or even kill the surrounding plants.

Chapter 4:

Handling Schedules in a BSF-Processing Facility

The described BSF treatment facility set-up produces enough 5-DOL to treat between nine and twenty one tons of biowaste per week. The capacity depends on the work schedule chosen. Depending on space and labour availability, one would choose a schedule which requires an everyday presence, seven days a week or that can be managed during a regular work week with Saturday/Sunday off (see Table 2).

Table 2: Capacity of the described BSF facility depending on work schedule

Work schedule	Waste capacity	Output of 5-DOL	# workers required	Area	Daily 5-DOL output fluctuation
1 Every day-Full capacity	21.0 ton/wk	±14 million/wk	3	40 m ²	Stable
2 Every day-Half capacity	10.5 ton/wk	±7 million/wk	2	35 m ²	Small fluctuation
3 Mon-Wed-Fri	9.0 ton/wk	±6 million/wk	1	35 m ²	Large fluctuation

The work schedules and its egg media- and feeding schedules (found below) use a date code format: **XX.Y**. This format allows for easy date calculating and date tagging of cages and containers. The XX-value indicates the calendar week of the year (week 01-52/53).
The Y-value indicates the day of the week (Monday-Sunday = 1-7).

Date: Tuesday, February 21 Code: 8.2

Week 8 of the year
Day 2 of the week

For all three work schedules, different task lists and feeding schedules have been designed.

Appendix A: The **work schedule** (appendix A1, A2 and A3) is a simplified version of the Steps described in detail in Chapter 3. A short explanation is provided for each task and the columns to the right are white when the task has to be done on that day and black on days that can be skipped. This schedule is meant to be placed in the colony, where the personnel can check off the tasks when done. Each work schedule covers four to five weeks and has to be renewed by the facility manager after this period.

Appendix B: The **egg harvesting schedule** (appendix B1, B2 and B3) is to keep track of the egg harvesting. The left column (Set-up) indicates the date when a new love cage is set-up. The code in the same row shows the code of the love cages from which eggies have to be harvested on the current day. The love cage representing the code in the last column (3rd harvest) will be dismantled after its eggies have been harvested.

The table presented here is meant to serve as a template for an Excel-sheet; an operator can easily update a schedule in Excel according to formulas.

	Set-up	1st harvest	2nd harvest	3rd harvest
	6.1	5.6	5.4	5.2
Today's code and ID of the love cage setup today	6.3	6.1	5.6	5.4
	6.5	6.3	6.1	5.6
	6.7	6.5	6.3	6.1

This love cage will be dismantled after harvesting today

ID of the love cages whose eggies have to be harvested today

Appendix C: The third schedule shows the **feeding regime of the nursery containers** (C1, C2 and C3). In the nursery containers, 5-DOL are fed about two weeks until they transform into prepupae. The prepupae are then put into pupation containers to eventually become flies. Nursery containers are fed a nutrient rich feed. The harvesting of prepupae relies on crawl-off. Towards the end of the feeding phase, the water content of the feed is increased, which allows prepupae to crawl out of the nursery container. The feeding schedule for the nursery container tells the operator which feed mixture has to be applied to which nursery container.

Date	Set-up	1 KG	2 KG	1 KG	1 KG	Dism.					
8.1	8.1	7.6	7.5	7.3	7.2	6.7	6.6	6.5	6.3	6.1	5.5
8.2	8.2	7.7	7.6	7.4	7.3	7.1	6.7	6.6	6.4	6.2	5.6
8.3	8.3	8.1	7.7	7.5	7.4	7.2	7.1	6.7	6.5	6.3	5.7

Today's code

Indicate the IDs of the nursery containers to be fed today

Number and colour indicate the amount and type of feed to be fed

ID of the nursery container to be dismantled today

The left white column indicates the current date. The second column indicates the date code for the nursery container that will be set-up on that day. The other cells along the row indicate the ID of the nursery containers to be fed today. The colour indicates the amount and type of feed they receive. The feed differs in terms of the amount of water added to the chicken feed (CF) and ranges from 70 - 100% water.

1kg / 30% CF / 70% H₂O	2kg / 30% CF / 70% H₂O	2kg / 15% CF / 85% H₂O	1kg / 100% H₂O
--	--	--	----------------------------------

The table presented here is meant to serve as a template for an Excel-sheet; an operator can easily update a schedule in Excel according to formulas.

Appendix D: The **log sheet** (Appendix D) is prepared for the data that will be collected on each day of operation. All the monitoring data for the productivity of the nursery can be collected on that sheet.

A7

Work schedule for rearing unit in the **every day-full capacity** setting. "xx" marks the calendar week and the numbers below indicate the day of the week (e.g. 1 is Monday, 2 is Tuesday, etc.). Mx refers to monitoring tasks below

Week	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	
Day (Monday – Sunday, 1–7)	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Clean lab (sweep floor and store all stuff on shelf)																					
Clean lab table (1 st with detergent, 2 nd with alc.)																					
Wash towels and lab coats (at 60-90 degrees)																					
M1: Count 5-DOL																					
	· Measure & count 2 times 2 grams																				
	· Measure total weight																				
	· Calculate total amount																				
M2: Take samples																					
	· Mass of empty tray																				
	· Mass of tray + material																				
	· Mass of tray + dry material (24h later)																				
	· 20 larvae per tray																				
M3: Count prepupae from nursery container																					
	· Weigh prepupae from each nursery container separate																				
	· Mix prepupae and weigh 2 samples of 200																				
M4: Weigh eggs																					
	· Full eggs from love cage																				
	· Empty eggs to love cage																				
M5: Count flies																					
	· Collect 20 flies from new love cage																				
	· Add acetate to cork jar and add flies (10 min)																				
	· Take flies out and weigh																				

A2

Work schedule for nursery in the **every day-half capacity** setting. "xx" marks the calendar week and the numbers below indicate the day of the week (e.g. 1 is Monday, 2 is Tuesday, etc.). Mx refers to monitoring tasks below

Week	Day (Monday – Sunday, 1–7)	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
		XX																				
Prepare new hatching containers (3)																						
· Add food (3 kg) and coco peat																						
· Place under hatching shower																						
Prepare new nursery container																						
· Add chicken feed (2 kg) to nursery container																						
· Cover with coco peat																						
· Add 15,000 5-DOL																						
· Place in transfer container																						
· Add coco peat to transfer container																						
Prepare new egg media																						
· Take eggie material from drying rack and sort																						
· Use new rubber bands																						
Lové cage maintenance (M4)																						
· Replace eggies (see appendix B2)																						
· Check water in dispenser																						
Remove (6 d) old love cage (see appendix B2)																						
· Collect dead flies for new attractant																						
· Clean attractant & boxes																						
· Wash love cage																						
Set-up new love cage (M5)																						
· Weigh full cage																						
· Move cage to love cage table																						
· Add attractant, eggies, shade box & full water container																						
Remove (3 wk) old dark cages																						
· Take (16) pupation containers out																						
· Empty pupation containers and clean																						
· Wash dark cage																						
Set-up new dark cage																						
· Add 16 pupation containers/dark cage																						
Fill water of ant traps																						
Clean nursery room (sweep floor and shelves)																						
Clean work tables (1st with detergent, 2nd with alc.)																						

Week	Day (Monday – Sunday, 1–7)	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
		XX																				
	Clean lab (sweep floor and store all stuff on shelf)																					
	Clean lab table (1 st with detergent, 2 nd with alc.)																					
	Wash towels and lab coats (at 60-90 degrees)																					
	M1: Count 5-DOL																					
	· Measure & count 2 times 2 grams																					
	· Measure total weight																					
	· Calculate total amount																					
	M2: Take samples																					
	· Mass of empty tray																					
	· Mass of tray + material																					
	· Mass of tray + dry material (24h later)																					
	· 20 larvae per tray																					
	M3: Count prepupae from nursery container																					
	· Weigh prepupae from each nursery container separate																					
	· Mix prepupae and weigh 2 samples of 200																					
	M4: Weigh eggs																					
	· Full eggs from love cage																					
	· Empty eggs to love cage																					
	M5: Count flies																					
	· Collect 20 flies from new love cage																					
	· Add acetate to cork jar and add flies (10 min)																					
	· Take flies out and weigh																					

A3

Work schedule for nursery in the **Mon-Wed-Fri** setting. "xx" marks the calendar week and the numbers below indicate the day of the week (e.g. 1 is Monday, 2 is Tuesday, etc.). Mx refers to monitoring tasks below

Week	xx																		
Day (Monday – Friday, 1–5)	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4
Remove oldest hatchling container (M1)																			
· Sieve/skim residue																			
· Enumerate 5-DOL																			
· Clean crate																			
Connect new love cage to dark cages																			
· Weigh empty cage																			
· Connect love cage to first dark cage																			
· Disconnect love cage after 30 minutes																			
· Weigh cage again																			
· Connect to next dark cage and repeat																			
Take samples (M2)																			
· Waste in, residue out & larvae out																			
· Take spoons from different crates																			
Prepare (16) new pupation containers																			
· $\frac{3}{4}$ compost, $\frac{1}{4}$ H ₂ O																			
· 3 kg of mixture per crate																			
· Cross-stack the crates																			
Remove (3 wk) old nursery container																			
· Remove material																			
· Use material for fly attractant																			
· Clean nursery container																			
Harvest and process prepupae (M3)																			
· Sieve prepupae from transfer container																			
· Add coco peat to transfer container and place back																			
· Weigh prepupae from each transfer container																			
· 800 prepupae/pupation container/day																			
Add food in nursery containers (see appendix C3)																			
Hatchling shower maintenance																			
· Remove and clean (7d) old egg media																			
· Add water (0.5L) to oldest hatchling containers																			

Appendix A3:

Week		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	XX	XX	XX	XX	XX	XX	
Day (Monday – Friday, 1–5)																												
Prepare new hatching containers (3)																												
· Add food (3 kg) and coco peat																												
· Place under hatching shower																												
Prepare two nursery container																												
· Add chicken feed (2 kg) to nursery containers																												
· Cover with coco peat																												
· Add 10,000 5-DOL to both containers																												
· Add coco peat to transfer containers																												
· Place in transfer containers																												
Prepare new egg media																												
· Take eggie material from drying rack and sort																												
· Use new rubber bands																												
Lov cage maintenance (M4)																												
· Replace eggies (see appendix B3)																												
· Check water in dispenser																												
Remove (6 d) old lov cage (see appendix B3)																												
· Collect dead flies for new attractant																												
· Clean attractant & boxes																												
· Wash lov cage																												
Set-up new lov cage (M5)																												
· Weigh full cage																												
· Move cage to love cage table																												
· Add attractant, eggies, shade box & full water bowl																												
Remove (3 wk) old dark cages																												
· Take (16) pupation containers out																												
· Empty pupation containers and clean																												
· Wash dark cage																												
Set-up new dark cage																												
· Add 16 pupation containers/dark cage																												

Week		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	XX	XX	XX	XX	
Day (Monday – Friday, 1–5)		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	Fill water of ant traps																														
	Clean nursery room (sweep floor and shelves)																														
	Clean work tables (1 st with detergent, 2 nd with alc.)																														
	Clean lab (sweep floor and store all stuff on shelf)																														
	Clean lab table (1 st with detergent, 2 nd with alc.)																														
	Wash towels and lab coats (at 60-90 degrees)																														
	M1: Count 5-DOL																														
	· Measure & count 2 times 2 grams																														
	· Measure total weight																														
	· Calculate total amount																														
	M2: Take samples																														
	· Mass of empty tray																														
	· Mass of tray + material																														
	· Mass of tray + dry material (24h later)																														
	· 20 larvae per tray																														
	M3: Count prepupae from nursery container																														
	· Weigh prepupae from each nursery container separate																														
	· Mix prepupae and weigh 2 samples of 200																														
	M4: Weigh eggsies																														
	· Full eggsies from love cage																														
	· Empty eggsies to love cage																														
	· Take flies out and weigh																														
	M5: Count flies																														
	· Collect 20 flies from new love cage																														
	· Add acetate to cork jar and add flies (10 min)																														
	· Take flies out and weigh																														

B1

Egg harvesting schedule for **every day-full capacity** setting. "xx" marks the calendar week. The "+1" indicates the following week and the "-1" indicated the previous week.

Appendix B1:

Set-up	1 st harvest	2 nd harvest	3 rd harvest	Set-up	1 st harvest	2 nd harvest	3 rd harvest
xx.1	xx-1.6	xx-1.4	xx-1.2	6.1	5.6	5.4	5.2
xx.2	xx-1.7	xx-1.5	xx-1.3	6.2	5.7	5.5	5.3
xx.3	xx.1	xx-1.6	xx-1.4	6.3	6.1	5.6	5.4
xx.4	xx.2	xx-1.7	xx-1.5	6.4	6.2	5.7	5.5
xx.5	xx .3	xx.1	xx-1.6	6.5	6.3	6.1	5.6
xx.6	xx .4	xx.2	xx-1.7	6.6	6.4	6.2	5.7
xx.7	xx .5	xx .3	xx .1	6.7	6.5	6.3	6.1
xx+1.1	xx .6	xx .4	xx .2	7.1	6.6	6.4	6.2
xx+1.2	xx .7	xx .5	xx .3	7.2	6.7	6.5	6.3
xx+1.3	xx+1.1	xx .6	xx .4	7.3	7.1	6.6	6.4
xx+1.4	xx+1.2	xx .7	xx .5	7.4	7.2	6.7	6.5
xx+1.5	xx+1.3	xx+1.1	xx .6	7.5	7.3	7.1	6.6
xx+1.6	xx+1.4	xx+1.2	xx .7	7.6	7.4	7.2	6.7
xx+1.7	This is how the egg harvesting schedule is built up: Every day , you set up a new love cage and harvest the eggs from love cages set up on Wednesday and Monday of the same week and Saturday of week 6		xx+1.1	7.7	Example: On Friday of week 7, you set up a new love cage and harvest the eggs from love cages set up on Wednesday and Monday of the same week and Saturday of week 6		
etc.			xx+1.2	8.1			
etc.			xx+1.3	8.2			
etc.			xx+1.4	8.3			
etc.			xx+1.5	8.4			
etc.			xx+1.6	8.5	8.3	8.1	7.6
etc.	etc.	etc.	xx+1.7	8.6	8.4	8.2	7.7
etc.	etc.	etc.	etc.	8.7	8.5	8.3	8.1
	etc.	etc.	etc.	9.1	8.6	8.4	8.2
	etc.	etc.	etc.	9.2	8.7	8.5	8.3
		etc.	etc.	9.3	9.1	8.6	This is how the sheet will be hanging on the wall of your colony. This example starts on Monday of week 6 of the year
		etc.	etc.	9.4	9.2	8.7	
		etc.	etc.	9.5	9.3	9.1	
		etc.	etc.	9.6	9.4	9.2	
		etc.	etc.	9.7	9.5	9.3	
				10.1	9.6	9.4	9.2
				10.2	9.7	9.5	9.3
				10.3	10.1	9.6	9.4
				10.4	10.2	9.7	9.5
				10.5	10.3	10.1	9.6
				10.6	10.4	10.2	9.7
				10.7	10.5	10.3	10.1
				11.1	10.6	10.4	10.2
				11.2	10.7	10.5	10.3

B2

Egg harvesting schedule for **every day-half capacity** setting. "xx" marks the calendar week. The "+1" indicates the following week and the "-1" indicated the previous week.

Appendix B2:

Set-up	1st harvest	2nd harvest	3rd harvest	Set-up	1st harvest	2nd harvest	3rd harvest				
xx.1	xx-1.6	xx-1.4	xx-1.2	6.1	5.6	5.4	5.2				
xx.3	xx.1	xx-1.6	xx-1.4	6.3	6.1	5.6	5.4				
xx.5	xx.3	xx.1	xx-1.6	6.5	6.3	6.1	5.6				
xx.7	xx.5	xx.3	xx.1	6.7	6.5	6.3	6.1				
xx+1.2	xx.7	xx.5	xx.3	7.2	6.7	6.5	6.3				
xx+1.4	xx+1.2	xx.7	xx.5	7.4	7.2	6.7	6.5				
xx+1.6	xx+1.4	xx+1.2	xx.7	7.6	7.4	7.2	6.7				
etc.	This is how the egg harvesting schedule is built up: Every other day , you set up a new love cage and harvest the eggs from love cages set up on Tuesday of the same week and Sunday and Friday of week 6			8.1	Example: On Thursday of week 7, you set up a new love cage and harvest the eggs from love cages set up on Tuesday of the same week and Sunday and Friday of week 6						
etc.			xx+1.2	8.3			7.2				
etc.			xx+1.4	8.5			7.4				
etc.			xx+1.6	8.7			7.6				
etc.			etc.	9.2			8.1				
			etc.	9.4	9.2	8.7	8.3				
			etc.	9.6	9.4	9.2	8.5				
				10.1	9.6	9.4	9.2				
				10.3	10.1	9.6	9.4				
				10.5	10.3	10.1	9.6				
				10.7	10.5	10.3	10.1				
				11.2	10.7	10.5	10.3				
				11.4	11.2	10.7	10.5				
				11.6	11.4	11.2	10.7				
				12.1	11.6	11.4	11.2				
				12.3	12.1	11.6	11.4				
				12.5	12.3	12.1	This is how the sheet will be hanging on the wall of your colony. This example starts on Monday of week 6 of the year				
				12.7	12.5	12.3					
				13.2	12.7	12.5					
				13.4	13.2	12.7					
				13.6	13.4	13.2					
				14.1	13.6	13.4	13.2				
				14.3	14.1	13.6	13.4				
				14.5	14.3	14.1	13.6				
				14.7	14.5	14.3	14.1				
				15.2	14.7	14.5	14.3				
				15.4	15.2	14.7	14.5				
				15.6	15.4	15.2	14.7				
				16.1	15.6	15.4	15.2				
				16.3	16.1	15.6	15.4				

B3

Egg harvesting schedule for **Mon-Wed-Fri** setting. "xx" marks the calendar week. The "+1" indicates the following week and the "-1" indicated the previous week.

Appendix B3:

Set-up	1 st harvest	2 nd harvest	3 rd harvest	Set-up	1 st harvest	2 nd harvest	3 rd harvest	
xx.1	xx-1.5	xx-1.3	xx-1.1	6.1	5.5	5.3	5.1	
xx.3	xx.1	xx-1.5	xx-1.3	6.3	6.1	5.5	5.3	
xx.5	xx.3	xx.1	xx-1.5	6.5	6.3	6.1	5.5	
xx+1.1	xx.5	xx.3	xx.1	7.1	6.5	6.3	6.1	
xx+1.3	xx+1.1	xx.5	xx.3	7.3	7.1	6.5	6.3	
xx+1.5	This is how the egg harvesting schedule is built up: Every Mon, Wed, Fri , you set up a new love cage and harvest the eggs from love cages set up on Monday of the same week and Friday and Wednesday of week 6		xx.5	7.5	7.2	7.1	6.5	
etc.			xx+1.1	8.1	Example: On Wednesday of week 7, you set up a new love cage and harvest the eggs from love cages set up on Monday of the same week and Friday and Wednesday of week 6			7.1
etc.			xx+1.3	8.3				7.3
etc.			xx+1.5	8.5				7.5
			etc.	9.1				8.1
			etc.	9.3				8.3
			etc.	9.5	9.3	9.1		8.5
				10.1	9.5	9.3		9.1
				10.3	10.1	9.5		9.3
				10.5	10.3	10.1		9.5
				11.1	10.5	10.3		10.1
				11.3	11.1	10.5		10.3
				11.5	11.3	11.1		10.5
				12.1	11.5	11.3		11.1
				12.3	12.1	11.5		11.3
				12.5	12.3	12.1		11.5
				13.1	12.5	12.3		12.1
				13.3	13.1	12.5		12.3
				13.5	13.3	13.1	This is how the sheet will be hanging on the wall of your colony. This example starts on Monday of week 6 of the year	
				14.1	13.5	13.3		
				14.3	14.1	13.5		
				14.5	14.3	14.1		
				15.1	14.5	14.3		
				15.3	15.1	14.5		14.3
				15.5	15.3	15.1		14.5
				16.1	15.5	15.3		15.1
				16.3	16.1	15.5		15.3
				16.5	16.3	16.1		15.5
				17.1	16.5	16.3		16.1
				17.3	17.1	16.5		16.3
				17.5	17.3	17.1		16.5
				18.1	17.5	17.3		17.1

C1

Feeding schedule for nursery container in **Every day-Full capacity** setting. "xx" marks the calendar week. The "+1" indicates the following week, the "-1" indicated the previous week and "-2" the week before that, etc. The colours are related to an amount of feed in a certain ratio of chicken feed (CF) to water.

Appendix C1:

Date	Set-up	1 KG	2 KG	2 KG	2 KG	2 KG	2 KG	1 KG	1 KG	Dism.
xx.1	xx.1	xx-1.6	xx-1.5	xx-1.3	xx-1.2	xx-2.7	xx-2.6	xx-2.5	xx-2.3	xx-2.1
xx.2	xx.2	xx-1.7	xx-1.6	xx-1.4	xx-1.3	xx-1.1	xx-2.7	xx-2.6	xx-2.4	xx-2.2
xx.3	xx.3	xx.1	xx-1.7	xx-1.5	xx-1.4	xx-1.2	xx-1.1	xx-2.7	xx-2.5	xx-2.3
xx.4	xx.4	xx.2	xx.1	xx-1.6	xx-1.5	xx-1.3	xx-1.2	xx-1.1	xx-2.6	xx-2.4
xx.5	xx.5	This is how the feeding schedule for the nursery container is built up: Every day , you set up a new nursery container and feed the nursery containers whose date codes can be found in the same row with the corresponding amount and type of feed						x-1.2	xx-2.7	xx-2.5
xx.6	xx.6							x-1.3	xx-1.1	xx-2.6
xx.7	xx.7							x-1.4	xx-1.2	xx-2.7
xx+1.1	xx+1.1							x-1.5	xx-1.3	xx-1.1
xx+1.2	xx+1.2	xx.7	xx.6	xx.4	xx.3	xx.1	xx-1.7	xx-1.6	xx-1.4	xx-1.2
etc.	etc.	etc.	etc.	etc.	etc.	etc.	etc.	etc.	etc.	etc.
etc.	etc.	etc.	etc.	etc.	etc.	etc.	etc.	etc.	etc.	etc.
6.1	6.1	5.6	5.5	5.3	5.2	4.7	4.6	4.5	4.3	4.1
6.2	6.2	5.7	5.6	5.4	5.3	5.1	4.7	4.6	4.4	4.2
6.3	6.3	6.1	5.7	5.5	5.4	5.2	5.1	4.7	4.5	4.3
6.4	6.4	6.2	6.1	5.6	5.5	5.3	5.2	5.1	4.6	4.4
6.5	6.5	6.3	6.2	5.7	5.6	5.4	5.3	5.2	4.7	4.5
6.6	6.6	6.4	6.3	6.1	5.7	5.5	5.4	5.3	5.1	4.6
6.7	6.7	6.5	6.4	6.2	6.1	5.6	5.5	5.4	5.2	4.7
7.1	7.1	6.6	6.5	6.3	6.2	5.7	5.6	5.5	5.3	5.1
7.2	7.2	6.7	6.6	6.4	6.3	6.1	5.7	5.6	5.4	5.2
7.3	7.3	7.1	6.7	6.5	6.4	6.2	6.1	5.7	5.5	5.3
7.4	7.4	7.2	7.1	6.6	6.5	6.3	6.2	6.1	5.6	5.4
7.5	7.5	7.3	7.2	6.7	6.6	6.4	6.3	6.2	5.7	5.5
7.6	7.6	7.4	7.3	7.1	6.7	6.5	6.4	6.3	6.1	5.6
7.7	7.7	7.5	7.4	7.2	7.1	6.6	6.5	6.4	6.2	5.7
8.1	8.1	7.6	7.5	7.3	7.2	6.7	6.6	6.5	6.3	6.1
8.2	8.2	7.7	7.6	7.4	7.3	7.1	6.7	6.6	6.4	6.2
8.3	8.3	8.1	7.7	7.5	7.4	7.2	7.1	6.7	6.5	6.3
8.4	8.4	8.2	8.1	7.6	7.5	7.3	7.2	7.1	6.6	6.4
8.5	8.5	8.3	8.2	7.7	7.6	7.4	7.3	7.2	6.7	6.5
8.6	8.6	8.4	8.3	8.1	7.7	7.5	7.4	7.3	7.1	6.6
8.7	8.7	8.5	8.4	8.2	8.1	7.6	7.5	7.4	7.2	6.7
9.1	9.1	8.6	8.5	8.3	8.2	7.7	7.6	7.5	7.3	7.1
9.2	9.2	8.7	8.6	8.4	8.3	8.1	7.7	7.6	7.4	7.2
9.3	9.3	9.1	8.7	8.5	8.4	8.2	8.1	7.7	7.5	7.3
9.4	9.4	9.2	9.1	8.6	8.5	8.3	8.2	8.1	7.6	7.4
9.5	9.5	9.3	9.2	8.7	8.6	8.4	8.3	8.2	7.7	7.5
9.6	9.6	9.4	9.3	9.1	8.7	8.5	8.4	8.3	8.1	7.6
9.7	9.7	9.5	9.4	9.2	9.1	8.6	8.5	8.4	8.2	7.7
10.1	10.1	9.6	9.5	9.3	9.2	8.7	8.6	8.5	8.3	8.1
										7.5

1 kg / 30% CF 2 kg / 30% CF 2 kg / 15% CF 1 kg Water

This is how the sheet will be hanging on the wall of your colony.
This example starts on Monday of week 6 of the year

C2

Feeding schedule for nursery container in **every day-half capacity** setting. "xx" marks the calendar week. The "+1" indicates the following week, the "-1" indicated the previous week and "-2" the week before that, etc. The colours are related to an amount of feed in a certain ratio of chicken feed (CF) to water

Appendix C2:

Date	Set-up	1 KG	2 KG	1 KG	1 KG	Dism.					
xx.1			xx-1.5	xx-1.3	xx-1.2		xx-2.6	xx-2.4			xx-3.5
xx.2	xx.2	xx-1.7			xx-1.3	xx-1.1			xx-2.2	xx-3.7	
xx.3	xx.3		xx-1.7	xx-1.5		xx-1.2	xx-1.1	xx-2.6	xx-2.3		xx-3.7
xx.4	xx.4	xx.2			xx-1.5	xx-1.3	xx-1.2		xx-2.4	xx-2.2	
xx.5		xx.3	xx.2	xx-1.7			xx-1.3	xx-1.1		xx-2.3	xx-2.2
xx.6	xx.6	xx.4	xx.3		xx-1.7	xx-1.5		xx-1.2	xx-2.6	xx-2.4	xx-2.3
xx.7			xx.4	xx.2			xx-1.5	xx-1.3			xx-2.4
xx+1.1	xx+1.1	xx.6		xx.3	xx.2	xx-1.7			xx-1.1	xx-2.6	
xx+1.2	xx+1.2		xx.6	xx.4	xx.3		xx-1.7	xx-1.5	xx-1.2		xx-2.6
xx+1.3	xx+1.3	xx+1.1			xx.4	xx.2			xx-1.3	xx-1.1	
xx+1.4		xx+1.2	xx+1.1	xx.6		xx.3	xx.2	xx-1.7		xx-1.2	xx-1.1
xx+1.5	xx+1.5	xx+1.3	xx+1.2		xx.6	xx.4	xx.3		xx-1.5	xx-1.3	xx-1.2
xx+1.6				xx-1.2	xx-1.1		xx-1.4	xx-2			xx-1.3
xx+1.7	xx+1.7							xx-3	xx-1.7	xx-1.5	
Xx+2.1							xx-4				xx-1.5
etc.	etc.						xx-5	etc.	etc.	etc.	etc.
6.1			5.5	5.3	5.2		4.6	4.4			3.5
6.2	6.2	5.7			5.3	5.1			4.2	3.7	
6.3	6.3		5.7	5.5		5.2	5.1	4.6	4.3		3.7
6.4	6.4	6.2			5.5	5.3	5.2		4.4	4.2	
6.5		6.3	6.2	5.7			5.3	5.1		4.3	4.2
6.6	6.6	6.4	6.3		5.7	5.5		5.2	4.6	4.4	4.3
6.7			6.4	6.2			5.5	5.3			4.4
7.1	7.1	6.6		6.3	6.2	5.7			5.1	4.6	
7.2	7.2		6.6	6.4	6.3		5.7	5.5	5.2		4.6
7.3	7.3	7.1			6.4	6.2			5.3	5.1	
7.4		7.2	7.1	6.6		6.3	6.2	5.7		5.2	5.1
7.5	7.5	7.3	7.2		6.6	6.4	6.3		5.5	5.3	
7.6			7.3	7.1			6.4	6.2			
7.7	7.7	7.5		7.2	7.1	6.6		6.3	5.7	5.5	
8.1				7.5	7.3	7.2		6.6	6.4		
8.2	8.2	7.7			7.3	7.1			6.2	5.7	
8.3	8.3		7.7	7.5		7.2	7.1	6.6	6.3		5.7
8.4	8.4	8.2			7.5	7.3	7.2		6.4	6.2	
8.5		8.3	8.2	7.7			7.3	7.1		6.3	6.2
8.6	8.6	8.4	8.3		7.7	7.5		7.2	6.6	6.4	6.3
8.7			8.4	8.2			7.5	7.3			6.4
9.1	9.1	8.6		8.3	8.2	7.7			7.1	6.6	
9.2	9.2		8.6	8.4	8.3		7.7	7.5	7.2		6.6
9.3	9.3	9.1			8.4	8.2			7.3	7.1	

1kg / 30% CF 2kg / 30% CF 2kg / 15% CF 1kg Water

This is how the sheet will be hanging on the wall of your colony.
This example starts on Monday of week 6 of the year

C3

Feeding schedule for nursery container in **Mon-Wed-Fri** setting. "xx" marks the calendar week. The "+1" indicates the following week, the "-1" indicated the previous week and "-2" the week before that, etc. The colours are related to an amount of feed in a certain ratio of chicken feed (CF) to water

Appendix C3:

Date	Set-up	1 KG	2 KG	2 KG	2 KG	2 KG	2 KG	2 KG	1 KG	Dism.
xx.1	xx.1	xx-1.5	xx-1.3	xx-1.1	xx-2.5	xx-2.3	xx-2.1	xx-3.5	xx-3.3	xx-3.1
xx.3	xx.3	xx.1	xx-1.5	xx-1.3	xx-1.1	xx-2.5	xx-2.3	xx-2.1	xx-3.5	xx-3.3
xx.5	xx.5	xx.3	xx.1	xx-1.5	xx-1.3	xx-1.1	xx-2.5	xx-2.3	xx-2.1	xx-3.5
xx+1.1	xx+1.1	xx.5	xx.3	xx.1	xx-1.5	xx-1.3	xx-1.1	xx-2.5	xx-2.3	xx-2.1
xx+1.3	xx+1.3	xx+1.1	xx.5	xx.3	xx.1	xx-1.5	xx-1.3	xx-1.1	xx-2.5	xx-2.3
xx+1.5	xx+1.5	xx+1.3	xx+1.1	xx.5	xx.3	xx.1	xx-1.5	xx-1.3	xx-1.1	xx-2.5
etc.	etc.	This is how the feeding schedule for the nursery container is built up: You set up new nursery containers and feed the nursery containers whose date codes can be found in the same row with the corresponding amount and type of feed								
etc.	etc.									
etc.	etc.									
etc.	etc.									
6.1	6.1	5.5	5.3	5.1	4.5	4.3	4.1	3.5	3.3	3.1
6.3	6.3	6.1	5.5	5.3	5.1	4.5	4.3	4.1	3.5	3.3
6.5	6.5	6.3	6.1	5.5	5.3	5.1	4.5	4.3	4.1	3.5
7.1	7.1	6.5	6.3	6.1	5.5	5.3	5.1	4.5	4.3	4.1
7.3	7.3	7.1	6.5	6.3	6.1	5.5	5.3	5.1	4.5	4.3
7.5	7.5	7.3	7.1	6.5	6.3	6.1	5.5	5.3	5.1	4.5
8.1	8.1	7.5	7.3	7.1	6.5	6.3	6.1	5.5	5.3	5.1
8.3	8.3	8.1	7.5	7.3	7.1	6.5	6.3	6.1	5.5	5.3
8.5	8.5	8.3	8.1	7.5	7.3	7.1	6.5	6.3	6.1	5.5
9.1	9.1	8.5	8.3	8.1	7.5	7.3	7.1	6.5	6.3	6.1
9.3	9.3	9.1	8.5	8.3	8.1	7.5	7.3	7.1	6.5	6.3
9.5	9.5	9.3	9.1	8.5	8.3	8.1	7.5	7.3	7.1	6.5
10.1	10.1	9.5	9.3	9.1	8.5	8.3	8.1	7.5	7.3	7.1
10.3	10.3	10.1	9.5	9.3	9.1	8.5	8.3	8.1	7.5	7.3
10.5	10.5	10.3	10.1	9.5	9.3	9.1	8.5	8.3	8.1	7.5
11.1	11.1	10.5	10.3	10.1	9.5	9.3	9.1	8.5	8.3	8.1
11.3	11.3	11.1	10.5	10.3	10.1	9.5	9.3	9.1	8.5	This is how the sheet will be hanging on the wall of your colony. This example starts on Monday of week 6 of the year
11.5	11.5	11.3	11.1	10.5	10.3	10.1	9.5	9.3	9.1	
12.1	12.1	11.5	11.3	11.1	10.5	10.3	10.1	9.5	9.3	
12.3	12.3	12.1	11.5	11.3	11.1	10.5	10.3	10.1	9.5	
12.5	12.5	12.3	12.1	11.5	11.3	11.1	10.5	10.3	10.1	
13.1	13.1	12.5	12.3	12.1	11.5	11.3	11.1	10.5	10.3	10.1
13.3	13.3	13.1	12.5	12.3	12.1	11.5	11.3	11.1	10.5	10.3
13.5	13.5	13.3	13.1	12.5	12.3	12.1	11.5	11.3	11.1	10.5

1kg / 30% CF 2kg / 30% CF 2kg / 15% CF 1kg Water

D

Appendix D:

Example of log sheet for daily data input of productivity parameters

Name responsible	Tina	Date code	12.2
------------------	------	-----------	------

Egg Data

Data love cage	Mass empty eggs (g)	Mass full eggs (g)
12.2	242.3	-
Date code of love cage managed	244.5	Weight of the new eggs placed in the love cage. Leave empty if love cage is dismantled today
11.5	-	277.1
		293.6

Today's code

Weight of the harvested eggs. Leave empty if love cage is set-up today

5-DOL Data

Date nursery box	# 5-DOL in 2 grams	Average	Total mass 5-DOL (g)	# 5-DOL
11.4	971	953	962	1,558

Total mass x Average : 2

Prepupal Data

Date nursery container	Mass pre-pupae (g)	Date nursery container	Mass pre-pupae (g)
10.6	113		
	145		
	67		
9.7	105		
Mass 200 PP (two samples from all PP)	1: 26.39	2: 25.59	Average: 25.99

Weight of random sample of 200 prepupae taken from today's pooled nursery container harvest

Prepupae in pupation box

Date of dark cage for pupation container	# of boxes	PP added per box today	Total PP
12.4	16	500	1500

Future date code of the dark cage that will be set up with these pupation containers

Cumulated prepupae per pupation container. See yesterday's log sheet for previous number

Love cage filling

Setting	Empty	1 st setting	2 nd setting	3 rd setting	4 th setting	5 th setting	mass 20 flies
ID of dark cage		9.3	10.3	11.3			1.689
Mass of love cage	914	921	1,144	1,634			

IDs of dark cages to which the love cage is connected to

s

Weight of empty love cage (including hanger)

Cumulated weight love cage after every connection to a dark cage (including hanger)

D

Appendix D:

Example of log sheet for daily data input of productivity parameters

Name responsible		Date code	
------------------	--	-----------	--

Egg Data

Data love cage	Mass empty eggies (g)	Mass full eggies (g)

5-DOL Data

Date nursery box	# 5-DOL in 2 grams	Average	Total mass 5-DOL (g)	# 5-DOL

Prepupal Data

Date nursery container	Mass pre-pupae (g)	Date nursery container	Mass pre-pupae (g)
Mass 200 PP (two samples from all PP)	1:	2:	Average:

Prepupae in pupation box

Date of dark cage for pupation container	# of boxes	PP added per box today	Total PP

Love cage filling

Setting	Empty	1 st setting	2 nd setting	3 rd setting	4 th setting	5 th setting	mass 20 flies
ID of dark cage							
Mass of love cage							

Comments

--

4

Appendix E:

Data monitoring sheet for BSF treatment unit

Date code of set-up	# crates	# 5-DOL/ crate	1 st feeding	2 nd feeding	3 rd feeding	Harvest date code	End weight	Larval harvest	Comments
	Total mass (kg)	Date code	Total mass (kg)	Date code	Total mass (kg)		Total mass (kg)	Total mass (kg)	
7.1	36	10,000	180	7.5	180	8.1	180	8.6	367 40.2 100% fruit waste
7.2	36	10,000	180	7.6	180	8.2	180	8.7	184 59.8 20% PKM + 80% fruits

Total weight of residue and larvae

Total weight of larvae

Date code of harvest. Feeding and harvest dates can be determined from the beginning

Total mass of waste fed to the pallet on the first day

Appendix E:

Master copy of data monitoring sheet for BSF treatment unit

F

Appendix F:

Data monitoring sheet for biowaste receiving and pre-processing. Use different sheets for different waste sources/types (biowaste from market, household, restaurant, agro-industry, ...). The data rows regarding dewatering can be omitted when no dewatering takes place.

Waste source:									
Date code	Initial weight of dewatering bin	Bin-1	Bin-2	Bin-3	Bin-4	Bin-5	...	Bin-n	Total
8.2	Shredded waste (kg)	42	45	36	38	42			566
	24 h dewatered (kg)	26	29	22	23	24			325
	48 h dewatered (kg)	21	22	16	17	19			246
	Shredded waste (kg)								
	Weight of dewatering bin after one day								
	48 h dewatered (kg)								
	Shredded waste (kg)								
	24 h dewatered (kg)								
	48 h dewatered (kg)								

G

Appendix G:

Lab log for measuring of dry matter in oven at 105°C

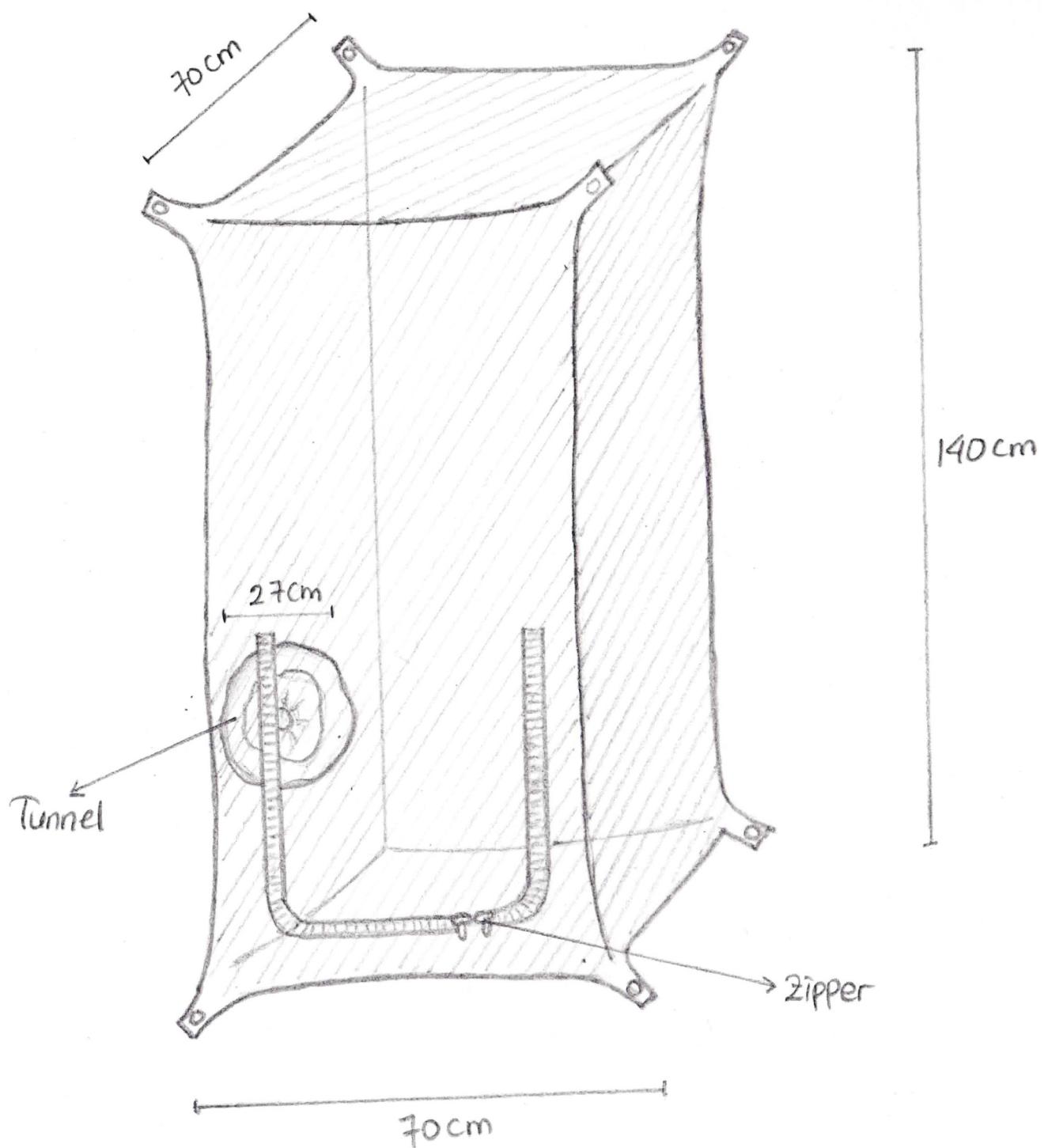
Date code	Description	Tray ID	Empty tray (g)	Wet weight and tray (g)	Dry weight and tray (g)
10.2	Dewatered waste	D	13.1	536.1	108.4
8.4	Residue	4	14.4	223.3	144.7
8.4	20 Larvae	%	3.13	6.45	4.20
Code of sample	ID of the tray. Is independent from its content and can thus be any number, sign or letter	Weight of empty tray (tare)	Weight of sample and tray before the drying	Weight of sample and tray after the drying	



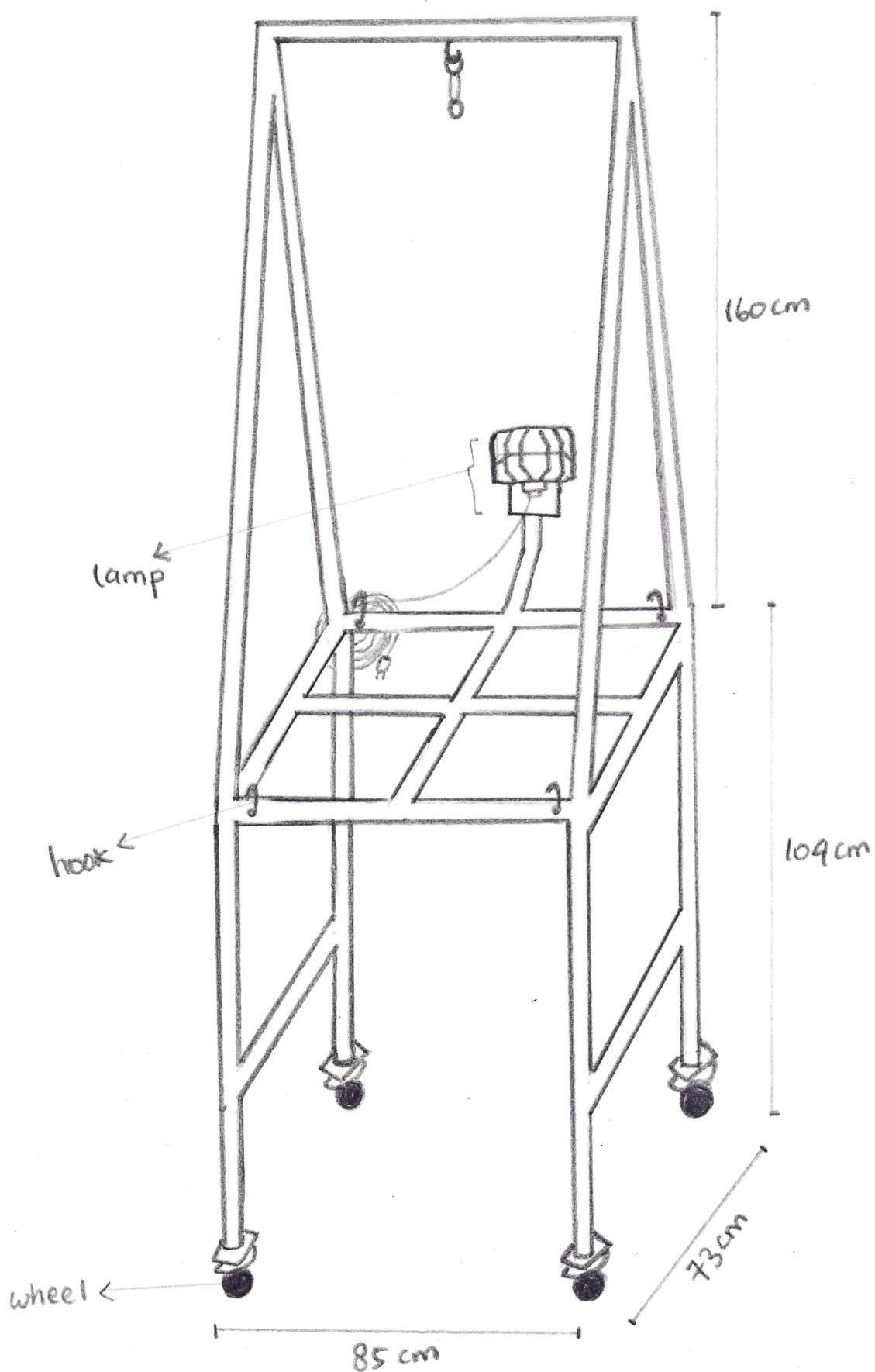
Chapter 5:

Blue Prints of Equipment

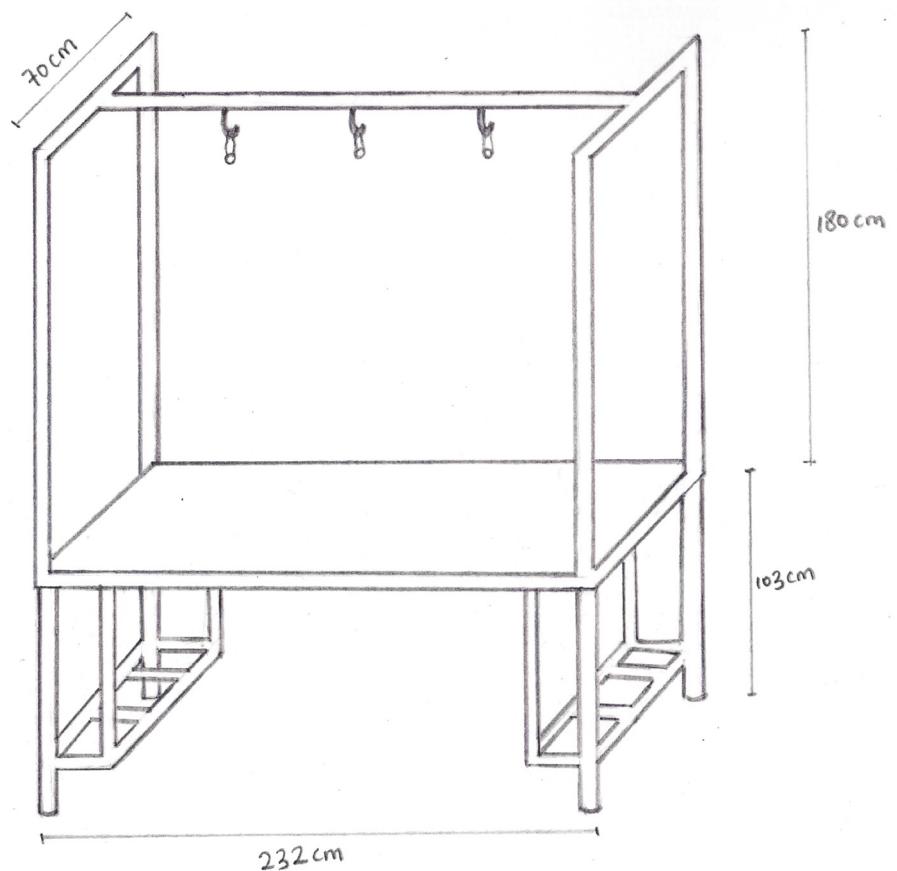
Blue print 1: **Love cage**



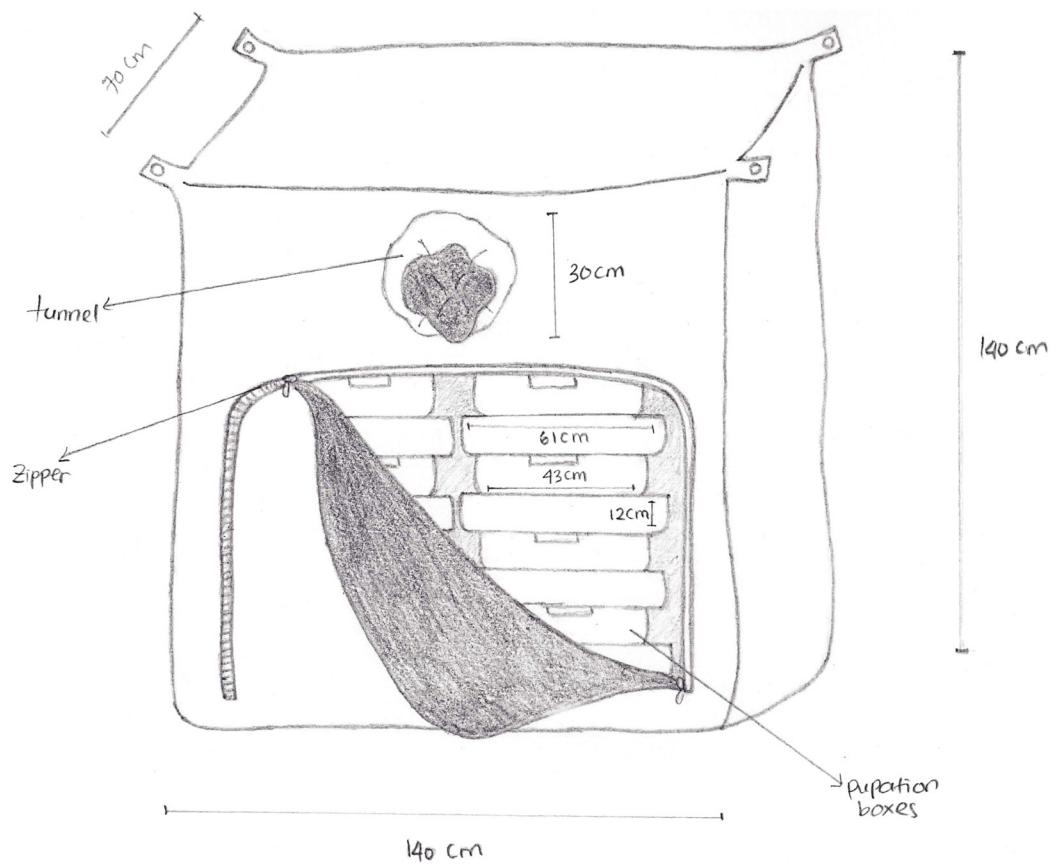
Blue print 2: **Mobile frame**



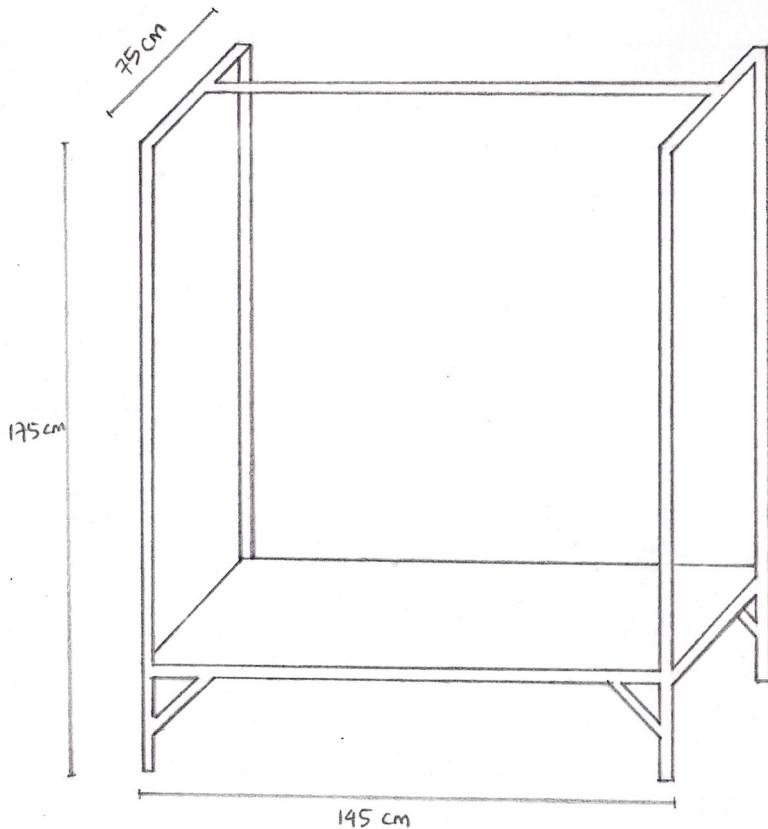
Blue print 3: **Love cage table**



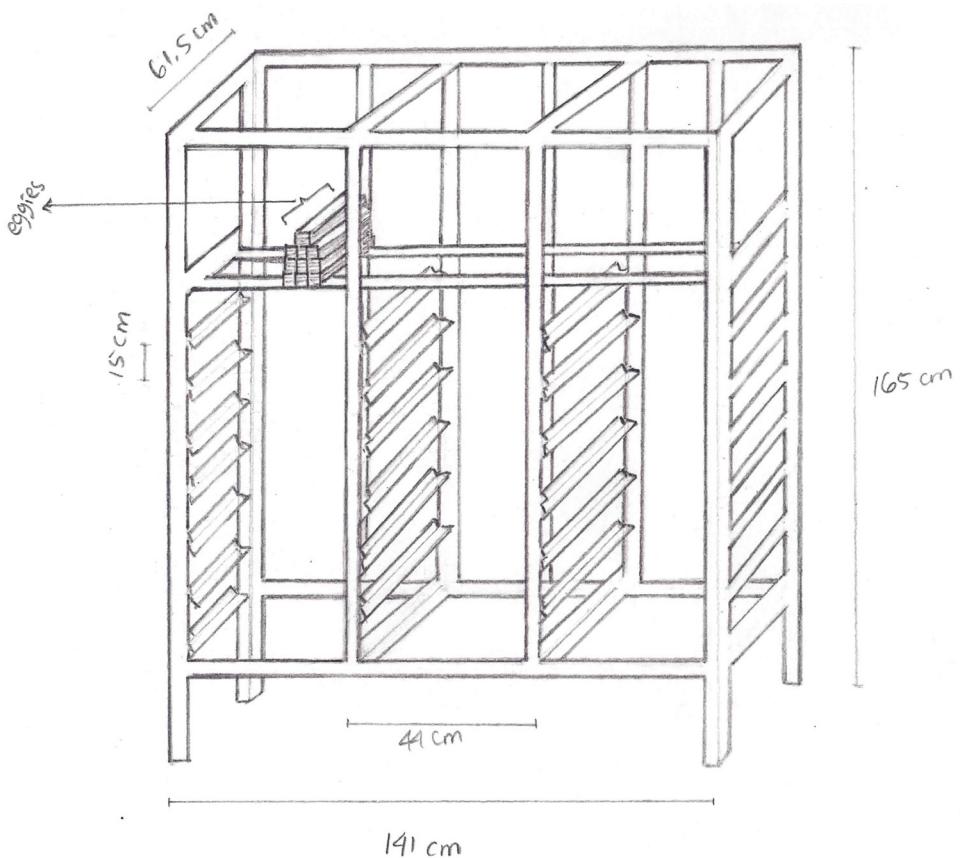
Blue print 4: **Dark cage**



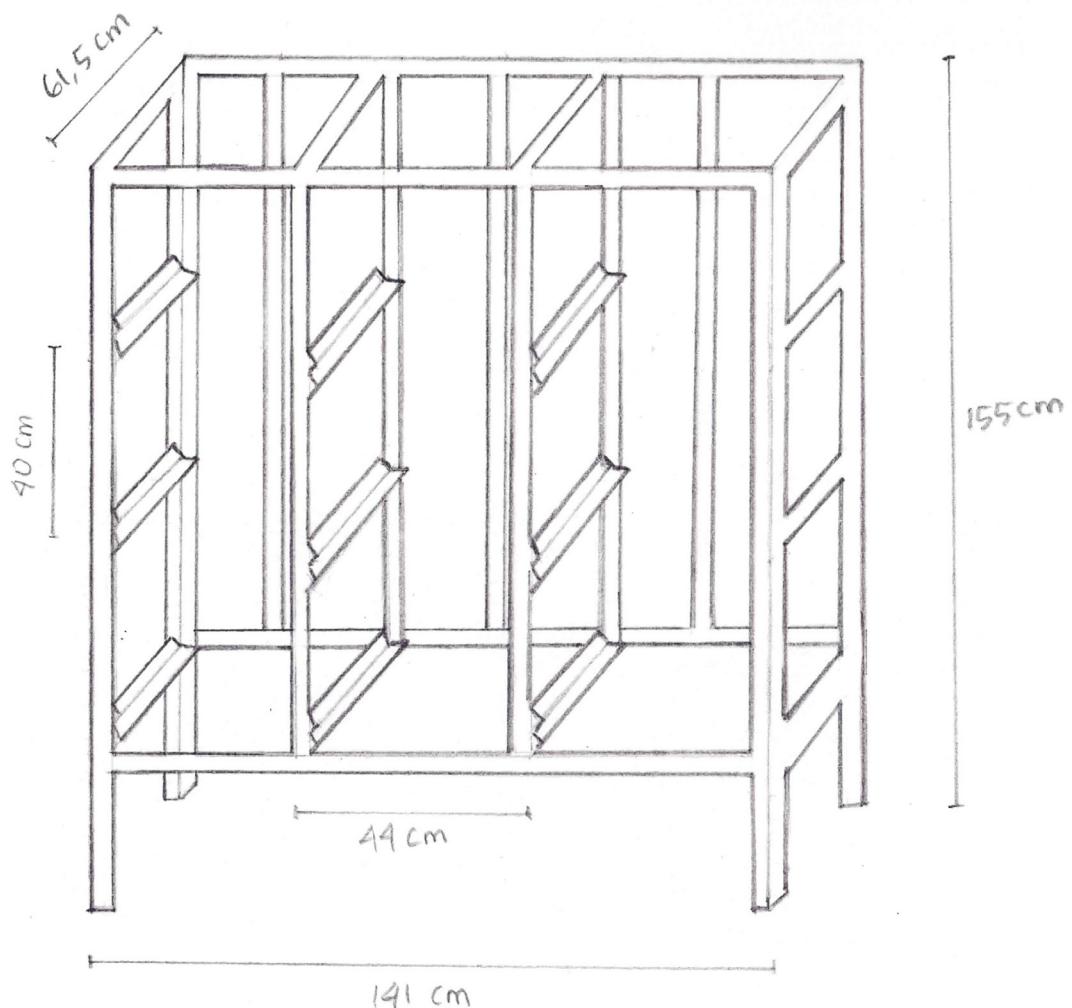
Blue print 5: **Dark cage table**



Blue print 6: **Hatching shower rack**



Blue print 7: **Nursery container rack**



Chapter 6:

Material Required in a BSF Processing Facility

6.1 Material for the BSF rearing unit

	Reference in the guidelines	Every day- Full capacity	Every day- Half capacity	Mon-Wed- Fri capacity
Love cage management				
Love cage	R1	7	4	4
Love cage hanger	R1	7	4	4
Love cage table	R1	2	1	1
Attractant container	R1	7	4	4
Shading basket	R1	7	4	4
Water bowl	R1	7	4	4
Cotton cloth	R1	7	4	4
Egg media ("eggie")	R1	7	4	4
Mobile love cage frame	R1	1	1	1
Attracting light	R1	1	1	1
Stick	R1	1	1	1
Ant trap	R1	8	4	4
Coloured rope (7 different colours)	R5	24	16	16
Binder clip	R1	4	4	4
Love cage management				
Dark cage and prepupae management				
Dark cage	R3	7	4	4
Dark cage frame	R3	6	3	3
Pupation container	R3, R8	128	64	64
Ant trap	R3	24	12	12
Pupation substrate (soil-like material)	R8	80 kg/week	40 kg/week	40 kg/week
Egg and 5-DOL management				
Metal shelve and hatching shower	R5	1	1	1
Hatching container	R5	24	12	12
Sieve (mesh size 1 mm)	R6	2	2	2
Cup for 5-DOL portions	R6	36	36	36
Nursery management				
Nursery container	R7	20	10	10
Transfer container	R7	20	10	10
Nursery rack	R7	2	1	1
General lab equipment and tools				
Protective clothing (gloves, mask, coat)	Always	Stocked	Stocked	Stocked
Precision balance (2 kg, 0.01 g)	R1, R5, R6, R7, R8	2	1	1
Bulk balance (15 kg, 0.5 g)	R5, R6, R7, R8	1	1	1
Tweezers	R6, R8	4	2	2
Click counter	R6, R8	2	1	1
Calculator	R6, R8	2	2	2
Masking tape	R1, R3, R5, R7, R8	Stocked	Stocked	Stocked
Marker pens	R1, R3, R5, R7, R8	Stocked	Stocked	Stocked
Spades, spoons and scoops	Everywhere	3	2	2
Jars, beakers and bowls	Everywhere	6	6	6
Plastic jar with cork pieces	R1	1	1	1
Dust bin, dustpan and brush	Everywhere	3	2	2

Machines				
Concrete mixer	R8	1	1	1
High pressure washer	R2, R4, R6, R7	1	1	1
Washing machine	R2, R4	1	1	1
Consumables, per week				
Chicken feed (kg)	R5, R7	25.2	12.6	14.4
Coco peat (kg)	R5, R7	1	0.5	0.5
Water (l)	Everywhere	1500	800	800
Matured compost/earth-like material (kg)	R8	80	40	40
Ethyl acetate (ml)	R1	2	1	1
95% alcohol solution (ml)	Everywhere	200	100	100
Cleansing agent (ml)	Everywhere	200	100	100

6.2 Material for the BSF waste processing unit

	Reference in the guidelines	Every day- Full capacity	Every day- Half capacity	Mon-Wed- Fri capacity
Waste receiving and pre-processing				
Bucket or other waste holding container	W1, W2	130	65	65
Dewatering bucket	W2	130	65	65
Cotton cloth	W2	200	100	100
Plastic frame for dewatering	W2	200	100	100
Waste treatment				
Conversion crate ("Larvero")	T1	2,808	1,404	1,404
Metal frame	T1	468	234	234
Pallet	T1	78	39	39
Harvesting				
Screen	H1	60	30	30
Harvesting container	H1	12	6	6
Bucket	H1	12	6	6
Drying container	H1	6	3	3
Shaking sieve (mesh size 3-5 mm)	H1	1	1	1
Post-treatment				
Gas stove	P1	1	1	1
Cooking pot	P1	1	1	1
Drying table	P1	6	3	3
General lab equipment and tools				
Protective clothing (gloves, mask, coat)	Always	Stocked	Stocked	Stocked
Precision balance (2 kg, 0.01 g)	T1, H1	2	1	1
Bulk scale (150 kg, 50 g)	W1, W2, T1, H1	4	2	2
Drying oven	T1, H1	1	1	1
Calculator	Everywhere	2	1	1
Masking tape	Everywhere	Stocked	Stocked	Stocked
Aluminium cup/pan	T1, H1	60	30	30
Marker pens	Everywhere	Stocked	Stocked	Stocked
Spades, spoons and scoops	Everywhere	6	3	3
Jars, beakers and bowls	Everywhere	Stocked	Stocked	Stocked
Dust bin, dustpan and brush	Everywhere	Stocked	Stocked	Stocked

Machines				
Shredder	W1	1	1	1
High pressure washer	Everywhere	2	1	1
Pallet trolley	T1	2	1	1
Consumables, per week				
5-DOL (x1,000)	T1	14,000	7,000	7,000
Coco peat (kg)	H1	2	1	1
Water (l)	Everywhere	2,000	1,000	1,000
Gas (l)	P1	42	21	21
95% alcohol solution	Everywhere	200	100	100
Cleansing agent	Everywhere	200	100	100

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Recycling organic waste material (biowaste) still remains fairly limited, especially in low- and middle-income settings, although this is by far the largest fraction of all generated municipal waste. This book deals with urban organic municipal waste from households, commercial activities, and institutions. It describes the approach of biowaste conversion by insect larvae, using the example of the Black Solider Fly (BSF), *Hermetia illucens*.

This engineered biosystem consists of feeding segregated biowaste to BSF larvae which have been reared in a nursery. Larvae grow on the waste feedstock and reduce its biomass. At the end of the process, larvae are harvested and, if necessary, post-processed to a suitable animal feed product.

This guide has been prepared for practical use, explaining the required materials and equipment, as well as each working step similar to a cookbook with its respective recipes. It includes all information necessary to develop and operate a BSF waste processing facility. The guide highlights the gaps where information is scarce or unavailable and points to further research and development that are required.

Two research projects provided the basis for this book. FORWARD is a 4-year-long applied research project that operated a pilot-scale BSF waste treatment facility at a local wholesale market of Puspa Agro in Sidoarjo, Indonesia. The SPROUT project on the other hand is a three-year multi-national project with SLU (Swedish University of Agricultural Sciences) in Uppsala Sweden and Pacovis AG Switzerland, geared towards developing a waste-to-value treatment with the Black Soldier Fly (BSF) larvae.