SUSTAVIANFEED

ALTERNATIVE ANIMAL FEEDS
IN MEDITERRANEAN POULTRY BREEDS
TO OBTAIN SUSTAINABLE PRODUCTS

EVALUATION OF THE UTILIZATION OF INSECTS AS A SUSTAINABLE FEED INGREDIENT

DELIVERABLE 3.1

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Document Responsible	ENTOMO
Contributors	Juan Antonio Cortes
Reviewed by	ALIA, UNITO and EGE

DOCUMENT AUTHORS AND AUTHORISATION	
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SUMMARY

The main objective of the deliverable is to report on the results of the implementation of the insect pilot in each location. The document pursuit to show how the pilots have been installed, the results on productivity obtained and to compare the positive and negative points of each facility. The document can be used as base for the decision taken about which kind of pilot is more suitable to be installed depending on the peculiar characteristics of each area. The deliverable is associated with task 3.1. Implementation of insects' farms at local sites. The document starts with the explanation of the three pilots and continue with the explanation of the experience in each of the locations, including the trainings, starting up and troubleshooting, productivity and other aspects related with the pilots like economic considerations.

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Acronyms and abbreviations

Abbreviation	Description
BSF	Black Soldier Fly
HVAC	Humidity Ventilation and Air Conditioning
IPP	Insect Production Pilot

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1 INTRODUCTION

In the context of the growing need to develop sustainable solutions for food production, the use of black soldier fly (BSF) larvae in chicken feed is presented as an innovative and efficient alternative. This practice not only contributes to the reduction of organic waste, but also offers a high-quality protein source, reducing the dependence on traditional feeds based on soy or fish, the production of which generates significant environmental impacts.

The incorporation of black soldier fly larvae into chicken diets and its's use as an environmental enrichment has been shown to be beneficial in several regions of the world. In countries such as South Africa and Indonesia, local projects have used this technology in rural communities to manage food waste while providing poultry farms with an accessible and sustai nable feed source. These models have inspired the implementation of similar projects in Europe, where organic waste reduction and local food production are both environmental and economic priorities.

In this pilot project, developed in the framework of a European consortium, three technological scales to produce BSF larvae have been evaluated: high technology scale to be implemented close to large waste production areas, a medium technology scale, suitable for centralized facilities, and a small scale for poultry farms producing chickens. The main objective of this pilot has been to determine whether local production of larvae, fed with organic waste generated in the same community, is efficient and profitable enough to justify its adoption in the long term.

The success of this activity would not have been possible without the active participation of local communities. In rural areas, where access to resources and technology may be limited, such initiatives offer multiple benefits. Firstly, it allows farmers to manage organic waste from their own activities, such as crop residues or unmarked food, transforming it into a valuable resource. Secondly, it improves the local economy by reducing the costs associated with the purchase of commercial feed and promoting food self-sufficiency. Finally, it contributes to the development of more resilient and sustainable production models, especially relevant in the context of climate change and economic fluctuations.

This pilot project represents an opportunity to assess the feasibility of this model in European rural communities. Its implementation can lay the groundwork for expanding the use of BSF in other animal production sectors, promoting a circular economy where waste becomes a resource, and reinforcing the role of rural communities as key actors in the transition towards more sustainable agricultural systems.

2 PILOT IMPLEMENTATION IN EACH LOCATION

The implementation of the insect producing pilots (IPP) entailed all the necessary actions to ensure that, starting from a situation of low knowledge of insect rearing, the partners involved were able to carry out the rearing independently in their respective locations. This involved, on the one hand, the construction of the pilots by Entomo and then their installation in situ.

As already mentioned in DLV 2.2., in the case of Tunisia there would be two types of pilots, on the one hand, a pilot with a medium technological level, which would be in ISA-CM, and on the other hand, a diversity of small pilots with a low technological level, which would be located in the farmers associated with Rayhana. The first case is characterised by climate control devices such as CO2 concentration, humidity and temperature, as well as different production elements to carry out the different phases of breeding, such as egg generation, larval hardening and larval fattening. There are also elements for cleaning and drying the larvae. The aim of this type of pilot is to serve as a test bed or demonstrator to produce larvae in a simple production process and to serve as an example for use in Tunisia. Beyond the project, the ISA -CM IPP (container) has been donated to ISA-CM to be used as a permanent entomological laboratory for carrying out tests with local substrates, theses with students, research and as a platform for disseminating the insect production system, where technology can be transferred and knowledge can be passed on to those people or entities interested in the development of this sector. In the second case, the Rayhana pilot, the main objective was to implement insect production at farm level, the user profile of this type of production being small farms isolated from urban centres but located a few kilometres away, with a production that provides an extra income for the family economy as well as guaranteeing the self-consumption of products. In this case, the IPP model had to be easily operated by the users and should not be energy demanding, so it would be exposed to climatic conditions. In this case also the larvae had to be fed with a diverse and locally available feed.

In addition to the physical implementation of the pilots, the other element necessary for these pilots to be functional is the implementation of trainings to train the main knowledge centres created by ISA-CM (at the academic level) and Rayhana (at the farm level) so that they could not only understand the process of larval production, but also be able to address any doubts that might arise from their affiliates.

The execution of the pilot activities suffered several delays mainly due to the delay in the construction of the ISA-CM IPP and later due to the difficulty in sending the IPP to Tunisia. Table 1 shows the final schedule for the execution of the pilots.

Table 1. Definitive calendar of insect pilot

No. Item	Actions to be conducted	Responsible partner	Deadline
1	Insect PILOT construction	ENTOMO	04/01/2024
2	Planning of dry insects needed for the feeding trial	ALIA, UMU, UNITO, EGE, ISA-CM, RAYHANA	07/03/2022
3	Pilot transport and installation	ENTOMO	28/10/2022
4	Workshop training in Tunisia	RAYHANA, ENTOMO	15/11/2022
5	Training Rayhana Team in Spain	RAYHANA, ENTOMO	05/10/2023
6	Workshop training Tunisia	ENTOMO ISA-CM	17/11/2023
7	Training workshop Rayhana Team	RAYHANA, ENTOMO	28/10/2024
8	Training workshop ISA-CM Team	ENTOMO ISA-CM	28/10/2024
9	Dry insect production	ENTOMO, ALIA, UMU, UNITO, EGE, ISA-CM, RAYHANA	Continuos

2.1 Murcia pilot

This pilot did not really need to be created as it was already located where the pilot plant in Murcia is located. This pilot is characterised by a high technological level, with a high level of control of all climatic parameters, such as CO_2, humidity and temperature, as well as measurements of ammonium and suspended particles. It has the capacity to produce a high level of larvae per square metre and machinery for intensive larval processing. The staff in the pilot has a long experience in insect production and years of working with insects even at the operator level.

In this pilot, larvae production work was carried out for the UMU (Figure 1) and UNITO trials. Production tests were also carried out and some production substrates of interest were tested, such as Opuntia stems, olive pomace and vegetable leaves, due to the interest that their use could have in other countries of the Mediterranean basin, where these products are very abundant and could have a beneficial effect.

Figure 1. Dry larvae supplied for UMU experiments

This pilot was also used to create economic estimates of BSF production and to study the life cycle. It was also used to elucidate what changes in production would have to be made to make BSF production economically viable as well as sustainable.

As one of Entomo's activities in the Murcia IPP, larval productivity trials were carried out using different types of waste/substrates, but which are commonly found in the pilots, or which are somehow abundant in the Mediterranean basin, so that it makes sense to incorporate them as a larval diet. Summarizing the experiment, to carry out the test, plastic boxes measuring 50X40X15 cm were used, which were filled with 5 kg of the substrate to be tested and a quantity of small larvae (5 mg/larvae) at 5 grams per box. The substrates to be tested were vegetable plant stems (tomato, bell pepper and cucumber), olive pomace, *Opuntia ficus-indica* stems, restaurant waste, beer bagasse and a mixture (diet mix) of olive pomace, Opuntia stems and fruits (25%, 25% and 50%, respectively). Time from small larva to emergence of first prepupae, mean final weight, total biomass weight, dry weight and amount of frass were recorded. Conversion and total productivity per kg of waste was estimated. Table 2 shows and summarise the results of the experiment.

Table 2. Results of the experiments on different waste sources

	Fattening(days)	Ave.weigh(mg)	Total biomass(g)	Dry matter(%)	Frass (kg)	conversion(1/X)	Produc/kg)(g)
Veg.shoots	22	79	227.479	19.25	2.016	22.0	8.75
Olive pomace	19	84	273.224	23.47	2.643	18.3	12.82
Opuntia shoots	14	193	613.025	31.22	1.980	8.2	38.27
Cantine waste	9	284	913.743	33.31	1.750	5.5	60.87
Beer bagasse	16	108	337.837	30.09	2.852	14.8	20.33
Mix	11	252	782.472	32.83	2.334	6.4	51.37

From the results, it could be observed how restaurant leftovers gave the best productivity with a ratio of 1 kg of about 5.5 kg of food and in the case of mix with 1 kg of fresh larvae for every 6.4 kg of food. Leaving this as suggested diets the restaurant scraps and the mixture of the different elements. Diets containing just olive pomace or horticultural shoots gave very poor production suggesting mixing them to achieve better productivity.

2.2 ISA-CM pilot

This pilot, as previously mentioned, represents the medium technological level, which means an average good production capacity in terms of kg of larvae produced per square meter of production. All the production processes such as egg generation, larval seed production, larval fattening, harvesting and drying can also be carried out. In addition, it contains the necessary elements to be able to carry out the processing of the food in a mixer, also the cleaning of the production trays and a space for changing clothes and a small space as a laboratory to take samples and observe them if necessary. All this makes it possible to achieve a production as mentioned in the indications (see deliverable D2.2.) of about 1.6kg of dried larvae per day from the 34 kg/day of waste from the canteen.

Pilot construction and installation in ISA-CM

For the realization of the pilot, there was a first design phase, taking as reference the climatic parameters of Tunisia as collected in deliverable D2.2. As main elements in the design, the climatic conditions of the area were considered, as they conditio ned the characteristics of the machinery to be installed to control the climate inside the breeding, understanding that the specific needs of the species are temperatures of around 28ºC and humidity of 70%, as well as CO_2 levels of around 1200 ppm, not only to improve the conditions of the breeding, but also for the conditions that the workers have to tolerate when carrying out their work. As an assembly platform, the refrigerated container was used as a base, as it has a good size (30m2), is resistant to maritime transport and has insulated walls that allow energy savings in cooling or heating.

The container was cleaned, the damaged refrigeration unit was removed, the exterior was painted, and the interior was refurbished to house the proposed parts. Figure 2 shows the design of the container as shown in the drawing.

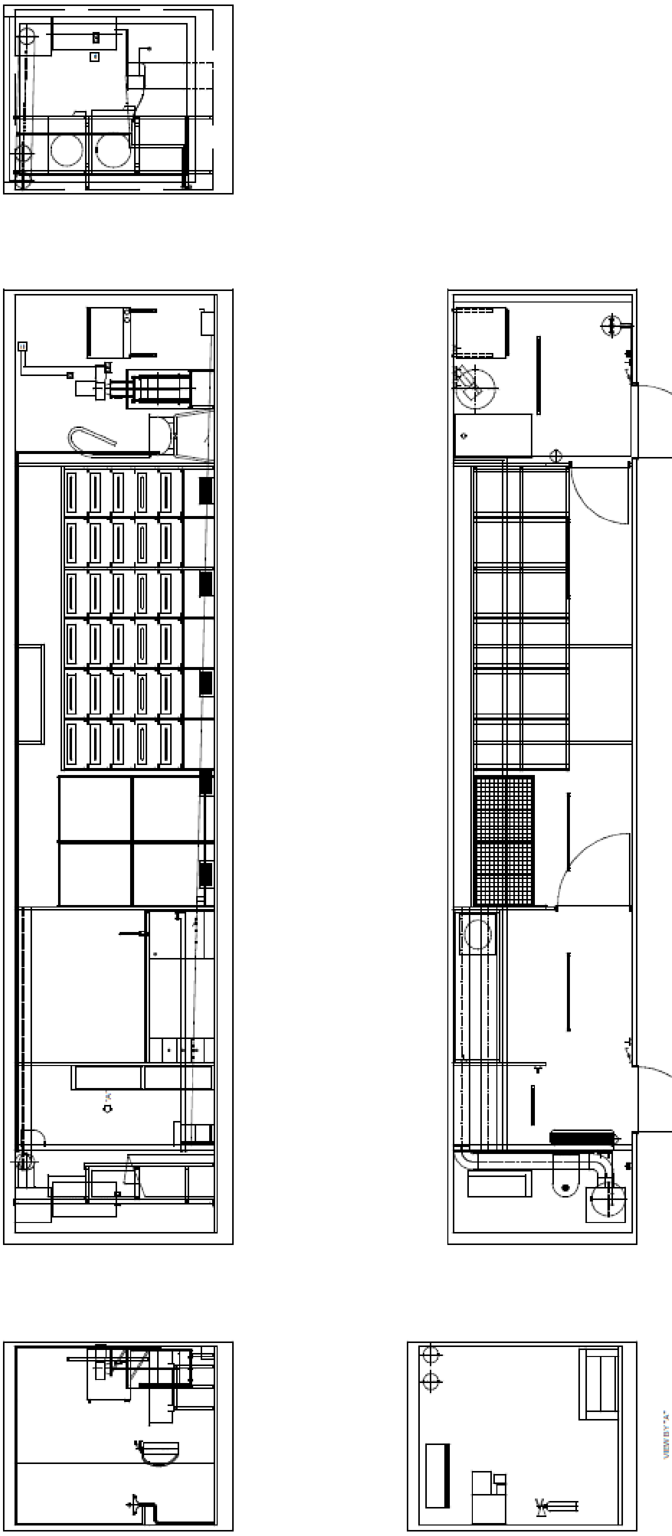

Figure 2. Plans of the container design

After designing the pilot inside the container and having the container ready for the construction of the entomological laboratory inside, an air distribution wall (Plenum) was placed, and the ventilation systems were placed in the false ceiling. Subsequently, the rest of the elements such as the rearing shelves, the adult cages and the cleaning and diet preparation area were placed, being built as shown in the Figure 3

Figure 3. Pictures of the inner part of the container once concluded

Once the pilot was fully completed, it was shipped to Tunisia, leaving the Port of Valencia and arriving at the port of Sousa. There it went through the customs clearance process and was then sent for installation at the location chosen by ISA-CM, together with the hen pilot. With this, the pilot was ready to be switched on and to do the production trainings.

Training in ISA-CM

To carry out BSF rearing, it is necessary to have a good knowledge of the biology of the animal, its nutrition and the techniques necessary to carry out each of the animal's growth stages. In the production system at the medium technological level, the following phases are considered: a) egg collection or adult handling; b) egg hatching and larval hardening; c) larval fattening; and finally, d) larval collection and pupation. Each of these phases requires several physical elements and tasks. All this necessary information was transmitted through two trainings. An introductory one was held during the 7th consortium meeting in Tunisia at the ISA-CM premises on 17/11/2023. The training was held in the auditorium of the university and the theme of this first training was an introduction to insects as an alternative source of income for farmers and how to carry out BSF rearing tasks. The Figure 4 shows the training in the auditorium.

Figure 4. First training in ISA-CM

To start with biological material, a BSF reproductive population of pupae that would give rise to adults and small larvae was provided to start fattening them on a standard diet. After several days of monitoring, this population achieved good larval growth. This population reached prepupal size by the end of the visit period and was ready to give rise to the next generation of adults. From the pupae provided, adults were obtained that managed to lay clusters of eggs, although these were not viable at first. In any case, continuous mating was observed. The Figure 5 shows the beginning of the biological material with the adults and small larvae added to the substrate.

Figure 5. Biological material giving and starting the colony in the ISA-CM IPP. Left small larvae started eating, right prepupa going to be released in the adult cages.

All this necessary information was transmitted through two training courses. An introductory one was held during the 7th consortium meeting in Tunisia at the ISA-CM premises on 17/11/2023. The training took place in the auditorium of the university and the theme of this first training was an introduction to insects as an alternative source of income for farmers and how to carry out BSF rearing tasks.

The second training was carried out over several days during Entomo's extended visit to Tunisia, the main date being the 23rd of October where the training first took place in an ISA -CM auditorium (see Figure 6) as a refresher on BSF rearing techniques and then went to the container where a population of BSF were already eating, adults and some eggs was already contained in order to demonstrate the operations in situ (see Figure 7). The attendance was mainly of animal production students from ISA-CM (see Figure 8) to stimulate interest in the technique and for the emergence of new vocations.

Figure 6. Second insect training at ISA-CM in the auditorium

Figure 7. Second training with biological material in the IPP

Figure 8. Group picture at the end of the training

At the end of the visit, it became clear that, at the end of the project, one of the problems that could arise is that the lack of knowledge in insect breeding would mean encountering failures that would be difficult to solve, or their solution would prevent an adequate use. It was therefore decided to create an ISA-CM-Entomo collaboration agreement, so that at the end of the project progress could be made on the insect issue(see ANNEX II). This agreement was signed (see Figure 9) and its scope included technical assistance, co-tutoring of students doing projects and theses on insects, dissemination of the benefits of insects, internships, research and project development to promote common interests.

Figure 9. Collaboration agreement sign ISA-CM-Entomo

2.3 Rayhanna pilot

The purpose of the Rayhana pilot is not to create a high-yield production unit, but to create a unit that is easy and economical to replicate, so that it can be easily assimilated by local farming populations, and they can benefit from this source of protein for animal feed. For this type of implementation, a much more horizontal approach to the problem was chosen, involving the local populations. Therefore, site visits were made, local materials were sought, t he knowledge and recommendations of the population were considered, and material was created for implementation in the area. The pilot had to meet the following requirements:

a) The materials used should be easy to find locally.
b) The procurement of the materials must be inexpensive.
c) The design should be simple without the need for complex tools.
d) The design should allow all stages of rearing to be carried out in a single element to simplify the work and reduce it as much as possible.

e) The design should at least partially compensate for unfavourable climatic conditions.

The pilot was developed in three phases:

Phase I: the first phase started with a technical visit by Entomo technical staff to Tunisia, this visit took place in December 2022 from the 13th to the 20th. In this visit they proceeded to visit farms to learn about the possibilities and working conditions, search for nearby materials to be able to build the pilot and training on BSF breeding.

Phase II: in this part, staff of the Rayhana team visited the facilities of the pilot in Murcia to learn everything they needed to know about the biology and breeding of BSF during several days in the facilities accompanied by the operators. Dates: 2 -5 October 2023 We also proceeded to the construction of what was to be the model to be implemented later in Tunisia and created graphic material and content for the BSF breeding guide/manual that would later be presented to the farmers in the form of a pamphlet" larvae breeding guide" see ANNEX I.

Phase III: This took place during the first and last week of October 2024, in which the production of biological material was implemented, the growth of the larvae was monitored, and the final training was carried out with the farmers on their own farms and at Rayhana's facilities.

During the phases mentioned above, construction, implementation and training were carried out at the same time, with feedback in each situation. Although the phases are shown separately, the implementation and training phases are shown separately to facilitate the reading of the document.

Pilot construction and installation

To arrive at the final design, an on-site visit to the situation of the farmers was carried out, as well as a visit to shops selling materials for the house and farm. In these shops it was observed what types of materials are present in the area, as well as the cost of implementing them. We also proceeded to purchase them and then proceeded to carry out the training. Figure 10 shows the outline of the design that it was decided to implement. For this design, it was decided to reduce in a single space what would otherwise be done in different phases and spaces. To achieve this, we based our design on the principle of the biopod, which is a plastic container in which organic waste is placed inside for the larvae to breed, and whose walls have ramps for the larvae to leave the container when they are ready to pre-suckle (at this stage the larvae migrate naturally in search of a dry place). These ramps direct the larvae to the outside so that they can be collected in a dry container, where they can then be given to the hens, or a small fraction can be kept continuing the process.

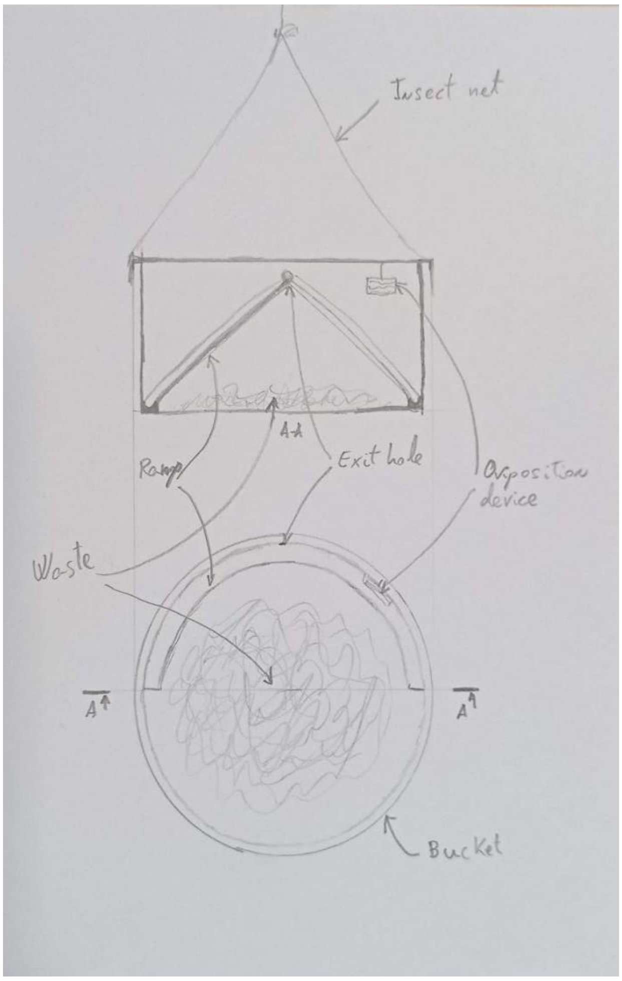

Figure 10. Draft proposed design for simple easy insect production on farm

The substantial difference is that biopod is designed to collect eggs from BSF-free adults, whereas BSF are not substantially present in Tunisia and are likely to be very rare or absent in summer and winter. To overcome this problem, the model of this pilot is fitted with a mesh on the top of the larval holding container to keep the adults confined. The design elements are as follows.

1. Plastic container at the base: this serves as a receptacle to receive the waste and for the larvae to fatten. For this element, it has been decided to use the plastic container because it is cheap, abundant, easy to acquire and because it is impermeable, keeping the leachates from the decomposition of the waste and thus retaining the humidity necessary for the larvae to fatten well and, incidentally, creating an environmental humidity near the base that guarantees the hatching of eggs.

2. Ramps on the sides: These ramps are made with cement or plaster, and their purpose is to allow the pre-pupae to climb once they have been fattening in the container for the necessary time. Cement (although gypsum can also be used) was chosen because it is a mouldable material that is easily found anywhere and has a good durability. The ramps are constructed in such a way that the slope of the ramp is less than 45Cº and that they end up in a hole at the top of one side.

3. Netting covering the container: This netting has several functions, on the one hand to prevent the adults from leaving the area and on the other hand to prevent the entry of adult blow flies, the larvae of which cause decomposition of the waste and compete for food with the BSF larvae. The space created should be high enough to allow the adults to fly so that they can mate (adults mate during flight). This height does not need to be more than 1 m and 50 cm is usually sufficient. In addition, if the netting is dense, it also serves to raise the relative humidity and temperature where the adults need it, and this temperature and humidity come from the decomposition of the waste.

4. Oviposition elements: This is any rough, grooved element that remains dry, as these are the conditions preferred by the adults to lay their eggs. Ideally, although these laying elements should be dry, it is advisable to keep them in a place with high relative humidity (above 80%) and close to a place with odors of decomposition and larval feeding, which is ideally hanging on one of the walls of the container near the waste but without touching it, as this is very humid.

Training in Rayhana

As mentioned at the beginning of this section, the implementation of the pilot in Rayhana was carried out in three phases and in each phase different objectives were achieved.

During the first phase, the area was visited and with the results obtained, it was concluded which design would be implemented with the farmers. Material was also purchased, and a training session was held with the farmers at Rayhana's facilities. The content of the training was as follows:

- Insects as a business activity
- Benefits of BSF rearing
- Introduction to the production stages
- General preparation of rearing material

Figure 11 shows several pictures of the training with the farmers.

Figure 11. First training with farmers in Rayhana facilities. Picture up shows materials and down farmers during implementation

During the second phase of the training, Rayhana staff traveled to the Entomo production pilot in Murcia, where they were taught how the larvae should be reared and the biology of the species. The objective is by the direct handling of the animals and by carrying out the production tasks, to be able to give a deeper understanding of their care. To this end, the Rayhana team accompanied the workers in all the tasks such as: a) preparation of laying nests; b) egg collection;

c) egg and hatchling quality control; d) hatchling hardening tasks; e) larval feeding and fattening tasks; f) larval collection; g) pupation process; and h) preparation of cages for adults to close the cycle.

Also, during this training, the creation and preparation of the material to be used in the rearing once the pilots were installed in Tunisia was carried out, consisting mainly of the preparation of the egg collection devices and the creation of the base pool of the production system. Figure 12 and 13 shows several images of the moment when the rearing materials were prepared.

Figure 12. Rayhana team showing the prepared material for insect breeding in training 2(Murcia)

Figure 13. Rayhana team in Entomo´s facilities preparing the insect breeding material

Finally, during phase 3 of the training, biological material was installed in the form of small larvae and pupae, which gave rise to the first BSF population. This same population was then taken to different farm locations where broodstock was started (Figure 14). In addition, rearing management, especially feeding, was explained to the farmers (Figure 15 and Figure 16)

Figure 14.Planning the works during Phase III training and insect material for starting insect production

Figure 15. Training at Rayhana farmer about material preparation and feeding

Figure 16. Completion of insect rearing simplify model at farm

Subsequently, a training session was held at Rayhana's facilities with farmers who were given more details of use, as well as more details of management using the biological material provided (Figure 17), thus completing the training process provided by Entomo.

Figure 17. Final training with farmers at Rayhana

3 PILOTS SUGESTED MANAGEMENT

Throughout the course of this task, notes were taken from observations and interviews with the task participants. From these interviews we gained an idea of how best each pilot could be operated and how it should be managed to get the best out of it. The m ain issues that have been assessed are maintenance costs, accessible food resources to feed the larvae, as well as the potential for sustainability and refloating in case of collapse.

3.1 Management of Murcia pilot

Background description

The pilot is characterized by high technology production with high level climate control, this means that HVAC systems maintain the temperature in each of the chambers at levels of 28-29ºC and a relative humidity of 75-85% while CO2 levels are kept below 1200 ppm, all of which usually translates into high energy consumption, which translates into a higher cost per unit produced and a higher carbon footprint.

The staff is made up of highly educated technicians and operators who carry out the day-to-day tasks of maintaining the larvae. This has a positive effect on rearing quality and control, but a negative impact on cost.

The larvae produced in the pilot were fed a cereal-based diet to achieve a stable population over time and avoid production problems. There are two problems with such feeding. On the one hand, the production cost of the larvae is too high to be able to offer the larvae in chicken feed in a real environment, on the other hand, the sustainability of the process would be in question as nutrients of vegetable origin would be fed to the larvae, assuming nutrient losses instead of directly nourishing a very efficient species in nutrition such as chickens.

Some of the operations are carried out relatively inefficiently, such as the use of a convection dryer to dry the larvae. It has recently been seen that the Entomo facility consumes around 3 kW to dry 1 kg of water, whereas the same amount of water could be evaporated with only 1 kW of power. This is due to the use of an inefficient electric convection oven. It is understood that such inefficiency makes the carbon footprint of the process too high.

The screening process to separate the larvae from the substrate is done by an orbital screener that has different meshes to separate each fraction. But particles that are the same size as the larvae often pass as contaminants to the larvae. This can be considered a lack of quality.

The pilot is normally used to perform different larval checks with different waste. The cohabitation of these residues with the larvae, even with dried larvae, can lead to contamination with pathogens such as Salmonella, which can cause quality problems.

Suggested management

Against the above background, the following steps are suggested:

The energy cost due to the precise climate control is difficult to modify, as it is expected to keep the rearing as close to optimal as possible, however, three guidelines could improve the energy efficiency of the process and thus the production cost associated with this part:

1. The installation of enthalpy recuperators in the fattening chambers (which are the most energy demanding) that recover the temperature of the outgoing air to recondition the temperature of the incoming air, which could improve energy efficiency by up to 25%.
2. Changing the setpoint temperatures of the chambers so that they are closer to the outside environment in each season, because, although the optimum production temperature is 28-29ºC, and at that temperature the fattening cycle takes a few days (14 days), rearing at 24ºC would take 16 days and at 33ºC it would take 11 days. But the intrinsic cost in energy to maintain optimum development is greater than the benefit of the larvae occupying the chamber space for longer in the case of overwintering and would produce a greater benefit in summer by occupying the chambers for less time. This improvement could reduce energy costs by 20%.

3. Maintain a higher occupancy of the chambers. This is because the chamber consumption is not proportional to the amount of load. It is estimated that high chamber occupancy could save 7% of energy.

To feed the larvae more efficiently, it would be necessary to feed them with waste from the vicinity of larval production. In terms of existing waste, the most suitable would be waste from the brewing industry, waste from oil production and waste from the destruction of vegetables produced in the region. With all this and making an estimate of the cost of this product, acquisition and transport, it gives an approximate cost of 7 euros per tons of products, which, assuming a productivity of 1 kg of fresh larvae for every 9 kg of food, would result in a cost of around 63 euros per tons of fresh larvae. The larvae produced in this way would be much more sustainable. In addition to the economic savings, considering that the cost of production with current grain is €350 per ton. As for the reduction of drying costs, this can be solved by installing a gas-heated vacuum dryer, which achieves an energy efficiency of evaporating 1 kg of water using 1 kW of heat.

To improve the screening process and to remove impurities, gravimetric vibrating screen should be added, which separates elements of different weights, so that contaminants such as stones, glass or plastics, even if they have passed the first sieving, will be separated in this system due to the differences in density.

To avoid cross-contamination between waste and final product, it is recommended that the product production areas be separated from the animal fattening and waste reception areas, and the flow of personnel, materials and equipment should always be in a dir ection that prevents contamination. Continuous analysis of batches will allow contamination to be identified and affected batches to be avoided.

These recommendations will improve production efficiency, reduce production costs, reduce the ecological footprint and avoid quality problems.

3.2 Management of ISA-CM pilot

Background description

In the case of ISA-CM, the pilot is located on the ISA-CM university campus surrounded by crop fields, some in greenhouses, and livestock experimental plots. Sousa's climatic conditions are characterised by mild winters and summers and often relatively high humidity. However, it is influenced by the direction of the winds, which, when they come from the Sahara, produce higher temperatures and very low relative humidity. In any case, the high temperatures that can be reached in summer seem more worrying than the low temperatures in winter.

The type of people who can take care of the rearing would be students or laboratory staff of the university who normally must attend the university on a regular basis, but with this comes the inconvenience that during the summer months the students are not present or even the staff may be on their holiday break.

As food for the larvae, one can expect to use mainly leftover food from the canteen, characterised by leftover bread, soups, pasta, pulses, fruit and vegetables, as well as waste from food preparation. It is generally considered that foods that are good and common in the human diet are suitable for feeding larvae, so canteen leftovers are suitable. As a limitation, only a limited amount of waste is generated in the canteen, and this waste is not present at weekends and during holiday periods when the canteen is closed because there are no diners.

From an energy point of view, the pilot has to be exposed to too high temperatures in summer, which, even if the pilot is equipped with appropriate insulation and a sufficiently good HVAC system to maintain optimal rearing conditions, the energy consumption during the summer period may be too high to make it worthwhile to maintain larval production during this period.

Suggested management

For the operation of the pilot, it is suggested to use as the main feed source the remains of the canteen, which should have a yield of approximately 1 kg of fresh larvae for every 4.5 kg of feed provided. In any case, in case of material shortages, a stock of chicken feed could be kept in reserve either to supplement the feed or to be used as a supply in case there is not enough in the canteen. On the other hand, the daily collection of feed from the canteen is certainly necessary to reach an agreement with the hostelry, but the daily grinding of the feed and its distribution to the animals can be a cumbersome and not always the most productive task. Instead of daily processing, it is suggested to pour all the collected contents into the mixing container with a capacity of 200 liters, together with an acidified solution with hydrochloric acid, the aim is to leave the remains macerating and at a pH below 4 so that microorganisms that could produce unpleasant odors do not thrive. Daily, the agitator can be put on after adding a new load, so that the mixture becomes more uniform, the particle size is reduced, the viscosity is increased and the digestibility by the larvae is improved. Then, when a complete batch of feed has been created (full tank), the contents can be poured into the trays and small larvae can be added to start digestion, without having to re-feed until the end of the cycle or only once a week. This avoids having one person feeding the larvae daily.

Although it is advantageous to have students interested in rearing larvae for their internships, theses or experiments, in many cases there may be circumstances that cause the production of larvae to become disordered. Advantageously, hardened BSF larvae can be stored at room temperature for 3 weeks when kept under suitable conditions and 6 weeks if kept at cooler temperatures and retaining their humidity. This principle can be used either to have a reserve population of larvae to be used gradually, or to start trials on an ad hoc basis or as a backup population in the event of a rearing error. In any case, this population should be kept in a different place than the pilot site and it would be better to keep it in the animal production laboratories. This form of preservation could also be used during the summer period to reduce maintenance work.

The summer period seems to be difficult to keep the pilot in operation, lack of people to look after the population, too high temperatures that would increase the energy consumption of the container too much, possible power outages that could stop the pilo t and consequently destroy the breeding, and lack of food as the canteen would be closed. Therefore, it is suggested that the best way to keep the larvae population at a low level of development would be to develop three strategies of low care and low larval development.

1. Keep small larvae in optimal condition to keep them for a period of 4 weeks. The first larvae will start to be retained from the eggs developed in the last weeks before the start of the holiday period.
2. Larvae that have been kept for 4 weeks and are almost at their biological limit should be fed on a low concentration diet, consisting of a milk solution, where the dry matter content has been reduced to 1.5 %, which is normally obtained by diluting one par t milk into 7 parts demi water. With this, the larvae develop steadily but very slowly, the only precaution being to add more diet as soon as it evaporates so that they never lack hydration. With this process, development can be prolonged for 6 weeks until the first prepupae begin to emerge. Currently, a normal diet is added so that all larvae reach the prepupal stage.
3. Once pupated, the pupae can be kept in cold storage, so that development can be delayed by 4 weeks.

Using all three strategies, the population can be maintained for a period of 20 weeks with very little effort. After this, eggs can be obtained from adults and rearing can begin in the normal way. For ease of management, it is recommended that rearing is carried out in batches starting once every two weeks to reduce the number of daily labor while maximizing production.

3.3 Management of Rayhanna pilot

Background description

For Rayhana, the pilot is not really located in a specific place but consists of a myriad of pilots implemented on the farms of the designated women. The location and meeting point is Rayhana's offices, where the team carries out various tasks. This location has several rooms with the function of offices, meeting rooms, a kitchen and rest area as well as a courtyard and garden around the house. The designated farms, on the other hand, are usually situated in locations away from the main urban centre but in places with a certain degree of habitability, or in other words adjoining farms with one or several semi-detached houses on each farm, which together form a slightly populated area. In the plots there is usually a mixture of self -consumption crops of fruit trees such as olives, grapefruit, pomegranate, etc. combined with the presence of some animals such as chickens, lambs, goats and cows and some meadows for the cultivation of cereals or vegetable gardens. The climatology in the Jendouba region is characte rised by summers that can be very hot, but also with winters that are very rainy, especially in the mountains to the north and the farmers located there are exposed to cooler temperatures and higher rainfall. Winter does not seem to be a handicap since although temperatures may drop, they are not so low as to kill the larvae, but rather to slow them down.

As workers, everyone is accustomed to domestic animal husbandry and therefore to persistent care, understanding that every task needs to be performed such as feeding or providing clean water if the animals are to maintain good productivity. People are well accustomed to work, although they perform many functions a day between looking after the house, children, animals and working outside the home.

There are not many sources of food available nearby, as there are no large producers in the vicinity. However, they are often surrounded by plants such as *Opuntia ficus-indica*, which can be a persistent resource. These can be a persistent resource in any season. There are also frequent weekly flea markets in nearby towns that generate a large amount of plant waste, as well as the waste generated in some restaurants in nearby towns.

Suggested management

The most appropriate management is for each farmer willing to join BSF breeding to carry out her own breeding by closing the whole cycle. However, as the population maintained by each cooperating farmer would be too small, there is a risk that the population could collapse and disappear, either during hot summers or due to dry summer winds. It would therefore seem interesting to have a center that would be responsible for maintaining a stable population and producing hardened larvae that could later be redistributed by the farmers who have lost their offspring.

For larval feeding, the most stable resource seems to be the use of Opuntia stems, which is very abundant in the area and can constitute 100% of the larvae's diet. Even though Opuntia is abundant, if we depend on this resource as the only food for the larv ae, the pressure on the plant in continuous pruning would be too much, so it would be better to proceed with plantations of this plant. A possible diet would be the use of olive pomace from oil production. This can constitute up to 30% of the final mixture, which could be accompanied by the vegetables collected in the markets and the remains of restaurants.

Although this type of larval rearing operation is possibly economical and easy to implement, due to the amount of waste from restaurants, vegetable waste from flea markets and olive pomace, it could be suggested to build a small farm that could produce larvae without having an intense energy consumption and then distribute them among the grape farmers or market them. This would optimize and professionalize the waste collection process, the rearing itself and the production of final products (dried larvae and fertilizer) that could be marketed locally.

The cost of production is difficult to estimate but by eliminating the cost of labor and purchasing the materials locally, it is possible that the amortization of the investment of each pilot (approximately 8€) could be recovered in a period of 12 months depending on the seasonal productivity and food provided. After that period any larvae produced would have a negligible cost. It is estimated that the maximum production per plastic container could be 1 kg/week, which in dry weight would result in approximately 300g of feed.

4 PROBLEMS ENCOUNTERED AND SOLUTIONS

During the execution of the pilots, the different problems encountered were observed and noted down to take measures that would help to improve their operability or improve their efficiency . Table 3, 4 and 5 it is shown the different cases encountered and the measures proposed to solve the problem.

4.1 Murcia IPP

Table 3. Problem encountered and solutions for Murcia IPP

Problem encountered	Proposed solution
High energy consumption both in the production of larvae and in the drying of the larvae. This leads to high production costs. -	In the case of production, the following measures will be adopted: - Increase the occupation of the chambers - Bringing the temperature set point closer to room temperature at the expense of changing the cycle length. - Implementing the use of enthalpy recuperators - Change the type of drying to gas drying.
Unsustainable feed as cereals is used in the formulation.	To solve this, the diet of the larvae will be changed to a more sustainable one, based on detritus fruits, olive pomace, and beer bagasse.
Presence of improper particles in the dried larvae	Improve the screening system and add a gravity separation system to separate particles such as plastic glass and metals from the larvae.
Productivity too low with some of the substrates	Perform nutritional analysis beforehand on each substrate and add the missing elements to improve nutrition a priori. In this way, problems of too low productivity for a substrate will not be encountered.

Contamination with pathogens	- Change workflows so that inputs (with contaminants) are not mixed with outputs (free of contaminants). - Store in separate locations - Implement analysis system to control contaminations -

4.2 ISA-CM IPP

Table 4. Problem encountered and solutions for ISA-CM IPP

Problem encountered	Proposed solution
Pilot mechanical problems such as condensation drips, drain failure.	Create a user's manual to understand how each of the equipment works so that ISA-CM has them available.
Lack of adult fertility	- - Revise the hours of illumination to at least 8 but ideally 12. - - Increase relative humidity to ensure oviposition. - - Check for longer maturity of oviposition attractant.
Larva mortality	Ensure that dietary moisture is adequate to prevent larval death.
Too high temperatures and low humidity during summer months	To limit IPP works during summer and enter in larvae low development strategies.
Lack of knowledge to solve problems during future problems	To create a collaboration agreement between ISA-CM and Entomo for technical assistance, co-tutoring student thesis, to prepare technology transfer conferences about insect and to perform research.

4.3 ISA-CM IPP

Table 5. Problem encountered and solutions for Rayhana IPP

Problem encountered	Proposed solution
Lack of enough food to supply to the insects	To use Opuntia as one of the feed sources and pick up waste from restaurants and open markets
Population eventual collapse at any pilot	To create a backup insect production located in Rayhana office or at the location of any of the partners where seeding larvae could be produced to re- distribute to any of the farmers who need it
Lack of climate control	Although difficult to solve, creating the backup population could restock with larvae when any farmer loses it
Problems for technical assistance	To create a collaboration Entomo- Rayhana for technical assistance after project finalization
Low productivity per bucket unit. Which cannot satisfy all the larvae needs per pilot, especially in those farms with high chicken population	To increase the number of buckets used in each farm or use a bigger recipient to carry the production.

5 CONCLUSIONS

The pilots related to insect rearing, IPP, have been implemented correctly, although with a certain delay due to delays both in the construction and completion of the IPP of ISA-CM, as well as the process of shipping the pilot by sea.

For the realization of the IPP it has taken not only the construction of them but also a series of trainings along the execution of the activity. In the case of ISA-CM there have been two trainings, the first as a workshop in the auditorium of ISA-CM and the second over several days that were distributed over a period of three weeks of work by Entomo that took place in October 2024. In the case of Rayhana there have been three trainings, one in Tunisia in 2022, another by the Rayhana team in 2023 and finally in parallel with ISA-CM in October 2024.

The problems encountered during the period of execution of the activity have been diverse, but in the case of the IPP in Murcia, they can be summarized as problems with production costs and quality control. In the case of ISA-CM, technical problems due to lack of training and delays in the installation of the IPP. In the case of Rayhana, it seems that there could be problems with the supply of inputs to feed the larvae and stability in their production. In any case, all the problems encountered could be solved and several proposals are made in sections 3 and 4 of this document. For technical assistance after the execution of the SustAvianFeed project, collaboration agreements have been established between ISA-CM and Rayhana, which will allow further development of their activities in the future.

The production cost of the pilots has been estimated, making it clear that in the case of IPP from Murcia the production of larvae would not be competitive at present, but it could be in the future. In the case of IPP of ISA-CM, similarly to what happens with the previous one, it will not be competitive economically speaking, since it has an energy consumption higher than the value of the larvae produced. In any case, both approaches would be economically adequate by rethinking the scale and management of the equipment used. In the case of Rayhana, the IPP model does appear to be economically viable and scalable, its only limitation being the ability to collect enough waste without incurring a high cost. For the above mentioned, it could be suggested the implementation of Rayhana's IPP model, taking it to a larger scale to take advantage of the economy of scale. Advantageously, if a good waste collection system is worked out, the climate, human resources and implementation costs would make the area suitable to make a good enough scale model to serve as an economic demonstrator of the application of this new production model using BSF.

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ANNEX I. Insect breeding guideline

SUSTAvianFEED

PRIMA

OCTOBRE 2023

LARVAE BREEDING GUIDE

دليل تربية اليرقات

Context السياق

This Guide has been realized within the framework of project :

SUSTAvianFEED: Alternative animal feeds in Mediterranean poultry breeds to obtain sustainable products

This project (grant Number 2015), is part of the PRIMA programme, supported by the European Union

مشروع أعلاف حيوانية بديلة في سلالات الدواجن في منطقة البحر الأبيض المتوسط للحصول على منتجات مستدامة

هذا المشروع (رقم المنحة 2015)، هو جزء من برنامج بريما، المدعوم من الاتحاد الأوروبي

SUSTAvianFEED - ALTERNATIVE ANIMAL FEEDS,IN MEDITERRANEAN POULTRY BREEDS TO OBTAIN SUSTAINABLE PRODUCT

This project (grant Number 2015), is part of the PRIMA programme, supported by the European Union.

مراحل البناء
BUILD YOUR KIT

Materials: المواد

Preparation of support for the kit

The nesting boxes
صناديق التعشيش

The nesting boxes correspond to the structure in which wild females lay their eggs. When the larvae hatch, they will drop into the food and immediately begin feeding. There is no need to harvest eggs.

تتوافق صناديق التعشيش مع الهيكل الذي تضع فيه الإناث البرية بيضها. عندما تفقس اليرقات، سوف تسقط في الطعام وتبدأ في التغذية على الفور. ليست هناك حاجة لحصاد البيض.

The different types of the nesting boxes :

الأنواع المختلفة لصناديق التعشيش:

1. WOODEN BOARDS

1.الالواح الخشبية

Stack thin wooden planks (3-4cm wide) two by two. Wild femelle will lay eggs between two planks to deposit a pile of several hundred eggs.

قم بتكديس ألواح خشبية رفيعة (بعرض 3-4 سم) اثنين في اثنين. تضع الأنثى البرية البيض بين لوحين لإيداع كومة من عدة مئات من البيض.

2.PIECES OF CARDBOARD

2. قطع من الورق المقوى

Cut out pieces of cardboard and stack them so as to leave the cells (holes) in the cardboard visible and accessible.

قم بقطع قطع من الورق المقوى ورصها بحيث تترك الخلايا (الثقوب) الموجودة في الورق المقوى مرئية ويمكن الوصول إليها

Warning: keep the cardboard dry, if it is wet the eggs will not develop well.

تحذير: حافظ على الورق المقوى جافًا، فإذا كان مبللًا فلن ينمو البيض جيدًا.

ابدأ تربية اليرقات
START YOUR BREEDING

1. Put food in the plastic growth tray

ضع الطعام في الحاوية النمو البلاستيكية

(+) Very good larval growth substrates.

(−) Also attract other species of flies which will parasitize the growth tank.

(−)

(+) ركائز نمو اليرقات جيدة جداً.

(-) تجذب أيضًا أنواعًا أخرى من الذباب التي تتطفل على حوض النمو.

2. 

Place the nesting boxes on the growth tray

ضع صناديق التعشيش في حاوية النمو البلاستيكية

3. Close the kit and observe colonization in the following days

Presence of eggs: you will have to wait 4 days before the eggs hatch

إغلاق المجموعة ومراقبة التعشيش في الأيام التالية

وجود البيض: سيتعين عليك الانتظار لمدة 4 أيام قبل أن يفقس البيض

نموذج تربية اليرقات
BREEDING KIT

متابعة مراحل تربية اليرقات
MAINTAIN YOUR BREEDING

1 Check the presence of eggs on the nesting boxes

التحقق من وجود البيض في صناديق التعشيش

في البداية سوف تظهر المحاصيل نفسها نحيفة قليلاً

At the beginning the harvests will show themselves a little skinny

The quantity of eggs will quickly increase: the smell given off by bio-waste will attract females

ستزداد كمية البيض بسرعة: فالرائحة المنبعثة من النفايات الحيوية ستجذب الإناث

2. Stir the growth tank and observe the presence of larvae

تحريك خزان النمو ومراقبة وجود اليرقات

3. Observe self-harvesting of larvae

After 2 to 3 weeks of rearing, the larvae which have fed sufficiently will climb along the plastic walls to exit the growth tank.

These larvae are characterized by a brown color. They will then come out of the tank and fall to the bottom of the barrel which acts as a collector.

مراقبة الحصاد الذاتي لليرقات

بعد 2 إلى 3 أسابيع من التربية، فإن اليرقات التي تتغذى بشكل كافٍ سوف تتسلق على طول الجدران البلاستيكية للخروج من خزان النمو.

وتتميز هذه اليرقات باللون البني. سوف يخرجون بعد ذلك من الخزان ويسقطون في قاع البرميل الذي يعمل كمجمع.

This guide has been realized by the two partner project :Rayhana and Entoumo

تم تنفيذ هذا الدليل من خلال المشروعين الشريكين:
ريحانة وإنتومو

ANNEX II. Memorandum of agreement for collaboration ISA-CM & Entomo

FRAMEWORK AGREEMENT BETWEEN ISA-CM AND ENTOMO CONSULTING S.L.

In Chott Mariem-Soussa October 25th 2024

THE AGREEMENT IS AMONG THE FOLLOWING PARTIES

On the one hand, Pr. Rajouène Majdoub, General Director of the ISA-CM University.

And on the other hand, Mr. Diego Amores de Gea, as chief executive officer of ENTO CONSULTING S.L.
INTERVIENEN

Pr. Madiha Hadj Ayed, for and on behalf of the Laboratory of "Management and control of animal and environmental resources in semi-arid area in the University of ISA-CM (hereinafter referred to as the University) acting in his current capacity, in accordance with the Statutes governing the University of ISA-CM.

And Mr. Juan Antonio Cortés Ortiz, in the name and on behalf of ENTOMO CONSULTING S.L., with Tax Identification Number B73936973, with registered office at Carretera de Murcia 103 C.P. 30430 Cehegin, Murcia (Spain).

Acting in their respective capacities and in the exercise of their respective powers, in order to agree on behalf of the entities they represent, and to that end

THE ABOVE PARTIES AGREE THAT

I- The current need to develop new, more sustainable production systems has led companies in various fields (livestock, pharmaceuticals, food, agriculture, cosmetics, etc.) to seek biotechnological solutions. Entomology has proved to be a very powerful and robust tool, but little exploited, to provide solutions to the present and future demands of these industries. ENTOMO CONSULTING S.L. is a company dedicated to the Research and Development of products and services related to entomology and biotechnology. On the other hand, the research group led by Professor Dr. Mrs. Mediha Ayed, of the University of ISA-CM, Department of Animal Production, has extensive experience and recognised prestige in studies on animal production in a wide range of fields, as well as in the optimisation of feeding and development of production methods and the use of new feed ingredients in livestock farming.

Página 1 de 5

entomo

ISA CM

II.- That both parties are interested in signing an agreement regulating the collaboration between the two Entities, which will henceforth be known as the Framework Agreement, and that the intervening parties submit it to the following

CLAUSES

FIRST

The purpose of this Agreement is to establish channels for the joint implementation of dissemination, training and research activities that are of benefit to both parties. By way of example and without limitation, the following are listed below:

a) To promote collaboration between the two entities, specifically with the research group of Professor Madiha Hadj Ayed. In this way, the objective of deepening the training and development of research related to the development and fine-tuning of insect mass rearing methods, for their application in livestock farming, and the development of environmental solutions for the use of insects in animal feed is established.

b) The promotion of Seminars and Courses, which should be given by professors related to the aforementioned research group and which should deal with subjects of interest to the different departments of the company.

c) Any other activity that, within the scope of this Agreement, is of mutual benefit, such as internships or thesis development.

SECOND

Both parties, by mutual agreement, shall set up a Joint Commission whose functions shall be the programming, monitoring and assessment of the activities derived from this Agreement. It shall be made up of two members from each of the parties and shall meet at least twice a year.

Each year a report shall be drawn up on the activities carried out under the Agreement, as well as a proposal for action for the following year.

Página 2 de 5

THIRD

By express agreement of both parties and at the proposal of the Joint Commission, different forms of collaboration may be established by means of the corresponding Specific Agreements, which will establish in detail the aspects related to the contributions of the parties, as well as the calendar of actions and the duration of the activities.

FORTH

This Framework Agreement shall enter into force upon signature and shall remain in force for a period of two years, renewable for equal periods, subject to the agreement of the parties.

FIFTH

The parties may amend this document by mutual agreement or terminate it by giving two months' written notice prior to the date on which they intend to terminate it.

SIXTH

For any questions that may arise from the interpretation and execution of the present agreement, the parties will try to reach a mutual agreement and otherwise expressly submit themselves to the jurisdiction of the Courts and Tribunals of the domicile of the University of ISA-CM, expressly renouncing any other jurisdiction that may correspond to them by better right.

SEVENTH

Both parties, UNIVERSITY OF ISA-CM and ENTOMOCONSULTING S.L. are obliged to comply with all applicable provisions on Data Protection and, in particular, with the provisions of Organic Law 15/99 of 13 December, on the Protection of Personal Data and other implementing regulations.

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ISA CM

And for the purposes set forth herein, they have signed this agreement, in duplicate, at the place and on the date indicated at the beginning.

For the entity
ISA-CM University

Signed. Rajouène Majdoub,
General Director

For the entity
Entomo Consulting S.L.

Signed: Diego Amores de Gea
General Director

And

Signed Pr. Madiha Hadj Ayed

And

Signed J.A. Cortés Ortiz

Pr. Zohra Lili
President of the institution
of Agricultural Research and Higher Education

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

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

Capacity: 200 kg/day of fresh larvae
Technological level: Medium

1. Introduction

The black soldier fly (Hermetia illucens, known by its acronym BSF) is a dipteran insect native to America, although it is now widely distributed in tropical, subtropical, and temperate zones around the world. In the last two decades, it has gained great relevance due to its ability to transform low-value organic waste into high-value protein and lipid biomass in an efficient and environmentally sustainable process. BSF larvae are responsible for this transformation. They have a crude protein content of between 40–45% and a fat content of between 25–35%, making them a viable alternative to fishmeal and soy in the formulation of feed for aquaculture, poultry farming, pig farming, and pet nutrition. In addition, their production requires fewer water resources and generates a much lower carbon footprint than conventional protein sources.
The BSF breeding process generates two main products are: a) fresh or processed larvae: these can be marketed as whole larvae, dried larvae, insect meal, or extracted oil and; b) Frass: a by-product resulting from the digestion of waste, rich in nitrogen, phosphorus, and potassium, which is used as an organic fertilizer in agriculture.
From an environmental point of view, the use of BSF contributes to waste reduction such as fruit, vegetables, and agricultural by-products that would otherwise end up in landfills to be recovered. The use of BSF align with the circular economy principles by transforming local waste into high-value inputs, closing the production cycle. And last but not least decreased negative impacts by reducing odors and emissions from uncontrolled waste decomposition.
The objective of this guide is to describe, in a detailed and replicable manner, the design and operation of a medium-scale plant capable of producing 200 kg of fresh larvae per day, using exclusively agricultural waste as substrate and with a medium level of technology. This means that practical and viable solutions are proposed (such as mechanical shredding, basic temperature and humidity control, and manual or semi-automatic harvesting systems), avoiding both high technological complexity and inefficient artisanal management. Suporting in that way the principles of the SustavianFeed project. Thes, this guide is intended as a reference document for agricultural producers, entrepreneurs, or technicians interested in implementing a system for utilizing agricultural waste through BSF breeding, with the aim of obtaining alternative protein, organic fertilizer, and a production model aligned with environmental sustainability.

2. Facility requirements

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

2.1 Required surface area

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

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

2.2 Minimum infrastructure

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

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

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

2.3 Recommended environmental conditions

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

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

2.4 Biosecurity and workflow

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

to drain liquid) and if dry components are also used to feed the larvae it should be stored in a dry area.
Processing and cleaning areas should be at the opposite end of the farm and physically separated. Even better, if after the cleaning area another compartment for processing is created where end product could be considered clean and ready to be stored.
For the transition areas it is recommended that personnel wear clothing and footwear exclusively for the plant, with footbaths or disinfection stations at the entrances or if it necessary, have dedicated personnel to each area, which is highly recommended if the production scale increases.

3. Biological cycle and production management

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

3.1 Adult breeding (fly farm)

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

1. Humidity must be 75% or above or else adults will not release the eggs.
2. Adults will not mate if they do not have intense light with a good amount of UV light, UV ligh does not need to be on continuously but at least couple of hours in the start of the photocycle is recommended.
3. Temperature during matting should be above 23ºC and preferably 29ºC for a good matting
4. Adults need a spot with an attractant substance (normally a recipient with rotten products) to encourage eggs releasing.
5. The place should be well vented as high concentration of females' pheromones discourage females to release eggs

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

Figure 2. Adult cages

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

Reproduction:

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

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

Figure 3. Oviposition device set on top of the atractant

A female can lay between 500–900 eggs during her life cycle (5–8 days).
Eggs are collected manually and transferred to the incubation room. It is recommended to collect the oviposition devices (see figure 4) daily so the larvae size/age difference will be little. Or else larvae growth will be less even during fattening

3.2 Egg incubation

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

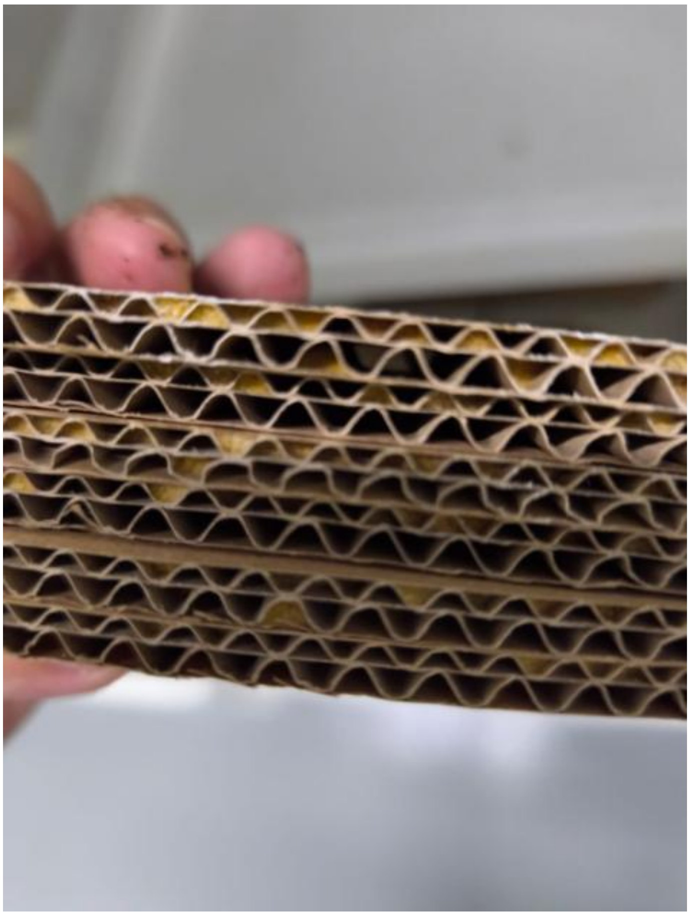

Figure 4. Oviposition device with eggs clutch inserted in the cardboard flutes

Environmental conditions:

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

The incubation normally takes 2.5 days although changes in temperature can change it
Handling:
The eggs are placed on trays with a thin layer of pre-moistened substrate (bran + grains+ water mixture). Eggs should be kept slightly separated from the wet diet or else hatchability will be compromised. Another option is to let the eggs hatch in an empty box (see figure 5) and transfer the small larvae to fresh diet. When the conditions are appropriated an average hatching rate of 85–95% can be expected.

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

3.3 Larval fattening

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

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


Figure 6. 5DOL ready for fattening

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

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

Figure 7. 5DOL seeding on fattening plastic boxes

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

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

Humidity control is not relevant while moist in the diet is enough (60%) to allow the larvae to eat. Constant ventilation to prevent gas (mainly CO_2) and heat accumulation.
If the process is adequate, 1 kg of fresh larvae per box can be collected and from 5 to 20 kg of waste have to be used (depending on nutrition density). The larval weight at the end of the cycle: 0.2–0.25 g per larva.

<u>3.4 Larvae harvest</u>

Optimal time for harvest is when the larvae have reached 18–22 mm and are whitish yellow in color. If larvae are not collected at this stage, they will start pupation with a lost of production. The time depends on feed quality, but for a good diet 9 days are commonly achieved. 12–14 days can be expected for average diet quality.
Collection method:
The most common method for collection is by vibrating screens or manual sieves to separate larvae from frass. Obviously vibrating screens are needed at a certain production scale.
It is recommended to keep 5% of the production to replenish the parent colony of adults (ensuring the sustainability of the system). Those larvae are refeed and let to pupate and keep at 80% humidity and 28°C during 8 days to produce adults.

3.5 Balance for production of 200 kg/day

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

4. Agricultural substrates and pretreatment

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

4.1 Recommended types of agricultural waste

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

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

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

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

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

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

From the nutritional point of view, fiber is not nutritious for the larvae and main nutrients are

simple sugars (fructose, sucrose, lactose) or starch rich products.
In the mediterranean basin olive pomace is very abundant and it could easily represent 30% of the total formula. Furthermore, olive pomace, when still humid can be preserved as silage and used year round although it is abundant just during a short season
Animal waste and manure are not allowed as substrates to feed the larvae if they are intended for animal feed.

4.2 Substrate quality criteria

To maintain optimal larval growth, the substrate must meet certain physical and chemical parameters:
Initial moisture content: 65–70%. Lower moisture content dries out the medium, while higher moisture content promotes unwanted fermentation and mold growth.
pH: between 6 and 7.5. Values that are too acidic (<5.5) or alkaline (>8) reduce the consumption rate.
Absence of chemical contaminants: pesticides, herbicides, heavy metals, or plastics must be completely excluded.
Uniformity: the more homogeneous the substrate is, the easier it is to handle and the more efficient larval consumption. Although, uniformity is normally difficult if large amounts of waste is needed year round

4.3 Substrate pretreatment

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

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

4.4 Balance for the production of 200 kg/day

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

5. Larvae management

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

5.1 Breeding units

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

5.2 Larvae seeding

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

5.3 Feeding during the cycle

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

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

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

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

5.4 Environmental conditions

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

5.5 Monitoring and control

Daily monitoring is key to ensuring efficiency:

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

5.6 Replenishment of the parent colony

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

6. Harvesting and separation

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

6.1 Optimal harvest time

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

Figure 10. 15DOL ready to be harvested

6.2 Larva–frass separation methods

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

1. Manual shaking or sieves:

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

2. Mechanical vibrating screens:

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

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Figure 11. mechanical sieving to separate larvae from frass

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

6.3 Post-harvest handling of larvae

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

6.4 Quality considerations

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

7. Processing and preservation

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

7.1 Initial processing

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

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

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

7.2 Processing options according to final destination

1. Fresh larvae

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

2. Scalded and refrigerated larvae

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

3. Dried larvae / Insect meal

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

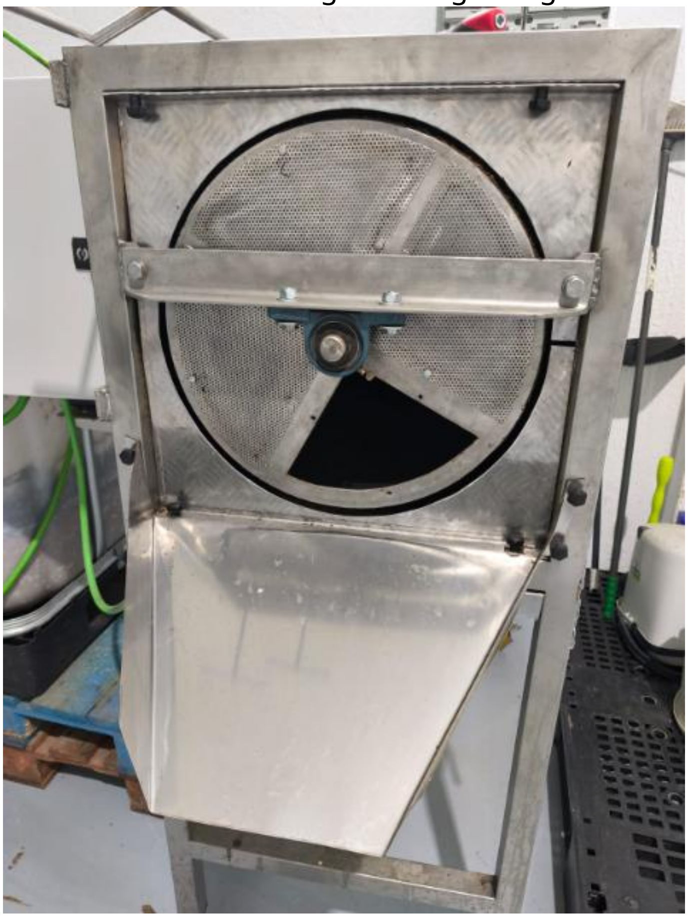

Figure 13. Drum dryer for larvae dehydratation

7.3 Preservation of frass

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

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

7.4 Hygiene and biosafety recommendations

For hygiene and safety the following recommendations should be followed:

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

8. Frass as by-product

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

Figure 14. frass after sieving

8.1 Typical composition of frass

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

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

Other components: chitin, beneficial microorganisms, and enzymes.
These values make frass comparable to traditional organic fertilizers (manure, compost), but with the advantage of a shorter and traceable production cycle.

8.2 Agronomic benefits

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

8.3 Management and processing of frass

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

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

3. Sieving and homogenization: to obtain a product with uniform particle size.
4. Packaging: in 25–50 kg bags or big bags for commercialization.

8.4 Storage and preservation

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

8.5 Estimated production volume

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

8.6 Market and practical application

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

9. Biosafety and hygiene

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

9.1 General principles of biosecurity

1. Prevention over correction: preventing contaminants from entering is more efficient than dealing with problems once they have arisen.
2. Unidirectional flow: from the entry of agricultural waste to the exit of final products, without any backflow that could contaminate clean areas.
3. Separation of areas: clearly differentiate between “dirty” areas (waste reception) and “clean”

areas (larvae processing, meal or frass storage).
4. Traceability: record substrate batches, sowings, and harvests to quickly identify the source of any incident.

9.2 Measures at waste reception

Main measures to apply:
Inspect agricultural waste to ensure it is free of plastics, glass, metals, or chemical residues.
Keep waste in a covered area separate from the rest of the facility.
Establish an exclusive, waterproof unloading area with leachate drainage.

9.3 Measures during larval rearing

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

9.4 Measures during harvesting and processing

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

9.5 Staff hygiene

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

9.6 Pest and external fauna control

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

9.7 Cleaning and disinfection protocols

1. Daily: cleaning of floors, equipment, and trays in use.
2. Weekly: disinfection of empty trays, tools, and common areas.
3. Monthly: deep cleaning of sheds, ventilation, and drains.

10. Daily operational summary

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

10.1 Receipt and preparation of substrate

a. Receipt: arrival of1000–1,200 kg of agricultural waste.
b. Sorting and removal of contaminants: manual removal of plastics, stones, metals, or non-biodegradable materials.

c. Shredding and mixing: reduction of particle size to <20 mm and homogenization of components (fruit, vegetables, dry by-products).
d. Adjustment of moisture and pH: achieve 65–70% moisture and pH 6–7.5.
e. Temporary storage: store the pretreated substrate for a maximum of 24–48 hours, in the shade and on an impermeable surface.

10.2 Incubation management

a. Checking egg trays (3–4 days of incubation).
b. Control temperature (27–30 °C) and humidity (70–80%).
c. Transfer hatchlings to rearing trays with freshly prepared substrate.

10.3 Feeding and monitoring of larval trays

a. Feeding: add substrate to the trays based on observed consumption (2–3 kg every 2–3 days).
b. Monitoring: Check the activity and health of the larvae, check for mold or fermentation, check substrate thickness (<8 cm) and check environmental conditions: maintain temperature at 27–30 °C and RH at 65–70%.

10.4 Larvae harvesting

a. Select 12–14-day-old trays for harvesting.
b. Separate larvae from frass by shaking or mechanical systems.
c. Sorting 90–95% for processing or sale (200 kg/day). And 3-5% for pupation and maintenance of the parent colony.

10.5 Post-harvest processing

Options:

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

Optionallly oil extraction could be an option to create insect melas. And in this case an oil expeller machine has to be used to extract the oils from the dry larvae
For the frass drying and storage (600–800 kg/day).

10.6 Cleaning and hygiene

a. Cleaning of trays, utensils, and work surfaces.
b. Disposal of unusable waste.
c. Checking footbaths, protective clothing, and tidiness of areas.

10.7 Records and traceability

a. Recording substrate entries (origin, quantity, date).
b. Recording incubation, fattening, and harvest batches.
c. Recording daily production (kg of fresh larvae, dry larvae, frass).
d. Recording incidents (temperature, mortality, contamination).