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Increasing Production Efficiency of Maggot with Integrated IoT Censor for Effective, Efficient, and Organized Prototype for Natural Feed in Aquaculture

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ABSTRACT

The need for feed determines 60-70% of aquaculture total production cost. Hence, the feed factor plays a very important role in performing an effective, efficient, inclusive, and sustainable aquaculture. The requirements needed to be a good cultivar are fulfilment of macronutrients and micronutrients, toxin-free, and accessibility. Maggot can be used as a natural feed alternative in cultivation activities due to its sufficient nutrients content. Since 2012, aquaculture activities in Indonesia have increased alongside the rising needs for food and population growth. In this research, we conducted a research on the cultivation process of maggot by constructing three effective, efficient, and organized prototypes to achieve natural feed alternative for fish. In the first prototype, the hatching container (70x80x50 cm) will be designed with IoT censor for environmental parameter that is accessible in real time via the Blynk IoT platform. The second prototype is the vertical biopond, in which the structure and plastic container will be used to grow maggot. The structure of vertical biopond will be that of two-rack wood shelf with size specification of 80x100x34 cm. An important note to take, all designs will be created vertically. The third prototype is a 3 in 1 stall that has three components which are green net (200x150x100 cm), pupation container (30x42x15 cm), and hatching container (20x23x10 cm). All three designs can optimize the provision of economical and ecological feed that supports the fulfilment of the Sustainable Development Goals in Indonesia.

Keywords: Aquaculture, Black soldier fly, Internet, Natural feed, and SDGs

ABSTRAK

Kebutuhan pakan menentukan 60-70% dari total biaya produksi budidaya. Oleh karena itu, faktor pakan memainkan peran yang sangat penting dalam mempertahankan budidaya yang efektif, efisien, inklusif, dan berkelanjutan. Persyaratan yang diperlukan untuk menjadi kultivar yang baik adalah terpenuhinya unsur hara makro dan mikro, bebas toksin, serta mudah didapat. Maggot dapat dijadikan sebagai alternatif pakan alami dalam kegiatan budidaya karena kandungan nutrisinya yang cukup. Sejak tahun 2012, kegiatan budidaya perikanan di Indonesia semakin meningkat seiring dengan meningkatnya kebutuhan pangan dan pertumbuhan penduduk. Dalam penelitian ini, kami melakukan penelitian tentang proses budidaya maggot dengan membangun tiga prototipe yang efektif, efisien, dan terorganisir untuk mencapai alternatif pakan alami untuk ikan. Pada prototipe pertama, wadah penetasan (70x80x50 cm) akan dirancang dengan sensor IoT untuk parameter lingkungan yang dapat diakses secara *real time* melalui platform *Blynk IoT.* Prototipe kedua adalah biopond vertikal, dimana struktur dan wadah plastik akan digunakan untuk menumbuhkan maggot. Struktur biopond vertikal berupa rak kayu dua rak dengan spesifikasi ukuran 80x100x34 cm. Catatan penting untuk diambil yaitu semua desain akan dibuat secara vertikal. Prototipe ketiga adalah kandang *3 in 1* yang memiliki tiga komponen yaitu waring hijau (200x150x100 cm), wadah pupasi (30x42x15 cm), dan wadah penetasan (20x23x10 cm). Ketiga desain tersebut dapat mengoptimalkan penyediaan pakan yang ekonomis dan ekologis yang mendukung pemenuhan *Sustainable Development Goals* di Indonesia.

Kata kunci: Akuakultur, *Black soldier fly*, Internet, Pakan alami, dan SDGs

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1. Introduction

Feed is an important factor in the success of fish cultivation due to its nutrient content that is suitable with the target that determines growth, development, and life sustainability of cultivates (Makkar et al., 2014). While feeding aquaculture, it is important to pay attention to the quantity and quality to ensure the fulfilment of feed for cultivators. The nutrient source in feed could come from high sources of protein like BSF (Black Soldier Fly) larva or *Hermetia illucens*, also known as maggot (Kroeckel et al., 2012 and Oonincx et al., 2015).

Maggot is one type of natural feed alternative that fulfills the cultivates protein need with protein contents around 30-45%, consisting of essential fatty acids (linoleic and lyolenate) and 10 kinds of essential amino acids (Shumo et al., 2019). Using maggot as an alternative feed tends to be easy, economic, practical, and environmentally friendly so that it can help push the concept of sustainable cultivation for aquaculture activists (Dörper et al., 2021; Salam et al., 2021; and Shelomi, 2020).

Therefore, the usage of the latest tools and design in increasing maggot production as natural feed alternative for cultivates needs to be studied further (Palma, et al., 2019). This is due to the fact that the maggot cultivation process requires suitable environmental parameter as well as a large area. Responding to the problem, the implemented strategy is by utilizing technology and analyzing latest designs which are more efficient so that the cultivation can be done more quickly and accurately. One of the solutions is by using the prototype regarding the maggot cultivation system that is built vertically with integrated IoT sensor which is very potential to be implemented. This cultivation system is designed to produce maggot as a natural feed alternative with high protein for fish and also as a more efficient organic waste reducer in comparison to the conventional system (Chew et al., 2021).

This prototype design is customized to the maggot life-cycle which includes a hatching container, vertical biopond to grow maggot, and BSF 3 in 1 fly cage. In the hatching container, there will be a sensor to measure the environmental parameter for maggot eggs using arduino microcontroller which is ESP32. This is because the maggot eggs characteristic that is very prone to breakage, thus requiring optimal environmental parameter monitoring periodically (Diener et al., 2011). This prototype is designed to be vertical with integrated digital information that can be easily accessed in real time. On the other hand, the second design which is the vertical biopond that will be used for maggot growing is modified to make it easier for maggot cultivators in the process of harvesting as well as utilizing minimum area of land. As for the third design, which is none other than the BSF 3 in 1 fly cage which includes a combination of reproduction cycle of BSF fly from a pupa until it returns in to the egg phase. According to the three tool designs, it is safe to say that this prototype can optimize the process of maggot cultivation that is economically and ecologically sustainable as well as supporting the sustainable development goals in aquaculture activities in Indonesia.

2. Material and Methods

2.1. Problem Analysis and Literature Study

Problem analysis and literature study are ways to collect theories regarding methods and solutions to answer the research questions. The references used in this research come from journals, books, internet, and interview results in which the validity is accountable. The purpose of this research activity is to strengthen theories, answer the research questions, and act as a guide in implementing the proposed prototype of maggot cultivation.

2.2. Prototype Making Steps

a) 2D and 3D Designs (*Modelling*)

The first step is to model the 2D and 3D designs along with their specifications by using modelling applications such as Blender, AutoCAD, and CorelDRAW. The initial design will be 2D, then it would be changed into a 3D design by perfecting the components used for the prototype. Afterwards, the 3D design will be transformed into an animation with specifications that is expected to represent the form of the maggot cultivation with integrated IoT sensor prototype. This animation will be the guide in making the real prototype.

b) Tools and Equipments Preparations

This step requires equipments such as IoT sensor, and other appliances for the prototype of maggot cultivation. The materials used include: DC 12 volt motor, volt change, breadboard, capacitor 1 microfarad, ESP32, jumper, LED, liquid pH sensor, light sensor, logic converter, multimeter, proximity sensor, push button, 1k ohm resistor, 220k ohm resistor, diode, temperature sensor, tin, USB cable, mosfet, heatsink transistor, buck converter, heatsink, thermal paste, cable, ironing cable, pc/laptop, mobile phone, ball bearing, screwdriver, 5A transformer, pliers, iron cutter, chisel, lathe, dead center carbide, center drill, chuck drill, camshaft, allen wrench, wrench, drill bit, calipers, electricity terminal station, transistor, switch, ic (circuit), regulator, duct tape, meter, hammer, saw, soldering iron, solder grease, plastic solder, scissors, screwdrivers, sandpaper, marker, bsf fly warping, maggot divider net, logs, woodpile, attractor, egg container, wood and plastic (by meters), net and wood, hollow iron 4x4, chain, gear, thumbtack, large nails, bolt, large basin, bucket, basin for medium for maggot, fermentation barrel, shovel for maggot medium, duster, sorting basin, pupa container, knife, scales, wooden shelf, box container.

c) The Making of Hatching Container Prototype

The hatching container prototype is made with hollow iron 4x4cm as shown in Figure 1. This prototype includes the foundation, frame, and plastic basin as the container for maggot cultivation during the egg phase. This prototype will be equipped with integrated IoT sensor for environmental parameter in the forms of pH, temperature, light intensity, and movement that could all be accessed in real time via Blynk IoT platform. The frame is designed vertically and rotating with 12 Volt DC dynamo.

d) The Making of Vertical Biopond to Grow Maggot

The components of the vertical biopond for growing maggot includes the frame and plastic container. The frame of the vertical biopond will consist of two-rack shelf made from wood with size specification of 80x100x34 cm. The biopond is specifically designed vertically in order to ensure utilization with minimum area of land as shown in Figure 2.

e) The Making of 3 in 1 Cage

The making of 3 in 1 cage requires wood, plywood, net, and transparent plastic (by meters) for the base. This 3 in 1 cage has three components which includes green net (200x150x100 cm), pupation container (30x42x15 cm) and egg hatching (20x23x10 cm) as shown in Figure 3. This pupation container will be conditioned in minimum light intensity in order to speed up pupa metamorphosis into fly (Čičková et al., 2015).

f) Programming and Assembling IoT and the Maggot Hatching Container with Sensor for Temperature, Humidity, Light Intensity, pH, and Location

IoT integration to the hatching container prototype is intended to monitor the optimal environmental parameter for maggot cultivation. Environmental sensor programming linked to the IoT uses arduino ESP23 microcontroller through the visual studio code application. The electronic devices that will be used to measure temperature and humidity (DHT22), light intensity (LED light), pH (proximity sensor). The prototype will work by moving clockwise with the DC 12 Volt motor. The result of the measurement can be accessed in real time via the Blynk application on mobile phone.

2.3. Organic Waste Fermentation in the Form of Coconut and Fruit Pulp

The purpose of this activity is to utilize organic waste as feed for maggot (bioconversion agent). This process takes ± 7 days by using molasses and EM4 to produce maggot feed with quality and to reduce foul odor from the organic waste. Through this mechanism, we hope to reduce the amount of organic waste in Indonesia.

2.4. Maggot Cultivation Process Using the Prototype

In the process of maggot cultivation, we use the vertical concept with cultivation pattern that uses storeyed containers to solve land limitations. The strength of this vertical cultivation system includes efficiency in land usage and convenience in moving, monitoring, and maintenance processes. In this prototype, the usage of IoT sensor can give maximum benefit for the society. IoT can be used to control electronic devices from far away. This advancement in technology helps human

Figure 1. Hatching Container Prototype

Figure 2. Vertical Biopond to Grow Maggot

Figure 3. 3 in 1 Cage

activities, especially in this time of Covid-19 pandemic.

2.5. Harvesting Maggot as a High Protein Fish Feed Alternative

Maggot produced from this cultivation process can be used as fish feed that is rich in nutrient contents such as protein (Džomba et al., 2019) and Henry et al., 2015). The protein content in maggot is higher than that of fish flour used as the main ingredient in fish feed. Aside from that, maggot can also be harvested according to the needs of cultivators with various sizes. The produce of maggot cultivation with integrated IoT will then be compared to the result of conventional cultivation system's produce in order to determine the difference in quantity that is produced by this maggot cultivation prototype.

2.6. Performance Examination of the Prototype

The making as well as the examining of this prototype are done at the Faculty of Fisheries and Marine, University of Diponegoro as a sample to collect data and implementation test. The offline implementation is done in accordance to the health protocol. The execution of this program took 4 months starting from the literature study until the making of the report

3. Results and Discussion

3.1. Hatching Container Prototype

The egg phase of BSF is a stadia that is prone to death, and this phase also determines the quality and quantity of the maggot (Hoc et al., 2019). This is why a prototype with integrated IoT sensor is needed in order to get maximum result (Zhang et al., 2013). The design of this prototype is vertical, thus it can be implemented within minimum area of land. Also, this prototype uses DC 12 Volt motor to make the prototype rotate clockwise, so that the process of analyzing maggot cultivation environmental parameter can be done more easily (Sabir et al., 2020).

3.2. Vertical Biopond Prototype to Grow Maggot

The purpose of making this vertical biopond prototype to grow maggot is to act as the container in which the life cycle of maggot as organic waste reducer that is high in protein takes place. The purpose of this prototype is to increase efficacy by facilitating a design of maggot cultivation with minimalist aspect so that the cultivation process can be done more effectively and more efficiently. This can be seen through the prototype's strengths which organizes the cultivation activity (automatically prevents pests, protecting the quantity of maggot in the usage of minimum area of land). The parameter of success of the usage of this prototype is the waste bioconversion that is successfully processed by maggot (Bortolini et al., 2020). In this growing phase, maggot could reduce 30 kg coconut pulp as well as 10 kg rotten fruit within 11 days with the output of 11.6 kg maggot as high protein fish feed.

3.3. 3 in 1 Cage Prototype

The parameter of success of the usage of this cage prototype is the occurrence of BSF fly sustainable cultivation cycle (egg-maggot-pupa-BSF fly). This is in accordance with the purpose of the 3 in 1 cage prototype design, which is to act as a container for the pupa to metamorphose into flies. This prototype also serves the purpose of a container for fly mating activities in order to produce more BSF eggs. In this process, we will produce 2.5 grams of maggot eggs

3.4. Optimal Parameters of Maggot Cultivation

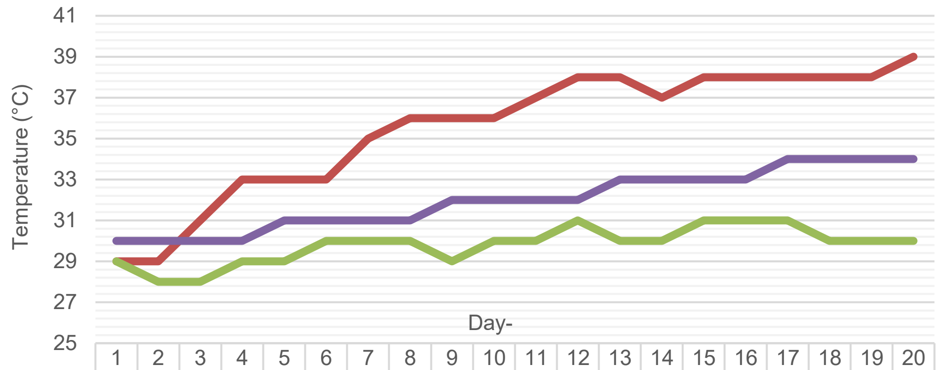
a) Temperature

The optimum temperature for maggot cultivation is (> 25 C) and in a humid state. The observation tool using a measuring instrument in the form of a 4in1 soil parameter (conventional tool) and IoT system which carried out every day at 08.00 and 18.00 WIB for 20 days. The purpose of this temperature measurement is to monitor and compare the range of temperature values between conventional and IoT system coding data. This is because if the temperature is too low, the metabolism of maggot decreases. The temperature data that compare environment quality of the maggot cultivation using conventional tool, IoT, and previous research can be shown in Figure 4.

The average temperature with IoT system is 29.8^{o}C, while using conventional cultivation system is 35.5^{o}C. The difference in the measurement results can be caused by the location of the prototype. The conventional system was located in the semi-outdoor, while the IoT system which need special maintenance was placed in the indoor rooms. This is influenced by the sunlight emission in the semi-outdoor that affects the room temperature (Vinola et al. 2020). Even though the difference range is wide, but the average value of the IoT system is close to the optimum value for maggot development, which is 30 ^{o}C. This was done by Tomberlin et al (2009), that the development of maggot will be slower at a temperature of 27 ^{o}C when compared to a temperature of 30 ^{o}C.

b) pH

The acidity level (pH) of the maggot media cultivation depends on the organic waste that is used. The content of the media is a mixture of bran and water in the form of paste. The pH data



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Conventional	29	29	31	33	33	33	35	36	36	36	37	38	38	37	38	38	38	38	38	39
The Maggot (with IoT)	29	28	28	29	29	30	30	30	29	30	30	31	30	30	31	31	31	30	30	30
References	30	30	30	30	31	31	31	31	32	32	32	32	33	33	33	33	34	34	34	34

Figure 4. Temperature Comparison with Conventional Cultivation, References and Prototype *[References: Mudeng et al. (2018)]*

that compares environment quality of the maggot cultivation using conventional tool, IoT, and previous research can be seen in Figure 5.

Based on Figure 5, the average pH of the measurement using conventional tool was 8.15, while using IoT system was 8.05. The optimum pH value of the media used to support maggot survivability is ranged between 6.5 – 7.5 (Isroi, 2008). However, Ardiansyah et al. (2021)'s research shows that high pH or low pH media doesn't affect the growth of the maggot.

c) Humidity

Humidity is one of the environment parameters that influence the nursery phase of maggot. The humidity data that compares environment quality of the maggot cultivation using conventional tool, IoT, and previous research can be shown in Figure 6.

Based on the Figure 6, it show that the humidity condition of cultivation media that measure with conventional tool and IoT system are wet. The humidity of nursery media be maintained between 60-80%, which tends to be wet (Handayani et al. 2021).

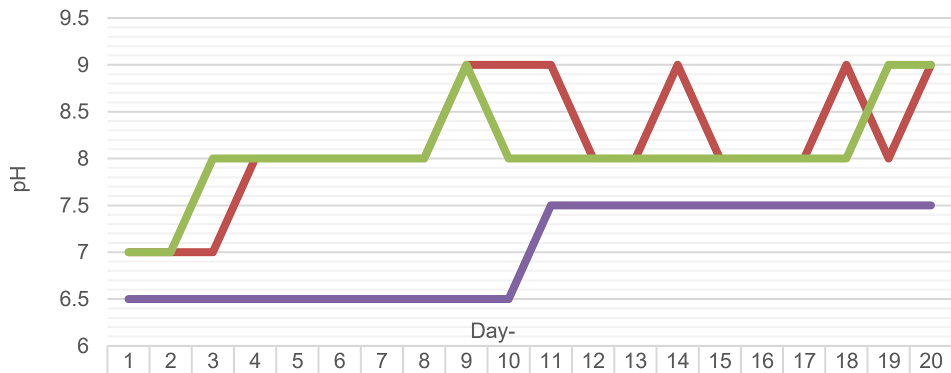
d) Light Intensity

The light intensity data that compares environment quality of the maggot cultivation using conventional tool, IoT, and previous research can be seen in Figure 7.

The average light intensity of media that is measured using conventional tool is higher than IoT system. This shows that light intensity is related to the temperature in the media (Mudeng et al., 2018). The temperature of prototype that is measured using conventional tool tends to be high due to the location. Therefore, if the intensity is too high, the maggot living medium gets hotter.

3.5. Cultivation Cycle Phases

The life cycle of BSF maggot generally consists of five phases which include eggs, larva, pre-pupa, pupa, and adult (Figure 8) which



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Conventional	7	7	7	8	8	8	8	8	9	9	9	8	8	9	8	8	8	9	8	9
The Maggot (with IoT)	7	7	8	8	8	8	8	8	9	8	8	8	8	8	8	8	8	8	9	9
References	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5

Figure 5. pH Comparison with Conventional Cultivation, References and Prototype *[References: Isroi (2008)]*

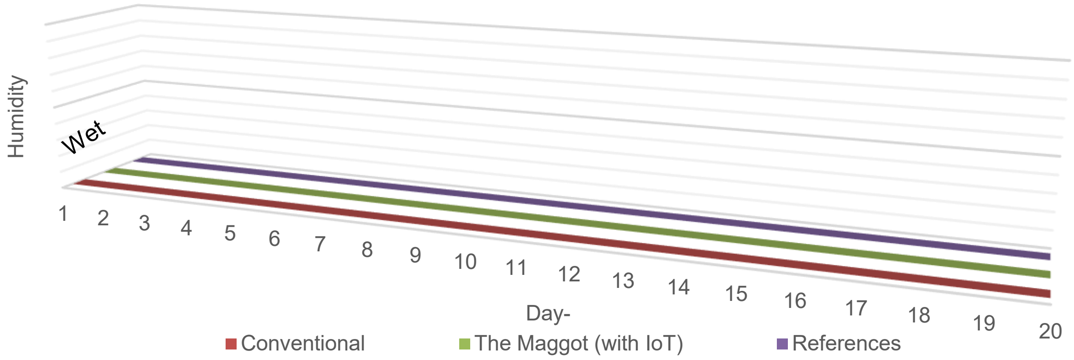


Figure 6. Humidity Comparison with Conventional Cultivation, References and Prototype *[References: Handayani et al. (2021)]*

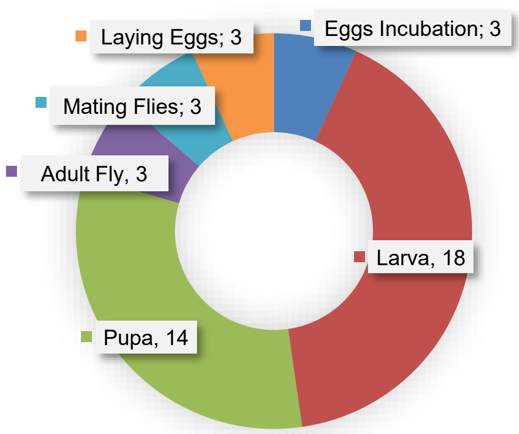


Figure 8. Cultivation Cycle Phases

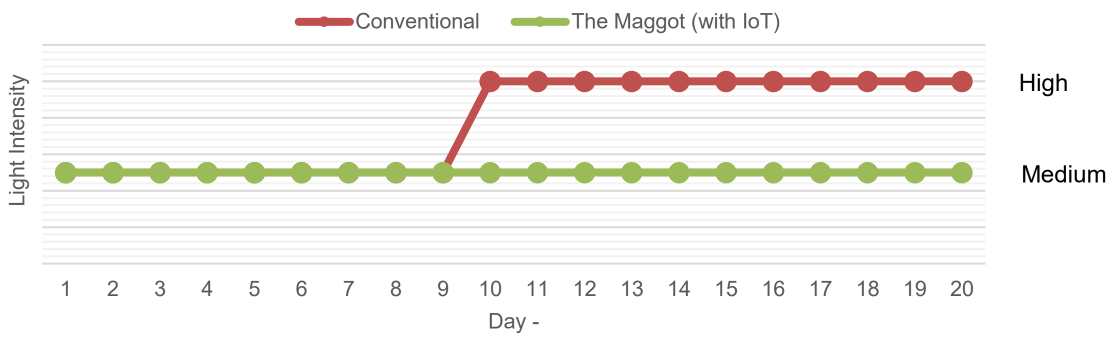


Figure 7. Light Intensity Comparison with Conventional Cultivation, References and Prototype *[References: Mudeng et al. (2018)]*

happens around 38-41 days (Tomberlin et al., 2009). Adult female fly will lay eggs around 5-8 days after breaking out of the pupa, and can generally lay up to 500 eggs per fly. The larva eggs will hatch within 4.5 days (±105 hours) (Purkayastha and Sarkar, 2021).

3.6. Distinctive Potential of the Prototype

Through the making of maggot cultivation prototypes which include three designs, we hope that to contribute in solving environmental and economic issues. Cultivation treatment with prototype is shown in Figure 9. Our contribution can be seen through the impact of our maggot as fish feed alternative, which can act as organic waste bioconverter (Silva and Hesselberg, 2020; and Smetana et al., 2016). By using this prototype with integrated IoT sensor, this will ultimately differ from conventional methods because this prototype can be used within minimum area of land and can be monitored from a distance. This is why the privilege provided by this prototype has potentials to enable the society to control environmental quality (temperature, humidity, light intensity, cultivation medium, and pH) in real time through PC or mobile phone.

4. Conclusion

Responding to the problems, the urgency to overcome systemic and universal problem of

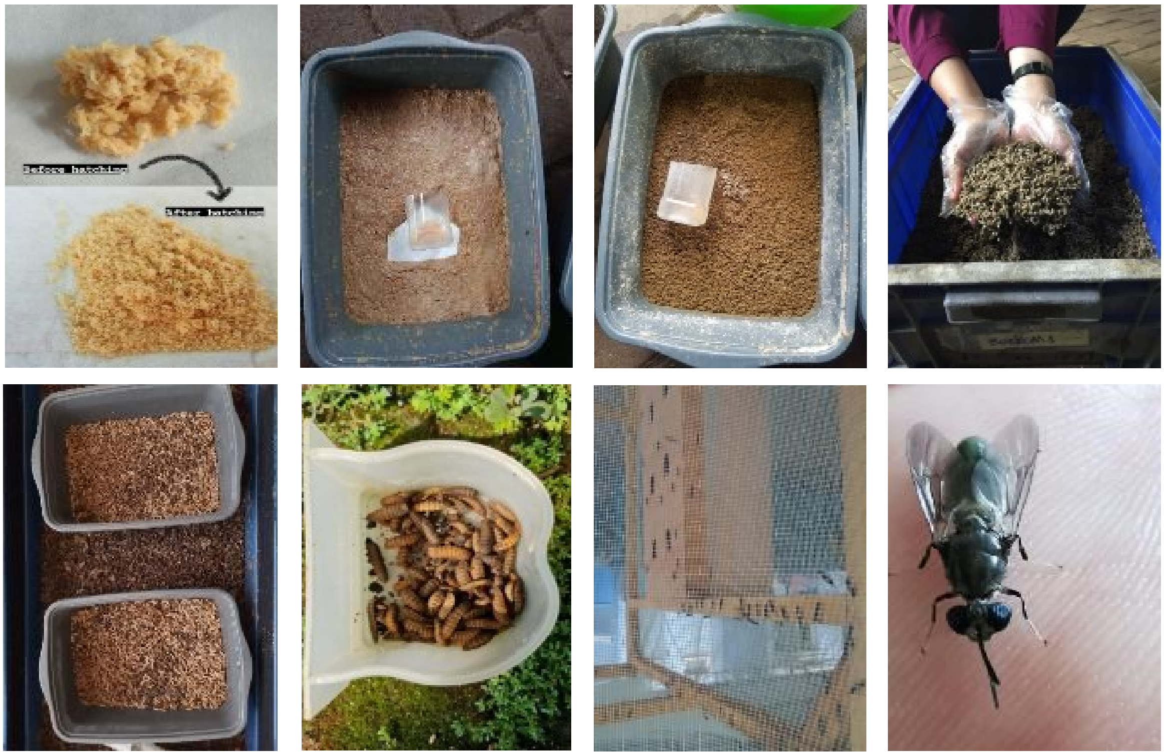


Figure 9. Cultivation Treatment with Prototype

organic waste to be solved rise as Indonesia is progressing to achieve sustainable development goals. The foundation of SDGs is especially useful in ensuring environmental integrity and life quality of the present and future generations. Efforts to reduce organic waste that could be done by the society at large includes the cultivation of BSF (Black Soldier Fly) larva or maggot. Maggot likes wet, organic food such as fruits, restaurant waste and market waste, which is why maggot is categorized as a bioconversion agent (Guo et al., 2021). This is in accordance with the percentage of organic waste that can be processed by maggot, which is around 66.4-78.9%.

This is exactly why maggot cultivation activities are very much suitable in developing countries due to the simplicity of the technology required, and the high selling value (Suckling et al., 2021). However, maggot cultivation activities in present time still use conventional method, which requires a lot of energy and area of land. Thus, current maggot cultivation style still needs physical analysis in order to determine the optimum environmental condition for the process. This is why the conventional method is not effective and not efficient in achieving maximum result.

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