Management of increasing economic value of organic waste with Maggot cultivation

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Abstract. Organic waste can have economic value, such as used for animal feed, fish, and fertilizer. Organic waste from human activities needs to be deciphered before it becomes an economically valuable product. Maggots (BSF flies) are larvae that can convert organic material into biomass and potentially break down organic waste. Garbage has become a problem in Jambi due to population growth, changes in consumption patterns, and people’s lifestyles, producing 1,600 m\(^3\) of waste per day. By utilizing maggot cultivation (BSF), community services activities can enhance the economic value of organic waste in Purwodadi Village, Tanjung Jabung Barat Regency, Jambi. This article aims to study organic waste management using maggot cultivation. The result is that this method can be an alternative for organic waste management. This method embarks a sustainable environment and increases resources which can be traded or utilized. Maggot bioconversion technology can deal with three main problems, namely: the generation of organic waste, high prices of protein sources, and increasing demand for animal feed. In conclusion, organic waste management using maggot cultivation brings a sustainable environment and enhances organic waste’s economic value. Therefore, it can be a useful alternative for waste management.

1. Introduction
Solid waste is a complex problem faced globally that has environmental and health impact [1]. An increase in the per capita waste production is correlated with economic activity such as growing populations, urbanization, and living standards [1] [2]. Based on that fact, Indonesia’s concrete waste production will continue to increase [3]. One of the regions in Indonesia that is experiencing this problem is Kota Jambi. The high population consumption rate is not accompanied by harmony in knowledge about waste and community participation in protecting the environment and managing waste. However, if appropriately managed, organic waste can be of economic value and help increase household income. In 2017, the city generated 1,537 m\(^3\)/day (approx. 580 tons) of solid waste, which composed 1/3 organic waste dominated by domestic household residents and restaurants [4]. The mismanagement of Kota Jambi solid waste causes a decrease in the carrying capacity of its landfill. Therefore, appropriate policies and actions are needed. The problem of organic waste can be overcome by processing it into other resources that are environmentally friendly and have high economic value, such as: energy, fertilizer, animal feed, and others. One of the advantages of organic waste is its high nutrient content.
Proper processing and extraction of organic waste can create a high protein source for livestock (chickens, ducks), fish, and others, making it economically profitable for farmers because the price is much lower compared to ordinary animal feed. By using the theory of health economics, there is one property that needs attention: contagiousness. Contagiousness is that there are externalities in waste management activities. If the waste is managed correctly, the implementing household will be avoided from diseases that arise, but the surrounding community will also enjoy the positive externalities. As a result of the loss of disease sources due to the garbage pile, public health has also increased. The stakeholder budget was initially used to treat sick people due to low cleanliness (rubbish heaps). Good waste management and economic value will provide positive externalities, namely improving the family economy. This positive externality will be an incentive for households to want to and sustainably do so. This intuition is essential considering that health is non-monetary so that the impact does not appear, while the money from waste management will have a real impact, namely additional family spending money [5].

Organic waste containing high nutrition can be processed into animal feed and fish at a low cost. As a fish feed, maggot has two functions: a protein source that can substitute a fish meal and as an alternative pellet that can be changed directly as a pellet. The application of maggot bioconversion technology uses Black Soldier Fly (BSF) as a biological agent to degrade organic waste. Maggot is a Black Soldier (Hermetia illucense) insect larvae that can convert organic material into its biomass. This technology can decompose organic waste in a short time, reduce odors, and be sustainable. The processed product of maggot bioconversion is animal feed with a high protein source. Bioconversion by BSF larvae, apparently able to reduce organic waste by up to 56%. BSF larvae can be sold directly by the community to customers (e.g. reptile breeders or bird markets), made into pellets and compost to be more profitable. This circular economic process involves the community for maggot cultivation and organic waste collection. With maggot bioconversion technology can solve four main problems, namely: the generation of organic waste, by degrading organic waste in a short time, the price of a high protein source, by producing sustainable protein sources, increasing demand for animal feed, by producing healthy feed and good quality and improving the economy of the community.

Maggot bioconversion can help reduce farmers’ capital so that it is expected to help the community get fish or poultry at affordable prices and help reduce landfill waste. Besides aiming to help the community get cheap feed, improve the household economy, and solve the waste problem, this activity will also be followed by indexed publications. One of the regions in Indonesia that experienced this problem was Jambi Province. Jambi is located on the east coast in the central part of the island of Sumatra. Jambi Province is geographically located between 0.45 ° North Latitude, 2.45 ° South Latitude and between 101.10 ° - 104.55 ° East Longitude. In the north, it borders Riau Province, in the east with the Berhala Strait, in the south, it borders South Sumatra Province and in the west with West Sumatra Province and Bengkulu Province. The strategic geographical condition among other cities in the surrounding provinces makes this province’s role quite important, especially with abundant natural resources.

Jambi Province is 53,435 km² with a population of Jambi Province in 2010 amounting to 3,088,618 people [6]. High population consumption is not accompanied by a harmony of knowledge about waste and community participation in protecting the environment and managing waste [7]. As a result, garbage from community activities accumulates to reduce the environment’s quality and disturb the surrounding community’s comfort. Various environmental problems that arise, such as the accumulation of waste, have an impact on the increasingly reduced availability of landfills (TPA), cause odors from spoilage of garbage, air pollution, which is a source of disease for human health [8]. The overload landfill will release methane gas (CH4) [9].

One serious problem that needs to be addressed is the management of waste generated by household activities and food stalls scattered in Jambi. For example, the amount of waste generated from Purwodadi Village, Tebing Tinggi District, Tanjung Jabung Barat Regency, and Jambi ranges from 105 m³ or equal to around ± 105 tons per day. The absence of waste segregation between organic and inorganic rubbish causes garbage accumulation in the Angso Duo market area and the Banjar’s gutter
area. From the results of observations in the field, the effort that has been made by the Department of waste handling in dealing with this garbage is by collecting rubbish in the garbage bin that has been provided for further disposal to the final landfill (TPA) of waste without further processing. However, the process of handling the waste is felt to be lacking can overcome the problem of organic waste because of the garbage that comes from vegetables. The local government’s role, community participation, and so that NGOs and youth organizations are needed as agents of change in the community to help the government realize the reduction of organic waste generation.

The problem above shows that the community’s knowledge and skills capacity in managing waste and waste is still very lacking. So that waste management with the zero-waste principle is critical. Because garbage and waste are sources of “disease” and disease vectors, with the 3R waste management training, people in the future will have better knowledge and skills to process the waste they produce so as not to pollute the environment and cause climate change. To be able to do this, all needs a good social institution and policy [10].

The partner community still does not have the strength of social institutions, so it has not been able to do 3R waste management. The main problem is limited knowledge, insight, and skills so that they are powerless to do this. Based on this, it is essential to create a sustainable village to solve the waste problem in Jambi City by increasing the economic value of organic waste. Besides being beneficial to the environment, it can also provide additional income for the community.

This paper aims to study an alternative of organic waste management to be implemented in Jambi Province using maggot cultivation as a tool. This paper will explain the process of converting waste into maggot. It will also explain how the process and result can benefit the people, one of the economic value. Hopefully, this research may contribute to waste management implementation better and locally inspire different stakeholders to convert waste into economic value.

2. Method
The method is using descriptive analysis based on literature studies. The first effort in integrated urban waste management starts with sorting starting from sources of waste producers, both from households, markets, industries, public facilities, commercial areas and other sources. Organic waste (food scraps, leaves, etc.) is separated from inorganic waste (plastic, glass, etc.). Organic waste can also be used for the agricultural sector. With the help of microorganisms (microbes), organic waste can be used for fertilizing plants, namely through the composting process. Compost results from partial/incomplete decomposition of a mixture of organic materials that can be artificially accelerated by populations of various microbes in warm, humid, and aerobic or anaerobic environmental conditions. In this case, organic waste can be utilized for maggot cultivation by referring to the cultivation stages as follows:

1. Hermetia illucens Flies Cultivation
   The initial stage of Hermetia illucens flies’ cultivation begins with collecting pupa Hermetia illucens on coconut cake. Larvae in the collection ± 1000 tails, then the pupae are hatched with a period of ± 7 days-1 month in several special containers that have been provided.

2. Cage Preparation and Growing Media Maggot
   The cages used have a size according to the scale of maggot development and on each side of the cage is covered with ram. The cage floor is provided by coconut cake (can be replaced with other types of rubbish which is educated by maggot), which has been mixed with water and covered with dried banana leaves (can also use cardboard pieces). The ratio of coconut cake to water is 2:1. This media is used to attract flies to lay eggs on dried banana leaves. Furthermore, the adult fly will mate in a cage and produce eggs. Hermetia illucens flies lay their eggs under dried banana leaves or in their folds. The illustration of the maggot cage is shown in Figure 1.
3. *Hermetia illucens* Egg Collection

*Hermetia illucens* fly eggs obtained were collected in aluminum foil and stored in a refrigerator at 5 °C. Hatching of flies eggs *Hermetia illucens* is done by removing fly eggs from the refrigerator and stored at room temperature before being put into the growing media. In the nursery, it is necessary to record and count the number of BSF eggs. In the nursery, the process must maintain a temperature between 28-40 °C and humidity between 60-80%.

4. Growing Media Maggot

Growing media in organic waste that has been separated from the market, households and restaurants as much as 20 kg mixed with cow dung from livestock waste as much as 20 kg. The type, composition and amount of waste can be adjusted to the source of waste and scale of management). Organic waste is placed in the bio pond and larvae are added. During his life, maggot eats everything included in the organic category, such as garbage and organic waste. Before being put into biopond, organic waste is first chopped and ground to produce a homogeneous and fine waste, so larvae quickly digest it.

5. Harvest Maggot

Maggots that are two weeks old are still in the media and then washed with water to facilitate the maggot’s separation from the media. Next, the maggot is weighed and ready to be accommodated in a plastic bag. Compost has also been separated from larvae, which can be used as a planting medium.

6. Turning into economic value

Maggot larvae can be sold as animal feed. Meanwhile, the compost can be sold as a fertilizer.

3. Results and discussion

Waste management system policies and strategies are needed to achieve sustainable development goals through integrated, effective, and efficient plans, programs, and activities. Waste management in Indonesia has been listed in RI Law no. 18 of 2008 concerning Waste Management that “waste management is a joint obligation between the regional government and the community”. Waste problems can be solved by regulations and policies and involve technical, social, economic, and cultural aspects. Waste management, through utilization efforts to become high-value-efficient materials, can improve people’s economic conditions in Jambi Province. This can be realized with the development of environmentally friendly waste management.

Waste problems through the 3R principle are running less effectively so that the Ministry of Environment states that handling 4R waste is the most effective and efficient principle in managing waste in Jambi Province. Organic waste in Jambi Province with abundant quantity can be processed into other resources, such as energy, fertilizer, animal feed, and others [11]. The potential of these resources can encourage local communities to manage and use waste wisely. One of the advantages of organic
waste is its high nutrient content. Proper processing and extraction of organic waste can create a high protein source for animals, fish, and others, making it profitable for animal farmers and vegetable and fruit farmers in Jambi Province. Based on the less effectively waste management problem, the aim is precise that communities have to implement those steps of alternative friendly waste management methods regarding maggot cultivation. The priority is maximizing the utilization of organic waste in Jambi to be modified into resources that create economic benefits by implementing a new friendly waste management method proposed to the Jambi Province government. Not only implement the new method of friendly waste management, but communities should also be encouraged to do so. Communities participation in successfully conducting steps of maggot cultivation as an alternative waste management method will embark sustainable environment of Jambi especially for reducing organic waste, changing the prior way of less effectively waste management method and increase many resources as a result of new waste management process which can be traded or utilized by communities. Thus, this method will solve one of the SDGs regarding waste management and enforce economic benefits for Jambi and communities.

Management of organic waste using environmentally friendly technology is far more economical in its management and can be the Jambi Province government’s choice for assisted by the local community. Optimal community participation in reducing the negative impact of waste [7]. The condition helps such participation that people move by incentives. People move by incentive is a term used to describe something that motivates or encourages someone to do something. Someone is choosing an activity based on their preferences [12]. Every individual’s preferences are different. People move by incentive is a benefit generated when the community jointly runs the planned program. The success of a program and the results obtained from that program are very dependent on the community’s participation and involvement in running the program. The benefits generated from the program will not be obtained if the community does not try to carry out activities and activities to achieve the program’s objectives.

One reason why this happens is someone consuming goods or services have a different level of satisfaction. Economic goods produce useful utilities to satisfy the desires or needs of consumers. The level of satisfaction, or often also referred to as Utility, is an economic term that is often used to describe someone’s decision. These benefits can be seen as both monetary and non-monetary. Monetary compost has value because it can be traded and used as a growing medium and maggot that can later be traded or used directly for animal feed and poultry. Non-monetary or that cannot be calculated as with the 4R process’s education, public awareness of organic waste increases, and other impacts we are not besotted with scattered views of waste because people will be accustomed to throwing garbage in designated places.

This waste management program can provide education to the community and a form of investment in human capital that provides personal benefits for those directly involved and for people who are not directly involved or not involved at all. Personal benefits derived from education are obtained and enjoyed directly by individuals who carry out education. The personal benefits of education include increasing public knowledge in organic waste management so that the community can independently utilize the education to manage environmentally friendly organic waste at a low cost. Also, education in this program can also make people more productive in waste management and make waste a product that is environmentally friendly, easily degraded and sustainable. It can later have a social impact on the local environment.

The social benefits of education are benefits that can not only be felt by individuals who carry out education but also other people who are either involved or not involved in the education and education of an individual and the value generated from the social benefits of one’s education outweighs the personal benefits gained an individual. One form of externalities or social benefits from this waste management education is its effect on the environment at that location. By increasing community productivity in organic waste management using environmentally friendly insect larvae technology, this can reduce the amount of waste available and be able to make environmental improvements optimally [13].
In addition, other supporting factors in managing waste are the level of education, knowledge, technological development and models of waste management, cleanliness actions and the existence of regulations on waste [14]. The development of environmentally friendly technology to treat organic waste can currently use insect larvae. Generally, the organisms that play a role in the bioconversion process are bacteria, fungi and insect larvae (family: Chaliforidae, Mucidae, Stratiomydae). In everyday life in animal waste, a chopper agent often found is the Diptera insect larvae. Insect larvae of the family: Stratiomydae, Genus: Hermetia, species: Hermetia illucens, found in palm oil waste. Hermetia illucens or Black Soldier Fly (BSF) larvae, better known as “maggot” [15] [16].

Black army fly larvae (Hermetia illucens) (Black Soldier Fly / BSF) have cellulotic activity in the presence of bacteria in their intestines [17]. The presence of bacteria in the larvae’s intestines helps the larvae convert organic waste in their intestines. BSF larvae are able to convert organic waste into fat and protein in their body biomass [18] [19] [20] [21] [22] [23] [24] BSF larvae contain a source of protein for animal feed, so it can be an alternative feed to replace conventional feed [15] [25]. Of the various insects that can be developed as feed, the BSF larvae protein content is quite high, which is 40-50% with a fat content ranging from 29-32% [26]. Rambet al. (2016) concluded that BSF flour has the potential as a substitute for fish meal up to 100% for broiler chicken feed mix without a negative effect on dry matter digestibility (57.96-60.42%), energy (62.03-64.77%) and protein (64.59-75.32%), although the best results are obtained from fish meal replacement of up to 25% or 11.25% in feed [27].

The application of this technology can be applied using easy and low cost facilities. The BSF fly life cycle has 5 stages, namely the adult phase, the egg phase, the pre-pupa phase, the pupa phase, and the insect phase. The illustration of BSF fly life cycle shown in Figure 2.

![Figure 2. Larvae Morphology, pupa, and adult flies BSF [28].](image)

Tomberlin et al. (2002) stated that BSF’s life cycle from eggs to adult flies lasts around 40-43 days, depending on environmental conditions and the media given feed [29]. A normal BSF female fly is capable of producing eggs ranging from 185 to 1235 eggs [30]. Other literature states that a female needs 20-30 minutes to lay eggs with a total egg production of 546-1,505 eggs in the form of egg mass, while female flies are reported to only lay eggs once during their lifetime, after which they die [31]. BSF insects have several characteristics including: (1) can reduce organic waste, (2) can live in a high enough pH tolerance, (3) does not carry disease genes, (4) has a high enough protein content (40-50%), (5) the life span as larvae is quite long (± 4 weeks), and (6) is easily cultivated [32] [33].

It was further mentioned that the number of eggs is directly proportional to an adult fly’s body size. Female flies that have a larger body size with wider wing sizes tend to be more fertile than flies with small stature and wings [9]. In addition, humidity is also reported to affect the egg-laying power of BSF.
flies. About 80% of female flies lay eggs at humidity conditions of more than 60% and only 40% of female flies lay eggs when humidity conditions are less than 60% [29]. Within two to four days, the eggs will hatch into one instar larvae and develop up to six instars within 22-24 days with an average of 18 days [33]. Judging from its size, newly hatched larvae from eggs measuring approximately 2 mm, then develops up to 5 mm. After a skin change, the larvae develop and grow more extensive with a body length reaching 20-25 mm, then enter the prepupa stage. Tomberlin et al. (2002) states that female larvae will be in the media longer and have heavier weights than male larvae.

At present, insect-based organic waste treatment using black soldier fly (BSF) larvae, *Hermetia illucens* L. (Diptera: Stratiomyidae) has not been popular and has not been widely studied in Indonesia. BSF larvae are an innovative strategy and sustainable methods for organic waste management that can reduce the burden of landfill waste and open new economic opportunities that are profitable for city dwellers and small-scale entrepreneurs or communities in developing countries [34]. BSF larvae are very active in eating a variety of organic materials, such as fruits and vegetables, market waste, kitchen waste, fish waste, oil palm cake, and livestock and human waste, so they are classified as bioconversion agents. The ability of BSF larvae to reduce organic waste has been reported as 66.4-78.9% [18]. Besides reducing waste, people are able to gain revenue by producing resources that can be traded from waste management process which encompass maggot cultivation. Organic waste contains resources that are needed by community after the waste management process is conducted. Maggots are able to change organic waste into high protein animal feed at low cost. The role of maggots to increase the economic value of organic waste is its ability by turning organic waste that is not possessed benefits into organic waste that can be used for high protein animal feed, fertilizer, energy and others. Those bioconversion products have economic value to increase the community’s prosperity by creating businesses to trade those resources.

The description above illustrates that handling organic waste in Jambi Province has not been effective, both policies, regulations, and local communities’ contributions. Knowledge, insights, skills, and economic conditions that tend to be weak make local people unable to make optimal environmental improvements. Therefore, the management of household and restaurant organic waste can be minimized using BSF larvae bioconversion technology to increase the economic value of organic waste with the active participation of local communities, thereby supporting the strategic policy of the Jambi Province waste area.

4. Conclusion

Friendly waste management from maggot cultivation brings a sustainable environment and enhances organic waste’s economic value.) Waste management by maggot cultivation creates organic waste’s economic value by turning organic waste into valuable resources that the community can trade and use. Improvement of community welfare can be made by providing direct and indirect activities to encourage their waste management participation [35]. Economic value in organic waste will encourage the community to earn the benefit of their own waste. As one of the areas that has waste problems, Jambi has not had complete infrastructure yet to manage waste well. It can be helped if the community is encouraged to reduce, reuse, and recycle the waste. Thus, the garbage is not accumulated and become a source of disease.

The incentive in the form of organic fertilizer that is worth selling will provide additional income for the family and encourage the community to continue doing this activity. The system for making organic fertilizer using larvae is not yet popular but it is very easy for the community to work on. This community empowerment in addition to helping the government will also help the community itself.

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