EFFECT OF ORGANIC WASTE PRETREATMENT ON CAPABILITY AND PROTEIN CONTENT OF BLACK SOLDIER FLY (BSF) LARVAL

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Abstract

This study was conducted to see the effect of size and freshness variations of organic waste on BSF growth. The research was conducted on laboratory-scale research at campus of Pasundan University and field-scale research on Pojok Kang Pisman at Bandung City-hall. In laboratory-scale research, the organic waste used is artificial organic waste whose composition is close to organic waste from market. Meanwhile in field-scale research, the organic waste used is from market organic waste. Variations in pretreatment were carried out by varying the organic waste size and freshness in laboratory-scale research and comparison in order of chopping and fermentation of organic waste in various cocopeat thickness in field-scale research. Maggot/BSF growth analysis was carried out by calculating the waste reduction index, Efficiency of Conversion Digested Feed, survival rate, and maggot protein tests. The results of the laboratory study showed that the smaller the size of the waste influenced increasing the WRI, SR and ECD values but had little effect on the protein content of the larvae. The protein content of larvae is suitable for chicken feed (19-21%). However, when the waste was fermented, there was a significant increase in WRI and SR, and the protein content of the larvae increased (32-34%), suitable for tilapia and catfish feed. Field research results with higher larval density in fermented waste resulted in higher WRI and ECD values compared to laboratory results with lower larval density. In addition, the treatment of chop-fermentation and fermentation-chopped sequences gave different water content values which affected the WRI and ECD values. The higher the water content, the lower the WRI and ECD values. The protein content of larvae in the field study was almost the same as in the laboratory study, ranging from (31-34%).

Keywords: *Black Soldier Flies, ECD, larval, protein, WRI*

Introduction

Waste in Indonesia is dominated by organic waste or waste that is easy to decompose (Yustiani et al., 2019). This type of waste includes food waste. Bioconversion is a process by involving microorganisms such as yeast, fungi, and bacteria or alternatives to terrestrial invertebrates such as insect larval to turn organic waste into higher-value products (Satori et al., 2021). Bioconversion is a continuous process that utilizes insect larval to transform organic waste. Furthermore, the insect larval convert nutrients from the waste and are stored as their biomass (Diener et al., 2015). Various types of organic waste processing have been widely developed, one of which is the use of Black Soldier Flies (BSF) larval. *Hermetia illucens* known as *Black Soldier Fly* (BSF) is an insect belonging to the order Diptera, Family *Stratiomyidae*, subfamily *Hermetinae*. Currently BSF is widely used as animal feed because it has high levels of nutrients (Barragan-Fonseca et al., 2017) (Cheng et al., 2017) and high protein (Mutafela, 2015). BSF larval are distributed almost all over the world. BSF larval eat anything that has been consumed by humans, such as food

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waste, garbage, fermented food, vegetables, fruits, meat, bones (soft), and animal carcasses. BSF fly larval are classified as "immune" and can live in quite extreme environments, such as in media/garbage that contain a lot of salt, alcohol, acids/acids and ammonia (Devic and Fahmi, 2015). BSF larval can reduce household organic waste, such as fruit, vegetables, and food waste. The percentage of organic waste reduction value reaches 62.68%-73.98%. These results vary because there are differences in treatment in feeding BSF larval. The harder the characteristics of the waste given to the BSF larval, the more difficult/ long the reduction process will be. In addition, humidity, temperature, and media type greatly influence the growth of BSF (Barragan-Fonseca et al., 2017). In addition to the ability of BSF larval to reduce waste, the final stage of larval called prepupa can be harvested alone (self-harvesting) resulting in high added value, namely containing 40% protein and 30% fat which is used as feed for fish and livestock instead of fish meal (Cheng et al., 2017) (Mutafela, 2017). The use of BSF as animal feed can cover the financing of waste management in low and middle countries (Diener, 2010). On the other hand, the fat content of BSF larval of 30% has the potential to become a raw material to produce biodiesel as an alternative energy.

The reduction of various organic wastes by BSF larvae has been studied by the researchers namely reduction of human waste material by 51.3% and reduction of poultry feed 84.9% (Tomberlin et al., 2009), (Rui et al., 2017). Furthermore, reduction of cow dung 33-58% and chicken manure 50% (Tomberlin and Sheppard, 2001) (Diener et al., 2015) and reduction of municipal organic waste 66-79% (Diener et al., 2011). Compared to types of animal waste, fruits, and vegetables, it turns out that kitchen waste has the highest reduction rate per day (Nguyen et al., 2015) (Liu et al., 2018), as well as restaurant waste (Spranghers, 2016). The rate of waste consumption by BSF larvae varies according to the type of waste, moisture content, numbers of larvae, larval size and temperature (Alvarez, 2012), (Rochaeni et al., 2021).

The larval of *Hermetia illucens* or Black Soldier Flies (BSF) have been propagated as organic waste converter agents because these larval feed on various decaying organic matter and produce prepupa containing crude protein and fat as feed for fish and other farm animals. BSF larval can reduce household organic waste, such as fruit, vegetables, and food waste. The percentage of organic waste reduction was vary depending on treatment in feeding BSF larval. This study was conducted to see the effect of size and freshness variations of organic waste on BSF growth.

Methodology

The research stages started from literature study, preparing tools and materials, preparing larvae and various organic waste conditions, observing larval growth, calculating the Waste Reduction Index, Efficiency of Conversion Digested Feed, and Survival Rate values from larval growth data, as well as protein testing on prepupa and pupa samples.

Preparation of Tools and Materials

Preparation of the study is carried out by preparing all the necessary tools and materials during the study. The tools that are prepared are all the needs during the implementation of the research. The necessary material is organic waste.

The necessary tools are as follows:

- A rectangular-shaped plastic container or breeding BSF larval, called biopond. Prepared 2 biopond for each variation.
- Foam for laying eggs of BSF larval to be hatched.
- Thermometer to measure the temperature and humidity of the air.
- Gram digital scales to weigh the weight of BSF larval and the weight of litter.
- A knife for cutting litter into smaller shapes.
- Cloth to close the reactor where the media is

to avoid annoying animals such as rats.
- Label paper and a notebook for recording information during the study.

The necessary materials are as follows:
- Larva BSF
- Organic waste.
- Cocopeat, 1 cm high in each biopond at laboratory scale, and 1, 1.5, and 2 cm in each biopond at field scale. Cocopeat is used to absorb the moisture content of organic waste.

Preliminary Research

Preliminary research aims to obtain waste composition for organic waste variations, waste sampling was carried out at the Cipageran Puri Market, Cimahi City. The stages of preliminary research are:
- Sampling of market waste by giving plastic bags to traders was carried out for 8 days.
- Plastic bags containing waste are taken from traders every day to be weighed and the composition of the waste is calculated to get the percentage of each type of waste.
- The waste that will be used in this laboratory scale research uses the same composition as the sampling results. Meanwhile, for field scale research used market organic waste as it is.

Laboratory scale research

- Waste size variations
  - 7 grams of BSF larval aged 10 days (equivalent to 500 tails) were put into each biopond.
  - Every 2 days, 100 grams of waste are added to each biopond with 3 variation in size, namely waste as it is, coarsely chopped waste (4 cm), and finely chopped waste (±1-2 cm). The addition of waste is carried out until the larval become prepupae (inactive feeding phase).
  - Every 2 days, before adding new waste, the remaining organic waste that is not eaten by the larval in each biopond is removed and weighed.
  - At the end of larval phase (prepupa), the total larval were counted and weighed on each biopond.
  - Larval aged 15 days, prepupae and pupae are taken from each biopond for protein testing in the laboratory.
- Waste Freshness Variations
  - 7 grams of BSF larval aged 10 days (equivalent to 500 tails) were put into each biopond.
  - Every 2 days, as much as 200 grams of organic waste is added to the biopond. The added waste has 3 variation of freshness, namely fresh waste, 2 days of fermented waste and 4 days of fermented waste. The addition of waste is carried out until the larval become prepupae (inactive feeding phase).
  - Every 2 days, before adding new waste, the remaining organic waste that is not eaten by the larval in each biopond is removed and weighed.
  - At the end of larval phase (prepupa), the total larval were counted and weighed on each biopond.
  - Larval aged 16 days, prepupae and pupae are taken from each biopond for protein testing in the laboratory.

Field-scale research

Variations in the order of fermentation and chopping of waste in various cocopeat thickness.
- 300 grams of BSF larval aged 5 days were put into each biopond.
- Every day, as much as 300 grams of organic waste is added to the biopond. The added waste has a different order of treatment, namely the waste that is fermented first and then finely chopped, and the waste that is finely chopped first and then fermented. Fermentation is carried out for 4 days each.
- There are 3 biopond with variation in cocopeat thickness namely 1, 1.5, and 2

cm.

- Every day, before adding new waste, the remaining organic waste that is not eaten by the larval in each biopond is removed and weighed.
- At the end of larval phase (prepupa), the total larval were weighed on each biopond.
- Larval aged 24 days are taken from each biopond for protein testing in the laboratory.

Calculation of WRI, SR and ECB

Calculation of the Waste Reduction Index with the Eq. (1) and (2) (Rofi et al., 2021).

$$WRI = \frac{D}{t} \times 100 \quad (1)$$

$$D = \frac{(W-R)}{W} \quad (2)$$

where WRI is Waste Reduction Index, D is waste degradation rate, t is time required to degrade waste, W is amount of garbage before degradation and R is amount of residue.

Calculation of the survival rate with the Eq (3) (Rofi et al., 2021).

$$SR = \frac{Y}{Z} \times 100 \quad (3)$$

Where SR isSurvival rate (%), Y is total number of larval that live end-of-rearing (larval) and Z is total number of larval that lived early in rearing (larval).

Calculation of the Efficiency of Conversion Digested Feed with the Eq. (4) (Rofi et al., 2021).

$$ECD = \frac{B}{(I-F)} \times 100 \quad (4)$$

where ECD is Efficiency of digestible organic waste consumption (%), B is larval weight gain during the larval feeding period (g), I is amount of organic waste feed consumed (g), F is weight of residual feed waste of organic waste and excretion results (g)

Laboratory Protein testing

This test was carried out to determine the value of protein contained in BSF larval by protein testing in the Food Engineering Laboratory of Pasundan University, where larval that had dried and became powder were taken as much as 5 grams. The steps for testing protein levels according to Indonesian Standard of SNI 01-2354.4 -2006.

Results and Discussion

Waste Composition

The result of the composition of market waste are shown in the following table. This composition was used in the research with a total weight of 100 grams of waste per biopond.

Table 1. Waste Composition

No	Type		Weight (grams)
1	Green vegetable	- Green mustard	8.3
		- Bok choy	4.1
		- Kale	4.3
		- Spinach	4.6
		- Broccoli	8.2
		- Carrot	4.6
		- Chicory	11.3
		- Chayote	4.4
2	Meat	- Chicken	12.3
		- Fish	18.2
3	Fruits	- Citrus Fruit	7.7
		- Apple	2.0
		- Bark	1.6
		- Pineapple	2.7
		- Mango	1.7
		- Tomato	3.0
		- Guava	2.9
	Total		100

Effect of waste size variation

Table 2 shows the results of waste reduction carried out by BSF larvae after 2 days. Fine-sized waste is consumed more than large-sized waste and waste as is (without treatment).

Table 2 Waste weight after 2 days of bioconversion process

Day to day	Garbage Weight (grams)			
	Beginning	Without Treatment	Coarsely Chopped	Finely Chopped
12	100	78.75	81.75	79.95
14	100	66.10	38.30	38.10
16	100	57.70	52.20	36.10
18	100	63.20	61.70	20.95
20	100	49.05	68.20	21.60
22	100	63.65	53.40	21.35
24	100	64.25	68.30	33.80

From Table 2 it can also be seen that on day 22 it produces the largest residual waste value which indicates the peak of the active phase of the larvae eating garbage, then the remaining waste rises again on day 24 which means that the larvae have stopped eating garbage, have started to switch to the pupa phase and are getting ready to turn into a fly.

Table 3 shows the percentage of reduced waste converted by larvae. From Table 2, the maximum percentage of finely chopped waste reduction reached 78.8%, while for coarsely chopped waste was 51.4%, and 54.7% for un-chopped waste. Coarsely chopped and un-chopped waste are both more difficult for larvae to consume. The average percentage of waste reduction per 2 days for finely chopped, coarsely chopped and un-chopped waste reached 63.1%, 38.6% and 40.1%. The un-chopped waste contains fine to large size waste.

Table 3. Percentage of waste reduction

Day to day	Garbage Reduction (%)		
	Un-chopped	Coarsely Chopped	Finely Chopped
12	22.3	19.9	20.2
14	39.1	48.3	62.3
16	46.1	41.1	60.2
18	40.3	42.1	77.0
20	54.7	36.5	78.7
22	37.9	51.4	78.8
24	40.0	32.6	64.6
Average	40.1	38.6	63.1

The value of the Waste Reduction Index (WRI), which considers processing time, shows that the average WRI value for finely chopped waste is much higher than coarsely chopped and un-chopped waste (Table 4).

Table 4. WRI comparison

Day to day	WRI		
	Un-Chopped	Coarsely Chopped	Finely Chopped
12	11.15	8.95	10.10
14	19.55	24.15	31.15
16	23.05	20.55	30.10
18	20.15	21.05	38.50
20	27.35	18.25	39.35
22	18.95	25.70	39.40
24	20.00	16.30	32.30
Average	20.00	19.30	31.60

In Table 5, the survival rate of larvae in finely chopped waste has the largest value with 96.7%. This shows that the smaller the size of the waste, the easier it is to digest by the larval and increase the potential for larval life.

Table 5. Larval Survival Rate affected by waste size

Treatment	Initial Number of Larval	Number of Live Larval	Survival Rate (%)
Without Chopped	500	461.5	92.3
Coarsely Chopped	500	471.5	94.3
Finely Chopped	500	483.5	96.7

In Table 6 show the increase in larval weight reaches higher weight gain for finely chopped waste. The ECD values increases as the size of the waste decreases.

Table 6. Weight Gain of Larval and ECD value

Treatment	Initial Weight (gr)	Final Weight (gr)	Weight gain (gr)	Total feed (gr)	Total residue (gr)	ECD (%)
Un-chopped	7	21.65	14.7	700	442.70	5.69
Coarsely Chopped	7	23.2	16.2	700	423.85	5.87
Finely Chopped	7	39	32.0	700	251.85	7.14

The results of the examination of protein levels in larvae were carried out in 3 stages, namely when they were 16 days old, the prepupa phase and the pupa phase, are shown in Table 7. From the table, the protein content of the larvae did not differ much between the waste not chopped, coarsely chopped, and finely chopped, ranging from 19-21% because the composition of the waste given is the same. This shows that the protein content of larvae wasn't affected by the size of the feeding waste. Compare with various SNIs for protein content of feed, the results obtained are suitable for laying hens or broilers, but not suitable for fish and catfish.

Table 7, Comparison of protein levels (%)

Larval Age	Un-chopped	Coarsely Chopped	Finely Chopped
16 days	19.212	20.26	20.30
Prepupa	19.175	21.48	21.36
Pupa	19.230	20.30	20.24

Effect of waste freshness variation

The variation of the freshness of the waste is done by varying the length of time the waste is fermented before being put into the biopond. Before fermentation, the waste is chopped using finely chopped, according to the best results in the previous stage of research. There were 3 variations, namely without fermentation, 2 days of fermentation, and 4 days of fermentation. Table 8 shows the remaining waste that was not eaten by the larvae after 2 days of bioconversion.

Table 8. Residue of waste in Biopond with fermentation variation

Day	Residual Waste in Biopond (grams)			
	Initial Weight	Without Fermentation	2 Days Fermentation	4 Days Fermentation
12	100	79.95	55.95	43.15
14	100	38.15	37.80	24.70
16	100	36.10	27.70	16.25
18	100	20.95	14.95	9.60
20	100	21.60	9.90	5.05
22	100	21.35	13.25	11.00
24	100	33.80	40.75	29.15
Average		35.99	28.61	19.84

Table 8 shows that the 4-day fermentation gave the lowest residual waste compared to the 2-day fermentation and without fermentation. This suggests that longer fermentation makes the waste softer for larvae to eat.

Table 9 shows that the highest percentage of reduction was found in bioponds with 4 days of fermentation (94.95%), compared to 2 days of fermentation and without fermentation. This is because the texture of the organic waste is soft due to the fermentation process and the larvae are in optimum condition to meet the nutrition before entering the prepupa phase, where the larvae will stop eating until they die as flies. Meanwhile, the time to reach the peak of reduction in bioponds without fermentation was slower (22 days) compared to bioponds with fermentation for 2 and 4 days (20 days). This happens because the larvae eat a longer rate of harder waste (Rochaeni et al., 2021). At the age of 12 days, the larvae gave a low percentage of reduction because the larvae had just hatched and were still in the stage of adapting to new food. Meanwhile, for the age of 20-24 days there was a decrease in the percentage reduction in all variations because the larvae had stopped eating and were about to enter the next phase. The larvae begin to enter the prepupa phase marked by a decrease in feeding intensity and the larval body is brown.

Table 9. Organic waste reduction percentage

% Reduction of Organic Waste By BSF Larval			
BSF Age (Days)	Without Fermentation	2 Days Fermentation	4 Day Fermentation
12	20.05	44.05	56.85
14	61.85	62.20	75.30
16	63.90	72.30	83.75
18	79.05	85.05	90.40
20	78.40	90.10	94.95
22	78.65	86.75	89.00
24	66.20	59.25	70.85
Average	64.00	71.40	80.20

WRI values of BSF larvae for variations in waste freshness are shown in Table 10 below.

Table 10. Waste Reduction Index Value

BSF Age (Days)	Waste Reduction Index (WRI)		
	Without Fermentation	2-Days Fermentation	4 Days Fermentation
12	10.0	22.0	28.4
14	30.9	31.1	37.7
16	32.0	36.2	41.9
18	39.5	42.5	45.2
20	39.2	45.1	47.5
22	39.3	43.4	44.5
24	33.1	29.6	35.4
Average	32.0	35.7	40.1

In line with the results of the reduction, the largest WRI value was obtained on day 20 in a biopond with 4 days of waste fermentation.

The Survival rate results of this study on freshness variation can be seen in Table 10.

Table 10. Survival Rates of Larval BSF affected by fermentation

Freshness	Initial number	Final number	SR (%)
Without Fermentation	500	483.5	96.7
2-Days Fermentation	500	476	95.2
4-Days Fermentation	500	486.5	97.3

From Table 10, the survival rate for all variations of waste freshness gives results above 95%, meaning that the ability of larvae to survive is not much influenced by the freshness of the waste, although at the 4-day fermentation variation the SR of the larvae was slightly higher.

Table 11 show that the ECD value of larvae was slightly influenced by the length of time the waste fermented. The longer the fermentation, the lower the ECD value. In the 4-day fermentation, the amount of organic digested was the largest, and the increase in larval weight was also the largest, but the increase in the amount of organic digested was not proportional to the increase in larval weight.

Table 11. ECD value affected by fermentation

Freshness	Initial weight	Final weight	Weight Gain	Total feed	Total residue	ECD
	(gr)	(gr)	(gr)	(gr)	(gr)	(%)
Without Fermentation	7	39	32.0	700	251.9	7.14
2-Days Fermentation	7	40.3	33.3	700	200.3	6.66
4-Days Fermentation	7	42.8	35.8	700	138.9	6.38

Table 12. BSF Larval Protein Levels on waste freshness variation

Age	Larva Protein Levels (%)		
	Without Fermentation	2-Days Fermentation	4-Days Fermentation
16 days	20.3	33.5	33.6
prepupa	21.4	34.6	34.7
pupa	20.2	32.4	32.3

From table 12, the protein content of larvae is strongly influenced by the freshness of the waste. The protein content of larvae in the 2-day and 4-day fermentation variation was higher than without fermentation waste. It means the high and low protein content of larvae is influenced by differences in the growing media used. Fermented fruit has the highest percentage of WRI value because the feed given has been overhauled by local microorganisms so that the fermented fruit has a soft texture (Rofi et al., 2021).

In addition, photosynthetic bacteria in fermenting local microorganisms will accelerate decay and produce amino acids that can degrade dietary fiber and nutrients in feed so that protein can be easily absorbed by BSF larvae. Another function of amino acids is to produce antimicrobial substances from actinomycetes bacteria in fermentation, thereby increasing the palatability of larvae in consuming the given feed (Rofi et al., 2021). The results of other studies show maggot flour contains crude protein ranging from 28.2 - 42.5% (Diener et al., 2015), 43.2% (Nguyen et al., 2015), while the results of the study used oil palm cake media, protein content is 44.01% (Rachmawati et al., 2015).

Compare with various SNIs for protein content of feed, the results obtained are suitable for fish and catfish, but not suitable for laying hens or broilers.

When chicken is given too high a protein, it will cause an excess supply of protein (including metabolic energy) and this excess is stored in the form of fat, especially in the abdomen. In addition, excessive protein levels will also cause increased levels of ammonia in the cage and chicken feces will become wetter. This condition can eventually trigger cases of respiratory disease in chicken (http://info.medion.co.id, accessed Aug 2022).

If feed with high protein is given to laying hens, then grower chickens that have excess fat deposits will decrease their performance, including: causing the development of egg follicles to be less than optimal, lead to prolapse trigger the occurrence of fatty liver syndrome (fatty liver syndrome) which can cause low egg production and death if the liver has been bleeding, the number of eggs that hatch in the abdominal cavity (internal lay) because when expenditure is blocked by fat deposits and continues to be peritonitis, if not treated immediately, E. coli bacterial infection will be easy to enter (http://info.medion.co.id, accessed Aug 2022).

Water content of fermented organic waste

Various conditions of waste treatment are carried out by maggot breeders, including chopping and fermenting waste. This research was conducted to validate which one gives the best results, chopping followed by fermentation or fermentation followed by chopping. The first step is to measure the water content of the waste that has been chopped and then fermented, and vice versa. According to the results of laboratory-scale research, fermentation was carried out for 4 days and the chopping was carried out by finely chopped. The results of the measurement of water content are shown in the following table.

Table 13. Organic Waste moisture

Sample	Moisture (%)
Chopping-Fermenting (CF) waste	83.2
Fermenting-Chopping (FC) waste	72.5

The optimum food moisture content for larvae is 60-90% (Eawag, 2017). The two conditions above meet the optimum conditions for water content, it is only seen that the waste that is chopped and then fermented has a higher water content than the waste that is chopped and then fermented.

Organic waste reduction

In the field research, at the beginning of the study, 300 grams of 5-day-old larvae were put into the biopond and the weight of the waste that was put into the biopond was also 300 grams per day. In this case the density of larvae is higher than laboratory studies so that the addition of waste can be done every day. Before adding a new daily waste, the remaining uneaten waste is weighed. Thus, the percentage reduction in daily waste eaten by the larvae can be calculated. The percentage of daily waste reduction is shown in the following table.

From Table 14 for all thicknesses of cocopeat, the percentage of reduction in chopped-fermented waste is lower than that of chopped-fermented waste. This is related to the water content of chopped-fermented waste which is higher than that of chopped-fermented waste. Based on the height of the cocopeat, the higher the cocopeat, the greater the percentage reduction. The function of cocopeat is to absorb the water content of the waste. The maximum reduction percentage was reached on day 19 in all variations, after which the reduction percentage decreased because the larvae began to stop eating and entered the next phase.

Table 14. Percentage of daily waste reduction

Age (day)	Initial weight (gr)	CF (1cm)	CF (1.5 cm)	CF (2cm)	FC (1cm)	FC (1.5 cm)	FC (2cm)
5	300	83.2	83.7	84.3	84.1	84.5	85.9
6	300	80.3	81.1	82.6	82.7	83.3	85.0
7	300	80.5	81.2	82.7	82.9	83.6	85.0
8	300	80.6	81.3	82.8	82.9	83.7	85.1
9	300	80.9	81.9	83.1	83.3	84.6	85.5
10	300	82.2	83.1	84.3	84.1	85.4	86.4
11	300	81.1	82.2	83.8	83.0	84.5	85.9
12	300	81.5	82.6	84.6	83.1	84.6	86.3
13	300	82.5	83.5	85.5	83.7	85.0	87.0
14	300	78.1	78.9	80.8	80.2	80.8	83.0
15	300	79.3	80.0	82.6	80.2	81.6	83.5
16	300	81.1	82.2	84.7	83.3	84.3	85.6
17	300	83.1	84.3	86.9	84.8	86.7	88.2
18	300	86.8	88.8	90.7	88.2	89.6	92.4
19	300	88.2	90.2	92.4	89.9	92.1	94.4
20	300	83.4	85.8	87.2	86.2	86.6	88.0
21	300	82.5	83.8	86.1	83.4	84.4	86.5
22	300	77.7	80.0	80.9	78.5	80.9	82.0
23	300	77.5	79.6	80.7	78.2	80.7	81.8
	Avrg	**81.6**	**82.8**	**84.5**	**83.3**	**84.6**	**86.2**

Note: CF=chopping-fermenting; FC= Fermenting-chopping; 1cm, 1.5cm, 2cm = thickness of cocopeat

WRI value

Because new waste is added every day, the WRI value will be the same as the percentage of waste reduction (Table 14). When compared with Table 10 in the 4-day fermented waste column, the WRI value is influenced by larval density (Alvarez, 2012). In field research, the density of larvae reaches 1 gram of larvae/1 gram of waste, while in laboratory studies it is only 7 grams of larvae/100 grams of waste.

ECD Value

In the field research there was no SR calculation because it was too difficult to calculate the number of larvae. In the calculation of ECD (Table 15) the largest ECD value is obtained at the largest WRI. This shows that fermented and chopped waste is more effective for larvae to digest than chopped and then fermented due to lower water content. Higher cocopeat thickness will absorb more water content, making conditions more comfortable for larvae. Field research ECD values were also higher than laboratory studies due to higher larval densities and thickness of cocopeat.

Table 15. ECD value

Waste	Weight			Total organic feeding (gr)	Total organic residue (gr)	ECD (%)
	Initial	Final	Gain			
CF (1cm)	300	594	294	5700	1048.95	6.32
CF(1.5cm)	300	787	487	5700	977.85	10.31
CF (2cm)	300	869	569	5700	881.1	11.81
FC(1cm)	300	811	511	5700	951.85	10.76
FC(1.5cm)	300	883	583	5700	880.1	12.10
FC(2cm)	300	1057	757	5700	788.15	15.41

Table 16 shows the protein content of the field research.

Table 16. Protein content

Phase	CF (1cm)	CF (1,5cm)	CF(2cm)	FC (1cm)	FC (1.5cm)	FC (2cm)
Prepupa	28.28	28.76	29.29	29.33	29.86	30.78

The protein content obtained ranged from 28-30%. There was no significant difference between the chopped and then fermented waste and the fermented and then chopped waste. Like research in the laboratory, fermented waste causes the value of protein to increase, suitable for fish but not suitable for chicken.

Conclusion

Pretreatment of waste to be processed using BSF larvae, in this case chopping and fermentation will affect the ability of larvae to reduce organic and larval protein content. The results of the study show that:

1. The average organic reduction percentage is 36.73% for waste as it is, 36.74% for coarsely chopped waste, and 64.01% for finely chopped waste.
2. Feeding is carried out every 2 days, then the WRI value of finely chopped waste is 31.6%, while coarsely chopped waste and non-chopped waste is lower. SR and ECD values in finely chopped waste also give the highest value.
3. The protein content of larvae in un-chopped, coarsely chopped, and finely chopped waste did not give a significant difference, ranging from 19-21%, suitable for laying hens or broilers, but not suitable for fish and catfish.
4. The effect of freshness of waste, which was simulated by fermentation time, showed that waste with 4 days of fermentation gave a higher percentage of reduction (80,20%), WRI (40,1), and SR (97,3%) than unfermented waste and 2 days of fermentation, but the ECD value gives the opposite result. This indicates that fermented waste is more suitable for larval growth.
5. The protein content of larvae in fermented waste (32-34%) is also much different from non-fermented waste (20-21%). The protein content of larvae in non-fermented waste is more suitable for breeders and laying hens, while the protein content of larvae in fermented waste is more suitable for fish and catfish.
6. From the field research with higher larva

density, the order of chopping and then fermentation or fermentation and then chopping influences the water content of the waste. Chopped-fermented waste has a higher water content than fermented-chopped waste.

7. The WRI and ECD value of larvae with fermented-chopped waste at all thicknesses of cocopeat was higher than the WRI and ECD value of chopped-fermented waste. The thicker the cocopeat, the more water it absorbs, the more suitable it is for the bioconversion of waste by larvae.
8. The protein content of larvae in field research is almost the same as in laboratory studies, ranging from 28-30%, suitable for tilapia and catfish, but not suitable for laying hens and broilers.

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