The Influence of Waste Ratio on Waste Consumption Level, Waste Reduction Index, and Growth of Black Soldier Fly Larvae

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Abstract. About 80% of the total amount of waste produced is generally organic waste, which is only seen as residual and has no economic value. Currently, the problem of organic waste is a problem that must be addressed immediately, and Black Soldier Fly is one of the solutions. This study aims to determine the influence of waste ratio on waste consumption level, waste reduction index, and larval growth during the breeding process. The waste used in this study is wet organic waste (SOB), which is food waste. On the other hand, dry organic waste (SOK) in the form of dry foliage was chosen because of its large amount and ease of finding; besides that, these two types of waste are often not appropriately managed. This research was conducted using a batch system, where only one substrate was given at the beginning of the study, which was divided into four ratios (SOB: SOK 250:750, SOB: SOK 500:500, SOB: SOK 750:250, and SOB: SOK 1000:0). The results significantly influence the provision of different waste ratios to waste consumption levels and waste reduction indices. The highest waste consumption rate is indicated at the ratio of SOB:SOK 1000:0 reaches 99.36%, and the lowest level indicated in ratio A only reaches 32.66% of SOB: SOK 250:750. The highest waste reduction index is indicated at a ratio of SOB: SOK 100:0 reached 2.84%, and the lowest was shown in the ratio of SOB: SOK 250:750, which only reached 0.94%.

Keywords: Wet Organic Waste (SOB) · Dry Organic Waste (SOK) · Waste Ratio · Recycle · Zero Waste

1 Introduction

The character and increase in the volume of waste are strongly influenced by the population growth rate, economic growth, and the rise in community living standards [1],

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which requires a lot of costs and an increasingly significant area of land. Meanwhile, the increase in waste is not offset by the public awareness to protect the environment. Waste that is disposed of as it is, is not separated by type and has not been processed and reused. Waste is not something that has no value anymore and does not always have to be disposed of and end up in a landfill, but several types of waste still have value when reused. As is well known, that type of waste generally consists of organic and inorganic waste. Organic waste is also divided into wet organic waste and dry organic waste. Wet organic waste is generally from food waste from the kitchen and markets, and dry organic waste comes from the house's yard in the form of dry leaves and other plant residues [2]. Inorganic waste is divided into paper, plastic, metal, textiles, glass, and others. Nature has a role in deciphering waste, especially organic waste. However, the decomposition process of organic waste is not balanced with the amount of waste that continues to be produced every day. In the end, organic waste will only end up in the landfill (Final Processing Site) without maximum management efforts. According to the Jakarta Environment Agency, waste produced in the Jakarta area continues to increase. In a day, Jakarta residents produce up to 7,500 tons of waste, with the most percentage of waste sources produced from households at 59.17% (SIPSN KLHK, 2017–2018). Meanwhile, TPST Bantar Gerbang, the center of waste processing from Jakarta, only leaves a capacity of 10 million tons of the total capacity of 49 million tons, and it is estimated that this Jakarta landfill will be complete in 2021 (DKI Jakarta Environment Agency, 2019).

According to [3], 80% of the total amount of waste is generally organic waste, which is only seen as residual and has no economic value. Jakarta and other major cities facing similar problems will be drowned in landfills and all impacts they will have on the environment and human health if conditions like this are not handled properly and correctly. Therefore, efforts are needed to manage and utilize organic waste to overcome these problems, and can be of economic value [4] [5] [6] [7]. One of the efforts that can be made is utilizing organic waste to feed Black Soldier Fly larvae. Black Soldier Fly or black soldier fly (Hermetia illucens) is one of the insects that began to be widely studied and cultivated. These flies come from America and are distributed to the subtropical and tropical regions of the world [8]. The results showed that these flies could degrade organic waste, where energy and nutrients from vegetable waste, food waste, animal carcasses, and feces will be extracted by larvae into their foodstuffs.

This research was conducted by utilizing Black Soldier Fly larvae to degrade organic waste by turning it into a food source, and later the larvae could be used as substitute feed for fish and organic waste [4] [5] [6] [7]. This study's composition of organic waste is wet organic waste (food waste) and dry organic waste (foliage). This type of waste is chosen because it is significant in number and easy to find, and this type of waste is often not managed properly. The final result of the research is determining the success of larval growth in degrading organic waste by giving it four different waste ratios to be its food source.

2 Methodology

The research was carried out using a cultivation scale experiment method which was carried out in a laboratory/workshop with a batch system using a bucket as a breeding container (reactor). The study was conducted from June 2020-July 2020. The final result from this study is to determine the effect of giving mixed organic waste between wet organic waste and dry organic waste on the consumption rate, reduction indexation, and growth of Black Soldier Fly larvae. The results of breeding larvae are then used for one or an alternative substitute option for fish feed. In addition, a literature study was carried out to collect information and data that supports research on the degradation of organic waste with the help of Black Soldier Fly larvae.

The preparation of breeding BSF larvae is carried out by preparing the tools and materials used during the study. The tools used in this study were a 20 L plastic bucket, cement cast bucket, spoon, sprayer, gloves, digital scales, a long tool (meter), a knife, a bucket lid, a Kassa cloth, a marker/marker, and label paper. The materials used in this study were Black Soldier Fly eggs, wet organic waste (food waste from the kitchen), and dry organic waste (dry foliage). The following is an overview of the reactors used (Fig. 1).

In preparation for leachate water management, the tools used are a 20 L bucket and measuring cup, as well as the necessary materials, namely collected leachate water and EM4. The research was carried out from June 2020 to July 2020 with the method of cultivation scale experiments in laboratories/ workshops with 3 (three) repetitions. The design of the BSF larvae seeding container is a plastic bucket with a volume of 20 L. The bottom of the bucket is hollowed out to make it easier for the resulting leachate water to come out through the gap and collect wastewater samples from wet and dry organic waste. The selection of wet organic waste types is based on observations in the field that show that a lot of food waste is disposed of without being utilized first and is not seasonal waste. In addition, types of dry organic waste are widely found, especially in yards, which are generally thrown away or even burned because they are considered to have no benefit.

The preparation of materials in the study, namely wet organic waste samples, was weighed with a weight of 250 gr, 500 gr, 750 gr, and 1000 gr. Samples of dry organic

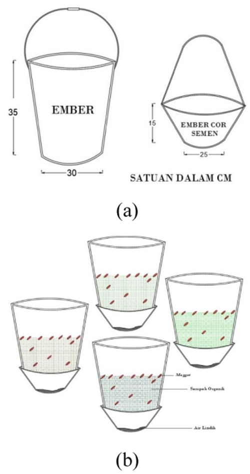

Fig. 1. (a) Dimensions of the reactor used; (b) BSF larvae breeding reactor

(a) (b) (c)

Fig. 2. (a) SOB; (b) SOK; (c) Black Soldier Fly Eggs

Table 1. Waste Ratio

Variations	Waste Ratio (gr)	Egg Weight (gr)	Number of Repetitions
A	250 SOB: 750 SOK	1.5	3
B	500 SOB: 500 SOK	1.5	3
C	750 SOB: 250 SOK	1.5	3
D	1000 SOB: 0 SOK	1.5	3
	Number of Reactors		**12**

waste were weighed weighing 250 gr, 500 gr, and 750 gr. Although the Black Soldier Fly eggs used are obtained from a particular seller who cultivates Black Soldier Fly, the weight of the eggs given to each reactor is the same at 1.5 g. Here's a sample image used (Fig. 2).

This study used a batch system, where organic waste was only given once during the breeding process at the beginning of the study. The organic waste given is divided into four ratios to determine the effect of the ratio of waste given on the ability to reduce waste and the development of larvae. Table 1 shows the ratio of a given litter.

Black Soldier Fly eggs are placed on organic matter that has been mixed with a ratio of waste composition in each reactor of 1.5 g. Although the reactor will not be filled with litter, about 3/4 of the height of the bucket will be given free space, which aims to make room for the larvae to move and develop.

During the vulnerable time, the study was observed every four days. On the 15th day of the breeding, the first measurement of weight and length was carried out, and subsequent measurements were carried out once every ten days. Weight and length measurements were performed on each reactor by taking ten larvae randomly as a representation of the increase in the weight and overall length of the larvae in one reactor. In addition, secondary data such as journals and other literature is also carried out as supporting and comparative data that can be used when writing reports.

The calculation consists of biomass, waste consumption rate, and waste reduction index. The value obtained will later become a supporting statement in proving the development of larvae and also shows the effect of the ratio of the litter to the development of larvae.

To calculate larval biomass, the weight of the larvae (gr) obtained by measuring the weight of the larvae divided by the number of larvae taken into a sample [9]. Here's Eq. 1:

$$\text{Larvae Biomass} = \frac{\text{Total Larval Weight (gr)}}{\text{Total Number of Larvae}} \tag{1}$$

To calculate the litter consumption is the amount of garbage the larvae could consume during the breeding process expressed in percent. This percentage is obtained by weighing the weight of the final litter in the past breeding divided by the weight of the litter at the beginning of breeding [9]. Here's Eq. 2:

$$\text{Waste Consumption} = \frac{\text{Initial Weight} - \text{Final Weight (gr)}}{\text{Initial Weight (gr)}} \times 100 \tag{2}$$

To calculate the waste reduction index, Diener (2009) defines the waste reduction index (waste reduction index) as the ability of larvae to reduce waste by considering the time the larvae eat, where the higher the WRI value, the higher the larvae's ability to reduce waste. This WRI value can be calculated using the following Eqs. 3 and 4 [10]:

$$\text{WRI} = \frac{\text{D}}{\text{t}}\text{X } 100. \tag{3}$$

$$\text{D} = \frac{\text{W-R}}{\text{W}} \tag{4}$$

where:

WRI = Waste reduction index (%)
D = Total waste reduction
t = Total time the larvae eat the litter (days)
W = The initial weight of the litter before degradation (gr)
R = The final weight of the litter after a specific time (gr)

The research data has been obtained, collected, processed, and further analyzed statistically using the IBM SPSS Statistical one-way Analysis of Variance (ANOVA) with a confidence level of 95% and a significance value smaller than 0.05 ($P < 0.05$) and a follow-up test (post hoc test) using Tukey to determine whether or not there is an effect of giving the ratio of waste to the level of waste consumption and the index of waste reduction by Black Soldier Fly Larvae.

3 Results and Discussion

In determining the effectiveness of the use of Black Soldier Fly larvae in reducing the ratio of waste given, it can be seen from the results of measuring the waste reduction and the level of waste reduction index.

3.1 Black Soldier Fly Larvae's Ability to Reduce Organic Waste

The Black Soldier Fly larvae breeding process ended on the 35th day of the breeding, and this is because all waste ratios in all reactors have entered the prepupae phase based on observations where the larvae crawl out, leaving the organic matter in the bucket (leachate water reservoir) under the reactor and are characterized by a change in color from beige/light brown to dark brown [11] [12]. On the last day of the breeding, the final weight of the garbage in all reactors was also carried out for the data to be later analyzed. Table 2. The initial and late weight of the litter.

Calculation methods in Eq. 2, Eq. 3, and Eq. 4 can be known as the value of the waste consumption rate and waste reduction index in determining the ability of Black Soldier Fly larvae to reduce the waste ratio.

3.2 Percentage of Waste Consumption

The method in Eq. 2, the percentage of waste consumption to the waste ratio given in the following table, is obtained.

The percentage of waste consumption shows the large amount of garbage consumed by the Black Soldier Fly larvae. Table 3 shows the average value of the highest percentage of waste consumption indicated in the ratio of waste D and the lowest percentage in the ratio of waste A. Shows that the waste most consumed by larvae is garbage with a ratio of D (1000 SOB: 0 SOK) or in other words, the more wet organic waste given, the higher the level of larvae consumption and for the least consumed waste by larvae is waste with a ratio of A (250 SOB: 750 SOK) in other words, the more the amount of dry organic waste given, the level of consumption of larvae waste is low [7].

Table 2. Initial weight and end of the garbage

Reactor	Waste Ratio	Initial Garbage Weight (gr)	Final Garbage Weight (gr)
1	A	1000	658.5
	B		408.9
	C		316.9
	D		5.8
2	A		672.5
	B		400.0
	C		308.4
	D		8.7
3	A		689.1
	B		528.4
	C		298.8
	D		4.7

Table 3. The result of calculating the percentage of waste consumption

Waste Ratio	**Average Waste Consumption (%)**	**Mean ± Std. Dev**
A	32.66	32.66 ± 1.532
B	59.35	59.35 ± 0.565
C	69.20	69.20 ± 0.906
D	99.36	99.36 ± 0.207

The results of the statistical analysis carried out using a one-way Analysis of Variance (ANOVA) on the percentage of larvae waste consumption showed a signification value (P) of 0.000 ($P < 0.05$) means rejecting H0. There is a significant influence on the ratio of waste given to the percentage of waste consumption in larvae. The results of the follow-up test (post hoc test) stated that there were significant differences in each of the ratios of waste given. Based on the output of multiple comparisons, a good level of waste consumption is found in the waste ratio D (1000 SOB:0 SOK); this can be seen from the highest average amount in the D waste ratio, while the poor waste consumption rate is found in the waste ratio A (250 SOB: 750 SOK). In addition to the ratio of waste D, a good level of waste consumption is found in the ratio of waste C (750 SOB: 250 SOK). This can be seen from the second highest average number after the ratio of waste D. The ratio of waste B (500 SOB: 500 SOK) shows the reduction rate of waste that is in the middle (not very good when compared to the ratio of waste D and B, but not too bad when compared to ratio A).

3.3 Waste Reduction Index

The value of the waste reduction index can be calculated by the calculation method based on Eq. 3 and Eq. 4; the results of the calculation of the waste reduction index can be seen in the Table 4. The calculation results in Table 4 shows the highest waste reduction index percent value at the D ratio (1000 SOB:0 SOK) reached 2.84% and was lowest at the A ratio (250 SOB:750 SOK), which only reached 0.94%. This is because the value of the waste reduction index is directly proportional to the value of waste consumption. The higher the value of the waste reduction index, the greater the amount of waste consumed by the larvae [9]. This can be seen in the waste ratio D, whose waste reduction index value is the highest, which shows the highest percentage of waste consumption compared to all existing waste ratios; in addition, the lowest waste reduction index is shown in ratio A which has the lowest waste consumption percentage value as well, besides that the most significant waste reduction index value indicates that the amount of organic waste given is appropriate for the larvae in decomposing organic waste in efficient for 35 days.

The results of the statistical analysis carried out using a one-way Analysis of Variance (ANOVA) on the waste reduction index by larvae showed a signification value (P) of 0.006 ($P < 0.05$), meaning that it rejected H0, where there was a significant influence on the ratio of waste given to the waste reduction index in larvae. The results of the

Table 4. Waste reduction index calculation results/WRI

Waste Ratio	Average WRI (%)	Mean ± Std. Dev
A	0.94	0.94 ± 0.044
B	1.58	1.58 ± 0.206
C	1.98	1.98 ± 0.026
D	2.84	2.84 ± 0.009

follow-up test (post hoc test) using Tukey stated that there were significant differences in each ratio of waste given. Based on the output of multiple comparisons, a good waste reduction index is found in the waste ratio D (1000 SOB:0 SOK). This can be seen from the highest average amount in the D waste ratio, while the poor waste reduction index is found in the waste reduction ratio A (250 SOB: 750 SOK). In addition to the D waste ratio, a good waste reduction index is found in the waste ratio C (750 SOB: 250 SOK). This can be seen from the second highest average number after the D waste ratio, and the waste ratio B (500 SOB: 500 SOK) shows the waste reduction index that is in the middle (not very good when compared to the ratio of waste D and B, however not too bad when compared to the ratio A).

3.4 Black Soldier Larvae Weight Measurement

Measurements of the weight gain of the larvae begin to be carried out on the 15th day of breeding and once every ten days on subsequent measurements. This weight measurement is necessary to find out the influence of the ratio of a given litter on the development of larvae. Measurements are made using digital scales. This weight was carried out on ten randomly taken larval samples, representing the total weight of the larvae in each reactor. Before weighing the weight, the larvae is turned off first to facilitate the weighing process and get a definite weight figure because if it is not turned off, the larvae will move continuously, making it difficult to measure. After turning off, the larvae are dried using tissues to absorb the water and food content attached to the larvae's body and then weighed.

During this breeding process, the larvae's weight measurements are carried out three times. The first measurements were carried out on the 15th day of breeding (June 24), the second measurement on the 25th day of breeding (July 4), and the third measurement on the 35th day of breeding (July 14). The following is a data table on the results of weight measurements during breeding (Table 5).

The results of measuring the weight of larvae are then used to determine the biomass of larvae by the calculation method of Eq. 1. Here are the results of the calculation of larvae biomass during breeding (Table 6).

The average value of larval weight tends to increase from several measurements with the increase in the breeding period, the highest average weight value is obtained at the D ratio of 0.37 gr/10 larvae on the 35th day of the breeding, and the lowest biomass average value is obtained at a ratio of C which is 0.19 gr/10 larvae on day 15 of breeding, this is because at the time of measurement the larvae in the reactor were still tiny compared to the reactor and other ratios. The ratio of waste with more wet organic waste shows an increase in larval weight optimally compared to the ratio of waste with more dry organic waste; in other words, larvae prefer wet organic waste over dry organic waste. Suppose more dry organic waste is given than wet organic waste. In that case, the development of larvae can be disturbed. This is possible because, in dry organic waste, compounds such as lignin, cellulose, and other compounds cannot be digested by enzymes owned by the larval body [13].

The weight measurement data obtained were analyzed statistically using Descriptive Analysis with a 95% confidence level can be seen in Table 7.

The average values of larval weight successively at measurement results 1, 2, and 3 were 0.21gr, 0.27gr, and 0.30gr. For consecutive standard deviations of 0.022, 0.017, and 0.054, where the standard deviation values on all averages of larval weight measurements

Table 5. Weight Measurement Results

Waste Ratio	Measurement 1 (gr/10 Larvae)	Measurement 2 (gr/10 Larvae)	Measurement 3 (gr/10 Larvae)
A	0.24	0.26	0.25
B	0.20	0.27	0.26
C	0.19	0.25	0.30
D	0.21	0.29	0.37

Table 6. Larval Biomass

Waste Ratio	Average Larval Biomass (gr/larvae)		
	Measure 1	Measure 2	Measure 3
A	0.024	0.026	0.025
B	0.020	0.027	0.026
C	0.019	0.025	0.030
D	0.021	0.029	0.037

Table 7. Ratio Of Weight Measurement and Wet Organic Waste

Weight Avg. (gr/10 larvae)	Ratio				Min	Max	Mean ± Std. Dev
	A	B	C	D			
1	0.24	0.20	0.19	0.21	0.19	0.24	0.21 ± 0.022
2	0.26	0.27	0.25	0.29	0.25	0.29	0.27 ± 0.017
3	0.25	0.26	0.30	0.37	0.25	0.37	0.30 ± 0.054

were equal to 0 (d = 0) or in other words, the data values were equal to the average so that the values of all data were the same and the data uniform.

3.5 Black Soldier Fly Larvae Length Measurement

The larvae length gain is carried out in conjunction with weight measurements; the larvae sample is measured in length using a length measuring instrument. During this breeding process, the larvae's length measurements are carried out three times. The first measurements were carried out on the 15th day of breeding (June 24), the second measurement on the 25th day of breeding (July 4), and the third measurement on the 35th day of breeding (July 14). The following is a data table on the results of length measurements during breeding (Table 8).

The average length of the larvae tends to increase from several measurements made during the breeding process, the highest average length value is obtained at the D ratio of 1.14 cm on the 35th day of the breeding, and the lowest average length value is obtained at the A ratio of 0.82 cm on the 25th day of breeding. It is because, at the time of measurement of larvae, that ratio is still tiny compared to other ratios. The ratio of waste with more wet organic waste shows that the increase in larval length takes place optimally compared to the ratio of waste that has more dry organic waste; in other words, larvae prefer wet organic waste to dry organic waste. If more dry organic waste is given than wet organic waste, the development of larvae can be disturbed; this is possible because, in dry organic waste, there are compounds such as lignin, cellulose, and other compounds that cannot be digested by enzymes owned by the larval body [13].

The weight measurement data obtained were analyzed statistically using Descriptive Analysis with a 95% confidence level in Table 9.

Table 8. Length Measurement Results

Waste Ratio	Average 1 (cm)	Average 2 (cm)	Average 3 (cm)
A	0.88	0.82	0.96
B	0.92	0.90	1.02
C	0.89	0.96	0.99
D	0.84	1.09	1.14

Table 9. Ratio Of Weight Measurement And Dry Organic Waste

Weight Avg. (gr/10 larvae)	Ratio				Min	Max	Mean ± Std. Dev
	A	B	C	D			
1	0.88	0.92	0.89	0.82	0.82	0.92	0.88 ± 0.042
2	0.84	0.90	0.96	1.02	0.84	1.09	0.95 ± 0.107
3	0.96	1.02	0.99	1.14	0.96	1.14	1.03 ± 0.079

The average values of larval lengths successively at measurement results 1, 2, and 3 were 0.88 cm, 0.95 cm, and 1.03 cm. For standard deviations successively of 0.042, 0.107, and 0.079, where the standard deviation values on all average measurements of larval lengths were equal to 0 ($d = 0$) or in other words, the data values were equal to the average so that the values of all data were the same and the data uniform.

3.6 Black Soldier Fly Larvae Breeding Observations

Observations and analysis of several parameters that occur during breeding larvae in degrading organic waste. These parameters are measurements of the temperature and humidity of the room where the study is located, in addition to the analysis of the results of the collection of leachate water produced during the breeding process.

Temperature and humidity in this breeding process became determinants in the successful breeding of the black soldier fly. Air temperature and humidity automatically with temperature measurement accuracy ±0.1 °C and humidity measurement accuracy ±5% RH. During the breeding process of Black Soldier Fly larvae obtained average temperature data of 27.5 °C, the highest temperature reached 29.9 °C, and the lowest temperature reached 26.7 °C. The average air humidity is 67.5%, the highest air humidity is 81%, and the lowest air humidity is 57%. Comparing the results of temperature and humidity measurements obtained with the ideal temperature and humidity in breeding Black Soldier Fly shows that the room conditions suitable for breeding Black Soldier Fly with an optimum temperature between 24 °C - 33 °C and with optimal air humidity between 60–70% [14].

3.7 Observations During the Breeding Process

The observations showed that Black Soldier Fly eggs entered the larval phase on day 3 of breeding in all litter ratios; on day three, there was also leachate water collection, but the amount collected was still minimal, so the number could not be measured. During the observation, there were several treatments given, namely, on the 11th day of the breeding, water was sprayed at the ratio of A, B, and C with the aim that the litter would not be too dry and make it easier for the larvae to eat it. It is also carried out the stirring of waste at the ratio of A, B, and C on the 19th day to supply the incoming air so that the larvae can develop adequately and also to level the moisture of the litter so that nothing is too dry or too humid. On the 25th day of the breeding, part of the reactor at the ratio of A, B, and C entered the prepupae phase, characterized by a change in larval color from beige to dark brown. However, the D ratio in all reactors is still in the larval phase, which is still light beige [12].

3.8 Utilization of Black Soldier Fly Larvae Breeding Results

This study was stopped after all larvae had entered the prepupae phase because this phase is the best phase in its utilization to be used as fish feed rich in nutrients such as protein, fat, calcium, phosphorus, and high caloric value [4] [6] [13]. The larvae resulting from this breeding are then used for pet koi carp feed and for the remaining organic waste to be used as fertilizer for plants. The following is a picture of the results of breeding into fish feed (Fig. 3).

(a)

(b)

Fig. 3. (a) Pre-pupae to pet fish; (b) Organic waste left as fertilizer

4 Conclusion

The conclusions that can be drawn from this study are: (1) there is a significant influence on the ratio of waste to the level of waste consumption by Black Soldier Fly larvae. The highest level of waste consumption is indicated in the ratio D (1000 SOB:0 SOK), with an average percentage of waste consumption reaching 99.36%, and the lowest level of waste consumption is shown in the ratio A (250 SOB: 750 SOK) with an average percentage of only reaching 32.66%; (2) there is a significant effect of the ratio of waste to the waste reduction index by Black Soldier Fly larvae. The highest waste reduction index is indicated in the ratio D (1000 SOB:0 SOK), with an average waste reduction index reaching 2.84%, and the lowest waste reduction index is shown in ratio A (250 SOB: 750 SOK), with an average of only 0.94%; (3) the growth rate of Black Soldier Fly larvae is measured by weight and length gain. The longest average of the larval body is indicated in the ratio D (1000 SOB:0 SOK), with a length of up to 1.14 cm. The shortest average is shown in ratio A (250 SOB:750 SOK), with an average of 0.82 cm. The highest average larvae biomass is shown in the ratio D (1000 SOB:0 SOK) reached 0.037 gr/larvae, and the lowest average biomass of larvae was shown in the ratio C (750 SOB:250 SOK), reaching 0.019 gr/larvae.

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