Rejected Products from Creamer and Milk Industry as Feeding Substrate for Maggot – Green Technology for Industrial Organic Waste Management and Circular Bioeconomy

Aulia Rodlia Fitriana[1], *Arseto* Yekti Bagastyo[1*], and *Deqi* Rizkivia Radita[1]

[1]Department of Environmental Engineering, Faculty of Civil Engineering and Planning, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia

Abstract. The creamer and milk industries produce organic waste, including rejected products. The rejected products have potential as maggot-feeding substrates. This research consists of two preliminary studies. This study analyzed the effects of substrate composition and the addition of milk-rejected on larval growth. The substrates were creamer (A), fruit-vegetable waste (B), and rejected bread (C). The dry weights of A:B:C in the first preliminary study: 5:2.5:2.5; 5:2:3; 5:1:4; 6:2:2; 6:1:3; 4:3:3; 4:2:4; and 4:1:5. The feeding rate was 40mg/larva.day per 2 days. The optimal compositions were 5:2.5:2.5 and 4:3:3. The larval mass reached 0.236 and 0.187 g/larva, and the Growth Rates were 6.45 and 4.39 g/day. The WRI was 5.46% and 4.19%. More creamer inhibited maggot growth due to the sticky substrate, which inhibited their respiration and movement. Maggot also requires a balanced B:C composition. These compositions were tested in the main research and added 1 more variation (3:3.5:3.5). Rejected milk has a positive effect on maggot growth. At the same composition, the highest average masses were 0.192 g/l (milk addition) and 0.187 g/l (without milk addition). It was concluded that rejected creamer and milk can be used as substrates for maggots with a balanced composition of other waste.

Keywords: larval growth; maggot; rejected creamer; rejected milk; waste reduction

1 Introduction

Annually, the F&B industry experiences growth. In 2023, the manufacturing industry's GDP in Indonesia was led by these industries with a 6.55% share. PT. Lautan Natural Krimerindo (LNK) and PT. Indolakto is the biggest creamer and milk industry in Indonesia. Both industries produce rejected products. These include products with leaky, punctured, or damaged packaging, insufficient or missing contents, and expired or rotten items [1]. Rejected products' content is similar to that of standard products but has changes in terms of packaging, volume, or nutritional composition.

* Corresponding author: bagastyo@enviro.its.ac.id

The rejected products still contain carbohydrates, proteins, and lipids. It has potential as a maggot feed. Maggot bioconversion generates high-protein, lipid-rich biomass [2]. The biomass can serve both as animal feed for poultry, fish, and pigs and as a raw material for producing biodiesel [3], [4], [5], [6]. The nutrient content of biomass relies on the substrate during cultivation. In addition to producing maggots, this bioconversion also produces frass that can be used as fertilizer [7] as well as waste casings from the pupal phase as a source of chitin [8]. This shows that the overall application of maggot bioconversion technology is promising to support green technology for waste management and circular bioeconomy [9]. This bioconversion technology using maggots also has positive effects on the environment, including lower land use [10], lower Greenhouse Gas emissions [11], rapid waste reduction, a non-disease-carrying vector, pathogen, and pest reduction [12].

Several factors, including substrate conditions and the environment influence bioconversion. Substrate conditions and the environment are key factors for the high efficiency of bioconversion. The substrate conditions were the composition, particle size, and feeding rate. Environmental conditions include water content, pH, temperature, and light intensity. Therefore, this study investigated the effects of feeding composition and strategies to improve larval growth.

2 Materials and methods

2.1 Maggot's source

Maggot eggs were obtained from a maggot breeder in Sidoarjo, East Java. Maggot larvae were raised using Pur 511 chicken feed. This type contains high protein levels and is used for broiler growth enhancement. The label specifies a maximum moisture content of 13%, a protein content of 23%, a lipid content of 5%, a fiber content of 5%, an ash content of 7%, a calcium content of 0.9%, and a phosphorus content of 0.6%. is feed ensures the production of top-tier, healthy larvae. The larvae hatch by hanging eggs using a tea strainer. The hatchling egg will land on the Pur 511 slurry upon hatching. After five days, the larvae are prepared for bioconversion.

2.2 Rearing substrate and conditions

The research was conducted in a workshop at the ITS Environmental Engineering Department. The reactor was shielded from light in a shaded, dark location with an aluminum net as part of the study. The ambient temperature is 28°C. The netting was installed to prevent contamination by house flies, rats, lizards, and other predators.

Maggot food consists of rejected products from the creamer industry (PT. LNK), vegetable-fruit waste, and bread crusts. The moisture content was adjusted by adding rejected milk with or without water. In Manyar's traditional markets, vegetable waste is generated, while fruit waste comes from markets in Pucang. Waste was collected every 2 days based on feeding frequency. Chinese cabbage, spinach, long beans, pineapple peel, salak, and mangosteen were the vegetables and fruits used. These fruits were chosen because they are available daily as fruit waste from the market. This study used green vegetables because they are considered nutrients. Green vegetables are protein-rich vegetables [13]. To enhance the moisture content of the substrate using discarded milk effectively, this research excludes vegetables and fruits with high water content. Dark green vegetables are chosen based on their availability in traditional markets. Dark green vegetables were dominated by green leafy vegetables such as mustard greens (including Chinese cabbage) and spinach at 30.6%. This study also used long beans as a substrate because legume vegetables are protein-rich vegetables. The protein content of long bean seeds can reach 27-31% [14]. These vegetables and fruits were mashed at a wet-weight ratio of 1:1. They were mashed using a blender (Philips HR2042 3000 Series).

Bread crust was purchased from a fresh bread factory located in Mojo, Gubeng sub-district, Surabaya. The factory was selected for its proximity to the experimental sites and its high availability. The bread crust was crushed with a chopper (HAN RIVER Blender HRJRJ04).

2.3 The experimental feeding

The larvae used for food testing were 5 days after hatching (5dol). Diets were categorized according to the dry-weight proportion of their substrates. The creamer was available in concentrations of 40%, 50%, and 60%. The food composition differences are outlined in Table 1. Feeding lasted for 14-16 days before entering the prepupae phase. This was marked by a change in larval color from white/cream to black. Feeding was performed every 2 days at a rate of 40 mg/larva.day. The determination of this rate is based on research conducted by [15].

Table 1. Variation of substrate composition of Lab. Scale 1

Variation name	Dry-weight ratio (%)		
	Creamer	Fruit-vegetables	Bread
V1	50%	25%	25%
V2	50%	20%	30%
V3	50%	10%	40%
V4	60%	20%	20%
V5	60%	10%	30%
V6	40%	30%	30%
V7	40%	20%	40%
V8	40%	10%	50%
Control	100%	0%	0%

In this study, a tubular plastic reactor with a diameter of 9 cm was used and covered with aluminum mesh. The density of larvae required for optimum development was 5 larvae/cm^2 [16]. This resulted in 320 larvae per reactor. The water content in the reactor was kept between 60% and 90% [17]. In addition, the pH was maintained within the range of 6.0 - 9.0 because this range is the optimum pH for a maggot-production system [18]. Meanwhile, the temperature was maintained between 27-33°C [19].

This preliminary study's initial results will next be used to assess the impact of incorporating rejected milk on substrate moisture regulation. Every 2-3 days, the maggot mass growth pattern was observed to measure the effect. The 2nd preliminary study's composition variations are the best outcome of the 1st preliminary study.

2.4 Controlling parameters

Daily monitoring of pH, moisture content, and larval behavior. Larval behavior was observed in the form of movement: active or not, on the surface of the substrate or inside it, scattered or gathered in certain locations, and by color. The larvae are weighed every 2-4 days. The number of larvae was 10 per sampling. Larvae were rinsed, dried, and weighed after being cleaned with water. The larvae were weighed and then placed back into the reactor.

2.5 Composition analyses

The nutrient content of the substrate, particularly that of rejected creamer and milk, was assessed through compositional analysis. The test measured crude protein, carbohydrate, total fat, ash content, and moisture content. The test took place in an accredited laboratory. Secondary data was used for calculating the characteristics of vegetable waste and rejected bread. SNI 01-2891-1992 specifies the methods for measuring crude protein content, ash content, total fat, and water content. The carbohydrate measurement method uses 5.4/IK/2/2.19.1 from the Directory of Fresh Food Testing Laboratories in 2023.

At the end of the experiment, all larvae were collected from each reactor to determine the biomass produced and larval weight. An analytical scale (OHAUS PR223) was used to weigh the samples. In addition, the moisture content of the larvae and frass was measured by drying them in an oven (MMM Venticell, type: LSIS-B2V/VC111, Made in Germany) at 105°C for 24 h, placing them in a desiccator for 15 min, and reweighing to determine water content.

2.6 Calculation

All calculations were based on dry matter. The waste reduction index (WRI) was determined based on the amount of residue (frass) at the end of the larval phase on days 14-16. Larvae are separated first with the frass. The WRI is calculated using the following formula [20]:

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

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

where WRI is the waste reduction rate, SR is substrate reduction, t is the time required to degrade waste (days), W is the total amount of feed provided (g), and R is the remaining substrate (g).

The efficiency of conversion of digested feed (ECDF) indicates the efficiency of larvae in converting feed intake into larval biomass. The ECD calculation formula is as follows [21]:

$$ECD_F = \frac{B}{(W-R)} \quad (3)$$

where B is the total biomass gained (g), W is the total amount of feed provided (g), and R is the remaining substrate (g).
The Growth Rate (GR) is calculated using the following formula [22]:

$$GR = \frac{final\ larval\ weight - initial\ larval\ weight}{rearing\ duration} \quad (4)$$

where GR is growth rate of larval (g/day).

3 Results

3.1 Substrate characterization

The sample from LNK comes in the form of a bone-white, slightly sticky powdered creamer. Fresh milk production yields rejected milk as a white byproduct. The nutritional compositions of the discarded creamer and milk in the experimental substrate are presented in Table 2.

Table 2. Nutritional composition of the rejected creamer and milk (%)

Parameters	Type of substrate	
	Rejected creamer	Rejected milk
Carbohydrate	76.8	5.71
Crude protein	2.16	2.64
Total lipid	15.5	1.52
Total ash	2.68	0.638
Water content	2.83	89.5

76.8% of rejected creamer consists of carbohydrates. The content of total fat (15.5%) is the second highest, followed by ash (2.68%) and crude protein (2.16%). Reject products' nutrient content can vary due to production activities and the occurrence of events leading to their formation. The creamer reject product was collected initially and homogenized for consistent nutrient content in the BSF larvae substrate. The creamer substrate was stored in an airtight, dry location, protected from rainfall. This containerization is crucial to prevent the LNK cream from absorbing excess water due to its hygroscopic properties. According to [23], the powdered LNK cream incorporates mono-diglyceride emulsifiers. This emulsifier's polar and nonpolar groups enable it to bind to fat and water-based emulsified compounds. Monoglycerides and diglycerides' hydroxyl groups form hydrogen bonds with water [24]. This property allows creamer to easily bind water, resulting in its quick clotting when exposed to air.

89.5% water, 5.71% carbohydrate, and 2.64% crude protein constituted the composition of the rejected milk. It will be stored in a freezer inside the jerry cans. Before adding to the larval feed substrate, the milk must be thawed and stirred until homogeneous. The milk addition was precisely measured and logged in a record book.

Bread and fruit-vegetable substrate characteristics are represented by [25].

Table 3. Nutritional composition of bread crust and fruit-vegetable

Parameters	Type of substrate							
	BC[1]	Fruit-vegetable						
		P[1]	M[1]	Sl[1]	LB[1]	CC[1]	S[1]	Mixed[2]
Carbohydrate	76.8	9.9	15.6	11.859	5.3	4.4	2.9	9.99

Parameters	Type of substrate							
	BC[1]	Fruit-vegetable						
		P[1]	M[1]	Sl[1]	LB[1]	CC[1]	S[1]	Mixed[2]
Crude protein	2.16	0.6	0.6	0.472	2.3	1.9	0.9	1.35
Total lipid	15.5	0.3	0.6	0.236	0.1	0.5	0.4	0.43
Total ash	2.68	0.3	0.2	0.8	0.6	1.4	1.3	

BC = bread crust; P = Pineapple; M = Mangosteen; Sl = Salak; LB = Long bean; CC = Chinese cabbage; S = Spinach
Source: [1] [19], [2] calculation

Fruit and vegetable waste are evenly mixed at a wet weight ratio of 1:1. Six types of fruit and vegetables should be mixed. 1.2 kg of fruit-vegetable substrate equals 0.2 kg of wet weight per type. The moisture content of the stirred fruit-vegetable blend was measured. The moisture content of fresh bread crust and fruit-vegetable mixture was identified as 83% based on lab tests. Table 4 displays the feeding frequency and nutritional estimation every 2 days.

Table 4. Substrate dry weight and nutritional estimation (gram)

Variation name	Fruit - Veggie	Creamer	Bread	Carbohydrate	Crude protein	Total Lipid
V1	6.4	12.8	6.4	13.57	0.86	2.08
V2	7.7	10.2	7.7	12.35	0.92	1.71
V3	9.0	7.7	9.0	11.13	0.98	1.33
V4	4.8	9.6	4.8	10.17	0.65	1.56
V5	5.8	7.7	5.8	9.26	0.69	1.28
V6	6.7	5.8	6.7	8.34	0.74	1.00
V7	3.2	6.4	3.2	6.78	0.43	1.04
V8	3.8	5.1	3.8	6.17	0.46	0.85
Control	4.5	3.8	4.5	5.56	0.49	0.67

3.2 Maggot's development

The research weighed each maggot (per larvae) to determine the development pattern for each substrate composition. The weight of harvested maggots significantly varied (Fig. 1). A maggot with the heaviest weight (236 mg) resulted from reactor V6 with a C:F-V:B ratio of 4:3:3. The maggot with the smallest size (30 mg) emerged when the food ratio was 6:1:3 (V5). In a 1:1 ratio of F-V:B, the substrate yielded the optimal maggot development. In the control reactor (where 100% creamer was used), maggots perished after 2 days of feeding. The larval GR can be seen in Fig. 2.

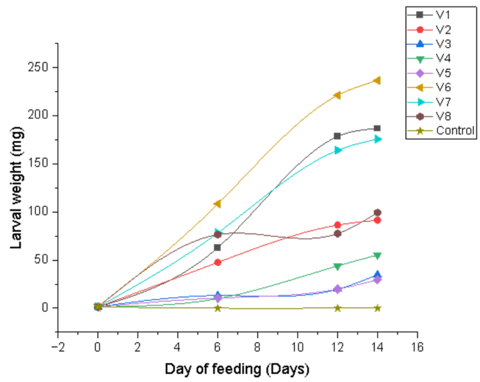

Fig. 1. Maggot's average weight based on the variation of substrate composition

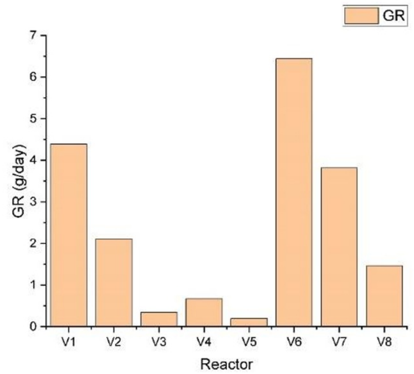

Fig. 2. Maggot's growth rate based on the variation of substrate composition

3.3 Waste Reduction Index (WRI) and Substrate Reduction (SR)

WRI and SR were calculated using the Calculation Formula (1) and (2). The correlation between WRI and SR can be seen in Fig. 3.

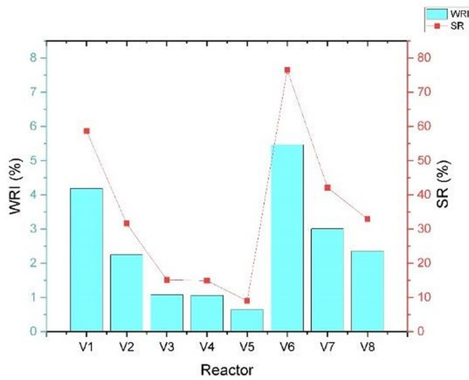

Fig. 3. The WRI and the SR are based on the variation in substrate composition

A higher SR value corresponds to a higher WRI value. The substrate reduction in reactor V6 reaches up to 76.47% with a WRI of 5.46%. The WRI value for this study surpasses those reported for other studies employing food and beverage industry by-products, with values of 2.4% for winery waste and 5.3% for brewery waste [26]. The V2 and V7 reactors yield the second and third-highest substrate reductions, respectively. The WRI value for reactor V5's reduction is 0.65%, resulting in a total reduction of only 9.04%. In Fig. 4 The relationship between WRI, SR, and larval dry weight is depicted.

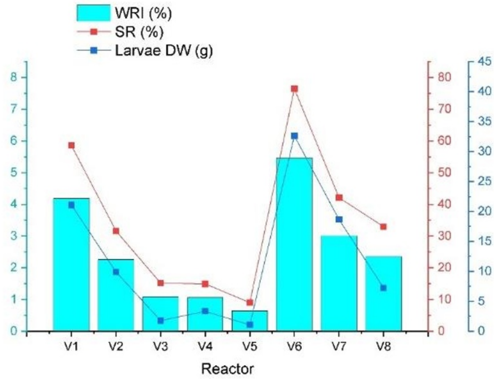

Fig. 4. Correlation Between WRI value, SR value, and larval dry weight

3.4 Efficiency of conversion of digested feed (ECD_F)

Formula (3) was used to calculate ECD_F. 24.4% ECD_F value was obtained in reactor V7 with a C:F-V:B ratio of 4:2:4. 23.6% came from V6, followed by reactor V1 with 19.8%, having C:F-V:B ratios of 4:3:3 and 5:2.5:2.5 respectively. Fig. 5 displays the ECD_F values for each reactor.

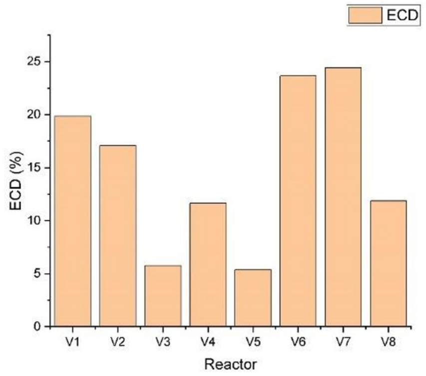

Fig. 5. The ECD_F based on the variation in substrate composition

3.5 Maggot's development with and without rejected milk

The optimum results of the Lab. Scale 1 will be continued to determine the effect of adding rejected milk as a regulator of substrate moisture content. These results include the composition of C:FV:B ratio of 4:3:3 and 5:2.5:2.5 using powder creamer. A new composition with less creamer content (30%) and a 1:1 FV:B ratio was introduced alongside the two existing variations. Thus, the 3 composition variations in the Lab. Scale 2 is the C:FV:B ratio of 3:3.5:3.5, 4:3:3, and 5:2.5:2.5. The number of reactors in the Lab. Scale 2 was 6 (3 reactors with the addition of rejected milk and 3 without the addition). The feeding rate and frequency used were 40 mg/larva per day and feeding once in 2 days. Variations in the composition of the Lab. Scale 2 can be seen in Table 5. The results of maggot growth can be seen in Fig. 6.

Table 5. Variation of substrate composition in the Lab. Scale 2

Variation name	Dry-weight ratio (%)			Rejected milk
	Creamer	Fruit-vegetables	Bread	
V1	50%	25%	25%	X
V2	40%	30%	30%	X
V3	30%	35%	35%	X
V10	50%	25%	25%	O
V11	40%	30%	30%	O
V12	30%	35%	35%	O

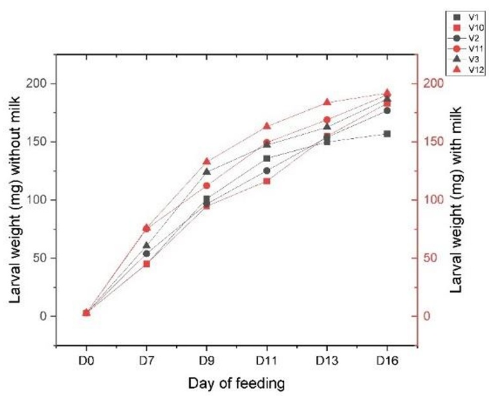

Fig. 6. Maggot's average weight based on the additional rejected milk

The addition of rejected milk led to the highest maggot growth in the reactor. The total addition of rejected milk is 10 ml per reactor. The maggot growth in the substrates of 3:3.5:3.5 (V12)and 4:3:3 (V11) was comparable at 191.8 mg/larvae and 190.3 mg/larvae respectively. Meanwhile, without the addition of rejected milk, the highest growth was also in the composition of 3:3.5:3.5 (V3), which amounted to 186.8 mg/larvae.

4 Discussion

4.1 Effect of substrate composition on Maggot's development

The development pattern is significantly shaped by the substrate's composition. Increasing the amount of creamer results in smaller larval masses (Fig. 1). The heaviest larvae were produced at 40% creamer composition. Larvae in the control reactor have died. The creamer's small particle size restricts the substrate's aeration rate. Adding more creamer decreases the substrate's porosity, thus lowering the oxygen diffusion/aeration rate [27]. Insufficient aeration can lead to oxygen deprivation for larvae. In this study, it was characterized by the behavior of larvae that were on the surface of the substrate and eventually died. This follows the research of [28], where a lower aeration rate will have a negative effect on larval growth so substrate reduction will decrease. At the same creamer percentage, the weight of larvae produced was best at a fruit-vegetable and bread ratio of 1:1. The greater the bread ratio added, the smaller the fruit-vegetable ratio. Adding more fruit-vegetable makes the substrate more porous and thus increases its aeration rate. An F-V:B ratio equal to 1:1 enhanced larval growth, compared to a substrate with F-V:B ratio is less than 1.

The larval stage generally occurs in 25 days [29]. In this research, the larval stage durations are 19 days for Lab. Scale 1 and 21 days for Lab. Scale 2. Protein content in the rearing substrate influenced larval development. Protein has a greater impact on larval growth compared to carbohydrates. Protein is more influential than carbohydrates when it comes to larval growth [30]. Larvae at the early instar stage require more protein for growth. According to [30] research findings, the highest protein concentration occurs in the early larval instar. So to get the best 5dol, the instar was raised by chicken fed which is rich in protein. In this study, the substrate for rearing resulted in a longer larval stage cycle due to its high carbohydrate and low protein content compared to food waste.

4.2 Effect of substrate composition on the Waste Reduction Index

The WRI value indicates the ability of the larvae to consume their food per unit time (day). Larvae of larger/heavier size consume more substrate, leading to increased SR and WRI values. This is following the results of the study which can be seen in Figure 3. A low WRI value signifies anaerobic conditions at the bottom of the reactor due to an abundance of substrate in the reactor. Anaerobic reactions in waste will produce methane gas (CH4), NH3, CO2, and H2O. The anaerobic state promotes an increase in the substrate's moisture content. CH_4 and NH3 can inhibit the process of substate degradation by maggot [15].

4.3 Effect of substrate composition on the efficiency of digested feed conversion

The ECD value indicates the larvae's ability to convert substrate into biomass [22]. High ECD values indicate high productivity in digesting and metabolizing substrate into biomass [21]. ECD values vary based on the composition of the substrate provided. The ECD value of reactor 7 is slightly higher than that of reactor 6 even though the mass of larvae in reactor 6 is greater, indicating that the substrate composition in reactor 7 makes it easier for maggots to metabolize into biomass. Based on the estimation calculations in Table 4, the substrate nutrition of reactors 7 and 6 only differ in carbohydrate content and only 0.1-gram difference, so the ECD value is only a small difference. The balanced F-V:B ratio has high ECD and WRI values, indicating that under these substrate conditions, maggots are efficient in reducing waste while collecting nutrients [31]. Meanwhile, if the F-V ratio is smaller than B, the maggot will be efficient in collecting nutrients only. Nutrient content, rearing substrate conditions, and environmental conditions of maggot rearing affect the ECD value. Another thing that affects the ECD value is the age of the larvae [32].

4.4 Effect of rejected milk on Maggot's development

Maggots that added rejected milk as a moisture regulator had relatively better growth than those without rejected milk. Rejected milk provides additional nutrients for maggot growth. The addition of rejected milk increases the carbohydrate, protein, and fat content of the substrate. The maggot mass increased significantly at 9 days of feeding until 14 days of feeding. After that, the mass still increased but not as significantly as at the age of less than 14 days. With the addition of rejected milk, larval growth is higher, especially up to 14 days of age. This study is in accordance with research conducted by [32]. In the study, the addition of expired milk can increase ECD value and maggot growth is getting better. Maggot can digest more expired bread and expired milk during early stage.

5 Conclusion

The composition of the food given influences maggot growth. The more creamer is given, the more inhibition of maggot growth will occur. This can occur because the creamer particles are very fine, increasing the bulk density and reducing oxygen levels in the substrate. Maggot growth was highest in the composition of C:F-V:B ratio equal to 4:3:3 and 5:2.5:2.5. At the same creamer content, maggot growth was best when the C:F-V:B ratio was equal to 1. Maggot growth characterized by maggot weight was directly proportional to the WRI and SR values. The bigger the maggot, the greater the WRI and SR values. The highest WRI and SR values were obtained in the reactor with a substrate composition of 4:3:3. However, the ECD value was slightly higher in the reactor with a composition of 4:2:4 than 4:3:3. In the composition of 4:2:4 maggot more efficiently metabolize nutrients into biomass. At 4:3:3, maggots can reduce substrate and absorb nutrients well.

Acknowledgment
The authors would like to thank the lecturers and laboratory staff at the Department of Environmental Engineering ITS Surabaya. Most importantly, we would like to thank PT. Lautan Natural Krimerindo, PT. Indolakto and vegetable and fruit traders at Manyar and Pucang Traditional as fruit-vegetable waste providers.

Data Availability Statement
All data generated or analyzed during this study are included in this published article. Data sharing is not applicable to this article.

Credit authorship contribution statement
Aulia Fitriana: Researcher, Writing–Original manuscript, Writing–Review and editing. **Arseto Bagastyo**: Supervision, Funding, Writing–Review and editing. **Deqi Radita**: Writing–Review and editing

References

1. H. I. Puspitasari, Identifikasi Faktor Penyebab Kecacatan Produk saat Distribusi di PT. Indolakto, Universitas Atma Jaya Yogyakarta (2018).
2. K. Bohm, G. A. Hatley, B. H. Robinson, and M. J. Gutiérrez-Ginés, Black Soldier Fly-based bioconversion of biosolids creates high-value products with low heavy metal concentrations, *Resour Conserv Recycl*, vol. 180, May (2022), doi: 10.1016/j.resconrec.2021.106149.
3. K. Hartinger *et al.*, Suitability of Hermetia illucens larvae meal and fat in broiler diets: effects on animal performance, apparent ileal digestibility, gut histology, and microbial metabolites, *J Anim Sci Biotechnol*, vol. 13, no. 1, Dec. (2022), doi: 10.1186/s40104-022-00701-7.
4. G. Cardinaletti *et al.*, Effects of graded dietary inclusion level of full-fat hermetia illucens prepupae meal in practical diets for rainbow trout (Oncorhynchus mykiss), *Animals*, vol. 9, no. 5, May (2019), doi: 10.3390/ani9050251.
5. I. Marie Håkenåsen, G. Holseth Grepperud, J. Øvrum Hansen, M. Øverland, R. Martinsen Ånestad, and L. Torunn Mydland, Full-fat insect meal in pelleted diets for weaned piglets: Effects on growth performance, nutrient digestibility,

gastrointestinal function, and microbiota, *Anim Feed Sci Technol*, vol. 281, p. 115086, (2021), doi: 10.1016/j.anifeedsci.2021.115086.
6. K. S. Lee, E. Y. Yun, and T. W. Goo, Optimization of feed components to improve Hermetia Illucens growth and development of oil extractor to produce biodiesel, *Animals*, vol. 11, no. 9, Sep. (2021), doi: 10.3390/ani11092573.
7. A. Abdelfattah *et al.*, Microalgae-based wastewater treatment: Mechanisms, challenges, recent advances, and future prospects, Jan. 01, (2023), *Editorial Board, Research of Environmental Sciences*. doi: 10.1016/j.ese.2022.100205.
8. R. Rosa *et al.*, Life Cycle Assessment of Chemical vs Enzymatic-Assisted Extraction of Proteins from Black Soldier Fly Prepupae for the Preparation of Biomaterials for Potential Agricultural Use, *ACS Sustain Chem Eng*, vol. 8, no. 39, pp. 14752–14764, Oct. (2020), doi: 10.1021/acssuschemeng.0c03795.
9. T. Liu *et al.*, Black soldier fly larvae for organic manure recycling and its potential for a circular bioeconomy: A review, *Science of the Total Environment*, vol. 833, Aug. (2022), doi: 10.1016/j.scitotenv.2022.155122.
10. R. Salomone, G. Saija, G. Mondello, A. Giannetto, S. Fasulo, and D. Savastano, Environmental impact of food waste bioconversion by insects: Application of Life Cycle Assessment to process using Hermetia illucens, *J Clean Prod*, vol. 140, pp. 890–905, Jan. (2017), doi: 10.1016/j.jclepro.2016.06.154.
11. G. Bosch *et al.*, Conversion of organic resources by black soldier fly larvae: Legislation, efficiency and environmental impact, *J Clean Prod*, vol. 222, pp. 355–363, Jun. (2019), doi: 10.1016/j.jclepro.2019.02.270.
12. S. Diener, C. Zurbrügg, and K. Tockner, Bioaccumulation of heavy metals in the black soldier fly, Hermetia illucens and effects on its life cycle, *J Insects Food Feed*, vol. 1, no. 4, pp. 261–270 (2015), doi: 10.3920/jiff2015.0030.
13. D. Kumar *et al.*, Nutritional components in green leafy vegetables: A review, ~ *2498 ~ Journal of Pharmacognosy and Phytochemistry*, vol. 9, no. 5 (2020) [Online]. Available: www.phytojournal.com
14. U. Nor Azmah, M. U. Makeri, S. Y. Bagirei, and A. B. Shehu, Compositional characterization of starch, proteins and lipids of long bean, dwarf long bean, mung bean and French bean seed flours, *Measurement: Food*, vol. 12, Nov. (2023), doi: 10.1016/j.meafoo.2023.100111.
15. E. S. Saragi, Penentuan Optimal Feeding Rate Larva Black Soldier Fly (Hermetia illlucens) dalam Mereduksi Sampah Organik Pasar, Institut Teknologi Sepuluh Nopember Surabaya, Surabaya (2015).
16. A. S. Parra Paz, N. S. Carrejo, and C. H. Gómez Rodríguez, Effects of Larval Density and Feeding Rates on the Bioconversion of Vegetable Waste Using Black Soldier Fly Larvae Hermetia illucens (L.), (Diptera: Stratiomyidae), *Waste Biomass Valorization*, vol. 6, no. 6, pp. 1059–1065, Dec. (2015), doi: 10.1007/s12649-015-9418-8.
17. L. Alvarez, The Role of Black Soldier Fly, Hermetia illucens (L.) (Diptera Stratiomyidae) in Sustainable Waste Management in Northern Climate, Canada (2012) [Online]. Available: https://scholar.uwindsor.ca/etd
18. J. Ma *et al.*, Dynamic Effects of Initial pH of Substrate on Biological Growth and Metamorphosis of Black Soldier Fly (Diptera: Stratiomyidae), *Environ Entomol*, vol. 47, no. 1, pp. 159–165, Feb. (2018), doi: 10.1093/ee/nvx186.
19. D. C. Sheppard, J. K. Tomberlin, J. A. Joyce, B. C. Kiser, and S. M. Sumner, Rearing Methods for the Black Soldier Fly (Diptera: Stratiomyidae) (2002). [Online]. Available: https://academic.oup.com/jme/article/39/4/695/904029
20. C. Jucker, D. Lupi, C. D. Moore, M. G. Leonardi, and S. Savoldelli, Nutrient recapture from insect farm waste: Bioconversion with hermetia illucens (L.)

(Diptera: Stratiomyidae), *Sustainability (Switzerland)*, vol. 12, no. 1, Jan. (2020), doi: 10.3390/su12010362.
21. A. Giannetto *et al.*, Hermetia illucens (Diptera: Stratiomydae) larvae and prepupae: Biomass production, fatty acid profile and expression of key genes involved in lipid metabolism, *J Biotechnol*, vol. 307, pp. 44–54, Jan. (2020), doi: 10.1016/j.jbiotec.2019.10.015.
22. S. Diener, C. Zurbrügg, and K. Tockner, Conversion of organic material by black soldier fly larvae: Establishing optimal feeding rates, *Waste Management and Research*, vol. 27, no. 6, pp. 603–610 (2009), doi: 10.1177/0734242X09103838.
23. Ditha, Ingin Tahu Beda Krimer Dan Susu? Begini Penjelasan Lengkapnya! Accessed: Sep. 03 (2024). [Online]. Available: https://fibercreme.com/ingin-tahu-beda-krimer-dan-susu-begini-penjelasan-lengkapnya/
24. C. F. Mamuaja, Lipida, Manado (2017).
25. Ministry of Health, TABEL KOMPOSISI TABEL KOMPOSISI PANGAN INDONESIA PANGAN INDONESIA (2020).
26. M. Meneguz *et al.*, Effect of rearing substrate on growth performance, waste reduction efficiency and chemical composition of black soldier fly (Hermetia illucens) larvae, *J Sci Food Agric*, vol. 98, no. 15, pp. 5776–5784, Dec. (2018), doi: 10.1002/jsfa.9127.
27. K. Nakasaki, Y. Nakano, T. Akiyama, M. Shoda, and H. Kubota, Oxygen Diffusion and Microbial Activity in the Composting of Dehydrated Sewage Sludge Cakes (1987).
28. L. Palma, S. J. Ceballos, P. C. Johnson, D. Niemeier, M. Pitesky, and J. S. VanderGheynst, Cultivation of black soldier fly larvae on almond byproducts: impacts of aeration and moisture on larvae growth and composition, *J Sci Food Agric*, vol. 98, no. 15, pp. 5893–5900, Dec. (2018), doi: 10.1002/jsfa.9252.
29. A. Prasetya, R. Darmawan, T. L. Benedita Araujo, H. T. B. Murti Petrus, and F. A. Setiawan, A Growth Kinetics Model for Black Soldier Fly (Hermetia illucens) Larvae, *International Journal of Technology*, vol. 12, no. 1, pp. 207–216 (2021), doi: 10.14716/ijtech.v12i1.4148.
30. J. J. A. Beniers and R. I. Graham, Effect of protein and carbohydrate feed concentrations on the growth and composition of black soldier fly (Hermetia illucens) larvae, *J Insects Food Feed*, vol. 5, no. 3, pp. 193–199 (2019), doi: 10.3920/JIFF2018.0001.
31. C. Scieuzo *et al.*, Enhancement of fruit byproducts through bioconversion by Hermetia illucens (Diptera: Stratiomyidae), *Insect Sci*, vol. 30, no. 4, pp. 991–1010, Aug. (2023), doi: 10.1111/1744-7917.13155.
32. D. A. P. Sari, A. T. Mumtaz, D. S. Irawan, P. Nursetyowati, and A. R. Djamaris, Utilization of black soldier flies to reduce grease waste and support zero waste, *International Journal of Recycling of Organic Waste in Agriculture*, vol. 12, no. 4, pp. 709–722, Dec. (2023), doi: 10.30486/ijrowa.2023.1981992.1611.