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Dry Media Formulation to Increase Productivity and Quality of Silkworms (*Tubifex* sp.) as A Natural Feed Development for Aquaculture

Yohanes Corne[1], Sinung Rahardjo[2*], Moch. Nurhudah[2] & Putu Angga Wiradana[3]

[1]Master Student of Jakarta of Technical University of Fisheries, Jakarta, Indonesia
[2]Departement of Fisheries Extension, Technical University of Fisheries, Jakarta, Indonesia
[3]Research Group of Biological Health, Study Program of Biology, Faculty of Health and Science, Universitas Dhyana Pura, Badung Regency, Bali, Indonesia
*Corresponding author, email: snngrahardjo@gmail.com
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ABSTRACT Silkworms (*Tubifex* sp.) are a type of natural food that is widely used for the needs of fish farming activities, especially in the freshwater fish hatchery phase. This study aimed to determine the effect of providing dried feed/media with varying doses on the productivity of silk worms. The study was conducted using a Completely Randomized Design (CRD) with three treatment groups and four replications which included administration of dry media at a dose of (P1) 150 g/m^2 (P2) 250 g/m^2 (P3) 350 g/m^2. The initial silkworm seeds were obtained from silk worm collectors or sellers in Cipayung-East Jakarta. Maintenance of silkworms was carried out for 55 days. The results of the diversity analysis showed that there was a significant difference in the dose of dry media in cultivating silkworms (P≤0.05). The best absolute weight growth, population growth, and productivity were shown in the media treatment with a dose of 250 g/m^2 (P2) with absolute biomass growth of 408.7 g, population growth of 209,381 individuals, and productivity of 1.3/m^2/cycle. The results of water quality observations are still in a relatively optimal range. Silkworms have the potential to be developed as a safe, environmentally beneficial, and inexpensive natural food for cultivated animals.

Keywords: *C. racemosa*; fermentation; hydrolysis; *L. plantarum*

INTRODUCTION

Aquaculture is a fast business capable of supplying high-quality animal protein sources (Ahmad *et al*., 2021; Van Doan *et al*., 2022). Other factors, like climate change, economic uncertainty, and increased competition for natural resource utilization, pose significant hurdles to adjusting plans to maintain food and nutritional security for the world population through the aquaculture sector (Naylor *et al*., 2021). According to data from the Food and Agriculture Organization of the United Nations (FAO), global fish consumption climbed by 3.1% per year between 1961 and 2017, nearly double the annual growth rate of the world population, which was 1.6% during the same time (FAO, 2020).

The maritime axis of the globe, which is a focal point for nearly 80% of aquaculture activities in Asia, passes through Southeast Asia, particularly in tropical regions like Indonesia. However, the aquaculture industry continues to face challenges, particularly in Asia. These include land scarcity (Galappaththi *et al*., 2020; Zhang *et al*., 2023), inadequate access to high-quality feed (García Beltrán & Esteban, 2022; Rahardjo *et al*., 2022; Vijayaram *et al*., 2022), pollution of the environment (Li *et al*., 2023; Wang *et al*., 2023), and ineffective planning and management of aquaculture systems (Wiradana *et al*., 2021). It is apparent that the development of sustainable aquaculture is still vital and crucial for the long-term survival of this industry in Asia, particularly in Indonesia.

Due to conditions that support the growth and spread of pathogens, intensive cultivation systems can result in a higher risk of disease incidence in farmed fish, resulting in reduced growth, productivity, and economic losses (Mugwanya *et al*., 2022). For a long time, antibiotics and chemical substances have been utilized to prevent and control diseases in agricultural animals (Okeke *et al*., 2022). Excessive use of antibiotics, on the other hand, can result in drug-resistant diseases, immune system suppression, environmental pollution, and buildup in animal tissue, all of which might jeopardize environmental and human health (Polianciuc *et al*., 2020). To prevent and/or control infections in fish, the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) propose the use of natural immunostimulants, natural diets, and pro-, pre-, and symbiotic applications in aquaculture. It is intended to strengthen the fish's immune system while avoiding future environmental, animal, and human health issues (Reverter *et al*., 2014; Cunha *et al*., 2018).

Silkworms (*Tubifex* sp.) are a type of natural food with the highest quality in terms of supporting the performance of both intensive and non-intensive agriculture systems, and are frequently utilized in feeding freshwater fish larvae (Chilmawati, 2015). Silkworms are prevalent in tropical places with muddy waters and organic matter, such as river watersheds (DAS), organic waste disposal streams, and lakes. To find food, the silk worm will bury its head in the mud, but the tip of its tail will stick out above the surface of the mud to breathe. In general, silkworms may thrive in mud substrates with a depth of 0-4 cm (Fajri *et al*., 2013).

Silkworms are ideal for feeding on fish seeds because they promote faster growth than other natural foods (Priyadi, 2010). Silk worms, according to Chahyaningrum ( ), are one sort of natural food that can boost the growth rate and survival of Siamese catfish seeds. The need for silk worms in catfish hatchery activities, for example, is particularly high since silk worm feeding begins at 3-15 days of age, and the demand for silk worm feeding in-

-ing begins at 3-15 days of age, and the demand for silkworm feeding increases every day. The production of silkworms can occur through cultivation or fishing in the wild. Dangerous microbes and heavy metals (food-borne pathogens) are drawbacks of naturally captured silkworms. Environmental conditions have a significant impact on the bioaccumulation of silkworms in opposition to contaminant agents, given that they are filter feeder animals. The quantity produced is insufficient to satisfy the demands of the cultivators, which constitutes a deficiency in the cultivation activities conducted.

The use of silkworms has already been examined. However, it has failed to explore the nutritional value, practicality, efficiency, and hygiene of the converted silkworms. Nurfitrianti *et al*. (2014) previously evaluated the performance of mud medium enriched with chicken manure and other by-product materials coming from animal and vegetable sources, such as fish silage and tofu dregs. The resulting mud medium supported the most silkworm biomass, with 57.93 g/container, 13,995 individuals/container, and a microbial protein concentration of 59.75%. However, the use of chicken manure for silkworm cultivation allows for the growth of *Salmonella* and E. *coli* bacteria, which have the potential to cause health concerns for the environment and farmed animals (Elsaidy *et al*., 2015; Alegbeleye *et al*., 2018; Black *et al*., 2021). Therefore, feed generated from animal waste does not comply with PERMEN-KP/NUMBER 55/2018 concerning fish feed, which specifies that fish feed, whether artificial or natural feed, must exceed food safety requirements for cultivated commodities and be environmentally friendly.

Silkworm cultivation technology has been developed using various systems, media, and containers. Because the cultivation media used has a large influence on the quality and growth of silkworms, choosing the proper media can be an indicator of success in silkworm cultivation (Wenda *et al*., 2018). Silkworm farming approaches such as traditional systems using paddy fields, apartment systems, and cement pond systems have all been used (Lestari *et al*., 2021), but each has advantages and disadvantages in adopting this technology. In general, farmers carry out cultivation activities in line with the availability of by-products as a living medium for silkworms as well as the technology available in their individual regions.

People require more practicable cultivation systems in the twenty-first century, particularly in the aquaculture industry. Prior investigations have utilized both dry feed and media that are capable of being packaged and preserved for extended durations in order to foster silkworm development. The formula for this nutrition was developed in prior investigations (Umidayati *et al*, 2020). The ingredients are 40% tofu dregs, 25% fish silage, 25% fine bran, and 10% mustard greens. Furthermore, the dry medium must be applied precisely in terms of the amount to be delivered. Consequently, this study aims to establish the appropriate dose of dry media for silkworm productivity and quality.

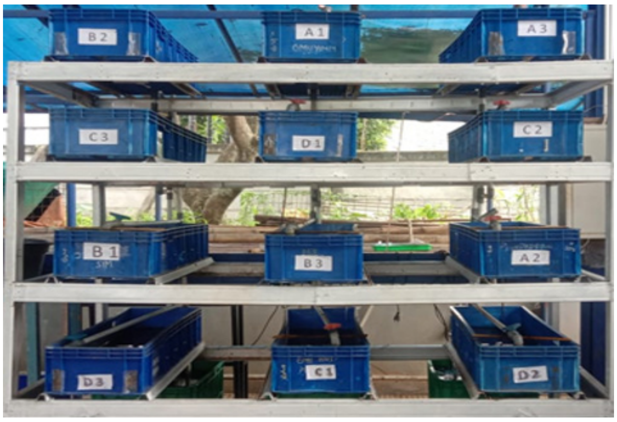
MATERIALS AND METHODS

Study Sites

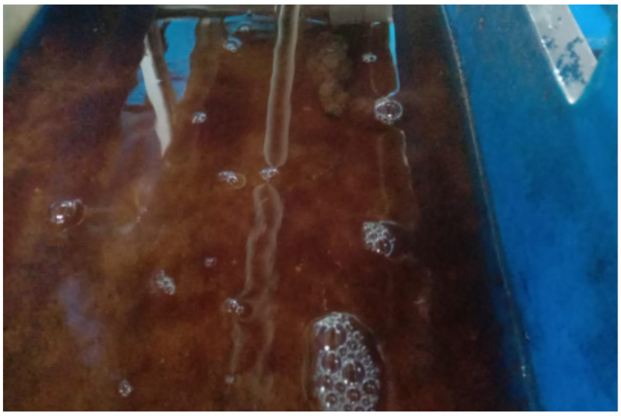
The study was conducted from May 28 to July 21, 2022, in the Cultivation Laboratory, Fisheries Business Expert Polytechnic, Pasar Minggu, Jakarta. The observation period for the use of dry media in the cultivation of silkworms was 55 days. Water quality (Temperature, pH, Dissolved oxygen (DO), Total Ammonia-N, and Nitrite) and microbiological (*Salmonella* spp. and *Escherichia coli*) analyses were performed at the Sukamandi Freshwater Fisheries Research Institute Test Laboratory.

Research design

This study used a completely randomized design (CRD) with three treatment groups and four replications. The first treatment (P1) received a media/feed dose of 150 g/m^2, the second treatment (P2) received a media/feed dose of 250 g/m^2, and the third treatment (P3) received a media/feed dose of 350 g/m^2. The experimental setup used in this study is depicted in Figure 1 below.



A.



B.

Figure 1. This study made use of an experimental setup. A. A series of silkworms (*Tubifex sp.*) rearing containers based on treatment groups, and B. silkworms employed in this study.

Research procedure

The media employed in this study was dried feed media made up of 40% tofu dregs, 25% fish meal, 25% fine bran, and 10% mustard greens. These materials were fermented with EM4 probiotics at a dose of 1 mL/kg and molasses solution at a dose of 10 mL/kg before 300 mL of clean water was added. The fermentation was carried out in a closed container using a bucket with a capacity of 250 L. The fermenting process lasted 5 days. After fermentation, the drying process is carried out for 24 hours at Cultivated Fisheries Production Business Service Center (BLUPPB) Karawang was carried out using an electric dryer with an operating temperature of 85 °C. The silkworm starter seeds used in this experiment were purchased from worm dealers in Cipayung, East Jakarta. Prior to stocking, the silkworms were quarantined for three days to eradicate pathogenic germs. The silkworms were then placed in maintenance containers made of HDPE with a stocking density of 1.140 g/m^2. Every three days, more media or feed based on the treatment dose was provided as part of the maintenance process.

Monitoring water quality entailed testing water quality measures as well as cleaning pumps and water pipes. Cleaning of the circulation holes and water pumps was performed every three days during water circulation research activities to eliminate dirt and moss deposits. The water flow used for each silk worm rearing container is 8 L/container. Temperature, pH, and *dissolved oxygen* (DO) levels in the water were tested twice daily (morning and evening), whereas ammonia and nitrite levels were examined at the end of the study. pH was measured using a pH meter, dissolved oxygen was measured with a DO meter, temperature was measured with a digital thermometer, and ammonia and nitrite were measured with a spectrophotometer.

At the age of 55 days, silkworms were harvested. The harvesting process was carried out by scooping the media and worms together with a sterile net scope measuring 1 µm, then placing the media and silkworms in a basin for 120 minutes and covering the top with black plastic to separate the silkworms and substrate (Suryadin *et al*., 2017). The collected silk worms were then weighed, and the population was determined.

Test parameters

Absolute biomass

Absolute biomass is estimated using the formula proposed by Fajri *et al*. (2013), which is as follows:

$$W=Wt-Wo$$

Where W = Absolute biomass
Wt = Stocking time biomass
Wo = Final rearing biomass

The silkworm population was calculated by counting directly from a 1 g sample, then counting the sample using a colony counter. After that, it is translated to the weight of biomass in each container (Hadiroseyani *et al*., 2008).

Silkworm productivity

Productivity figures are derived from absolute weight increase calculations, which are then transformed into kg/m^2/cycle units. Productivity estimations are done out using the formula proposed by Lutfiyanah & Djunaidah (2020):

$$Productivity=(Wt-Wo)/L$$

Where
Wt = Final Biomass (kg)
Wo = Initial Biomass (kg)
L = Maintenance container area (m2)

Nutritional content analys

The infrared (NIR) analysis method was used to test silkworm materials and media at the National Research and Innovation Agency laboratory, while the biochemical or proximate method was used to test the nutritional content of silkworms at the chemistry laboratory of Fisheries Business Expert Polytechnic Jakarta. The tests were carried out in accordance with the Indonesian National Standards using the Official Methods Chapter 4 approach (Wiradana *et al*., 2019). Protein content was determined using the Kjeldahl method, ash content was determined using an ash furnace at 500 °C for 4 hours, and fat content was determined using the Soxhlet fat extraction method.

Yield (%)

Yield is the ratio of dry weight to raw material amount, expressed in percentage units (Lisa *et al*., 2015). This was done to identify the difference between wet and dry media and will be the main product of this research. Yield is determine using the formula developed by Lumba *et al*. (2020).

$$Yield = \frac{dru \quad weight}{wet \quad weight \quad (fermentation)} \times 100\,\%$$

Confirmative test for pathogenic bacteria

Pathogenic bacteria confirmative tests are performed to assess the content of contaminating bacteria such as *Salmonella* spp. and *Escherichia coli* identified in growth media and silk worms generated. Confirmatory testing for *Salmonella* spp. is performed in accordance with SNI 01-2332.2-2006, whereas testing for E. *coli* bacteria is performed in accordance with SNI 01-2332.1-2006.

Statistical analysis

Data was analyzed using one-way ANOVA and Duncan Multiple Range's test to evaluate the level of influence of differences between different experimental treatment dosages with probability (α=5%) using a linear equation model (Djauhari *et al*., 2017).

RESULTS AND DISCUSSION

Nutrient content of silk worm media and feed

Based on the results in Table 1, it is clear that the nutritional value of fermented media and dry feed media differs. The protein level of the fermented media material was 28.87%, whereas the dry feed media was 23.04%. This demonstrates that the protein content of fermented feed media is significantly higher than the protein content of dry feed media. The findings of nutritional tests on dry media acquired greater values than earlier studies, namely protein content 17.89%, water content 2.07%, ash content 15.94%, fat content 8.7%, and carbohydrate content 55.01% (Yazid *et al*., 2022).

Table 1. Results of nutritional testing of feed ingredients.

Nutritional Composition (%)	Material Type				
	Tofu Dregs	Fish Meal	Bran	Fermentation Media	Dry feed media
Proteins	14.64	29.4	5.36	28.87	23.04
Water content	1.97	11.29	13.19	28.47	26.96
Ash Content	17.77	10.99	8.26	12.09	9.85
Fat	14.64	29.24	13.94	3.81	6.38
Alanine	1.76	0.78	0.56	0.57	0.32
Arginine	7.88	2.96	1.07	5.57	4.57
Aspartic acid	0.96	0.19	0.13	1.21	1.18

Note: Fermentation media is a dried silkworm food media with a composition including: 40% tofu dregs, 25% fish meal, 25% fine bran, 10% mustard greens, 1 ml/kg EM4 probiotic, and 10 ml/kg molasses solution.

Nutritional deficiencies can be produced by the heating process, which causes denaturation of the feed's protein composition. Drying at 80 °C may not be optimal for usage in the drying process for this feed ingredient. This is consistent with the findings of Nuraeni *et al*. (2017), who discovered that temperature and drying time influence lowering feed protein content. Similarly, heating or drying can cause protein inhibitors to become inhibited or inactive, which is positively connected with a decrease in feed protein levels (Mohan & Long, 2015). The protein content of silk worm feed media plays an essential impact in silk worm growth. This is consistent with the belief of Kusumorini *et al*. (2017) that the composition or protein content of feed has a significant impact on the growth and productivity of silk worms. Amino acids, which are made up of protein in feed, have a significant function in maintaining the production of agricultural animals (Iskandar & Fitriadi, 2017). These results suggest that the amino acid content of the feed media is fairly high. The water content in the medium and dry feed media was 26.96%, which was much lower than the water content value in the fermented feed media, which was 28.47%. Based on this data, the lower the water content in the silkworm feed media, the more it can affect the storage time (Nastiti *et al*., 2014). In this study, the yield value was 94.69%. Based on the results of the rendement data, the rendement produced is very good, because the high value of a material demonstrates its economic value and is a better source of nutrition for animal performance (Putranto *et al*., 2015).

The dried feed medium has an ash content of 9.85%. According to the results of this investigation, the ash content is rather high. The ideal ash content, according to Gunawan & Khalil (2015), is 13%. Ash content is a leftover substance produced by the combustion of organic materials that has been analyzed to estimate the mineral content of the material (Lisa *et al*., 2015). According to Nuraeni *et al*. (2017), the lower the ash content, the lower the mineral content. The fat percentage of the dry feed medium is 9.85%. Low fat content and relatively low-fat content in the media allow oxygen to infiltrate the soil, causing silkworms to look for food by dipping their heads at a depth of 2-3 cm.

Performance of silkworm cultivation

Observing the absolute weight increase, population growth, and productivity are all aspects of silk worm farming performance. Table 2 shows the results of determining the performance of silk worm cultivation using dry feed material.

Table 2. Silkworm cultivation performance.

Parameter	Media/feed Dosage		
	(P1)	(P2)	(P3)
Absolute biomass (g)	226.2 ±11.08^{b}	408.7±46.6^{c}	94.5±45.3^{a}
Population (tail)	160.220±9.542^{b}	209.381±2.4038^{c}	60.745±1.0414^{a}
Productivity (kg/m2/cycle)	0.7275±0.03^{b}	1.3100±0.14^{c}	0.3000±0.70^{a}

*Mean values with different superscript letters on the same row indicate significantly different results (P<0.05).

According to the table above, the best absolute weight rise with a maintenance period of 55 days was 408.7 g in treatment (P2). Treatment (P1) had the highest production of 226.2 g, while treatment (P3) had the lowest yield of 226.2 g and 94.5 g, respectively, when compared to treatments (P2) and (P1). These findings are far superior to prior research, which found that the absolute weight increase value obtained was 48.67 g with a stocking amount of 100 g (Yazid *et al*., 2022).

Differences in media and feed dosage cause variations in media thickness, which are directly related to absolute weight gain. This is due to the media's role in helping silkworms reproduce optimally. The protein content and organic elements in cultivation media and feed affect silkworm growth rate (Fajri *et al*., 2013; Barades & Witoko, 2018). The organic material concentration in silkworm feed media is the consequence of bacterial degradation of molasses-derived carbon (C) (Syaputra *et al*., 2017). Protein absorption efficiency is heavily influenced by the source and quality of protein in the feed media (Hastuti *et al*. 2016). Energy can be obtained from fat sources and carbon contained in feed media, while nitrogen aids in the development of microorganisms. There was a decrease in absolute weight increase observed in Treatment (P3).

According to the data presented in Table 2, treatment (P2) yielded the greatest silkworm population growth, consisting of 209,381 individuals. Treatment (P1) achieved the second highest growth, with 160,220 individuals, whereas treatment (P3) demonstrated the lowest population growth, with 60,745 individuals. The findings of the diversity analysis revealed that variations in media dosage had a statistically significant impact on the abundance of specific individuals ($P \leq 0.05$).

Treatment (P2) yielded the most substantial results in terms of total population expansion, with a capacity of 209,381 individuals per container. The most favorable population results, according to growth findings from previous research (Yazid *et al*., 2022), were 59,458 individuals. These results were significantly superior to those of previous research. The data suggests that silk worms are capable of reproducing due to the presence of a sufficient quantity of organic matter within their habitat. Reductions in the nutritional value of the habitat will impede the reproductive and growth processes.

At a rate of 1.3 kg/m^2/cycle, treatment (P2) achieved the greatest productivity value. Productivity of 0.72 kg/m^2/cycle was achieved in treatment (P2). Treatment (P2) exhibited a marginally higher productivity of 0.30 kg/m^2/cycle in comparison to treatment (P3). According to previous studies (Pardiansyah *et al*., 2014), the silkworms achieved their maximum productivity at a rate of 0.97 kg/m2. The findings from the diversity analysis indicated that the productivity of the silk worms produced was influenced by the administration of varying concentrations ($P \leq 0.05$).

Productivity is strongly related to biomass production, therefore, the results obtained are roughly the same as the biomass obtained in each treatment. According to the findings of the research, the best productivity was obtained with a value of 1.3100 kg/m^2 in treatment (P2) and the lowest was obtained with a value of 0.3000 kg/m^2 in treatment (P3). According to prior research, the highest productivity of raising silkworms using dry food media was reached at a value of 0.466 kg/m^2 (Yazid *et al*., 2022). Meanwhile, Umidayati *et al*. (2020) had the highest productivity of 1.2 kg/m^2. According to Febrianti *et al*. (2020), the peak growth cycle for silkworms occurs at the age of 10 days, and harvesting is done on the 40th day for best results.

Silkworm nutritional content

The findings of silk worm proximate analysis revealed that the maximum protein content was obtained in treatment with a dose of 250 g/m^2 (P2), namely 77.89%, followed by treatment with a dose of 150 g/m^2 (P1) at 60.14%, and treatment with a dose of 350 g/m^2 (P3) at 44.6%. This demonstrates that high doses do not necessarily result in an increase in protein content in silkworms (Table 3).

When compared to studies conducted by Hidayat (2016), the nutritional content of silkworms in the best treatment (P2) is substantially higher, notably protein 57%,

Table 3. Proximate test results for silkworms.

Nutritional composition (%)	Nutrient composition of Tubifex fed experimental feed [1]		
	(P1)	(P2)	(P3)
Water content	81.25±2.5	408.7±46.6^c	70.50±4.6
Proteins	60.14±2.5	77.89±5.5	44.6±6.3
Fat	12.6±5.6	9.1±2.2	3.2±1.3
Ash	1.3±1.05	2.2±0.54	4.2±1.70

Description: [1] Feeding dose treatment (P1) 150 g/m^2 (P2) 250 g/m^2 (P3) 350 g/m^2. Proximate testing was carried out based on the dry weight of the silkworms.

fat 13.3%, crude fiber 2.04%, ash content 3.6%, and water 87.7%. Despite the increased protein content of silkworms, the value remains within the range required for fish larvae. In this study, the protein content of silk worms was not directly related to population size or biomass, with the treatment with the lowest biomass (P1) having a greater protein content than the treatment with the highest biomass (P3). Each treatment with a dose of 250 g/m^2 (P2) produced 1.62% fat, followed by treatments with a dose of 150 g/m^2 (P1) producing 2.25% fat and treatments with a dose of 350 g/m^2 (P3) producing 1.25% fat.

Based on these findings, it is thought that silk worms can store fat as an energy reserve (Hidayat, 2016). Silkworm fat contains omega-3 (C18:3n-3 and C20:5n-3) and omega-6 (C18:2n-6c and C20:4n-6) fatty acids, both of which are required for the growth and survival of fish larvae (Setiawan *et al*., 2013). The low protein content in treated silkworms (P3) is thought to be due to the energy requirements for feed in the treatment (P3) having met the basic energy needs (basal metabolism and normal activity) of silkworms, allowing protein to be more utilized for the development of egg cells (Setiawan *et al*., 2013). Based on the number of individuals, biomass, and fat content of silk worms, it can be determined that the best yield of silk worms (P2) can be recommended as a natural diet that can be fed to fish larvae and ca n be used as a production-scale business.

Confirmation of Salmonella spp. and Escherichia coli.

The presence of foodborne bacteria that accumulate in the bodies of silkworms captured in the open is a likelihood hazard of the high concentration of organic material found in household waste, which has an impact on the natural existence of silkworms. Salmonella spp. and Escherichia coli consist primarily of these microorganisms. *Escherichia coli* bacteria with a 211 Positive EFC of 20 APM/gram were determined to produce the most fruitful research outcomes with regard to silk worms, according to the outcomes of the completed experiments. Additionally, the yield of 333 positive EFC 20 APM/g was increased when silk worms were cultivated with tofu remnants contaminated with *Eschericia coli* bacteria. Broadly speaking, growth media specifically designed for pathogenic microorganisms are those that possess elevated levels of protein and water. E. *coli*, a bacterium, is frequently employed as a bioindicator in environmental contexts, particularly in cases involving the contamination of warm-blooded animal feces (Wiradana *et al*., 2020). However, aquatic environments characterized by elevated salinity generally impede the development of this organism (Wiradana *et al*., 2019; Maulidya *et al*., 2021). *Salmonella* spp. contamination was not detected in silkworms captured in the field (Table 4) or in silkworms treated with tofu dregs medium (best results). Conversely, silkworms isolated from the wild exhibited positive results.

Table 4. Contamination of *Escherichia coli* and *Salmonella* spp. in silkworms.

Source of worms	*Salmonella spp.*	*Eschericia coli*
The best research results of silkworms	Salmonella negative	211 Positive EFC 20 APM/g
Silkworms are produce using tofu dregs	Salmonella negative	333 Positive EFC 20 APM/g
Natural caught silkworms	Positive for Salmonella	350 Positive EFC 20 APM/g

Diverse digestive tract disorders may be influenced by the prevalence of *Salmonella* spp. and *Escherichia coli* in farmed animals (Umidayati *et al*., 2020). Conversely, Salmonellosis is a foodborne illness that can induce gastrointestinal infections via the ingestion of food or water contaminated with the Salmonella genus; this organism is responsible for the development of enterocolitis (Porto *et al*., 2022). The prevalence of *Salmonella* spp. in wild silkworms can be attributed to poor water quality, which is a carrier of contamination (residual human activities, agricultural and industrial waste) (Klase *et al*., 2019; Saingam *et al*., 2020). Therefore, it is not suggested to feed natural food to wild silkworms because they are particularly sensitive to infection in cultured animals (Feye *et al*., 2021; Popa & Popa, 2021; Sargeant *et al*., 2021).

Water quality

The pH value is in the range of 6.50-7.23, the temperature is in the range of 26-28°C, the dissolved oxygen is in the range of 1.2-4.9 mg/L, ammonia is in the range of 0.56-28.1 mg/L, and nitrite is in the range of 0.10-0.21 mg/L. Table 5 shows the water quality parameter values observed over the course of 55 days.

The water quality parameters in each treatment have nearly identical results. This is due to the fact that each treatment takes place in the maintenance room and uses the same water supply. Although low pH values occurred in treatment (P3), they were nonetheless within silk worm maintenance criteria. Silk worms can survive in pH ranges ranging from 5.5 to 8.0. The pH value changes as rearing time and nutrition are increased. Chilmawati *et al*. (2013) assert that the standard water pH for silkworms falls within the range of 6 to 8. Consequently, the pH value utilized in this investigation to cultivate silk worms remains within the parameters prescribed for maintenance purposes. The temperature within each silk worm rearing container ranges between 26-28°C.

The observed temperature fluctuations remain within the acceptable range for silkworm cultivation, as defined by Pursetyo *et al*. (2011), which suggests that the ideal temperature range is between 26 and 30°C. Although

Table 4. Water quality parameters for rearing silkworms.

Water quality parameters	Treatment[1)] (P_1)	(P_2)	(P_3)	Standart values
Temperature (°C)	26-28	26-28	26-28	26-30[1]
pH	6.50-8.0	7.0-8.0	6.50-8.0	6.0-8.0[2]
Dissolved oxygen (mg/L)	1.2-4.7	1.4-4.9	0.8-3.5	>3.0[3]
Total Amonnia-N (mg/L)	0.56-0.95	1.8-2.8	12.0-28.1	<3.6[4]
Nitrite/NO2 (mg/L)	0.10-0.20	0.05-0.07	0.016-0.021	0.01-0.04[4]

Note: The standard value of each water quality parameter refers to Pursetyo *et al*. (2011)[1], Chilmawati *et al*. (2013)[2], Akhril *et al*. (2019)[3], Anggraini (2017)[4].

temperature parameters do not impose a limiting factor on oligochaete silkworms (Shafrudin *et al*., 2005), significant increases in water temperature will induce metabolic changes that can be observed in the silkworms. To ascertain the impact of temperature fluctuations on the physiological responses of these silk worms, additional research is required.

The growth of silkworms is significantly impacted by the dissolved oxygen level, as a deficiency in this parameter leads to physiological disturbances and an increase in silkworm mortality. The concentration of dissolved oxygen in treatment (P3) was found to be the lowest at 0.8 mg/L, while treatment (P2) had the highest concentration at 4.9 mg/L. Adult silkworms can survive for up to 48 days in anaerobic conditions at a temperature of 2°C (Pardiansyah *et al*., 2014). Conversely, for growth and development to occur, the oxygen content during the embryonic phase must be greater than 2 mg/L (Hildayanti, 2012).

On day 55 of treatment (P3), the highest ammonia content was found to be 28.1 mg/L. This can be attributed to silk worm metabolism as well as the addition of feed and medium to the rearing container, which degrade since they are not completely digested. According to Mizwar *et al*. (2021), the high amount of ammonia in the media is generated by bacteria that do not play an appropriate role in the nitrification process. The lowest ammonia content was obtained in treatment (P1), with a value of 0.56 mg/L, while the ideal ammonia value for worm cultivation was <3.6 mg/L (Anggraini, 2017). Surprisingly, the P3 group had an ammonia concentration of up to 3.86 mg/L, which may be connected to lower productivity (Kamaruddin *et al*., 2021).

CONCLUSION AND RECOMMENDATION

Conclusion

Overall, variations in dried feed dosage have a substantial impact on the development performance of silkworms (P≤0.05), according to the findings of this study. An absolute weight increase of 408.7 grams, a population growth of 209,381 individuals, and a resultant productivity of 1.310 kg/m2/cycle indicate that the optimal dose of dry media is 250 grams/m2 administered every three days.

Recommendation

Further research is required, particularly to test the efficiency of the optimal dose in this study on larval growth and cultured fish nutrition, to give commercial value. The content of pollution agents such as heavy metals, microplastics, and antibiotic residues, on the other hand, is still required. Similarly, research into the effect of temperature on the physiological response of silkworms is still needed to achieve optimal silkworm survival and quality.

AUTHORS' CONTRIBUTIONS

YC and SR: Conceptualization, drafting scripts, acquiring projects, and designing. YC, SR, and MN: collecting data, monitoring, and conducting the research. YC: sampling, observation, and technical laboratory. SR and PAW: Supervision, editing, and review of manuscripts. All authors discussed the results and contributed to the final manuscript.

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