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# Effect of culture media composition on chitin content, nitrogen retention, crude fat digestibility, and growth of mealworms (*Tenebrio molitor*)

## *Pengaruh komposisi media biakan terhadap kandungan kitin, retensi nitrogen, kecernaan lemak kasar, dan pertumbuhan dari ulat hongkong (Tenebrio molitor)*

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**ABSTRACT**

The purpose of this study is to investigate how different culture media compositions affect *Tenebrio molitor* nutritional value. A Completely randomized design (CRD) including three treatments and six replications was the methodology employed at a significant level of 5%. Duncan's multiple range test (DMRT) was used to analyze the significant differences found. The treatments were T1 (100% CF), T2 (50% CF + 50% TD), and T3 (100% TD), which were various combinations of the commercial feed (CF): tofu dreg (TD). Chitin content, nitrogen retention, crude fat digestibility, feed consumption, weight gain, and feed conversion were the variables that were observed. The results indicated that changes in the culture media's make-up had a significant effect ($P<0.01$) on the mealworms' chitin content, nitrogen retention, feed consumption, weight gain, and feed conversion. However, there was no discernible change in crude fat digestibility ($P>0,05$). The best results were fou chitin content 9.61%, nitrogen retention rate 80.89%, a crude fat digestibility rate of 89.48%, feed consumption 264.88 g/1,000 larvae, weight gain 72.12 g/1,000 larvae, and a feed conversion rate 3.68.

**ABSTRAK**

*Tujuan dari penelitian ini adalah untuk mempelajari bagaimana berbagai komposisi media kultur mempengaruhi nilai gizi Tenebrio molitor. Metode RAL yang mencakup tiga perlakuan dan enam replikasi adalah metodologi yang digunakan pada tingkat signifikansi 5%. Uji rentang berganda duncan (DMRT) digunakan untuk menganalisis perbedaan signifikan yang ditemukan. Perlakuannya adalah P1 (100% RK), P2 (50% RK + 50% AT), dan P3 (100% AT), kombinasi dari media biakan pakan komersial (RK): ampas tahu (AT). Kandungan kitin, retensi nitrogen, kecernaan lemak kasar, konsumsi pakan, pertambahan berat badan, dan konversi pakan adalah variabel yang diamati. Hasilnya menunjukkan bahwa perubahan dalam komposisi media biakan berpengaruh sangat nyata ($P<0,01$) terhadap kandungan kitin, retensi nitrogen, konsumsi pakan, pertambahan berat badan, dan konversi pakan pada ulat Hongkong. Namun, tidak ada perubahan yang signifikan dalam kecernaan lemak kasar ($P>0,05$). Studi ditemukan sistem pemberian pakan dengan menggunkakan 100 % ampas tahu dengan kandungan khitin 9.6% retensi nitrogen sebesar 80,89%, kecernaan lemak kasar sebesar 89,48%, konsumsi pakan 264,88 g/1,000 larva, pertambahan berat badan 72,12 g/1,000 larva, dan konversi pakan sebesar 3,68.*

*Kata kunci:*
*Ransum komersial*
*Ulat Hongkong (Tenebrio molitor)*
*Kualitas nutrisi*
*Ampas tahu*

## INTRODUCTION

Feed must contain all the nutrients required by livestock in balanced amounts. A common problem farmers face is dependency on imported feeds like fish meal, which leads to higher feed costs. Although Indonesia has abundant fishery resources, locally produced fish meals often do not meet the quality standards required for livestock feed. Therefore, there is a need to seek alternative animal protein sources, such as mealworms (*Tenebrio molitor*).

Mealworms are the larvae of the cereal-eating beetle *Tenebrio molitor*. These larvae are known for their ability to consume organic waste like food scraps and convert it into nutrient-rich pupae. Mealworms have significant potential as an economic venture for communities due to their ease of breeding and high market demand, making them a promising business opportunity. According to Siddiqui et al. (2024) mealworms are used to feed various animals such as fish, birds, reptiles, and poultry. Therefore, the quantity and quality of mealworm farming need to be improved. Economically, mealworms are valuable and beneficial as they can be cultivated and sold as a source of animal protein.

The nutritional composition of *Tenebrio molitor*, according to Jajic et al. (2020) is characterized by a high crude protein content of 48%, fat content of 40%, ash content of 3%, and a complete profile of amino acids (glutamic acid 6.44%, alanine 4.53%, aspartic acid 4.30%, isoleucine 4.12%, tyrosine 3.86%, glycine 3.67%, arginine 3.60%, phenylalanine 3.06%, leucine 2.96%, lysine 2.67%, proline 2.67%, serine 2.38%, methionine 1.76%, threonine 1.47%, and valine 0.65%), linoleic fatty acid 0.70%, linolenic acid 2.24%, as well as minerals like calcium (5.65%), sodium (13.71%), potassium (10.00%), and magnesium (3.50%).

Farmers generally use commercial feed as the medium for cultivating mealworms. Commercial feed is a mixture of several ingredients formulated according to livestock's specific nutritional and energy needs. The commercial feed used in this study is Bravo 311-Vivo feed, containing 22.50% crude protein, 5% fat, 5% crude fiber, 0.90% calcium, 0.60% phosphorus, and 3,100 kcal/kg of metabolizable energy (PT Charoen Pokphand Indonesia Tbk., 2013).

However, cultivating mealworms using commercial feed is expensive due to the high cost of the feed. Alternative feeds, such as tofu dreg, can be used to address this issue. Tofu dreg are a byproduct of the tofu manufacturing process, containing 28.36% crude protein, 5.52% fat, 7.06% crude fiber, and 45.44% nitrogen-free extract (Nuraini et al., 2024), with a metabolizable energy (ME) of 2972 kcal/kg (Diaz-Vargas et al., 2016). Mealworms have preferred tofu dreg as a feed medium, which can enhance their nutrient intake (Makkar et al., 2014).

According to Nuraini et al. (2024) the composition of different culture media, including a mixture of commercial feed and tofu dreg, affects the nutritional content of mealworms. The preferred medium for mealworm rearing is 100% tofu dreg, resulting in a mealworm weight of 85.28 g, a crude protein content of 49.69%, a crude fat content of 16.27%, and a crude fiber content of 13.98%, but still not studying the effect on chitin, nitrogen retention, crude fat digestibility of *Tenebrio molitor*. Similarly, Yu et al. (2024) have explored the utilization of various industrial food wastes as alternative feed sources for mealworms, such as okara, barley spent grain (BSG), sesame oil meal (SOM), and spent coffee grounds (SCG). The paper indicates that mealworms fed with okara exhibited moderate growth performance, achieving protein levels comparable to those in the oatmeal-fed control group. Variations in culture media composition will influence the chitin content, nitrogen retention, and crude fat digestibility of mealworms. A higher weight of mealworms indicates a higher chitin content, which requires further investigation into the chitin levels in mealworms. High crude protein content does not necessarily equate to high-quality protein, so the protein quality must be evaluated by measuring nitrogen retention. Likewise, high crude fat content does not guarantee high-fat digestibility, necessitating an assessment of fat digestibility in mealworms. Different culture media compositions, including mixtures of commercial feed and tofu dreg, affect feed consumption, weight gain, and mealworm conversion. No studies have examined the impact of substituting commercial feed with tofu dreg on mealworm growth. Based on the above description, it is necessary to study how different culture media compositions impact *Tenebrio molitor* nutritional value.

## MATERIALS AND METHODS

### Research Materials

The materials used in this study included the culture media consisting of Bravo-311 commercial feed (produced by PT. Charoen Pokphand) obtained from a poultry shop in Padang and tofu dreg sourced from a tofu factory

Table 1. Nutritional content of the mealworm culture media

| Treatment | Crude protein (%) | Crude fat (%) | Crude fiber (%) | ME (kcal/kg) |
|---|---|---|---|---|
| A (100% CF) | 23.30 | 7.57 | 3.40 | 3,100 |
| B (50% CF + 50% TD) | 24.50 | 5.50 | 5.00 | 2,965 |
| C (100% TD) | 26.11 | 3.50 | 6.60 | 2,830 |

Note: CF: Commercial feed; TD: Tofu dreg. Source: Nuraini et al. (2024).

in Padang. The mealworms were obtained from a mealworm farmer in Padang Pariaman.

The equipment used in this study included an analytical balance for weighing the mealworms, biopon containers (30x20x10 cm) for the mealworm culture media, sieves to separate the mealworms from the culture media, tools for counting mealworms (such as the Counter app on Android), and a metabolic cage (60x30x20 cm) for observing nitrogen retention and crude fat digestibility.

## Research Methodology

### Research Implementation

Tofu dreg was dried to a moisture content of 14%. The culture media compositions were prepared according to the treatments, with 500 g each. Mealworms were weighed to obtain their initial body weight, and 1,000 larvae (20 g) aged ten days were placed in biopon containers containing the culture media. Fresh papaya slices measuring 5x5x0.5 cm were placed nine points above the culture media. The dried papaya slices were replaced with fresh ones every two days. On the 15$^{th}$ day, the mealworms underwent molting, and the shed skins were separated from the media every three days by fanning and lifting. The mealworms were reared until they were 30 days old. Temperature was recorded daily, in the morning and evening, until the mealworms were harvested.

### Harvesting of Mealworms

Mealworms were harvested at 30 days old (20 days after being placed in the media). Harvesting was done by sieving through a 2-mesh sieve to separate the mealworms from the media. The mealworms were then weighed to obtain their fresh weight. After that, they were steamed for 10 minutes to kill the larvae and dried in an oven at 50°C (Nuraini et al., 2022). The dried mealworms were then weighed to obtain their dry weight and finely ground for chitin content analysis.

### Research Design

The study was conducted using a Completely randomized design (CRD) consisting of three treatments and six replications. The treatments were as follows:

T1 = 100% Commercial feed
T2 = 50% Commercial feed + 50% Tofu dreg
T3 = 100% Tofu dreg

### Measured Parameters

**Chitin Content (%)**

Chitin content (initial and final) was analyzed using No & Meyers (1989) method. The procedure involves demineralization, deproteinization, and extraction with acetone. The chitin testing procedure involved heating with 1 N HCl, with a ratio of mealworm powder to HCl of 1:15 (w/v). For 1 g of mealworm, 15 ml of HCl was used, and the mixture was stirred for 3-4 hours at 65°C to remove minerals. The mixture was filtered, and the residue was washed with water until neutral. Deproteinization was performed using 35% NaOH at a 1:10 (w/v) ratio for 4-5 hours at 65°C, followed by filtration and washing with water until neutral. The residue was extracted with acetone to remove pigments, rewashed with water until neutral, filtered, and dried in an oven at 65-75°C, then cooled and weighed. The change in chitin content of the mealworm powder was calculated using the formula using No & Meyers (1989) method:

$$\text{Chitin (\%)} = \frac{X - y}{X} \times 100\%$$

Description:
X: Chitin content of unprocessed mealworm powder
Y: Chitin content of processed mealworm powder

**Nitrogen Retention (%)**

Nitrogen retention was measured using the method of Sibbald & Wolynetz (1985). Feces were collected from 22 six-week-old broiler chickens weighing about 1,500 g. Eighteen chickens were used for the primary treatment and four for endogenous nitrogen measurement. The chickens were fasted for 24 hours and placed in metabolic cages equipped with drinking water and a plastic sheet to collect feces. After the 24-hour fasting period, the broilers were force-fed 15 g of mealworms. This procedure was conducted following standard ethical guidelines for animal research, ensuring minimal distress to the broilers. Feces were collected over 36 hours, sprayed with 0.3 N $H_2SO_4$, and then air-dried at room temperature for approximately 5 hours. After 5 hours, the feces were oven-dried at 60°C for 24 hours, then weighed. The excreta was ground and analyzed for nitrogen content. Nitrogen retention (%) was calculated using the formula using the Sibbald & Wolynetz (1985) method (Figure 1).

**Crude Fat Digestibility (%)**

The crude fat digestibility of mealworms was tested on broilers according to Sibbald & Wolynetz (1985), with modifications. The broiler chickens used for fat digestibility testing were the same as those used for nitrogen retention testing (without endogenous measurement). The excreta was ground and analyzed for crude fat content using the Soxhlet method (AOAC, 2016) (Figure 2).

**Feed Consumption (g/1,000 larvae)**

Feed consumption was calculated by subtracting the final feed amount from the initial feed amount using the following formula using Hartiningih & Fita Sari (2014) method:

Feed consumption (g/ 1,000 larvae) =

Initial feed amount (g) - Final feed amount (g)

**Weight Gain (g/1,000 larvae)**

Weight gain of mealworms was determined by weighing the initial and final weight of mealworms after harvesting using an analytical balance with the following formula using Hartiningih & Fita Sari (2014) method:

$$\text{Final weight}\left(\frac{\text{g}}{\text{1,000 larvae}}\right) - \text{Initial weight}\left(\frac{\text{g}}{\text{1,000 larvae}}\right)$$

**Feed Conversion Ratio**

The feed conversion ratio was calculated based on the amount of feed consumed divided by the weight gain using the following formula using Hartiningih & Fita Sari (2014) method:

$$\text{FCR} = \frac{\text{FC (g/1,000 larvae)}}{\text{WG (g/1,000 larvae)}}$$

Description:

FCR = Feed conversion ratio
WG = Weight gain (g/1,000 larvae)
FC = Feed consumption (g/1,000 larvae)

**Data Analysis**

All data were statistically analyzed using variance analysis and DMRT follow-up tests based on a Completely Randomized Design (CRD) according to the procedure by Steel & Torrie (1995).

$$\text{N Retention} = \frac{\text{N consumption (g/head)} - (\text{N excreta (g/head)} - \text{N endogenous (g/head)})}{\text{N consumption (g/head)}}\ x\ 100$$

Figure 1. N consumption: dry matter of the consumed feed ×\times× nitrogen (%) of the feed. N excreta: the amount of dry matter excreted ×\times× nitrogen (%) of the excreta. N endogenous: the amount of dry endogenous excreta ×\times× nitrogen (%) of the endogenous excreta.

$$\text{Crude fat digestibility} = \frac{(\text{FC} \times \text{CFF}) - (\text{AEE} \times \text{CFE})}{\text{FC} \times \text{CFF}} \times 100\%$$

Figure 2. FC = Feed consumption (g); AEE = Amount of excreta excreted (g); CFF = Crude fat in feed (%); CFE = Crude fat in excreta (%).

## RESULTS AND DISCUSSION

### Effect of Treatment on Chitin Content in Mealworms

The effect of different culture media compositions on the chitin content, nitrogen retention, and crude fat digestibility of mealworms is shown in Table 2.

Table 2 shows that the highest chitin in mealworms was found in treatment T3 (100% tofu dreg) at 9.61%, while the lowest was in treatment T1 (100% commercial feed) at 6.79%. Variance analysis results indicated that the media composition significantly affected (P<0.01) the chitin content of mealworms.

The lower chitin content in mealworms in treatments T1 and T2 (6.79% and 8.08%, respectively) was due to the lower fresh production in these treatments (72.15 g and 51.12 g, respectively). The low fresh production of mealworms was associated with the low crude protein content of the culture media in treatments T1 and T2 (22% and 24.5%, respectively). According to Hawana (2019), larvae's body weight depends on the media's nutritional content.

The high chitin content in mealworms in treatment T3 (9.61%) was influenced by the high fresh production of mealworms (81.10 g). This high fresh production was due to the high crude protein content of the culture media in treatment T3 (26%). Media with high crude protein content produces larger mealworms, thereby increasing their chitin content. This is due to the 100% tofu dreg media containing high protein (26%). Research by Kröncke & Benning (2023) shows that higher protein levels in the media also result in superior mealworm weight, consequently increasing chitin content.

Moreover, tofu dreg has high palatability due to their texture and flavor, which are preferred by mealworms, as evidenced by the high feed consumption in the tofu dreg media (721 g). This is supported by Makkar et al. (2014), who stated that tofu dreg is preferred, enhancing nutrient intake for mealworms.

The selected chitin content in mealworms for this study was found in treatment T3 (100% tofu dreg) at 9.61%. This chitin content is lower than that reported by Song et al. (2018), who found that the chitin content in mealworms can reach 18.01% using a commercial chicken feed.

### Effect of Mealworm Media Growth Treatment on Nitrogen Retention Quality

Table 2 shows that the highest nitrogen retention in mealworms was found in treatment T3 (100% tofu dreg) at 80.89%, while the lowest was in treatment T1 (100% commercial feed) at 72.27%. Variance analysis results indicated that the culture media composition significantly affected (P<0.01) nitrogen retention in mealworms.

The lower nitrogen retention in mealworms in treatments T1 and T2 (72.27% and 75.19%, respectively) was related to the low protein consumption in these treatments (6.05 g/head and 6.30 g/head, respectively). Low protein consumption results in lower amounts of crude protein used and retained in mealworm bodies. This is because the low crude protein content in mealworms was due to the low crude protein content of the culture media in treatments T1 and T2 (22% and 24.5%, respectively). This aligns with Kröncke & Benning (2022), who showed that mealworms are highly selective in their feed consumption, so the nutritional content of mealworms corresponds to the media consumed.

The high nitrogen retention in mealworms in treatment T3 (80.89%) was related to the high protein consumption in treatment T3 (7.21 g/head). High protein consumption was also due to the high crude protein content in mealworms in treatment T3 (47.90%). The high crude protein content of mealworms was due to the

Table 2. Chitin content, nitrogen retention, and crude fat digestibility of mealworms (*Tenebrio molitor*)

| Treatment | Chitin (%) | Nitrogen retention (%) | Crude fat digestibility (%)$^{ns}$ |
|---|---|---|---|
| A (100% CF) | 6.79$^{b}$ | 72.27$^{b}$ | 92.33 |
| B (50% CF + 50% TD) | 8.08$^{b}$ | 75.19$^{b}$ | 90.41 |
| C (100% TD) | 9.61$^{a}$ | 80.89$^{a}$ | 89.48 |
| SE | 0.48 | 1.20 | 0.76 |

Note: $^{abc}$Different superscripts in the same coloum indicate highly significant differences (P<0.01). ns: Not significantly different (P>0.05). SE: Standard error; CF: Commercial feed; TD: Tofu dreg.

high crude protein content of the culture media in treatment T3 (26%). This is consistent with Nuraini et al. (2022), who showed that the crude protein content of mealworms depends on the crude protein in the media; hence, if the media has high crude protein, protein consumption will also be high, and consequently, nitrogen retention in mealworms will also be high. High nitrogen retention indicates good crude protein quality in mealworms. This is supported by Marbun (2020), who stated that high nitrogen retention reflects high protein quality. High or low nitrogen levels in feces affect nitrogen retention; the less nitrogen excreted through feces, the more nitrogen remains in the livestock's body.

The chitin content in treatment T3 (9.61%) is still relatively low and does not affect nitrogen retention in treatment T3. As long as the chitin concentration in mealworm feed remains within safe limits, nitrogen retention will not be negatively impacted. Chitin only becomes problematic at very high concentrations, which can interfere with protein digestibility and reduce nitrogen absorption efficiency. Chitin tends to reduce the digestibility of nutrients such as protein and lipids in animal feed, both in monogastric animals, as studied by Marono et al. (2015), and in fish, as studied by Karlsen et al. (2017). This indicates that the presence of chitin in feed can be a factor that hinders organisms' absorption of essential nutrients.

The selected nitrogen retention in mealworms for this study was found in treatment T3 (100% tofu dreg) at 81.14%. This result is higher than that reported by Volek et al. (2021), who found that nitrogen retention in mealworms using media with crushed vegetables, potatoes, and fruits ranged between 73.33% and 80.67%.

### Effect of Mealworm Media Growth Treatment on Crude Fat Digestibility

Table 2 shows that the highest crude fat digestibility in mealworms was found in treatment T1 (100% commercial feed) at 92.33%, and the lowest was in treatment T3 (100% tofu dreg) at 89.48%. Variance analysis results indicated that the culture media composition did not significantly affect (P>0.05) the crude fat digestibility of mealworms.

The crude fat content influences crude fat digestibility in mealworms. In this study, the crude fat content in mealworms ranged from 20.10% to 28.02%. According to Moningkey et al. (2019), digestibility measurement is essentially an effort to determine the number of substances that can be absorbed by the digestive tract by measuring the amount of feed consumed and the amount of feed excreted through excreta. The level of fat digestibility can be affected by digestion efficiency and nutrient absorption from mealworms consumed by broilers.

Crude fat digestibility is also influenced by the crude fat content in the culture media, ranging from 16.27% to 28.66%. This indicates that the digestibility of crude fat in mealworms is affected by the nutrients in the culture media. The better the nutrients in the media, the better the digestibility of crude fat in mealworms. This opinion is supported by Polii et al. (2020), who stated that the digestibility value of feed depends on its nutrient content. High crude fat digestibility is associated with the easily digestible chemical structure of crude fat.

Crude fat digestibility is also influenced by the chitin content in mealworms. Broek & Boeriu (2019) stated that chitin has the ability to bind fat, which can be excreted with feces. This is supported by Nuraini et al. (2023), who showed that chitin content also affects fat reduction in quail egg yolk. Therefore, the higher the chitin content in mealworms, the lower the crude fat digestibility obtained.

The selected crude fat digestibility was found in treatment T3 (100% tofu dreg) at 89.48%. This study's result is higher than that of Mastoraki et al. (2022), which reported a crude fat digestibility of mealworms at 73.60%.

### Effect of Treatment on the Growth of Mealworms

The effect of different culture media compositions on feed consumption, weight gain, feed conversion ratio, and survival rate of mealworms is presented in Table 3.

Table 3 shows that the highest feed consumption of mealworms was in treatment T3 (100% tofu dreg) at 264.88 g, while the lowest feed consumption was in treatment T1 (100% commercial feed) at 261.76 g. Variance analysis results indicated that the type of culture medium significantly affected (P<0.01) the feed consumption of mealworms.

The low feed consumption of mealworms in treatment T1 (100% commercial feed) at

Table 3. Feed consumption, weight gain, feed conversion ratio, and survival rate of mealworms using commercial feed and tofu dreg media

| Treatment | Feed consumption (g/1,000 larvae) | Weight gain (g/1,000 larvae) | Feed conversion ratio |
|---|---|---|---|
| A (100% CF) | 261.76$^{c}$ | 64.99$^{c}$ | 4.03$^{a}$ |
| B (50% CF + 50% TD) | 263.27$^{b}$ | 68.78$^{b}$ | 3.83$^{b}$ |
| C (100% TD) | 264.88$^{a}$ | 72.12$^{a}$ | 3.68$^{c}$ |
| SE | 0.37 | 0.95 | 0.05 |

Note: $^{abc}$Different superscripts in the same coloum indicate highly significant differences (P<0.01). SE: Standard error; CF: Commercial feed; TD: Tofu dreg.

261.76 g was due to the low crude protein content in the media at 23.30%. This is because low crude protein content in the media affects feed consumption in mealworms.

The high feed consumption of mealworms in treatment T3 (100% tofu dreg) at 264.88 g was due to the high crude protein content in the media at 26.11%. Crude protein content affects the amount of feed consumed by mealworms, as they are selective in their feed consumption. This is consistent with Fitasari & Santoso (2015), who reported that mealworms are highly selective in their feed consumption, so their nutritional content corresponds to the media consumed.

Furthermore, feed consumption in mealworms is influenced by the nutrient content of the media used; the higher the nutrient content in the culture media, the higher the feed consumption rate. This is consistent with Purnamasari et al. (2019) who stated that the larval consumption rate is influenced by the availability of sufficient nutrients in the feed media. The metabolic energy factor also affects the feed consumption rate of mealworms. The lower the metabolic energy of the culture media, the higher the feed consumption, as mealworms require the necessary metabolic energy. According to Fitasari & Santoso (2015) livestock can utilize metabolic energy for various physical activities, maintaining body temperature, metabolism, and tissue formation. The fine texture of tofu dreg, because they are ground, and the smallmouth of mealworms contribute to higher feed consumption (264.88 g), while the relatively coarse particle size of commercial feed makes it difficult for mealworms to consume, resulting in lower feed consumption (261.76 g). As mealworms grow, they enter the pupal stage and require larger amounts of feed to meet their nutritional needs. This is consistent with Hapsari et al. (2018), who reported that mealworms aged 50-60 days are approaching the pupal stage, increasing their feed consumption to meet their nutritional needs.

The selected feed consumption in this study was treatment T3 at 264.88 g per 1,000 larvae or 26.49 g per 100 larvae, which is higher than the finding of Iding et al. (2020), where the feed consumption of mealworms using a mixture of commercial chicken feed in pellet form (75% concentration) with styrofoam (ad libitum) was 36 g per 100 larvae.

**Effect of Treatment on Weight Gain of Mealworms**

Table 3 shows that the highest weight gain in mealworms was in treatment T3 (100% tofu dreg) at 72.12 g, while the lowest weight gain was in treatment T1 (100% commercial feed) at 64.99 g. Variance analysis results indicated that the type of culture medium significantly affected (P<0.01) the weight gain of mealworms.

The low weight gain of mealworms in treatment T1 (100% commercial feed) at 64.99 g was due to the low crude protein content in the media at 23.11%. This is because the low crude protein content in treatment T1 affects the weight gain of mealworms, which is influenced by the crude protein content of the mealworm feed.

The high weight gain of mealworms in treatment T3 (100% tofu dreg) at 72.12 g was due to the high crude protein content in the media at 26.11%. Crude protein content affects the weight gain of mealworms produced; high protein content in the media can meet the protein needs of the larvae, resulting in high fresh weight gain, and consequently, increased weight gain. This shows that the higher the protein content in the mealworm culture medium, the higher the weight gain of the mealworms, as they are selective in their feed consumption. This is consistent with Fitasari

& Santoso (2015) who reported that mealworms are highly selective in their feed consumption, so their nutritional content corresponds to the media consumed.

Hartiningih & Sari (2014) state that a higher protein content produces superior mealworm weight. According to Iding et al. (2020) the feed quality influences the nutritional supply for larval development. According to Herlinda et al. (2005), high body weight in larvae is produced by feeding with high and suitable dietary content. As body weight increases, so does the weight gain of mealworms. The culture medium is digested by mealworms and absorbed through the intestines. The intestine is the leading site of digestion and nutrient absorption, supported by bacteria that aid digestion, particularly crude protein. This is consistent with Putra & Restyaningih (2022) who reported that mealworms have *Exiguobacterium sp.* Strain YT2 bacteria in their intestines that produce extracellular enzymes to catalyze the depolymerization of organic fragments. According to Sulistiani (2017) tofu dreg contains nutrients such as protein and carbohydrates that microorganisms can decompose. According to Nuraini et al. (2024) these proteins are broken down in the body into simpler monomers, and amino acids are released more abundantly as digestion proceeds efficiently, allowing for rapid body weight gain due to growth and tissue biosynthesis.

The selected weight gain in this study was treatment T3 at 72.12 g per 1,000 larvae or 7.21 g per 100 larvae. This result is higher than the finding of Iding et al. (2020), where the weight gain of mealworms using a mixture of commercial chicken feed in pellet form (75% concentration) with styrofoam (ad libitum) was 5.3 g per 100 larvae.

### Effect of Treatment on Feed Conversion Ratio of Mealworms

Table 3 shows that the highest feed conversion ratio in mealworms was in treatment T1 (100% commercial feed) at 4.03, while the lowest was in treatment T3 (100% tofu dreg) at 3.68. Variance analysis results indicated that the type of culture medium significantly affected ($P<0.01$) the feed conversion ratio of mealworms. The high feed conversion ratio in mealworms in treatment T1 (100% commercial feed) at 4.03 was due to the low feed consumption and weight gain in treatment T1, resulting in a high feed conversion ratio. The low feed conversion ratio in mealworms in treatment T3 (100% tofu dreg) at 3.68 was due to the high weight gain produced in treatment T3 at 72.12 g, although the feed consumption was also high at 264.88 g. A low feed conversion ratio is considered good. The selected feed conversion ratio in this study was treatment T3 at 3.68. This result is higher than that of Fitasari & Santoso (2015), where the selected feed conversion ratio for mealworms was 3.32 using a mixture of polar, corn bran, dried gamblong, dried tofu dreg, and palm oil. According to Eberle (2022) the conversion of *Tenebrio molitor* feed is influenced by a variety of factors, including environmental conditions, nutritional inputs, and biological characteristics. The optimal temperature for *Tenebrio molitor* rearing ranges between 25°C and 30°C, and RH levels between 60% and 75%. According to Rho & Lee, n.d. (2023) diets high in carbohydrates and moderate in protein content are generally optimal for growth, with a protein: carbohydrate (P: C) ratio of 1:1 to 1:2 being recommended. Kröncke & Benning (2022), mealworms require a diet rich in carbohydrates and proteins for osptimal growth. Studies have shown that diets containing 67.3–71.5% carbohydrates, 19.9–22.8% proteins, and 8.6–10.0% lipids are ideal for maximizing biomass growth and feed conversion.

## CONCLUSIONS

This study concludes that a 100% tofu dreg medium can replace a 100% commercial feed medium and is the selected medium for mealworm (*Tenebrio molitor*) cultivation. The results showed a chitin content of 9.61%, nitrogen retention of 80.89% (dry matter), crude fat digestibility of 89.48% (dry matter), feed consumption of 264.88 g per 1,000 larvae, weight gain of 72.12 g per 1,000 larvae, and feed conversion ratio of 3.68.

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