Research Article

The Effect of *Tenebrio molitor* Caterpillar in the Diet on Production Performance of Laying Quail

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Abstract | The *Tenebrio molitor* caterpillar (Tmc) is an alternative source of animal protein. This research aims to study the effect of the *Tenebrio molitor* caterpillar in concentrate and tofu dregs growth media on nutrient content and determine the Tmc effect in the diet on the production of laying quail. The study was divided into two stages of research. Phase 1 of the laboratory experiment determined the composition of the concentrate and tofu dregs media on the nutrient content of *Tenebrio molitor*. This study method was a completely randomized design (CRD) with six treatments and three replications. The treatment variations consist of commercial ration (CR) and tofu dregs (TD) were treatment P1 (100% CR), P2 (80% CR + 20% TD), P3 (60% CR+ 40% TD), P4 (40% CR + 20% TD), P5 (20% CR + 80% TD) and P6 (100% TD). The observed variables were fresh weight, crude protein, and crude fat of Tmc. The Phase 2 application to laying quails is the utilization of *Tenebrio molitor* caterpillars in the diet. This stage used a Completely Randomized Design (CRD) with five treatments and four replications. Provision of *Tenebrio molitor* caterpillars consisted of 0%, 3%, 6%, 9%, and 12% in the diet of laying quail. The parameters measured were feed consumption, daily egg production, egg weight, egg mass, and feed conversion. Phase 1 showed that the difference in growth media composition had a significant effect ($P<0.01$) on fresh weight, crude protein, and crude fat. The Phase 2 variance analysis results showed that the use of Tmc in the diet had no significant effect ($P> 0.05$) on feed consumption, egg production, egg weight, egg mass, and feed conversion. The study concluded at stage 1 that 100% tofu dregs medium was the best treatment to improve the nutrient content of the *Tenebrio molitor* caterpillar. Stage 2 concluded that the *Tenebrio molitor* caterpillar could be used up to 12% in laying quail rations (substituted 100% fish meal) and maintain the same egg production as control.

Keywords | Commercial ration, Tofu dregs, *Tenebrio molitor*, Nutritional content, Quail egg production

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INTRODUCTION

Feed is the main requirement in all fields of the livestock business, including in the case of poultry. Feeding is intended for livestock to meet their daily needs and grow and produce. Feed must contain all the nutrients needed by the animal's body but still in a balanced amount. Some of the nutrients needed by livestock include carbohydrates, fats, proteins, vitamins, water, and minerals. The supply of conventional feed ingredients still depends on imported feed, such as fish meal, so the feed price is high. Indonesia itself has abundant fishery resources. However, another problem related to local Indonesian fish meals is the quality that does not meet the requirements of fish meals for animal feed ingredients.

Efforts to find alternative feed ingredients for protein sources include the *Tenebrio molitor* caterpillar (Tmc). The cultivation of the Tmc is one of the communities with the most potential businesses to develop. Tmc cultivation is easy to do, requires little cost, and has promising business opportunities because the demand for Tmc is increasing. *Tenebrio molitor* caterpillars are used to feed birds, fish, and poultry. Therefore, the Tmc farming business needs to improve quantity and quality.

Purnamasari (2018) found that the nutritional content of *Tenebrio molitor* caterpillars included 37.80% crude protein, 28.63% crude fat, 13.36% ash content, 7.28% crude fiber, and 84.31% dry matter, the same content of complete and high amino acids (arginine 12.95%, alanine 25.68%, proline 16.94%, lysine 10.65% and taurine 17.53%), fatty acids (linoleic 0.70% and linolenic 2. 24%) and minerals (calcium 55.65%, sodium 13.71%, potassium 10.00%, and magnesium 3.50%).

The Tenebrio molitor caterpillar's protein content depends on the growth medium's nutritional content. Cultural media commonly use concentration (Fitasari and Santoso, 2015). Breeders still use concentrate for Tenebrio molitor caterpillar fattening media, but it is recommended to reduce costs. The concentrate is combined with cheaper agricultural waste. Therefore, a combination of concentrate and agricultural waste was used in this study.

The chicken concentrate is a semifinished feed containing animal and vegetable protein low in carbohydrates and fiber. According to Pratiwi (2016), the nutritional content of chicken concentrate is 35% crude protein, 8.3% crude fat, 3% crude fiber, 10% calcium, and 1.1% phosphorus, metabolizable energy (ME) 3300 kcal/kg. Tofu dregs can also be used as a medium for Tmc to grow. Tofu dregs are waste from the tofu processing industry that can be used as animal feed. The nutritional content of tofu waste is 25.91% protein, 3.71% fat, and 5.97% ash (Nuraini et al., 2017).

The results of research on media for the growth of Tmc have been carried out by Rolita et al. (2017), who reported that the different types of feed given showed differences in the growth yield and fresh weight of *Tenebrio molitor* caterpillars. The use of these media types can improve the protein quality of the media to increase the production of Tmc; as a result, it will affect the crude protein, fat and fresh weight of *Tenebrio molitor*.

Tmc, as an animal protein source, can reduce the use of fish meals in quail's diet. Quail farming has advantages, namely, faster production at the age of six weeks. The quails have started laying eggs, do not require significant capital, are relatively easy to maintain, and can be cultivated on limited land. According to Livestock and Animal Health Statistics (2020), Indonesia's quail population and quail egg production have increased. The quail population increased from 14.06 million to 14.82 million, and the production of quail eggs increased from 23.575 tons to 24.205 tons, proving that quail is a poultry commodity with potential and is in great demand among the public.

MATERIALS AND METHODS

Stage 1 determination of the best growth medium composition on nutrient content of *Tenebrio molitor* caterpillars

The material used in this study was a growth medium consisting of commercial ration (CR) and tofu dregs (TD). The commercial ration used was Bravo 311 produced by PT Charoen Pokphan. Tofu dregs are dried and finely ground.

Experimental design

A completely randomized design (CRD) with 6 treatments and 3 replications used in this study. The treatment given are:

P1 = 100% CR; P2 = 80% CR + 20% TD; P3 = 60% CR + 40% TD; P4 = 40% CR + 60% TD; P5 = 20% CR + 80% TD; P6 = 100% TD

Care and cultivation of *Tenebrio molitor* caterpillars

One thousand *Tenebrio molitor* caterpillars that were ten days old were put into a Biopon (plastic container) containing 500 grams of media (according to treatment), and as drinking water, fresh young papaya was added at a size of 5 cm x3 cm x 0.5 cm and placed at 9 points above the culture medium. The phone was covered with streaming cloth, and the edges were tied. Fresh young papaya was taken and replaced with a new papaya every two days. On the 15th day, the Tmc changed its skin, and the skin was separated from the media. The Tmc was kept until the age of 30 days. Harvesting of Tmc was carried out on the 30th day after they were introduced into the media. Tmc was harvested by sieving to separate the Tmc from the media and then weighed to obtain fresh weight. Then, the Tmc was boiled to kill the larvae and dried in the sun until dry. The dried *Tenebrio molitor* caterpillars were weighed to obtain their dry weight.

Variables

The parameters measured were fresh weight (g), crude protein (%), and crude fat (%).

Data analysis

The data were analyzed by one-way analysis of variance (ANOVA) in a completely randomized design (CRD).

Duncan's multiple range test determined the differences between treatments; p <0.05 considered significantly different.

RESULTS AND DISCUSSION

Stage 1: Determination of the best medium composition on the nutrient content of *Tenebrio molitor* caterpillars

The growth medium composition affected (p<0.05) the fresh weight, crude protein, and crude fat of *Tenebrio molitor* caterpillars, as shown in Table 3.

The effect of the medium composition on the fresh weight of *Tenebrio molitor* caterpillars

The highest fresh weight of *Tenebrio molitor* caterpillars was found in treatment P6 (100% tofu dregs medium), which was 80.28 g, and the lowest fresh weight of Tmc was found in treatment P3 (media 60% commercial ration + 40% tofu dregs), which was 60.41 g. The ANOVA showed that the growth media composition had a very significant effect (p<0.01) on the fresh weight of Tmc.

The effect of the medium composition on the crude protein content of *Tenebrio molitor* caterpillars

The growth medium composition affected (p<0.05) the crude protein content of Tmc. The highest crude protein content of Tmc in 100% tofu dregs medium was 49.69%, and the lowest crude protein content was 36.14% in 60% commercial ration + 40% tofu dregs medium.

The effect of the medium composition on the fat content of *Tenebrio molitor* caterpillars

The growth medium composition affected (p<0.05) the fat content of Tmc. The high-fat content found in the 100% commercial ration medium was 28.66%, and the low crude fat content was 16.27% in the 100% tofu dregs medium.

Stage 2: Utilization of *Tenebrio molitor* caterpillars in laying quail diet

Birds

The birds used in this research were 200 quails (*Coturnix-coturnix japonica*) in the seven weeks laying phase (40% production) until 15 weeks.

Experimental design

This research was evaluated using an experimental method designed with a completely randomized design (CRD) method with five treatments and four replications. Each group consists of 10 quails as a unit of the experiment. The provision of Tmc in the quail diet consists of 0%, 3%, 6%, 9%, and 12% *Tenebrio molitor* caterpillars. The feed ingredients, the content of food substances, and the metabolic energy of the ration ingredients (as feed) are shown in Table 1. The composition of rations, food content, and energy of research rations can be seen in Table 2. The ration was prepared with isoprotein (20%) and isoenergy (2800 kcal/kg) according to Djulardi (1995).

Variables

The parameters observed were feed consumption (g/bird/day), quail-day egg production (%), egg weight (g/bird), egg mass (g/bird/day), and feed conversion.

Data analysis

The data obtained were processed statistically by analysis of diversity according to Steel and Torrie (1995). Differences between treatments were tested with Duncan's multiple range test (DMRT).

Stage 2: Utilization of *Tenebrio molitor* caterpillars in laying quail diet

The effects of the utilization of *Tenebrio molitor* caterpillars in the diet on the production performance of laying quails are provided in Table 5. The selective result medium for cultivation *Tenebrio molitor* caterpillars in stage 1 was used in stage 2 (100% tofu dregs medium).

Table 1: Feed ingredients, nutrient contents (%), and metabolic energy levels (kcal/kg) of feed ingredients that make up the rations (as feed)[a].

Feed ingredients	Crude protein (%)	Fat (%)	Crude fiber (%)	Ca (%)	P available (%)	ME. (Kcal)[b]
Ground corn	9.58	2.66	2.50	0.38	0.19	3300
Soybean meal	43.76	2.49	3.00	0.63	0.36	2240
Fish flour	64.00	2.85	2.45	3.10	1.89	2540
T. molitor Caterpillars	45.00	13.84	6.10	0.17	0.80	3351[a]
Rice bran	12.34	5.09	14.50	0.69	0.26	1630
Coconut oil	-	100.00[b]	-	-	-	8600
Mineral B12	-	-		49.00[c]	14.00[b]	-
Top mix	-	-	-	0.06[c]	-	-

a: Nuraini *et al*. (2021b); b: Scott *et al*. (1982); c: Product Packaging Labels of PT. Medion

Table 2: Nutrient and metabolic energy of diet formulation (%), food content (%), and metabolic energy (kcal/kg) of quail ration[a].

	Formation (%)				
Feed ingredients	**A**	**B**	**C**	**D**	**E**
Yellow corn	52.50	52. 50	52. 50	52. 50	52. 50
Soybean meal	13.25	14.50	16.25	18.00	19.75
Rice bran	13.75	12.75	11.00	9.75	8.50
Fish meal	12.00	9.00	6.00	3.00	0.00
T. molitor caterpillars	0.00	3.00	6.00	9.00	12.00
Coconut oil	3.00	2.75	2.25	1.75	1.25
Mineral B12	5.00	5.00	5.50	5.50	5.50
Top mix	0.50	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00	100.00
Crude protein	20.20	20.06	20.04	20.08	20.12
Crude fat	5.77	5.86	5.68	5.52	5.37
Crude fiber	3.93	3.94	3.86	3.85	3.84
Ca	3.20	3.11	3.27	3.19	3.10
Available P	1.11	1.08	1.12	1.09	1.06
ME	2816.23	2831.11	2823.48	2823.99	2824.51
Metionin	0.43	0.41	0.40	0.39	0.38
Lisin	0.90	0.95	1.00	1.04	1.10

Table 3: The nutrient content of *Tenebrio molitor* caterpillars.

Treatment	Fresh weight (g)	Crude protein (%)	Crude fat (%)
P 1 (100% CR)	69.46[ab]	44.98[a]	28.66[a]
P 2 (80%CR + 20% TD)	54.83[b]	35.44[b]	27.38[a]
P 3 (60% CR + 40% TD)	50.41[b]	36.14[b]	26.18[a]
P 4 (40% CR + 60% TD)	51.84[b]	38.38[b]	23.92[a]
P 5 (20% CR + 80% TD)	76.91[a]	46.11[a]	20.27[b]
P 6 (100% TD)	85.28[a]	49.69[a]	16.27[b]
SE	8.32	5.05	1.08

*: very significantly different effect (P<0.01); C: Concentrate; TD, Tofu Dregs.

The effect of Tmc in the diet on feed consumption of laying quails

Increasing the levels of Tmc present in the diet did not affect (p>0.05) the feed consumption of laying quail. The utilization of Tmc until 12% was similar to feed consumption in control. Feed consumption in the control treatment was 21.25 g/head/day, and feed consumption was similar in the 12% Tmc treatment group at 21.45 g/head/day.

The effect of Tmc in the diet on quail-day egg production of laying quails

The levels of Tmc in the diet did not affect (p>0.05) the quail-day egg production of laying quails. Increasing Tmc levels to 12% was similar to 0% Tmc. The quail-day egg production in the control group was 61.05%, and the quail-day egg production in the 12% Tmc treatment group was 61.32%.

The effect of Tmc in the diet on egg mass production of laying quails

The levels of Tmc in the diet did not affect (p>0.05) the egg mass production of laying quail. Increasing Tmc levels to 12% in the diet was similar to the effect of the 0% Tmc/control group on egg mass production. The egg mass production in the control group was 6.65 g/head/day and was still similar to that in the 12% Tmc treatment group (6.63 g/head/day).

The effect of Tmc in the diet on feed conversion of laying quails

The feed conversion of laying quail did not affected (p>0.05) by the levels of Tmc in the diet. Increasing Tmc levels to 12% was similar to feed conversion to the control

group. The feed conversion in control was 3.20, similar to the 12% Tmc treatment group (3.23) and the 12% Tmc treatment group.

Table 4: Amino acid contents of *Tenebrio molitor* larvae.

S. No	Amino acid profile	%
1	Aspartic acid	3.70
2	Threonine	1.54
3	Serine	2.06
4	Glutamate	3.86
5	Glysine	2.30
6	Valine	2.33
7	Methionine	0.32
8	Ileucine	1.69
9	Leucine	3.49
10	Tyrosine	2.94
11	Phenylalanine	2.01
12	Histidine	1.09
13	Lysine	4.75
14	Arginine	2.01

Source: Nuraini *et al*. (2021).

Stage 1: Determination of the best growth medium composition on the nutrient content of *Tenebrio molitor*

The effect of the medium composition on the fresh weight of *Tenebrio molitor* caterpillars

The high fresh weight *Tenebrio molitor* caterpillars in treatment P6 (100% tofu dregs medium) were not significantly different from the fresh weight of Tmc in treatment P5 (20% commercial ration + 80% tofu dregs). The high fresh weight caused by the crude protein content of the medium was also high in the P6 treatment, which was 26.81%, and almost the same as the crude protein P5 treatment (25.4%). The high protein content of the media can meet the protein needs of the caterpillar larvae so that high fresh production of caterpillars is produced. Hartiningsih and Fitasari (2014) showed that a higher protein content also produces a higher fresh weight of *Tenebrio molitor* caterpillars because they are very selective in consuming feed, so the nutritional content of Tmc follows the media they consume.

The fresh weight was also high in treatment P1 because it used a 100% commercial ration medium (consisting of fish meal and soybean meal with essential amino acids such as lysine and methionine, rice bran, vitamins, mineral, etc.) that are needed for larvae growth so that the fresh weight also high.

The fresh weight content of Tmc in the P6 treatment (100% medium tofu dregs) was 42.64 g, in line with Hartiningsih and Fitasari (2014) research that the higher the protein content is, the higher the fresh weight of *Tenebrio molitor*.

Effect of treatment on the crude protein content of *Tenebrio molitor* caterpillars

The high crude protein content of Tmc in the P6 and P5 treatment media caused by the crude protein content of media was also high in the P6 treatment (26.81%) and similar to the crude protein content in the P5 treatments (26.25%). The high protein content of the media requires the larvae to produce high crude protein for Tmc. The higher the protein content in rearing media, the higher the crude protein of *Tenebrio molitor* caterpillars (Fitasari and Santoso, 2015; Hapsari et al., 2018). *Tenebrio molitor* caterpillars are very selective in consuming feed so that the protein content of the *Tenebrio molitor* caterpillar follows the media they consume.

The crude protein content of Tmc is also high in P1 (100% commercial ration) treatment because of the amino acids, vitamins, and minerals of commercial ration. Commercial ration 311 Charoen Pokphan production contains fish meal, soybean meal, rice bran, vitamins, and minerals. The nutrition of commercial ration is essential for the growth of *Tenebrio molitor* caterpillars. According to Purnamasari (2018) reported that *Tenebrio molitor* caterpillars had 48% crude protein.

Table 5: Feed Consumption, quail-day egg production, egg weight, egg mass, and feed conversion of laying quail (7-15 Weeks ^{ns}).

Parameter	Treatment				
	A	B	C	D	E
Feed consumption (g/bird/day)	21.25±0.04	21.15±0.05	21.36±0.02	21.52±0.02	21.45±0.02
Quail-day egg production (%)	61.05±0.14	61.02±0.04	61.19±0.10	61.22±0.08	61.32±0.07
Egg weight (g/egg)	10.89±0.01	10.82±0.02	10.84±0.04	10.81±0.09	10.82±0.05
Egg mass (g/bird/day)	6.65±0.02	6.60±0.03	6.63±0.01	6.62±0.04	6.63±0.05
Feed conversion	3.20±0.04	3.20±0.01	3.22±0.02	3.25±0.07	3.23±0.06
Income over feed cost (Rp/kg)	5.494	5.082	5.429	6.097	6.198

Ns: non-significant (P>0.05).

This study's crude protein content of Tmc was 49.69% in the 100% tofu dreg media group. This result is higher than that of Purnamasari (2018), which found that the crude protein content of *Tenebrio molitor* was 48% with 100% concentrate media. The results of this study are also lower than the results obtained by Oonincx et al. (2015), who found that *Tenebrio molitor* caterpillars reared for 32 days using 60% grain + 20% brewer's yeast + 20 carrot slices produced *Tenebrio molitor* caterpillars with a crude protein content of 53.6%. The protein content of *Tmc* was lower than the protein content reported by Zhao et al. (2016); the crude protein content of the caterpillars was 51.5% using wheat, wheat bran, and carrot media. The *Tenebrio molitor* caterpillar rearing media affects the nutritional content of *Tenebrio molitor*. Fitasari and Santoso (2015) and Hapsari et al. (2018), *Tenebrio molitor* caterpillars are very selective in consuming feed, so the quality is on the media they consume. This study's results are lower than those of Nuraini et al. (2021a), who found that the crude protein of Tmc is 71.13% using 50% concentrate + 50% tofu dreg media fermented using Natura Organic Decomposer microorganisms.

Effect of treatment on the fat content of the *Tenebrio molitor* caterpillar

The high fat content of Tmc in treatment P1 (100% concentrate medium) was not significantly different from the fat content in crude fat Tmc in P2 (80% concentrate + 20% tofu dregs medium), treatment P3 (60% concentrate + 40% tofu dregs medium), and treatment P4 (40% concentrate + 60% tofu dregs medium). This difference was caused by the fat content of the media being high in treatments P1, P2, P3, and P4, which were 8.13%, 7%, 6.08%, and 5.02%, respectively (Table 6). The medium's crude fat content affects the crude fat content of the resulting *Tenebrio molitor* caterpillars. The higher the fat content of the media, the higher the fat content of the larvae (Aldi et al., 2018).

Table 6: The nutrient content of medium for rearing *Tenebrio molitor* caterpillars[a].

Treatment	Crude protein (%)	Crude fat (%)
P 1 (100% CR)	24.01	8.13
P 2 (80% CR + 20% TD)	24.57	7.00
P 3 (60% CR + 40% TD)	25.07	6.08
P 4 (40% CR + 60% TD)	25.65	5.02
P 5 (20% CR + 80% TD)	26.25	4.07
P 6 (100% TD)	26.81	3.07

[a]: Nuraini *et al* (2021b); CR: Commercial Ration; TD: Tofu Dregs.

The lowest fat content in the Tmc was in treatment P6 (100% tofu dregs), which was 16.27%. The low crude fat in the P6 treatment was due to the low crude fat in the medium, namely, 3.07%. According to Nuraini et al. (2017), the fat content of tofu pulp is 2.71%.

The fat content of Tmc in this study was 16.27% in the P6 treatment (100% tofu dregs medium). This result is lower than the result obtained by Ravzanaadii et al. (2012), where the crude fat content of Tmc with wheat bran media is 32.70%, and lower than the research of Purnamasari (2018), where the crude fat content of *Tenebrio molitor* caterpillars is 28.63% with concentrate media.

Stage 2: Utilization of *Tenebrio molitor* caterpillars in laying quail diet

The effect of Tmc in the diet on feed consumption of laying quails

The feed consumption using *Tenebrio molitor* caterpillar flour in the quail diet ranged from 20.10 to 20.40 g/head/day. The palatability of the feed affects consumption. A ration with high palatability will lead to higher ration consumption and vice versa (Adha et al., 2016). In addition to palatability, according to Wahju (2004), ration consumption is also influenced by the ration's shape, smell, and color. Treatment E (using 12% *Tenebrio molitor* caterpillar meal/reducing 100% fish meal) still showed almost the same shape, smell, and color as treatment A (use 0% caterpillar meal/use 100% fish meal). Reducing the use of fish meal with *Tenebrio molitor* caterpillars up to 12% by 100% does not interfere with the consumption of quail rations. Treatments A to E has the same palatability. Feed consumption that was not significantly different between treatment A and treatments B, C, D, and E showed the utilization of Tmc palatable (preferred) by quail, despite a reduction in the utilization of fish meal by 100%. Treatments B, C, D, and E contain Tmc but still have the same palatability as treatment A, which does not contain Tmc but contains more fish meal. The similar palatability between treatment A and treatments B, C, D, and E showed that the quality of the diet in treatments B, C, and D did not differ from the quality of treatment A. The feed consumption did not differ between treatments because also the rations were composed of iso-protein and iso-energy (Table 2), caused the amount protein and energy that consumption of quail also the same.

The consumption of quail rations (aged 7-15 weeks) using 12% *Tenebrio molitor* caterpillars was 21.45 g/head/day. This result is also lower than the study conducted by Mawaddah et al. (2018) where the ration consumption is between 22.66-23.32 g/head/day using larvae flour in the ration of laying quail aged 8-13 weeks. This result is higher than the study conducted by Zahra et al. (2012), who obtained feed consumption ranging from 18.06-20.18 g/head/day for 9-12 weeks of quail consumption. This feed consumption was higher than the feed consumption observed by Nuraini et al. (2017), who showed that the

feed consumption of quails (age 7-11 weeks) ranged from 21.20-22.03 g/bird/day.

Egg production using Tmc in treatments B, C, D, and E was not significantly different between treatment A (0% Tmc and 100% fish meal) due to feeding consumption, which was also the same in treatments B, C, D, and E. The use of Tmc up to 12% (100% fish meal reduction) can cover the nutritional content of fish meal because Tmc contains high levels of amino acids such as lysine (4.75%) and methionine 0.43% (Nuraini et al., 2021b). The critical amino acid content in poultry, namely, lysine in Tmc flour, is 4.75% (Table 4) (Nuraini et al., 2021), higher than the amino acid lysine content in fish meal, which is 2.71 (Sitompul, 2004), so it can provide the same egg production. According to Mousavi et al. (2013), an adequate and balanced amino acid content in the ration will provide optimal productivity.

The daily egg production of laying quail aged 7-15 weeks consuming 12% *Tenebrio molitor* caterpillars was 61.32%. This result is lower than the research conducted by Amran et al. (2021), showing that the daily egg production of laying quail aged 28-32 weeks with the provision of BSF larvae flour in quail rations ranged from 71.13-71.96%. This study's results were higher than those of research conducted by Ardi (2017), who found that the production of quail eggs aged 7-11 weeks resulted in egg production of 49.17%. This research result was lower than that of Nuraini et al. (2017), who reported hen-day egg production in laying quails for the 7-12 week layer period of 70.45%.

Tmc was not significantly different for egg weight because each treatment had almost the same protein and feed energy content. The nutritional content influences egg weight in the feed ration (Sodak, 2011), especially the amino acid methionine (Yuwanta, 2010). Amrullah (2003) found that protein consumption influences egg weight, especially amino acid methionine consumption. Protein consumption in treatment A was the same as protein consumption in treatment B, 4.13%, 4.06%, and 4.09%, and the amino acid methionine in treatment A was the same as treatment B, treatment C, treatment D, and treatment E. Tmc used up to 12% in the laying quail ration, reducing the use of fish meal by 100% while still giving the same egg weight. Tmc flour has an amino acid content of methionine of 0.99%, which is high enough to cover the deficiency of the amino acid methionine, which is minimally given according to (SNI, 2006) as 0.40. The weight of quail eggs is primarily influenced by protein consumption, age, livestock, temperature, and environment (Zulfan et al., 2020). The weight of quail eggs is influenced by the quantity of ration consumed and the quality of the ration, especially the protein content contained in the ration (Mozin, 2006). Protein deficiency will cause a decrease in egg weight and the amount of egg albumen produced. Kulsum et al. (2017) added that protein in feed affects albumin and egg yolk protein synthesis. These two components are the largest in determining egg weight.

The weight of quail eggs for quails aged 7-15 weeks consumed 12% Tmc flour was 10.82 g/head/day. This result is higher than the study results conducted by Amran et al. (2021), where the weight of quail eggs ranged from 10.36-10.38 g/head/day at the age of 28-32 weeks fed with BSF larvae flour. This result is higher than the study results conducted by Ningsih (2020). The egg weight is 10.10 g/head/day at 7-13 weeks.

The egg mass from Tmc in the ratio of laying quail ranges from 6.60-6.65 g/head/day. The egg mass was not significantly different due to egg weight and production, which were also not significantly different. Sestilawarti et al. (2013) stated that the percentage of egg production and egg weight affect egg mass. The egg mass is closely related to egg weight and production and is strongly influenced by the protein content and quality of the ration (Mawaddah et al., 2018). According to Mousavi et al. (2013), optimal productivity is obtained from sufficient and balanced protein and amino acid content in the ration. Egg mass describes egg production in weight units. The egg mass in treatment E with Tmc was up to 12% (100% fish meal reduction), which was the same as the egg mass in treatment A with the use of 0% Tmc (100% fish meal). Tmc had a good effect on egg production despite reducing 100% fish meal use. The egg mass of laying quail aged 7-15 weeks consumed 12% *Tenebrio molitor* caterpillar flour was 6.63 g/head/day. This result is higher than the results of a study by Maknun et al. (2015) on the effect of treatment on ration conversion.

In terms of feed conversion, the feed conversion that was not significantly different between treatment A and treatments B, C, D, and E was due to the same feed consumption and egg mass in treatments A, B, C, D, and E. Setiawan (2006), the feed conversion ratio is used to measure the efficiency of the use of the feed-in producing eggs. Feed conversion can indicate the production coefficient; a smaller value indicates a more efficient use of feed to produce eggs. Feed conversion is influenced by feed consumption and egg mass, so if there is an increase between them, the feed conversion values will remain balanced.

The feed conversion from Tmc meal in the quail diet ranged from 3.20 to 3.25. The ration conversion was not significantly different in each treatment because the protein and energy content in the rations of each treatment were almost the same. Using a Tmc flour level of 12% (reduction in the use of 100% fish meal) in quail rations is also as efficient for egg production as using a Tmc flour

level of 12% in quail rations. Control rations used a lot of fish meal. The feed consumption of the resulting products can be determined by calculating the feed conversion. The low conversion rate in quail indicates that livestock is more efficient in utilizing the feed they consume to live and produce (Amran et al., 2021b). Ansyari et al. (2012) found that the lower the feed conversion was, the better the feed quality. Balanced or not, the nutrients in the ration required by quail determine the high or low quality of feed. Feeds that lack nutritional elements will cause quail to eat more to meet their body's needs. Amran et al. (2021) stated that the palatability of the ration also influenced the ration conversion. Increased palatability of rations can be caused by taste, color, and aroma. The high palatability results in high ration consumption and maximum productivity, resulting in low conversion. Campbell et al. (2009) added that in addition to the nutritional content of the ration, egg production, and egg weight, the palatability of the ration could also affect the conversion of the ration. Reducing fish meal by 12% caterpillar meal can be carried out without negatively impacting quail egg production while maintaining the ration conversion.

The conversion of quail rations in quail aged 7-15 weeks by consuming Tmc flour up to 12% is 3.25. The results of this study are lower than the results of the research conducted by Ansyari et al. (2012) that the ration conversion obtained from the substitution of fish meal and 25.88% BSF larvae meal in the ration of laying quail aged 1-6 weeks resulted in feed conversion of 4.51. Added by Mawaddah et al. (2018), the conversion of the ration of laying quail aged 8-13 weeks to the substitution of MBM with 6.18% larval flour resulted in a feed conversion of 4.27. This result is higher than the result from the research conducted by Marsudi and Cahyo (2012), showing that the conversion of quail rations between 7-60 weeks of quail age ranged from 2.99 to 3.03.

CONCLUSIONS AND RECOMMENDATIONS

The study concluded that the 100% tofu dregs medium is the best treatment to improve the nutrient content of the *Tenebrio molitor* caterpillar. The *Tenebrio molitor* caterpillar can be used up to 12% in the feed (substituted 100% fish meal) and maintain the production of laying quail rations.

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NOVELTY STATEMENT

Previous research has never been done on improving *Tenebrio molitor* caterpillar nutrient and its application in laying quail feed. This study found a suitable alternative feed for substitution fish meal and ration formulation for quail with 12% Tmc in the diet (substituted 100% fish meal) of laying quail.

AUTHOR'S CONTRIBUTION

Nuraini contributed to creating the research ideas, designing experiments, analyzing the data, and writing this article. Ade Djulardi and Robi Amizar contributed to using Tmc to quail and check the written paper. Yuliaty Shafan Nur and Yessi Chwenta Sari contributed to analyzing data and assisted in revising the article.

Ethics

The committee has approved this research of Research Ethics of the Faculty of Animal Science of Universities Andalas Padang, Indonesia, and therefore, no ethical issues may arise after its publication.

Conflict of interest

The authors have declared no conflict of interest.

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