Research Article

Black Soldier Larvae Versus Fish Meal Concerning the Growth of Muscovy Ducks

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Abstract | Black soldier flies are used to make animal feed with quite high nutritional content and enough nutrients to make animal feed. We aimed to explore the appropriate level of supplementation of black soldier fly larvae in the diet of Muscovy ducks at 7-12 weeks old. A total of 200 Muscovy ducks were randomly assigned to five dietary treatments. The treatments named as following: CTL - control diet with fishmeal; LP20, LP40, LP60 and LP80 as replacing 20%, 40%, 60% and 80% of fishmeal protein with larval protein (LP) in the control diet with four replications, each replication with 10 ducks (5 males and 5 females). The results showed that the weight gain of the LP20, LP40, and LP60 treatments was as high as the CTL treatment. The FCR of ducks at CTL treatment (3.40) and LP20 treatment (3.44) was significantly ($P<0.05$) lower than LP60 treatment (3.52) and LP80 treatment (3.59). It is possible to replace 60% of the fish meal protein with the black soldier fly larvae protein, providing the highest profit without affecting the growth of broiler Muscovy ducks during the 7 to 12 weeks period.

Keywords | Black soldier fly larvae protein, Fish meal, Growth, Muscovy duck

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INTRODUCTION

Muscovy ducks (*Cairina moschata*) are originally from South America and domesticated by indigenous tribes. Muscovy ducks are favored in many countries for their high meat yield, distinct flavor, and low-calorie content (Surai, 2016). Muscovy ducks were a source of animal protein and could be used for meat and egg production. Therefore, increasing duck meat production has received more attention in recent times (El-Soukkary *et al*, 2005).

In Vietnam, some previous studies emphasized the effect of feed on growth performance and carcass quality on Muscovy ducks (Dong and Ogle, 2003; Tu *et al*., 2012). Many research results showed that Muscovy ducks were able to consume many agricultural waste products (brewery waste, duckweed, palm kernel, and *Silybum marianum* seeds) with high meat productivity and efficiency economic value (Dong and Ogle, 2003; Tu *et al*., 2012; Ruben *et al*., 2020; El-Garhy *et al*., 2022). In addition to these waste products can be used as feed for ducks. Currently, there are quite new products that help farmers reduce production costs. Black soldier flies are a special, harmless insect, distributed all over the world and do not carry pathogens like house flies. Black soldier flies are used to make animal feed with quite high nutritional content. The nutritional composition of black soldier flies before pupation is 43-51% protein, 15-18% fat, 2.8-6.2% calcium, 1-1.2% phosphorus, and enough nutrients to make animal feed. Thus, we aimed to explore the appropriate supplementing level of black soldier fly larvae in the diet of Muscovy ducks at 7-12 weeks old to support the growth and performance.

MATERIALS AND METHODS

Housing and management

The present study was carried out on a local farm in Binh Minh district, Vinh Long province (Vietnam) from May to September 2023. The experimental farm pens are open-air type, with temperature and humidity depending on the external environment. The average temperature during the experiment ranges from 28-32°C, with humidity ranging from 60-90%. The Muscovy ducks were purchased from a local farm in Binh Minh district, Vinh Long province. The Muscovy ducks were vaccinated with hepatitis antibodies, cholera, and H5N1 vaccines. House for ducks was made by wood and tole. Experimental ducks were confined in pens with 5.0 m^2/10 ducks (5 males and 5 females), which were surrounded by wood, plastic net and its floor was overlaid with 20 cm of sand and rice straw layer in its surface for bedding. Feeders and drinkers were put in front of each cage. Feeders and drinkers were cleaned daily every morning and chicken litters were removed weekly. The ducks were fed 3 times daily at 7.00, 13.00 and 17.00 h and feed offered to the ducks was weekly adjusted by an increase from 5 % to 10% according to real feed intake. Ducks were freely to access water and fed 1 of 5 diets, including fish meal (FM) as CTL and 20%, 40%, 60% and 80% of the FM protein were replaced with black soldier fly larvae (BSFL) protein.

Experimental design

From 7-12 weeks old, all Muscovy ducks were kept in pens, feeding the base diet consisting of 17% crude protein and 2,850 metabolizable energy kcal/kg (Table 1). The ducks had *ad libitum* access to feed and water throughout the experiment.

All ingredients were carefully mixed according to their ratio in five diets. Then the mixtures were extruded through a 2-6 mm diameter die plate using an extruder (Binh Minh Corp., Vietnam). Feed for the experiment was mixed separately for each treatment. The feed was then dried at 45°C for 24 hours and stored in plastic bags at room temperature before use to ensure the stability of the nutritional composition of the diet throughout the experimental period.

A total of 200 Muscovy ducks from 7 to 12 weeks old were randomly assigned to five dietary treatments. The treatments named as following: CTL- control diet with fishmeal; and LP20, LP40, LP60 and LP80 as replacing 20%, 40%, 60% and 80% of fishmeal protein with larval protein (LP) in the control diet with four replications.

Measurements and data collection

The growth traits were followed during the study period including body weight at the starting time and final time of the experiment, body weight gain, average daily feed intake (ADFI), and feed conversion ratio (FCR). Daily feed intakes were calculated according to the total feed consumption of 10 ducks (5 males and 5 females)/pen was calculated based on feeds consumed. At the beginning of the experiment, all 10 ducks/experiment units were weighed individually and then weekly.

Table 1: Ingredient proportion and chemical composition of diets.

Item	Treatment				
	CTL	LP20	LP40	LP60	LP80
Fish meal	16.0	12.8	9.6	6.4	3.2
BSFL meal	-	4.3	8.7	12.9	17.2
Corn meal	19.0	18.0	17.2	17.2	16.1
Rice bran	32.3	32.2	32.0	31.0	31.0
Soybean meal	12.0	12.0	12.0	12.0	12.0
Wheat meal	13.7	13.7	13.5	13.5	13.5
Premix	4.0	4.0	4.0	4.0	4.0
CMC	3.0	3.0	3.0	3.0	3.0
Total	100	100	100	100	100
Chemical composition (%) & gross energy (GE, kcal/kg DM)					
DM	94.7	95.2	94.5	94.9	95.1
OM	89.0	89.2	89.4	89.1	89.5
CP	17.1	17.2	17.3	17.2	17.3
EE	4.9	5.7	6.5	7.0	7.4
CF	4.0	4.1	4.3	4.5	4.8
Total ash	11.0	10.8	10.6	10.9	10.5
ME (kcal/kg)	2,880	2,875	2,870	2,862	2,850

Source: Janssen (1989).

Economic analysis

Economic analyses were done by using current prices in Vietnamese dong (VND) to calculate the differences in total income and total expenses (including feeds, ducklings, labor, vaccines, and medicines) and net profit per treatment.

Statistical analyses

The data was recorded by using Excel software. The variance was analyzed based on the General Linear Model of Minitab software version 18.0:

$$Yij = \mu + Gi + \xi ij$$

Where; Yij: traits observed; μ: general mean, Gi: influence of genotype; ξij: random error (Minitab, 2018).

RESULTS AND DISCUSSION

The feed intake

Table 2 showed that feed intake in CTL treatment was higher than LP20, LP40, LP60, and LP80. This could be explained by the fact that treatments that replaced black soldier fly larvae with fish meal and ducks consumed less food than CTL treatments. However, the weight gain of the LP20, LP40, and LP60 treatments was as high as the CTL treatment. This result indicates that replacing fishmeal protein with black soldier fly larvae did not affect duck weight gain.

Table 2: The feed intake of Muscovy ducks (g/bird/day) from 7 to 12 weeks old.

Weeks old	Treatments					SEM	P
	CTL	LP20	LP40	LP60	LP80		
7	148.6	147.7	148.7	146.9	146.8	0.05	-
8	159.2[a]	157.4[ab]	156.4[b]	157.3[b]	155.5[b]	0.56	0.028
9	165.1[a]	162.2[ab]	159.0[b]	160.8[c]	158.2[c]	1.03	0.011
10	169.4	169.3	168.7	171.9	169.4	0.91	-
11	174.0[a]	171.5[b]	169.6[b]	170.6[b]	169.0[b]	0.59	0.003
12	177.9[a]	176.9[a]	171.6[b]	173.0[b]	172.5[b]	1.04	0.007
Average	165.7[a]	164.2[b]	162.3[c]	163.4[c]	161.9[c]	0.73	0.044

a, b values with no common superscripts within a row for each site differ significantly (p<0.05).

Table 3: Duck weight at 7-12 weeks old (g/bird).

Weeks old	Treatments					SEM	P
	CTL	LP20	LP40	LP60	LP80		
7	1,452	1,443	1,440	1,453	1,457	6.73	-
8	1,753[a]	1,762[a]	1,755[a]	1,745[ab]	1,736[b]	5.90	0.035
9	2,091[a]	2,091[a]	2,054[a]	2,082[a]	2,052[b]	3.80	0.001
10	2,426[a]	2,420[a]	2,400[a]	2,404[a]	2,363[b]	7.51	0.002
11	2,789[a]	2,784[a]	2,794[a]	2,775[a]	2,685[b]	7.11	0.001
12	3,142[a]	3,127[a]	3,100[a]	3,022[a]	3,023[b]	7.44	0.002
Final of 12 weeks old	3,502[a]	3,449[a]	3,405[a]	3,400[ab]	3,363[b]	8.57	0.001
Average	2,451[a]	2,439[a]	2,421[a]	2,412[ab]	2,383[b]	6.72	0.055

The growth performance

Table 3 presented that at 7 weeks old, the duck weight in CTL, LP20, LP40, LP60, and LP80 treatments were insignificant. The reason was that at the beginning of the experiment, the ducks were fed the same type of food with the same nutritional composition.

At 8 weeks old, duck weight in CTL, LP20, and LP40 treatments tended to increase (P<0.05) compared to LP80 treatment. During 9-12 weeks old, the increasing trend was more obvious in CTL, LP20, LP40, and LP60 treatments compared to LP80 treatment. At the end of 12 weeks, the average weight of ducks in CTL, LP20, and LP40 treatments was the highest (P<0.05) and the lowest (P<0.05) was in the LP80 treatment.

Dong and Ogle (2003) evaluated the effect of brewery waste for replacement in growing duck diets at 1-84 days old. Eva *et al.* (2018) surveyed the growth of Muscovy ducks (in Brazil) with diets containing 2,960 ME kcal/kg and 22% CP in the initial phase (1–15 days) and 2,800 ME kcal/kg and 18% CP in the growth phase (16–90 days). The results of Ruben *et al.* (2020) indicated that Muscovy duck weight at 12 weeks old was 1,938 g/bird (50% palm kernel supplementation), 2,101 g/bird (75% palm kernel supplementation), and 1,881 g/bird (100% palm kernel). Linh *et al.* (2022) stated that the final weight of Muscovy ducks at 12 weeks old was 2.662 g/bird. The reason for the difference between the above results was due to care, nutrition, and locations.

Table 4 shows that the average weight gain of ducks in the LP80 treatment was the lowest (P<0.05), followed by the LP60 treatment, and the highest (P<0.05) was in the LP20 and the LP40 treatment at 7 weeks old. At 12 weeks old, weight gains in CTL and LP60 treatments were the highest (P<0.05), followed by LP80, LP20, and LP40 treatments.

Table 4: The weight gain of Muscovy ducks (g/bird/day).

Weeks old	Treatments					SEM	P
	CTL	LP20	LP40	LP60	LP80		
7	43.1[ab]	45.6[a]	45.0[a]	41.7[b]	39.9[c]	0.59	0.001
8	48.1	47.0	42.7	48.1	45.1	0.90	-
9	47.9	47.0	49.4	46.0	44.4	0.79	-
10	51.9[b]	52.0[b]	56.3[a]	53.0[b]	46.0[c]	1.05	0.008
11	50.4[a]	49.0[a]	43.7[b]	35.3[c]	48.3[a]	0.51	0.007
12	51.4[a]	46.0[b]	43.6[c]	54.0[a]	48.6[b]	0.55	0.001
Average	48.8[a]	47.8[a]	46.7[ab]	46.4[ab]	45.1[b]	0.71	0.054

Average weight gain during the experimental period. The lowest weight gain was in the LP80 treatment, the remaining treatments gained equivalent weight.

Pham and Le (2022) presented, the daily weight gain of Muscovy ducks was 40.4-49.7 g/bird/day (add 1-2% shrimp hydrolyzate to the base diet). Dong and Ogle (2003) presented that the daily gain of Muscovy ducks was 30.1 g/bird/day (75% brewery waste supplementation), 30.4 g/bird/day (50% brewery waste supplementation) and 28.0 g/bird/day (25% brewery waste supplementation). The results of Linh *et al.* (2022) showed the weight gain of Muscovy ducks was 34.5 g/duck with diets containing 19.9% CP and 1.49 ME ((MJ/bird/day) at 7-12 weeks old. Thus, the present result indicated that duck weight gain was higher than in the study of Linh *et al.* (2022) and the reason was the differences in care and nutritional conditions.

The FCR of Muscovy ducks at 7-12 weeks old

Table 5 shows the average FCR of ducks at CTL and LP20 treatments were lower (P<0.05) than in LP60 and LP80 treatments.

Table 5: The FCR of Muscovy ducks.

Weeks old	Treatments					SEM	P
	CTL	LP20	LP40	LP60	LP80		
7	3.45 ^{ab}	3.24 ^{c}	3.30 ^{c}	3.52 ^{ab}	3.68 ^{a}	0.051	0.001
8	3.31	3.35	3.66	3.27	3.45	0.060	-
9	3.45 ^{ab}	3.45 ^{ab}	3.22 ^{c}	3.50 ^{a}	3.56 ^{a}	0.047	0.003
10	3.26 ^{b}	3.26 ^{b}	3.00 ^{c}	3.24 ^{c}	3.68 ^{a}	0.062	0.004
11	3.45 ^{c}	3.50 ^{ab}	3.88 ^{a}	4.83 ^{a}	3.50 ^{ab}	0.044	0.016
12	3.46 ^{ab}	3.85 ^{a}	3.94 ^{a}	3.20 ^{c}	3.55 ^{ab}	0.032	0.001
Average	3.40 ^{b}	3.44 ^{b}	3.48 ^{ab}	3.52 ^{a}	3.59 ^{a}	0.048	0.015

^{a,b,c} values with no common superscripts within a row for each site differ significantly (p<0.05).

Nha and Thuy (2022) presented, the FCR of Muscovy ducks was 2.90-3.4 (add 1-2% shrimp hydrolyzate to the base diet). Dong and Ogle (2003) stated that the FCR on local Muscovy duck (1-84 days old) was 3.94 (50% brewery waste supplementation) and 3.25 (control treatment). Tu *et al.* (2012) used duckweed as a replacement for soybean meal in a basal diet of rice bran on the growth performance of local Muscovy ducks (in Vietnam) at 1-84 days old. The duckweed from the fertilized ponds contained about 30% protein (high protein duckweed). The FCR of ducks was 4.32 (control treatment) and 4.51 (high protein duckweed). Ruben *et al.* (2020) used palm kernel as an alternative to soybean meal for Muscovy duck diets (1-12 weeks old). The results indicated that FCR was 4.36 (control treatment), 4.82 (50% palm kernel supplementation), 4.69 (75% palm kernel supplementation), and 5.08 (100% palm kernel supplementation). El-Garhy *et al.* (2022) surveyed the effectiveness of dietary supplementation of *Silybum marianum* seeds on the growth performance of Muscovy ducks (0-4 weeks old). The results showed that FCR was 2.47 (control treatment) and 2.19 (4 g/kg feed supplementation). The results of Linh *et al.* (2022) showed the FCR was 3.26 at 7-12 weeks old that had lower than the current study.

Economic efficiency was calculated based on feed costs, duckling prices, and selling prices of ducks at the end of the experiment. This efficiency did not include labor. Table 6 presents the profit rates in LP80 were higher (P<0.05) than in LP60 treatment, LP40, LP20, and CTL treatments. The profits in LP80 and LP60 were higher (P<0.05) than CTL treatment.

The profits of CTL were lower than the LP20, LP40, LP60, and LP80 treatments. The results of Dong and Ogle (2003) showed the profits of using brewery waste for Muscovy duck diets (1-84 days old) was 195,000 VND/bird (50% brewery waste supplementation) and 169,000 VND/bird (control treatment). Linh *et al.* (2022) indicated the highest profit in Muscovy ducks (63,251 VND/bird) was lower than in the present study. The reason for this difference is due to feed costs, medical costs, duckling costs, and time.

Table 6: Economic efficiency of Muscovy ducks at 7-12 weeks old.

Items	Treatments				
	CTL	LP20	LP40	LP60	LP80
Initial experiment time (bird)	40	40	40	40	40
Final experiment time (bird)	40	40	40	40	40
Mortality (%)	0	0	0	0	0
Duckling price (VND/bird)	18,000	18,000	18,000	18,000	18,000
Duck weight in the final experiment (kg/bird)	3,502	3,449	3,405	3,400	3,363
Unit selling price of duck (VND/kg/bird)	50,000	50,000	50,000	50,000	50,000
Total feed (kg/bird)	8.33	8.39	8.43	8.49	8.55
Unit selling price of feed (VND/kg)	10,500	9,700	8,900	8,100	7,300
*** Expenditure**					
Total cost of feed (Vietnam dong/bird)	87,500	81,385	74,983	68,771	62,451
Electric and water (VND/bird)	5,000	5,000	5,000	5,000	
Depreciation of barns (VND/bird)	5,000	5,000	5,000	5,000	
Total expenditure (VND/bird)	97,500	91,385	84,983	78,771	72,451
*** Revenues**					
Selling of ducks (VND/duck)	175,000	172,450	170,250	170,000	168,150
Profits (VND/duck)	77,500	81,085	85,267	91,229	95,699
Profit rates (%)	100	104	110	117	123

CONCLUSIONS

It is possible to replace 60% of the fish meal protein with the black soldier fly larvae protein, providing the highest profit without affecting the growth of broiler Muscovy ducks during the 7 to 12 weeks.

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NOVELTY STATEMENT

Using protein from black soldier fly larvae contributes to environmental protection. Research shows that Muscovy ducks can use 60% of black soldier fly larvae protein to replace fishmeal protein, providing the highest profit without affecting the growth of broiler ducks.

AUTHORS'S CONTRIBUTION

The author comes up with ideas, conducts research, analyzes data and completes the article. Authors contribute equally.

Conflict of interest

The authors have declared no conflict of interest.

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