

Original Research Paper

Fermented Green Vegetable Soybean Meal Increases Dressed Carcass Meat and Bone Weight in Black-Boned Chickens (Fah Luang Chicken, *Gallus gallus*)

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Article history

Received: 21-02-2017

Revised: 21-06-2017

Accepted: 29-08-2017

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Abstract: To use effectively waste green vegetable soyabean (edamame) and to improve the dressed carcass meat in black-boned chickens (Fah Luang chicken, *Gallus gallus*), fermented edamame meal was fed to black-boned chickens from 4 to 16 weeks of age. At 4 weeks of age, 20 birds (10 male and 10 female birds) were used to measure the initial weights of dressed carcass meat and each bone part. Another 60 birds were divided into 2 groups with 3 replicates of 10 chickens (5 male and 5 female birds) each. The control group received a basal formula diet only and the experimental group was fed 40 g fermented edamame meal per bird for a period of 30 min before being fed the basal formula diet. The weights of whole body, each dressed carcass muscle part and each bone part increased in the chickens fed fermented edamame meal ($p < 0.05$). The feed cost per Kg body weight gain decreased ($p < 0.05$). Income over feed cost per Kg body weight gain, as well as income over feed cost and strain per bird, increased in the fermented edamame meal group ($p < 0.05$). These facts suggest that the feeding of fermented edamame meal to black-boned chicken induces the chicken's production due to increase of dressed carcass muscle, cheap feed cost (USD/Kg body weight gain) and high income (USD/bird), suggesting the potential for commercialization of waste edamame meal as a feed ingredient for black-boned chickens.

Keywords: Waste Edamame, Native Chicken, Meat Improvement, Feed Cost, Feeding

Introduction

Immature soybean seeds (*Glycine max* (L.) Merrill) harvested at an R6 immature stage (Fehr and Caviness, 1977) at 80% maturity (Simonne *et al.*, 2000) are consumed as green vegetable soyabean (edamame) in almost every country. Edamame is popular as a snack and an appetizer with beer and national consumption averages 159,900 tons annually in Japan (Nguyen, 1997). Also in Thailand, a lot of edamame are exported. The processing of edamame due to increasing commodification has caused a large amount of non-standardized edamame due to small-sized and broken seeds and they are thrown away as waste edamame without being effectively used.

However, compared with agronomic soyabeans, edamame contain lower trypsin inhibitors and fewer indigestible oligosaccharides, but a greater number of vitamins (Rackis, 1978) and higher levels of phytic acids (Gupta *et al.*, 1976). Nutritionally, edamame is rich in protein (Johnson *et al.*, 1999; Miles *et al.*, 2000), monounsaturated fatty acids (Johnson *et al.*, 1999), vitamin C, vitamin E, dietary fiber (Johnson, 2002), vitamin A, calcium, isoflavones (Masuda, 1991; Rao *et al.*, 2002), as well as calcium, phosphorus, iron, sodium, potassium, vitamin B1, vitamin B2, niacin and ascorbic acid (Miles *et al.*, 2000). Functionally, edamame strengthen bones and teeth, lower cholesterol and prevent cardiovascular disease (Rao *et al.*, 2002).

Although these nutritional and functional values of edamame is well studied, few studies have been found in the literature on the effect of waste edamame on the improvement of growth performance, other than that the fermented edamame improved body weight gain and immune capacity in black-boned chickens (Buwjoom *et al.*, 2016).

The broiler strain has been commonly bred as a poultry meat product. More recently, there has been an increased interest in healthy, low-fat and chewy poultry meats in the whole world. To produce such lower fat and uniquely textured poultry meat, Tatsuda and Fujinaka (2001) crossed the slow-growing (meat-type) native Japanese breeds and the fast-growing White Plymouth Rock (broiler) lines. Ikeobi *et al.* (2002) used a cross between a commercial broiler and a White Leghorn layer line because of an increasing demand for human diets that reduce fat intake (Lagarrigue *et al.*, 2006). Although many attempts have been made to improve native chicken production by introducing exotic breeds via cross-breeding and to produce hybrids with high production performance, these improved native chickens were not accepted by some consumers, because the hybrids did not meet their expectations regarding meat quality (mainly taste). In Thailand, the quality of most Thai native chicken meat is much better than that of crossbred and broiler chickens (Kammongkun and Leotaragul, 2015) due to the lower content of fat, cholesterol and triglycerides (Pongduang *et al.*, 2013). In particular, black-boned chickens had a high meat quality (Pripwai *et al.*, 2014) and low content of fat and cholesterol (Jaturasitha *et al.*, 2008; Wattanachant, 2008). As the Asian region has many kinds of indigenous chickens with meat that is lean and resilient in texture, it is better to use native chickens that have not been subjected to genetic improvement or modification to promote poultry production. In spite of the fact that many investigations on Thai indigenous chickens have involved a breeding approach based on genetic improvement, few studies involving feeding experiment to increase the quantity of each dressed carcass meat part have been examined.

In this study, to use effectively the fermented edamame, as well as to decrease the production costs associated with native chicken meat due to an increase in each dressed carcass meat part, black-boned chickens (Fah Luang chicken, *Gallus gallus*) were fed fermented edamame meal from 4 to 16 weeks in age and the weight of each dressed carcass muscle part and each bone part was compared with those of the control.

Materials and Methods

Fermented Edamame Meal Preparation

Among edamame, pods deemed not to have a good shape or size, as well as edamame with no seed or small seeds were treated as waste edamame in frozen food factories. The waste edamame, including seeds and pods,

was cut into small pieces, dried and grinded. After weighing the raw edamame chips, the edamame chips, sugar and salt were mixed at a ratio of 100: 4: 1, respectively and this mixture was put in plastic bags for fermentation without oxygen for 7 days. The fermented edamame meal was used for up to 5 days for feeding experiments because edamame meal became bad after 5 days.

Chemical Analysis

The fermented edamame meal sample was analyzed for crude protein and crude fiber as dry matter basis, according to methods described by Buwjoom and Maneewan (2008).

Birds and Housing

A total of 80 black-boned chickens were used. At 4 weeks of age, 20 birds (10 male and 10 female) were randomly selected to be measured for the weights of dressed carcass meat, such as pectoralis major, pectoralis minor, wing muscle, thigh muscle, sartorius muscle, hind limb muscle and whole edible muscle as well as each bone such as wing bone, thigh bone, sartorius bone, hind leg bone and total bone. The remaining 60 birds, allotted in groups according to a completely randomized block design, were divided into 2 groups with 3 replicates of 10 chickens (5 male and 5 female birds) each at 4 weeks of age. The control received the basal formula diet only Table 1. The experimental group was fed 40g fermented edamame meal per bird for a period of 30 min before being fed the basal formula diet, to reduce the total feed cost by reducing consumption of the basal formula diet. The feed intake of the experimental group was calculated from these consumptions of the basal formula diet and the fermented edamame meal. The birds had ad libitum access to feed and water from 4 to 16 weeks of age. Weekly feed intake and weight were recorded to calculate aspects of chicken production such as body growth, feed cost and income.

Muscle and Bone Sampling

At 16 weeks of age (the end of the experiment), the 10 birds per group (5 male and 5 female birds) were killed by slitting the carotid to induce blood loss, followed by removal of the visceral organs and skinning. Each skinned whole body was wrapped in a nylon bag and cooled by soaking in ice-water for more than 15 min. The whole body meats were divided into the pectoralis major, pectoralis minor, wing, thigh and sartorius. The bone and the intermuscular fat were taken out by peeling the muscles from each dressed carcass meat part. The muscle weight of each part was determined by subtracting the weight of the bone and intermuscular fat from the weight each part. Each measured value was expressed as a mean from the male and the female values. The weights of each dressed carcass meat and bone part were compared with those of the initial weights at 4 weeks of age to determine the growth of each dressed carcass meat part and each bone part.

Table 1. Feed composition of formula diet (0-8 and 9-16 weeks of age)

Ingredients (kg)	0-8 W	9-16 W
Corn	55.00	41.50
Soybean meal	23.17	7.65
Rice bran	21.08	49.58
Salt	0.25	0.25
Dicalcium phosphate	-	0.52
Premix	0.50	0.50
Total	100.00	100.00
Cost (bath)	10.97	10.20
Calculated nutrient composition(% air dry)		
Protein	19.00	14.50
ME (KcalME/kg)	2,800.00	2,600.00
Fiber	5.34	6.22
Fat	6.93	11.64
Calcium	0.09	0.18
Phosphorus, available	0.32	0.49
Methionine	0.28	0.15
Lysine	1.2	0.63

Premix contains 2.20 million units Vitamins A; 0.45 million units vitamin D3; 2.50 g vitamin E; 0.40 g vitamin K3; 0.20 mg vitamin B1; 0.90 g vitamin B2; 0.30 g Vitamin B6; 0.004 g vitamin B12; 1.10 g pantothenic acid; 4.00 g Nicotinic acid; 0.060 g folic acid; 0.040 g biotin; 8.00 g Fe; 1.60 g copper; 14.00 g manganese; 8.00 grams zinc; 0.12 g iodine; 0.032 g selenium; 0.60 g cobalt; 0.036 g potassium; 162.20 g choline chloride; add feed media until 1.00 kg

Statistical Analysis

Growth performance, feed cost and income between the control and the experimental groups were also calculated from these 3 replicates. The results were evaluated using SPSS (a statistical analysis software program). Statistical differences among treatments were separated using the F-test at 5% significance level.

All experimental and animal management procedures were performed according to the Ethics, Principles and Guidelines for the Use of Animals for Scientific Purposes, National Research Council of Thailand.

Results

The chemical composition of fermented edamame meal is as follows: The content of crude protein and crude fiber as dry matter basis were 23.00 and 16.03%, respectively.

Table 2 shows the initial weights of fresh body, pectoralis major, pectoralis minor, wing muscle, thigh muscle, sartorius muscle, hind limb muscle, whole edible muscle, wing bone, thigh bone, sartorius bone, hind leg bone and total bone in the 4-week-old black bone chickens before starting the feeding experiment using fermented edamame meal. Compared with the control at the end of the feeding period (at 16 weeks of age), the final fresh body weight, as well as all values of each dressed carcass muscle part and each bone part increased in the chickens fed fermented edamame meal ($p < 0.05$) Table 3.

Table 2. Initial weights of fresh body, each dressed carcass meat and bonepart (g) in the black bone chickens (Fah Luang chicken) at 4 weeks of age (Mean \pm SEM, n = 20)

Item	Initial weight (g)
Initial body weight	153.07 \pm 15.53
Pectoralis major	7.06 \pm 0.82
Pectoralis minor	2.48 \pm 0.16
Wing muscle	4.31 \pm 0.26
Thigh muscle	8.13 \pm 0.53
Sartorius muscle	7.01 \pm 0.35
Hind leg muscle	15.15 \pm 0.88
Whole edible muscle	28.99 \pm 1.64
Wing bone	5.27 \pm 0.48
Thigh bone	2.6 \pm 0.21
Sartorius bone	3.5 \pm 0.60
Hind legs bone	6.10 \pm 0.80
Total bone	11.36 \pm 1.36

Table 3. Final weights of fresh body, each dressed carcass meat and bone part(g) in the control and black bone chickens (Fah Luang chicken) fed fermented green vegetable soybean meal at 16 weeks of age (Mean \pm SEM, n = 10)

Item	Treatment		P-value
	Control	Fermented feed	
Final body weight	937.73 \pm 46.24 ^b	1113.59 \pm 96.3 ^a	0.0109
Pectoralis major	75.84 \pm 6.76 ^b	91.62 \pm 6.68 ^a	0.0104
Pectoralis minor	30.78 \pm 2.78 ^b	37.33 \pm 2.80 ^a	0.0104
Wing muscle	72.00 \pm 5.73 ^b	81.25 \pm 4.34 ^a	0.0317
Thigh muscle	100.43 \pm 8.19 ^b	127.30 \pm 13.94 ^a	0.0104
Sartorius muscle	75.80 \pm 5.14 ^b	96.37 \pm 9.72 ^a	0.0059
Hind legs muscle	176.23 \pm 12.53 ^b	223.67 \pm 23.53 ^a	0.0075
Whole edible muscle	354.85 \pm 24.62 ^b	433.88 \pm 33.42 ^a	0.0054
Wing bone	23.51 \pm 2.88 ^b	29.21 \pm 3.94 ^a	0.0462
Thigh bone	14.22 \pm 14.22 ^b	18.19 \pm 1.62 ^a	0.0044
Sartorius bone	19.17 \pm 1.74 ^b	23.61 \pm 1.42 ^a	0.0045
Hind legs bone	33.40 \pm 2.87 ^b	41.80 \pm 2.79 ^a	0.0033
Total bone	56.91 \pm 5.23 ^b	71.01 \pm 6.15 ^a	0.0082

^{a,b}Means followed by different letters are significantly different ($p < 0.05$)

Also in regard to the daily weight gain of the fresh body, each dressed carcass muscle part and each bone part during 4 to 16 weeks of age increased in the chickens fed fermented edamame meal ($p < 0.05$) Table 4. The black bone chickens fed fermented edamame meal showed no change in feed intake (but for a low value), but they increased in body weight gain, resulting in improved feed efficiency ($p < 0.05$) Table 5. Feed cost per bird, as well as cost of feed and strain per bird, did not differ between the control and the experimental groups, but the feed cost per Kg body weight gain decreased ($p < 0.05$). Income over feed cost per Kg body weight gain, as well as income over feed cost and strain per bird, increased in the fermented edamame meal group ($p < 0.05$).

Table 4. Weight gain (g) per day of fresh body, each dressed carcass meat and bone part in the control and black bone chickens (Fah Luang chicken) fed fermented green vegetable soybean meal at 16 weeks of age (Mean±SEM, n = 10)

Item	Treatment		P-value
	Control	Fermented feed	
Whole body growth	9.34±0.64 ^b	11.44±1.07 ^a	0.0098
Pectoralis major	0.82±0.08 ^b	1.01±0.07 ^a	0.0097
Pectoralis minor	0.34±0.03 ^b	0.41±0.03 ^a	0.0113
Wing muscle	0.81±0.07 ^b	0.92±0.05 ^a	0.0330
Thigh muscle	1.10±0.10 ^b	1.42±0.16 ^a	0.0105
Sartorius muscle	0.82±0.06 ^b	1.06±0.12 ^a	0.0061
Hind legs muscle	1.92±0.16 ^b	2.48±0.28 ^a	0.0077
Whole edible muscle	3.88±0.31 ^b	4.82±0.39 ^a	0.0053
Wing bone	0.22±0.03 ^b	0.29±0.05 ^a	0.0435
Thigh bone	0.14±0.01 ^b	0.19±0.02 ^a	0.0054
Sartorius bone	0.19±0.02 ^b	0.24±0.02 ^a	0.0067
Hind legs bone	0.32±0.03 ^b	0.43±0.04 ^a	0.0044
Total bone	0.54±0.06 ^b	0.71±0.08 ^a	0.0088

^{a,b}Means followed by different letters are significantly different (p<0.05)

Table 5. Growth performance, feed cost and income in the control and black bone chickens (Fah Luang chicken) fed fermented green vegetable soybean meal at 16 weeks of age (Mean±SEM, n = 3)

Item	Treatment		P-value
	Control	Fermented feed	
Feed intake (W4-16) (g/bird)	4,406.97±232.76	4,052.21±190.10	0.1700
Body weight gain (W4-16) (g/bird)	787.95±39.15 ^a	957.22±39.13 ^b	0.0100
Feed efficiency (W4-16) (%)	17.88±0.06 ^a	23.62±0.14 ^b	0.0000
Feed cost (USD /bird)	1.30±0.04	1.35±0.05	0.0960
Feed cost (USD/ Kg body weight gain)	1.66±0.05 ^a	1.41±0.03 ^b	0.0038
Cost of feed and strain (USD/bird)	2.73±0.04	2.78±0.05	0.9600
Income over feed cost (USD/ Kg body weight gain)	2.06±0.05 ^b	2.30±0.03 ^a	0.0038
Income over feed cost and strain (USD/bird)	0.75±0.08 ^b	1.36±0.09 ^a	0.0050

^{a,b}Means followed by different letters are significantly different (p<0.05)

Discussion

Although soyabean meal is the most commonly used protein source in poultry diets, soyabean prices have reached the highest values in years, researchers have proposed alternatives for poultry diets such as *Nigella sativameal* (Abd El-Hack *et al.*, 2016). However, we have tried to develop locally produced waste feed ingredients to reduce production costs. Most of the edamame produced in Thailand has been exported to Japan as a snack. During the steps involved in processing edamame, around 3,000 to 4,000 tons per year are wasted as a by-product from one frozen food factory in the Chiangmai area and the wasted edamame used as fertilizer and dairy cow feed.

On the other hand, now global food culture has been changing from high calorie foods like a broiler meat to light foods like native lean chicken meat. In line with this demand, many genetic improvements in broiler chicken cross-breeding using lean chickens have been conducted. In Thailand, lean type indigenous chickens traditionally have been bred. However, as Thai consumers prefer low fat and antibiotic-free white meat (Wattanachant, 2008), a

Thai indigenous chicken, especially the black-bone chicken, is a higher price to buy, approximately two or three times higher than that of commercial broilers (Chotsangkad and Kongrattananun, 1999).

In this study, compared with the control, the body weight gain increased in the edamame group at 16 weeks of age. This increased body weight corresponds with results described in black-bone chickens fed fermented edamame meal (Buwjoom *et al.*, 2016). The present increase in body weight gain is induced by an increase in each dressed carcass muscle part and each bone part. Although the bone weight increase does not contribute to meat production, the increased bone weight means strong bones. Such a phenomenon suggests the possibility that feeding fermented edamame meal to hens might strengthen the eggshell, because edamame strengthens bones and teeth (Rao *et al.*, 2002). As country roads in the some Asian regions are unpaved, some eggs are broken during transportation. Therefore, eggs strengthened by edamame may contribute to the egg industry as being the hardest to break during transportation. On the other hand, in regard to poultry

production, the present increase in each dressed carcass muscle part is the most valuable result. In the case of heavy-type chickens such as broiler chickens, an improvement in growth performance is comparatively difficult, because weight gain has been maximized by gene improvement. On the contrary, in the case of the present lean-type chicken, the weight gain seems to be easily elevated even by 22.02% crude protein in fermented edamame meal, because lean chickens are more prone to protein efficiency than fat chickens (Leclercq and Guy, 1991). In addition, the fermentation of feed elevated the concentration of lactic acid (Engberg *et al.*, 2006; Heres *et al.*, 2003a) and the numbers of lactic acid bacteria (Winsen *et al.*, 2001; Heres *et al.*, 2003a), reducing *Salmonella enteritidis*. Fermented liquid feed could reduce the transmission of *Salmonella* in chicken flocks (Heres *et al.*, 2003b) and fermented feeds and fermentable carbohydrates improved the gut environment in non-ruminants (Niba *et al.*, 2009). These literatures suggest that the present fermented edamame meal resulted in increased meat weight due to its improving the gut environment by fermentation. To reduce the cost of wage and increase the benefits, Pukkalanun and Pattanachatchai (2015) recommend that the chicken farmers should promote the native chicken's potential and that the rearing period should be less than 7 months. However, in this study, production costs were lowered only by feeding fermented edamame meal. The present feed efficiency during 4 to 16 weeks of age was improved because the feed intake was not changed (low value), but body weight gain increased in the fermented edamame meal group. Feed cost (USD/bird), as well as the cost of feed and strain (USD/bird) were not different between the control and experimental groups, but feed cost (USD/Kg body weight gain) was cheaper in the experimental group, resulting in an increased income over feed cost (USD/Kg body weight gain) and increased income over feed cost and strain (USD/bird). This result suggests that the fermented edamame meal has a commercialization value in fermented waste edamame.

Conclusion

In conclusion, the feeding of fermented edamame meal to black-boned chickens could increase each dressed carcass meat part and each bone part of the birds, lower chicken production costs and raise the profits of poultry farmers. These facts suggest that the feeding of fermented edamame meal induces the chicken's production due to increase of dressed carcass muscle, cheap feed cost (USD/Kg body weight gain) and high income (USD/bird), suggesting the potential for commercialization of waste edamame meal as a feed ingredient for black-boned chickens.

Author's Contributions

Sukit Khantaprab and Nattakarn Khantaprab, Kohsyo Yamauchi, Sontaya Niwat and Chamnian Yosraj: Conception and design and/or acquisition of data and/or analysis and interpretation of data.

Buaream Maneewan and Tonglian Buwjoom: Drafting the article or reviewing it critically for significant intellectual content.

Koh-en Yamauchi: Final approval of the version to be submitted and any revised version.

Declaration Interest

The authors state no conflict of interest and are responsible for the content and writing of this article.

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