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Utilization of house fly-maggots, a feed supplement in the production of broiler chickens

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Abstract: *Recent studies have suggested the utilization of maggots as a feed supplement for enhanced broiler performance. Maggots, which are a major dietary source of protein, appear during the biodegradation of chicken droppings using house flies. The objective of the present study was to investigate the effect of maggot supplementation on the meat quality and growth performance of broiler chickens. A total of 600 one-day-old male commercial broiler chicks (Ross) were randomly assigned into 5 treatment groups consisting of 40 replicates of 3 birds. The birds were fed either a basal diet or the basal diet supplemented with 5.0, 10.0, 15.0 and 20.0% maggots. Overall, broiler chicken performance was influenced by the optimal amino acid profile; high protein (63.99%) and essential amino acid content (29.46%), or high protein digestibility (98.50%) of the maggots. Maggot supplementation caused linear increases in live weight gain but not the feed conversion ratio. The diets of 10 and 15% maggots was the most efficient in terms of average weight gain for the 4-5 week old broiler chickens(p<0.05). It also significantly increased dressing percentage, breast muscle, and thigh muscle (p<0.05). No differences were observed for liver, abdominal fat, or meat color, and the crude protein contents of breast muscle were constant. However, in the maggot-fed broilers, breast muscle lysine and tryptophan levels increased significantly as compared to the birds fed the basal diet (p<0.05). These results indicate that feeding diets containing 10 to 15% maggots in chicken dropping after biodegradation can improve the carcass quality and growth performance of broiler chickens.*

Key words: *Maggots, Broiler, Performance, Carcass quality, Amino acids*
PDF of full length paper is available online

Introduction

The problems of environmental pollution such as water, domestic waste, air pollutants are serious pending to solve in industrialization. The insects such as earthworm, maggots play a significant role in recycling many forms of waste and other accumulated nutrients in the environment (Dwivedi and Tripathi, 2007; Laishram *et al.,* 2007; Parthasarathi *et al*., 2007).

It is well known that maggots, which appear during the biological treatment of chicken droppings, improve the growth rate of broiler chickens. The pollution problems caused by livestock effluent, and the mass accumulation of poultry waste, could be solved by using chicken droppings as a growth medium for certain living organisms,, including house flies (*Musca domestica* L.)(Boushy, 1991); the resulting maggots offer a high protein feed for livestock such as poultry and fish (Zuidhof *et al*., 2003; Ogunii *et al*., 2007).

Insects in adult, larval, and pupal forms are naturally ingested by wild birds and free range poultry. Some research has demonstrated that insects can be used as selective feed for poultry (Despines and Axtell, 1995), in which turkey poultry were successfully fed darkling beetle (*Alphitobius diaperinus*) larvae and crickets, respectively. Calvert *et al*. (1969) suggested that dried house fly pupae left by house flies growing in poultry waste, and having high protein (63.1%) and fat (15.5%) contents, were a better source of quality feed than soybean meal and could be substituted for soybean meal in chick feed during the first two week after birth. In addition, Inaoka *et al*. (1999) successfully fed poultry maggots and pupae growing on chicken feces. Dried maggots and pupae contain 56.9 and 60.7% crude protein, and 20.9 and 19.2% crude fat, respectively; they have protein and amino acid compositions similar to fish meal; and can replace 7% of the fish meal in broiler chicken feed. Many earlier studies are available on the utilization of maggots as poultry feed supplement (Onifade *et al*., 2001).

However, their efficacy in broiler chicken production is still questionable. In particular, the efficiency of maggots on broiler growth performance is still unknown in terms of carcass characteristics and the attainment of market weight. Therefore, the objective of this study was to evaluate the carcass quality and growth performance of broiler chickens receiving dietary maggot supplementation.

Materials and Methods

Chemical analysis: Fresh maggots were grown in a medium containing a mixture of powdered milk, sugar, and fresh layer droppings, and were then dried in a 55°C forced draft oven for one day. The following methods were used to determine the nutrient composition of the dried maggots (Table 1): proximate composition was determined by the AOAC method (1995); crude protein was analyzed using the Kjeldahl method (Tecator, Kjeltac system 1002); gross energy (GE) was determined by an adiabetic bomb calorimeter (Parr Instrument Co., Model 1261, USA); mineral composition was analyzed by an inductively coupled plasma atomic emission spectrophotometer (Jobin Yvon Co., Model JY 38 plus., France); and fatty acid composition was determined by gas chromatography (HP 6890, Hewlett Packard Co., USA) using the modified methods of Folch *et al*. (1957) and Morrison and Smith (1964). The standard solution for fatty acid analysis was PUFA No. 2 (animal source) from

Supelco (USA). The amino acid profile of the maggots and the amino acid contents of breast muscle were determined by an automatic amino acid analyzer (Hitachi L-8800, Japan). Most of the amino acids underwent acid hydrolysis using 6 N HCl for 24 hr at a temperature of 110°C, and were then measured by reaction with PITC (phenyl-isothiocyanate) derivative reagent (White *et al.*, 1988).

ME and digestibility of amino acids: The metabolizable energy (ME) of the maggots was measured using the balance experiment methodology of Farrell (1978). The birds were trained to take their daily feed allowance within an hour following a 23-hour fast. The feed had a maggot content of 30%. In order to determine energy intake and discharge and calculate ME, the weight of feed taken was recorded and excrement was collected quantitatively for 24 successive hours. The apparent protein and amino acid digestibility of the dried maggots (Table 2) was determined after feeding a purified diet and gathering all the droppings. The purified diet contained 40.0% corn starch, 20.0% glucose, 5.0% α-cellulose, 3.0% corn oil, a 2.0% mixture of vitamins and minerals plus other additives, and 30% dried maggots in ratio by weight. This experimental feed was fed *ad libitum* to four-week-old broiler chickens for seven successive days, and then the compositions of the feed and excrement were analyzed to determine apparent digestibility (Tanksley *et al*., 1981).

Animal experiments: The study used 600 one-day-old male commercial broiler chicks (Ross). The chicks were fed in concrete floor pens with 2.8 m×2.0 m partitions by repeat pens, and contained rice hull litter as bedding. Each pen was equipped with a cylindrical hand feeder and an automatic water supply system so the birds could take sufficient feed and water. The temperature and other feeding conditions in the pens were controlled according to the recommendations for commercial broiler chickens. Lighting was provided on a 24 hr basis. Both the feed and water were supplied *ad libitum*. All the experimental procedures complied with the provisions of the scientific and ethical animal protection law presented in the European Laboratory Animal Treatment License (SCT-w 94058). For the control group, a basic feed containing corn and soybean meal (SBM) was prepared to fully meet the nutrient requirements of the broilers as presented in the NRC feeding standards (1994). For the experimental feed, the basic feed was supplemented with 5.0, 10.0, 15.0, or 20.0% maggots, to make four test groups. Soybean meal, ground yellow corn, and soybean oil were added as necessary to ensure the feeds for all 5 groups had identical total crude protein and ME contents (Table 3). The feed was manufactured every other week and supplied in mash form. The 600 commercial broiler chicks were randomly assigned to 5 treatment groups × 3 repeat pens, resulting in 120 birds assigned to each treatment group and 40 birds in each repeat pen. Every week during the 35-day experimental period, individual birds were weighed and feed intake was determined in each pen. Each week, cumulative weight gain and feed intake were determined and the ratio of cumulative gain to feed was calculated.

Carcass characteristics: After the 35-day feeding experiment, 30 birds from each treatment group (10 from each repeat pen) were slaughtered to determine dressing percentage (the percentage of live animal that ends up as carcass), liver weight, abdominal fat, and breast and thigh muscle weights. Meat color was determined for 9 birds from each treatment group (3 birds from each repeat pen). Specifically, a piece of breast muscle was exposed to air for 30 minutes for color development; the same sample was then measured five times for Hunter color values (L*, lightness; a*, redness; b*, yellowness) using a colorimeter (Chromameter CR-300, Minolta, Japan). Here, colorimetry was performed by standardized chromaticity using standard color plates (Y=93.5, X=0.3132, y=0.3198).

Table - 1: Chemical analysis of maggots as a resource of nutrient for broiler chickens

Item	Nutrient composition
Proximate analysis (%)	
Moisture	5.28
Crude protein	63.99
Ether extract	24.31
Crude ash	5.16
Carbohydrate	1.25
Energy (Kcal kg^{-1})	
Gross energy	5,524
Metabolizable energy (ME)	4,140
Minerals	
Calcium (%)	2.01
Phosphorus (%)	1.32
Sodium (%)	0.66
Iron (mg kg^{-1})	604
Copper (mg kg^{-1})	34
Zinc (mg kg^{-1})	237
Manganese (mg kg^{-1})	56
Fatty acids (%)	
Myristic acid (C14:0)	6.83
Palmitic acid (C16:0)	26.74
Palmitoleic acid (C16:1n7)	25.92
Stearic acid (C18:0)	2.32
Oleic acid (C18:1n9)	21.75
Linoleic acid (C18:2n6)	16.44
Saturated fatty acid (SFA)	35.89
Unsaturated fatty acid (UFA)	64.11

Statistical analysis: The data were analyzed by one-way ANOVA using the GLM procedure of SAS (SAS Institute, 2003), with “pen” as the experimental unit for performance and “bird” as the experimental unit for carcass characteristics. Differences in the average values among treatment groups were examined by Duncan’s multiple range tests. Statistical significance was declared at a probability of $p<0.05$.

Results and Discussion

Table 1 summarizes the nutrient content of the dried maggots. The data indicate they were rich in high quality crude protein (63.99%) and contained a high level of crude fat (24.31%). Our analysis results for protein, amino acid, and fat contents were different from those reported by Calvert *et al.* (1969), probably due to differences in either the analysis procedures employed or the medium used to produce the maggots. In our study, we added the eggs of house flies to a fixed ratio mixture of powdered milk and sugar, which was then sprinkled on chicken droppings to produce maggots during biodegradation of the droppings. In optimum feeding conditions, this method reaches 70 to 75% effectiveness in processing droppings and can produce maggots equivalent to a tenth of the weight of the droppings inputted. Currently, approximately 10 tons of dried maggots are produced every day by this method**.** The cost of maggot production per ton was 9.45$ (Medilavatec, Co., Ltd, Korea).

The maggots showed higher calcium, phosphorus and ME content (4.14 kcal g^{-1}) than soybean meal (2.25 kcal g^{-1}) (NRC, 1994). The maggots contained higher percentages of palmitoleic acid (16:1n7), oleic acid (18:1n9), and linoleic acid (18:2n6) as essential fatty acids than the house fly pupae (Calvert *et al*.,1969).

Table 2 summarizes the amino acid composition and apparent digestibility of the dried maggots and soybean meal used for broiler chicken feed. The maggots had higher amino acid content than the soybean meal and contained a higher percentage of essential amino acids (29.46%) than nonessential amino acids (28.22%). Specifically, the maggots contained higher percentages of the essential amino acids lysine, arginine, phenylalanine, tryptophan, and valine. With regard to protein quality, maggots are comparable to meat and bone meal as well as fish meal and are superior to soybean meal (NRC, 1994). Teotia and Miller (1974) suggested for growing chicks, house fly pupae are a good source of limiting amino acids, particularly arginine, lysine, and methionine. As compared to soybean meal, maggots can supply sufficient amounts of all the essential amino acids, except for arginine, isoluecine, and leucine. It was also stated that since maggots have low levels of methionine and cysteine, it would be necessary to provide methionine along with feed that contains maggots. It is known that methionine has a sparing effect on cystine (NRC, 1994). The maggots had great apparent digestibilities for protein (98.50%) and essential amino acids (94.80%) more than the soybean meal. Therefore, based on the accumulated data, maggots can provide sufficient protein and energy for broiler chicken feed, and also contain sufficient amounts of essential amino acids, fatty acids, and other nutrients necessary for broiler growth. The economic analysis was calculated using the Korean broiler chicken production cost model (Heung-Seong feed Co., Korea. This information is important to broiler procedures where maggots is produced and is available for inclusion in poultry diets. Feed cost and total cost of production were 0.18, 0.17, 0.16, 0.15, and 0.14 dollars per kg feed, and 0.32, 0.28, 0.27, 0.25, and 0.24 dollars per kg live weight in control, 5, 10, 15, and 20% maggots-supplemented diets, respectively.

Table 4 summarizes live weight gain, feed intake, and the feed conversion ratio by broiler chick growth stage until 35 days on the experimental diets. At five weeks from starting the diets, weight gain was significantly higher in the chicks receiving diets 10 or 15% maggot supplementation than in the control group, but not the feed conversion ratio ($p<0.05$); however, feed intake was not significantly different among the treatment groups. Greater weight gain in the maggot-fed groups was due to the high crude protein digestibility and essential amino acid profile of the maggots (Table 2). The costs determinants for broiler production include growth rate per growth unit and feed costs, and broiler growth and weight gain can be largely controlled by the intake of the first-limiting nutrient and the

Table - 2: Amino acid composition and coefficient of apparent digestibility of maggots and soybean meal (SBM) for broiler chickens

Amino acid	Composition (%)		Coefficient	
	Maggots	SBM	Maggots	SBM
Crude protein	63.99±6.81[1]	44.60±7.15	0.985±0.002	0.980±0.001
Essential amino acids	29.46±0.21	18.34±0.24	0.948±0.002	0.924±0.002
Arginine	3.63±0.12	3.67±0.23	0.956±0.001	0.939±0.001
Histidine	1.98±0.35	1.15±0.13	0.937±0.003	0.901±0.002
Isoleucine	1.46±0.17	1.76±0.12	0.922±0.001	0.933±0.001
Leucine	2.90±0.24	3.26±0.31	0.947±0.002	0.927±0.002
Lysine	5.22±0.18	2.54±0.15	0.976±0.006	0.927±0.001
Methionine	2.34±0.20	0.70±0.26	0.956±0.003	0.930±0.003
Phenylalanine	3.57±0.35	2.31±0.17	0.968±0.002	0.947±0.002
Threonine	2.27±0.11	1.76±0.18	0.933±0.001	0.893±0.004
Tryptophan	3.17±0.16	0.10±0.20	0.939±0.001	0.932±0.005
Valine	2.92±0.25	1.09±0.11	0.945±0.003	0.911±0.002
Nonessential amino acids	28.22±0.22	16.59±0.27	0.947±0.002	0.922±0.001
Alanine	4.85±0.15	3.01±0.13	0.957±0.004	0.938±0.003
Aspartic acid	2.21±0.21	3.23±0.17	0.932±0.002	0.951±0.001
Cystine	0.42±0.15	0.36±0.20	0.927±0.001	0.876±0.002
Glutamic acid	5.71±0.15	1.75±0.18	0.951±0.001	0.912±0.001
Glycine	3.27±0.13	3.68±0.11	0.955±0.002	0.932±0.002
Proline	1.58±0.14	1.55±0.17	0.934±0.003	0.901±0.003
Serine	5.63±0.22	1.81±0.30	0.956±0.004	0.925±0.001
Tyrosine	4.55±0.17	1.20±0.14	0.961±0.002	0.938±0.002

[1]Mean values ± S.E. (n=5)

Table - 3: Ingredient and chemical composition of the experimental diets[1]

Ingredients (%)	Diets for broiler chickens									
	0 to 3 weeks					4 to 5 weeks				
	T1	T2	T3	T4	T5	T1	T2	T3	T4	T5
Yellow corn	50.42	54.10	59.02	60.82	65.40	56.42	60.10	64.62	70.62	70.92
Soybean meal	32.00	26.42	20.00	19.50	11.52	30.00	24.42	19.00	11.00	3.00
Wheat bran	-	-	-	-	-	-	-	-	-	3.00
Corn gluten meal	8.00	6.00	5.10	-	-	4.00	2.00	-	-	-
Soybean oil	6.00	5.00	2.50	1.50	-	6.00	5.00	3.00	-	-
Maggots	-	5.00	10.00	15.00	20.00	-	5.00	10.00	15.00	20.00
DL-methionine	0.20	0.20	0.10	0.10	-	0.20	0.20	0.10	0.10	-
L-lysine,HCl	0.30	0.20	0.20	-	-	0.30	0.20	0.20	0.20	-
Limestone	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Tricalcium phosphate	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25
Salt	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Mineral premix[2]	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Vitamin premix[3]	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Total calculated values[4]	100	100	100	100	100	100	100	100	100	100
ME(Kcalkg^{-1})	3,200	3,200	3,200	3,200	3,200	3,200	3,200	3,200	3,200	3,200
Crude protein (%)	23.00	23.00	23.00	23.00	23.00	23.00	20.00	20.00	20.00	20.00
Lysine (%)	1.34	1.35	1.35	1.38	1.37	1.28	1.26	1.30	1.32	1.27
Methionine (%)	0.62	0.64	0.60	0.65	0.55	0.58	0.62	0.58	0.61	0.60

[1]T1: Control; T2-T5: Diets containing 5.0, 10.0, 15.0 or 20.0% dried maggots, respectively, [2]Contained per kilogram of diet: Fe, 80; Zn, 80 ; Mn, 70; Cu, 70 ; I, 1.20 ; Se, 0.30 and Co, 0.70 mg, respectively. [3]Contained per kilogram of diet: vitamin A, 10,500 IU; vitamin D_3 4,100 ; vitamin E, 45 ; vitamin K_3 3.0 ; vitamin B_1 2.5 ; vitamin B_2 5 ; vitamin B_6 5 ; vitamin B_{12} 0.02 ; biotin, 0.18 ; niacin, 44 ; pantothenic acid, 17 and folic acid, 1.5 mg,respectively, [4]Calculated by NRC(1994)

Table - 4: Effect of dietary maggots on growth performance in broiler chickens

Item	Diets containing maggots (%)					PSEM[1]
	Control	5.0	10.0	15.0	20.0	
0 to 3 weeks						
Live weight (g)	658	698	665	662	671	7.59
Feed intake (g)	925	931	928	919	941	9.58
FCR[2]	1.40	1.33	1.39	1.39	1.40	0.02
4 to 5 weeks						
Live weight (g)	1,020^{b}	1,077^{b}	1,113^{a}	1,123^{a}	1,107^{b}	9.94
Feed intake (g)	1,889	1,861	1,854	1,852	1,835	35.73
FCR	1.85^{a}	1.72^{b}	1.66^{b}	1.65^{b}	1.66^{b}	0.04
0 to 5 weeks						
Live weight (g)	1,638^{b}	1,775^{a}	1,778^{a}	1,785^{a}	1,778^{a}	20.06
Feed intake (g)	2,814	2,792	2,782	2,771	2,776	41.20
FCR	1.71^{a}	1.57^{b}	1.56^{b}	1.55^{b}	1.56^{b}	0.02

[1]Pooled standard error of mean values, [2]Feed conversion ratio=feed intake / weight gain, ^{a,b}Values with different superscripts within a row differ significantly ($p<0.05$)

Table - 5: Effects of dietary maggots on carcass characteristics in broiler chickens[1]

Carcass weight (I%)	Diets containing maggots (%)					PSEM[1]
	Control	5.0	10.0	15.0	20.0	
Dressing	64.19^{b}	66.07^{a}	65.85^{a}	65.87^{a}	65.34^{a}	0.65
Breast muscle	17.27^{c}	18.84^{b}	19.51^{ab}	19.35^{ab}	18.77^{b}	0.24
Thigh muscle	22.10^{b}	23.47^{a}	23.14^{a}	23.74^{a}	23.58^{a}	0.11
Abdominal fat	2.28	2.16	2.41	2.28	2.33	0.19
Liver	2.88	2.91	2.85	2.97	3.01	0.14

[1]Pooled standard error of mean values, ^{a,b}Values with different superscripts within a row differ significantly ($p<0.05$)

Table - 6: Effects of dietary maggots on meat color of breast muscle from broiler chickens

Item*	Diets containing maggots (%)					PSEM[1]
	Control	5.0	10.0	15.0	20.0	
L*	46.77	46.97	47.55	47.51	46.88	0.74
a*	5.80	5.25	5.73	6.01	5.78	0.22
b*	9.10	8.85	9.67	9.70	8.94	0.28

L*, lightness; a*, redness; b*, yellowness, [1]Pooled standard error of mean values

Table - 7: Effects of dietary maggots on amino acids content of breast muscle in broiler chickens

Amino acid	Diets containing maggots (%)					PSEM[1]
	Control	5.0	10.0	15.0	20.0	
Crude protein	23.74	23.69	24.18	23.81	24.02	0.54
Essential amino acids	11.26	11.66	11.81	11.86	11.54	0.03
Arginine	1.09[b]	0.97[b]	1.07[b]	1.50[a]	0.99[b]	0.01
Histidine	1.06[a]	0.82[ab]	0.75[b]	1.01[ab]	0.96[ab]	0.02
Isoleucine	0.94	0.67	0.75	0.81	0.74	0.01
Leucine	1.85[a]	1.49[b]	1.35[b]	1.23[b]	1.60[ab]	0.02
Lysine	1.44[c]	2.24[b]	2.58[a]	2.01[b]	1.96[b]	0.01
Methionine	0.68[a]	0.62[ab]	0.47[ab]	0.61[ab]	0.36[b]	0.01
Phenylalanine	1.02	1.07	0.95	0.96	0.89	0.01
Threonine	1.02	0.90	1.07	0.94	0.85	0.02
Tryptophan	1.20[b]	2.04[a]	1.97[a]	1.83[a]	1.98[a]	0.01
Valine	0.96[ab]	0.84[b]	0.85[b]	0.96[ab]	1.21[a]	0.35
Nonessential amino acids	10.39[a]	9.60[c]	10.21[ab]	10.10[ab]	10.04[b]	0.02
Alanine	1.17[a]	0.84[b]	1.08[ab]	0.98[ab]	1.25[a]	0.02
Aspartic acid	1.98[a]	0.93[c]	1.07[c]	1.44[b]	1.36[b]	0.01
Cystine	0.26	0.41	0.33	0.27	0.30	0.10
Glutamic acid	3.79[a]	3.59[ab]	3.31[b]	3.03[bc]	2.98[c]	0.02
Glycine	0.93[ab]	1.07[a]	0.95[a]	0.64[b]	0.78[ab]	0.02
Proline	0.74	0.89	0.79	0.70	0.73	0.02
Serine	0.82[b]	1.12[b]	1.54[a]	1.84[a]	1.78[a]	0.01
Tyrosine	0.70[b]	0.75[b]	1.14[ab]	1.20[a]	0.86[b]	0.02
Total	21.65[b]	21.26[c]	22.02[a]	21.96[a]	21.58[b]	0.57

[1]Pooled standard error of mean values, [a-c]Means with different superscripts within a row differ significantly (p<0.05)

utilization of the nutrients within feed (Leenstra, 1989). In poultry, increased dietary protein digestibility aids weight gain in chicks, and weight gain is seen as a result of protein accumulation related to nutrient changes and the given energy content of the feed (Boorman and Eillis, 1996). Relatively high concentrations of dietary amino acids are needed to optimize feed utilization and to support the rapid growth of meat-type chickens. Tissue that has substantial protein content largely contributes to increases in body weight; thus, for this type of chicken, adequate amino acid nutrition is vital for a successful feeding program (NRC, 1994). The results of this study suggest that improving weight gain in broilers through maggot supplementation should prove to be profitable in terms of the chick growth rate, feed conversion ratio, and feed costs. Poultry and other birds eat insects; and since they inherited an ability to degrade maggot protein from their wild bird ancestors (Despines and Axtell, 1995), maggots can be used broadly as a source of animal protein.

Table 5 shows the carcass evaluation results after 35 days of maggot supplementation. The evaluations were conducted with 30 birds taken at random from each treatment group (10 per repeat group). Significant differences were shown between the treatment groups and control group for carcass variables such as dressing percentage, breast muscle, and thigh muscle. Birds from the groups receiving maggot supplementation tended to show significantly higher dressing percentage, breast muscle, and thigh muscle (presented as a ratio to carcass weight) than the control group (p<0.05); while there were no statistically significant differences in liver weight and abdominal fat among the treatment groups. Differences between the treatment and control groups were probably caused by an increased rate of protein accumulation with maggot supplementation, due to the maggots' optimal essential amino acid profile (particularly lysine) and high protein digestibility (Table 2). Higher levels of dietary amino acids are needed to optimize feed utilization efficiency than are needed to maximize weight gain; and the dietary requirement for lysine in order to maximize breast muscle yield in broilers is greater than that needed to maximize weight gain (Acar *et al*., 1991; Bilgili *et al*., 1992). In feeding broilers, nutritional factors such as the protein and energy content of feed can greatly affect carcass characteristics and fat accumulation (Leenstra, 1989). Zuidhof *et al*. (2003) suggested that weight gain in broilers could be attributed to protein accumulation related to nutrient changes and the given energy content of feed.

Table 6 presents the meat color observed in the broiler breast muscle. Nine birds were taken and examined from each treatment group (3 from each repeat pen). There were no significant differences between the groups. Since meat color is a criterion by which consumers determine meat freshness and quality, it is very important to maintain the fresh meat color unique to chicken (Zhu and Brewer, 1998). Breast muscle crude protein and amino acid contents (Table 7) were not significantly different among the treatment groups; however, birds from the experimental groups tended to show significantly higher lysine and tryptophan contents than the control group ($p<0.05$).

It is important to note that the broiler chicks receiving supplemental dried maggots showed greater weight gains than the control group chicks receiving soybean meal (Table 4). This is because the maggot-containing feed had an enhanced nutrient composition as compared to the soybean meal feed, especially for essential amino acids. It also had greater protein and essential amino acid digestibility (Table 2). Therefore, it is considered that maggots, which are the secondary product of biologically processed chicken droppings using house flies, are an appropriate source of protein and energy to help broiler chicks grow and gain weight. It is expected that the utilization of maggots in feed could serve to solve the environmental pollution problems that are caused by the successive accumulation of chicken droppings. In addition, pursuing economic efficiency through feed recycling could prove to be very advantageous in the animal industry.

In conclusion, by feeding diets containing 10 or 15% maggots in broiler chickens, the live weight until attainment of market weight and yields of chicken meat significantly increased. Furthermore, our results suggest that lysine and tryptophan levels of breast muscle were markedly increased when feeding diets containing 5 to 20% maggots. It was obvious that the high protein digestibility of the maggots may acts on the deposition of amino acids in chicken meat. Increased knowledge of the available nutrient profile of maggots as well as least-cost formulation would likely increase the value of maggots relative to diets for broiler. Therefore, the maggots can effectively be used as a diet of low cost for production of high quality carcass and promotion of growth performance in broiler chickens, and also reduction of environmental pollution due to manure (Verheyden *et al.*, 2007; Parthasarathi *et al.*, 2007). In this study, the 10 to 15% level of maggots was the optimal level being suggested for profitable adoption in broiler chickens.

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