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# Effects of Dietary Exogenous Hydrophilic Emulsifier Supplementation on Growth Performance and Carcass Traits in Broilers

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***ABSTRACT*** The effects of dietary exogenous hydrophilic emulsifiers on the growth, nutrient digestibility, and carcass characteristics of broilers were evaluated. A total of 200 one-day-old broilers (Ross 308) were allotted to one of four treatment groups in a randomized complete block design in five replicates with 10 birds per pen during a 5-week growth experimental period. Birds were fed a corn-soybean meal-based diet with or without the addition of 0.025, 0.050, or 0.075% exogenous hydrophilic emulsifiers. The diets contained 3,025 and 3,075 metabolizable energy/kg for Phases 1 and 2, respectively. For each phase and the overall experimental period, body weight gain (linear, $P<0.05$) and feed conversion ratio (linear, $P<0.05$) improved in proportion to the dietary exogenous hydrophilic emulsifier level, while the average daily feed intake was not affected by dietary treatment. Improvement in growth performance by dietary treatments was observed during the last two weeks rather than the first three weeks of the growth phase. In carcass traits, abdominal fat content increased as dietary exogenous hydrophilic emulsifier level increased (linear, $P<0.05$), whereas dietary emulsifier level did not affect the relative weight of the liver, breast, and leg muscles. In conclusion, addition of dietary exogenous hydrophilic emulsifiers from 0 to 0.075% in broiler diets improved the growth rate and feed efficiency of broilers without any deleterious effects on nutrient digestibility, although a corn-soybean meal-based diet had less energy content (3,025 and 3,075 metabolizable energy/kg) for 0-3 weeks and 3-5 weeks, respectively.

(Key words: broiler, carcass traits, growth performance, hydrophilic emulsifier)

## INTRODUCTION

As fat has the highest energy value with 9 kcal/g compared to protein and carbohydrate, it is an expensive ingredient in animal diet. Recently, the price of major feed ingredient is continuously increased due to several reasons such as severe drought and biofuel production, total feed cost is always great concern by animal producers (Geoffrey, 2008). Moreover, the use of supplemental fat and oil in broiler chicken diet as an energy source has become a widespread practice in the feed industry (Melegy et al., 2010), but fat utilization is most important in young bird due to immatured physiological function (Wiseman and Salvador, 1989). Marzooqi et al. (1999) demonstrated that inefficient digestion and absorption of fat have occurred in young chickens due to a low level of endogenous lipase secretion in GI tract. Furthermore, a low rate of bile salt synthesis in young chicks is considered a potential confounding factor (Jackson et al., 1971). It is well known that emulsifier promotes the incorporation of fatty acids into micelles in chicks (Polin, 1980). Augur et al. (1947) and Polin (1980) represented that digestibility of fat increased when emulsifier was mixed with fat in diet before it was fed to rats and chicks. Recently, several dietary emulsifiers were introduced but a few researches investigated the effect of dietary exogenous emulsifiers on performance of broiler (Polin, 1980; Overland et al., 1993; Cantor et al., 1997; Chen and Chiang, 1998; Smulikowa et al., 1999; Soares and Lopez-Bote, 2002). Also, its effects of broiler's growth performance showed inconsistent results. Therefore, this experiment was conducted to evaluate the effects of different levels of dietary exogenous hydrophilic emulsifier on growth performance, nutrient digestibility and

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carcass traits in broilers.

## MATERIALS AND METHODS

### 1. Animals, Diets and Housing

All experimental procedures involving animals were performed in accordance with the Animal Experimental Guidelines of the Seoul National University Institutional Animal Care and Use Committee. A total of 200 one day-old broiler (Ross 308), with an average body weight of 44.0 g were used for 5-week feeding trial at Seoul National University experimental farm. Broilers were allotted to each treatment in 5 replicates with 10 chicks per pen in a randomized complete block design. The birds were fed the experimental diets for 5 weeks (Phase 1: 0 to 3 weeks, Phase 2: 3 to 5 weeks). The experimental diets were formulated to meet or exceed the nutritional requirement of Korean Feeding Standard (KFS) for poultry (2007). However, experimental diet for 5 weeks intentionally contained less than 75 kcal of ME/kg compared to the dietary energy suggested by KFS for poultry (2007). Different levels of exogenous hydrophilic emulsifier were supplemented in the diets at 0, 0.025, 0.050, or 0.075% (Tables 1 and 2). Exogenous hydrophilic emulsifier was powder type of sodium stearoyl-2-lactylate (SOLMAX®50).

**Table 1.** Composition of experimental diet (Phase 1, 0 to 3 weeks); as-fed basis

| Item | Exogenous hydrophilic emulsifier[1] (%) | | | |
|---|---|---|---|---|
| | 0 | 0.025 | 0.050 | 0.075 |
| Ingredients (%) | | | | |
| Corn | 52.98 | 53.00 | 53.05 | 53.07 |
| Soybean meal | 31.29 | 31.30 | 31.32 | 31.34 |
| Wheat bran | 1.16 | 1.10 | 1.01 | 0.94 |
| Corn gluten meal | 5.27 | 5.27 | 5.27 | 5.27 |
| Tallow | 3.50 | 3.50 | 3.50 | 3.50 |
| Fish meal | 2.75 | 2.75 | 2.75 | 2.75 |
| Dicalcium phosphate | 0.85 | 0.85 | 0.85 | 0.85 |
| Limestone | 1.59 | 1.59 | 1.59 | 1.59 |
| Salt | 0.22 | 0.22 | 0.22 | 0.22 |
| Liq. DL-Methionine | 0.09 | 0.09 | 0.09 | 0.09 |
| Liq. Choline-Cl (50%) | 0.10 | 0.10 | 0.10 | 0.10 |
| Anticoccidials | 0.05 | 0.05 | 0.05 | 0.05 |
| Vitamin-mineral premix[2] | 0.15 | 0.15 | 0.15 | 0.15 |
| Emulsifier[1] | 0.00 | 0.03 | 0.05 | 0.08 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 |
| Calculated nutrient composition | | | | |
| Metabolizable energy (kcal/kg) | 3,025 | 3,025 | 3,025 | 3,025 |
| Crude protein (%) | 23.00 | 23.00 | 23.00 | 23.00 |
| Total lysine (%) | 1.19 | 1.19 | 1.19 | 1.19 |
| Total methionine (%) | 0.52 | 0.52 | 0.52 | 0.52 |
| Ca (%) | 1.00 | 1.00 | 1.00 | 1.00 |
| Available P (%) | 0.45 | 0.45 | 0.45 | 0.45 |

[1] Diets contained 0, 0.025, 0.050, 0.075% SOLMAX®50 (Kimin Inc., Seoul, Republic of Korea) on an as-fed basis.

[2] Provided the following quantities of vitamin-mineral mixture per kg of complete diet: vitamin A, 18,000 IU; vitamin $D_3$, 3,750 IU; vitamin E, 30 mg; vitamin $K_3$, 2.7 mg; vitamin $B_1$, 3 mg; vitamin $B_2$, 9 mg; vitamin $B_6$, 4.5 mg; vitamin $B_{12}$, 30 mg; Cal-Pan, 15 mg; niacin, 37.5 mg; folic acid, 1.5 mg; biotin, 75 mcg; Mn, 97.5 mg; Zn, 97.5 mg; Fe, 75 mg; Cu, 7.5 mg; Co, 375 mcg; I, 1.5 mg; Se, 225 mcg; Antioxidant, 9 mg.

**Table 2.** Composition of experimental diets (Phase 2, 3 to 5 weeks); as-fed basis

| Item | Exogenous hydrophilic emulsifier[1] (%) | | | |
|---|---|---|---|---|
| | 0 | 0.025 | 0.050 | 0.075 |
| Ingredients (%) | | | | |
| Corn | 58.09 | 58.08 | 58.22 | 58.14 |
| Soybean meal | 26.89 | 26.90 | 26.92 | 26.94 |
| Wheat bran | 1.21 | 1.18 | 1.00 | 1.03 |
| Corn gluten meal | 5.45 | 5.45 | 5.45 | 5.45 |
| Tallow | 3.50 | 3.50 | 3.50 | 3.50 |
| Fish meal | 2.00 | 2.00 | 2.00 | 2.00 |
| Dicalcium phosphate | 0.80 | 0.80 | 0.80 | 0.80 |
| Limestone | 1.48 | 1.48 | 1.48 | 1.48 |
| Salt | 0.22 | 0.22 | 0.22 | 0.22 |
| Liq. DL-Methionine | 0.06 | 0.06 | 0.06 | 0.06 |
| Liq. Choline-Cl (50%) | 0.10 | 0.10 | 0.10 | 0.10 |
| Anticoccidials | 0.05 | 0.05 | 0.05 | 0.05 |
| Vitamin-Mineral premix[2] | 0.15 | 0.15 | 0.15 | 0.15 |
| Emulsifier[1] | 0.00 | 0.03 | 0.05 | 0.08 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 |
| Calculated nutrient composition | | | | |
| Metabolizable energy (kcal/kg) | 3,075 | 3,075 | 3,075 | 3,075 |
| Crude protein (%) | 21.00 | 21.00 | 21.00 | 21.00 |
| Total lysine (%) | 1.05 | 1.05 | 1.05 | 1.05 |
| Total methionine (%) | 0.46 | 0.46 | 0.46 | 0.46 |
| Ca (%) | 0.90 | 0.90 | 0.90 | 0.90 |
| Available P (%) | 0.40 | 0.40 | 0.40 | 0.40 |

[1] Diets contained 0, 0.025, 0.050, 0.075% SOLMAX®50 (Kimin Inc., Seoul, Republic of Korea) on an as-fed basis.
[2] Provided the following quantities of vitamin-mineral mixture per kg of complete diet: vitamin A, 18,000 IU; vitamin $D_3$, 3,750 IU; vitamin E, 30 mg; vitamin $K_3$, 2.7 mg; vitamin $B_1$, 3 mg; vitamin $B_2$, 9 mg; vitamin $B_6$, 4.5 mg; vitamin $B_{12}$, 30 mg; Cal-Pan, 15 mg; niacin, 37.5 mg; folic acid, 1.5 mg; biotin, 75 mcg; Mn, 97.5 mg; Zn, 97.5 mg; Fe, 75 mg; Cu, 7.5 mg; Co, 375 mcg; I, 1.5 mg; Se, 225 mcg; Antioxidant, 9 mg.

The product was provided by Kimin Inc. (Seoul, Republic of Korea).

All broilers were housed in a rice hull floored, equipped with a feeder and an automatic waterer and allowed *ad libitum* access to feed and water during the whole experimental period. The ambient temperature was maintained at 35℃ for 2 days, 31℃ in the first week and then temperature was gradually decreased by 2℃ per week to 22℃ at the end of the experiment.

## 2. Experimental Procedure

Body weight (BW) and feed intake were recorded at the end of phase 1 and phase 2 to calculate the BW, body weight gain (BWG), average daily feed intake (ADFI) and feed conversion ratio (FCR).

A total of 20 5-week-old broilers were slaughtered for the anatomy trial. Five broilers were selected from each treatment at the end of the experiment. After slaughtering, liver, left breast muscle, left leg muscle samples were collected and weighed. Abdominal fat, considered to be that surrounding the gizzard and intestines, was carefully dissected and weighted. The relative weights of organs and muscle to live BW were calculated.

### 3. Statistical Analysis

The experimental data were analyzed using the General Linear Model (GLM) procedure of SAS software (ver. 9.1; SAS Institute, 2004, Cary, NC, USA). Data on growth performance, a pen was considered as an experimental unit, while individual bird was the experimental unit for carcass data. Linear and quadratic effects for equally spaced treatments were assessed by measurement of orthogonal polynomial contrast. Statistical significance was set at $P<0.05$ and tendencies at $0.05 \leq P \leq 0.10$.

## RESULTS AND DISCUSSION

### 1. Growth Performance

The effects of different levels of dietary exogenous hydrophilic emulsifier on growth performance in broiler are presented in Table 3. During the Phase 1 (0 to 3 weeks), BW and BWG were decreased linearly ($P<0.05$) as dietary emulsifier level increased. However, the BW, BWG, and FCR for Phase 2 (3 to 5 weeks) were linearly improved ($P<0.05$) as dietary emulsifier level increased. For the overall period (0 to 5 weeks), BWG, and FCR were linearly improved ($P<0.05$) in proportion to dietary emulsifier level, while ADFI showed a tendency of quadratic response ($P=0.09$) by dietary emulsifier level.

The observed result of improved growth performance of broilers fed the diets with emulsifier supplementation for the overall period was consistent with the previous findings. Smulikowa et al. (1999) reported that there are significant positive effects of 1% crude rapeseed lecithin in 7 days old chickens. Zobac et al. (1998) also observed that a substantial increase of BW in 21 days old broilers was observed when lecithin was added to diets. Guerreiro (2011) reported that there was no effect of dietary emulsifier on the growth performance of 7-day-old broilers. Dietary emulsifier in broiler diet did not improve the performance of 7-day-old broilers due to their low lipase activity during this period (Jeason et al., 1992; Nir et al., 1993). Lipase activity is improved at 7-day-old broiler but it is less than matured chicken. Azman et al. (2004) found that added soybean oil or beef tallow in broiler diet with lecithin did not make any difference in performance during starter period (0 to 14 days). Marzooqi et al. (1999) demonstrated that inefficient digestion and absorption of fat have occured in young chickens due to a low level of endogenous lipase production. Also a low rate of bile salt synthesis in young chicks is considered a potential confounding factor (Jackson et al., 1971). In chickens the activity and net duodenal secretion of lipase increases as the chick ages (Noy et al., 1995). Nir et al. (1993) observed that fat absorption increases with bird age, as young broilers have a physiological limitation to absorb that nutrient. Those physiological limitations of the digestive system of poultry may be overcome using endogenous and/or exogenous strategies to maximize feed digestion and absorption. Thus, dietary exogenous hydrophilic emulsifier could improve the growth performance of broilers during phase 2 (3 to 5 weeks). The experimental diets were formulated to meet or exceed the nutritional requirement of Korean Feeding Standard (KFS) for poultry (2007). However, experimental diet intentionally contained less than 75 kcal of ME/kg compared to the dietary energy suggested by KFS for poultry (2007) to show the benefit through the addition of dietary exogenous hydrophilic emulsifier, metabolizable energy (ME) in KFS for poultry (2007) was 3,100 and 3,150 kcal of ME/kg for phase 1 (0-3 week) and phase 2 (3-5 week), respectively. And metabolizable energy (ME) in experimental diet was 3,025 and 3,075 kcal of ME/kg for phase 1 (0 to 3 weeks) and phase 2 (3 to 5 weeks), respectively. Waewaree (2016) demonstrated that low energy diet with lysophospholipid could minimize detrimental effects by increasing in bird BW during grower period. Hyun(2014) observed that low energy diet with lysophospholipid could

**Table 3.** Effects of exogenous hydrophilic emulsifier on growth performance of 0 to 5-week-old broiler

| Item | Exogenous hydrophilic emulsifier[1] | | | | SEM[2] | P values | |
|---|---|---|---|---|---|---|---|
| | 0 | 0.025 | 0.050 | 0.075 | | Linear | Quadratic |
| Body weight (g/bird)[3] | | | | | | | |
| Initial | 44.0 | 44.0 | 44.0 | 44.0 | - | - | - |
| Week 3 | 825.1 | 824.8 | 811.2 | 811.7 | 2.821 | 0.04 | 0.25 |
| Week 5 | 1,726.3 | 1,722.2 | 1,810.4 | 1,824.1 | 14.413 | 0.01 | 0.12 |
| Body weight gain (g/bird) | | | | | | | |
| 0 to 3 weeks | 781 | 780 | 767 | 767 | 2.822 | 0.04 | 0.02 |
| 3 to 5 weeks | 945 | 941 | 1,043 | 1,056 | 15.080 | 0.01 | 0.08 |
| 0 to 5 weeks | 1,682 | 1,678 | 1,766 | 1,780 | 14.413 | 0.01 | 0.12 |
| Average daily feed intake (g/bird) | | | | | | | |
| 0 to 3 weeks | 50 | 49 | 50 | 50 | 0.210 | 0.77 | 0.33 |
| 3 to 5 weeks | 113 | 113 | 116 | 115 | 0.530 | 0.20 | 0.24 |
| 0 to 5 weeks | 75 | 78 | 76 | 76 | 0.312 | 0.84 | 0.09 |
| Feed conversion ratio (feed/gain) | | | | | | | |
| 0 to 3 weeks | 1.36 | 1.34 | 1.38 | 1.37 | 0.510 | 0.40 | 0.18 |
| 3 to 5 weeks | 1.69 | 1.70 | 1.57 | 1.54 | 0.020 | 0.01 | 0.08 |
| 0 to 5 weeks | 1.54 | 1.60 | 1.49 | 1.46 | 0.010 | 0.01 | 0.02 |

[1] Diets contained 0, 0.025, 0.050 and 0.075% SOLMAX®50.
[2] Standard error of the mean.
[3] Values are means of five replicate pens per treatment with each pen having 10 birds.

improve growth performance without growth retardation in broiler.

## 2. Carcass Traits

The effects of different levels of dietary exogenous hydrophilic emulsifier on carcass traits in broiler are presented in Table 4. As the dietary emulsifier level increased, a linear and quadratic increases in relative weight of abdominal fat were observed ($P$<0.01). However, there were no significant differences in relative weights of liver, breast and leg muscles. Guerreiro (2011) did not observe any difference in carcass traits of broiler when dietary emulsifier was supplemented. In addition, Cho et al. (2012) demonstrated that dietary emulsifier did not affect the relative weight of liver, breast meat, abdominal fat and gizzard in broilers. In contrast, Kassim and Suwanpradit (1996) reported that low energy diet in broiler chickens from 21 to 42 days of age significantly reduced the abdominal fat percentage and total body fat deposition. Rabie and Szilagyi (1998) also showed that the abdominal fat deposition was reduced significantly in low energy diet in broilers from 18 to 53 days of age. Regarding these results, deposition of abdominal fat was decreased by low dietary energy intake. The current study found that the dietary emulsifier level increased, a linear response was observed in relative weight of abdominal fat. It is possible that dietary emulsifier could partly be attributed to the improved absorption of dietary saturated fat from tallow (Vila and Esteve-Garcia, 1996). Fouad and El-Senousey (2014) observed that increasing dietary energy level to improve feed conversion leads to the increased deposition of fat. Sanz (1999) reported that abdominal fat weight was significantly affected by the dietary fat source. Moreover, inclusion of saturated fats in

**Table 4.** Effects of exogenous hydrophilic emulsifier on relative weights of organs of 5-week-old broilers[1]

| Item | Exogenous hydrophilic emulsifier[2] | | | | SEM[3] | *P* values[4] | |
|---|---|---|---|---|---|---|---|
| | 0 | 0.025 | 0.050 | 0.075 | | Linear | Quadratic |
| Liver (g/100g BW) | 2.00 | 2.31 | 2.46 | 1.89 | 0.069 | 0.75 | 0.30 |
| Abdominal fat (g/100g BW) | 0.93 | 1.41 | 1.25 | 1.90 | 0.080 | 0.01 | 0.01 |
| Breast muscle (g/100g BW) | 7.41 | 8.82 | 8.09 | 8.49 | 0.191 | 0.15 | 0.10 |
| Leg muscle (g/100g BW) | 8.75 | 9.71 | 9.36 | 8.17 | 0.271 | 0.49 | 0.87 |

[1] A total of 20 broilers were used at 5-week-old of age and the average body weight per each treatment was 1,770 g, 1,760 g, 1,760 g, and 1,760 g, respectively.
[2] Treatments: diets contained 0, 0.025, 0.050, 0.075% SOLMAX®50.
[3] Standard error of mean.
[4] Values are means for five boilers per treatment.

broiler diets produced higher fat accumulation both intramuscular fat and abdominal fat than unsaturated fat (Sanz, 1999). Vila and Esteve-Garcia (1996) suggested that abdominal fat deposition increased with increasing fat inclusion level in birds fed tallow. Current study showed abdominal fat level was between 0.93 and 1.9 g/100g BW, and it was lower range compared to Waewaree (2016) and Hyun (2014). Waewaree (2016) reported that 5 week- old broiler had 1.13-1.21 g/100g BW of abdominal fat, and Hyun (2014) observed that 5 week- old broiler had 1.72 -2.18 g/100g BW of abdominal fat.

## 적 요

본 연구는 지방의 이용성을 증가시켜주는 사료첨가용 친수성 유화제(SOLMAX®50)를 육계사료에 수준별 첨가시 육계의 성장성적, 도체성적에 미치는 영향을 검증하고자 수행되었다. 총 200수의 1일령 육용종 수평아리(Ross 308)를 공시하여 4처리 5반복, 반복 당 10수씩 난괴법으로 배치하였다. 처리구는 옥수수-대두박 기초사료에 0, 0.025, 0.050, 0.075%의 수용성 유화제를 첨가하였으며, 사료내 대사에너지함량은 phase1과 phase2 각각 3,025 kcal/kg와 3,075 kcal/kg이었다. 시험에 사용된 수용성 유화제는 주식회사 기민에서 공급받았다. 사양시설은 왕겨 바닥의 평사로 펜별로 사료 급이기와 급수기를 동일하게 설치하였으며, 사료와 물은 무제한 자유채식 및 음수가 가능하도록 하였다. 총 5주 동안의 사양실험에서 유화제의 첨가수준이 증가함에 따라 증체량 및 사료효율이 유의적으로 개선되었다(linear, $P<0.05$). 반면 사료섭취량에는 처리구 간에 유의적인 차이는 발견되지 않았다. 유화제 첨가에 따른 성장효과는 전기 3주보다 후기 2주에 더 큰 긍정적인 영향을 미치는 것으로 관찰되었다. 5주의 사양실험 후 처리구별로 5수씩 선발하여 도체분석을 실시하였다. 도체성적에서 유화제의 첨가수준이 증가함에 따라 복강지방의 무게가 증가하였으나(linear, $P<0.05$), 가슴근육, 다리근육, 간의 무게에 있어서는 유화제의 효과가 나타나지 않았다. 결론적으로 한국가금사양표준(2007)의 에너지 요구량보다 낮은 에너지사료에 유화제의 첨가수준을 0.075%까지 증가시킴에 따라, 육계의 성장성적은 향상되었고 계육생산에는 부정적인 영향을 미치지 않았다.

(색인어: 육계, 친수성 유화제, 성장성적, 도체특성)

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## REFERENCES

Augur V, Rollman HS, Deuel HJ 1947 The effect of crude lecithin on the coefficient of digestibility and the rate of absorption of fat. J Nut 33:177.

Azman MA, Ciftci M 2004 Effects of replacing dietary fat with lecithin on broiler chicken zootechnical performance. Rev Med Vet 8:445-448.

Cantor A, Vargas HR, Pescafore AJ, Straw ML, Ford MJ 1997 Influence of crude soybean lecithin as a dietary energy source on growth performance and carcass yield of broilers. Poult Sci 76:109.

Chen MH, Chiang SH 1998 The Metabolizable energy value of lecithin and factors affecting its efficacy in improving the digestibility of fat in broilers - fat source and age. J Chinese Sos Anim Sci 27(4):459-472.

Cho JH, Zhao PY, Kim IH 2012 Effect of emulsifier and multi-enzyme in different energy density diet on growth performance, blood profiles, and relative organ weight in broiler chickens. J Agri Sci 4:161-168.

Fouad AM, El-Senousey HK 2014 Nutritional factors affecting abdominal fat deposition in poultry: a review Asian Australas. J Anim Sci 27:1057-1068.

Geoffrey SB 2008 Livestock feed cost, concerns and options. CRS Report for Congress. RS 22908.

Guerreiro NA 2011 Emulsifier in broiler diets containing different fat sources. Brazilian J Poult Sci 13:119-125.

Hyun YK 2014 Effect of lysophospholipids supplementation on growth performance, nutrient digestibility, blood profiles and carcass traits in broilers. Thesis of Seoul National University.

Jackson BT, Smallwood RA, Piasecki GJ 1971 Fetal bile salt metabolism. 1. The metabolism of sodium cholate 14C in the fetal dog. J Clin Invest 50:1286-1294.

Jeason SE, Kellog TF 1992 Ontogeny of taurocholate accumulation in terminal ileal mucosal cells of young chicks. Poult Sci 71:367-372.

Kassim H, Suwanpradit S 1996 The effect of energy levels on the carcass composition of the broilers. Asian J Anim Sci 9:331-335.

Korean Feeding Standards for Poultry 2007 Korean Ministry for Agri and Forest.

Marzooqi R, Leeson S 1999 Evaluation of dietary supplements of lipase, detergent, and crude porcine pancreas on fat utilization by young broiler chicks. Poult Sci 78:1561-1566.

Melegy T, Khaled NF, El-Bana R, Abdellatif H 2010 Dietary fortification of a natural biosurfactant, lysolecithin in broiler. African J Agri Res 5(21):2886-2892.

Nir I, Nitsan Z, Mahagua M 1993 Comparative growth and development of the digestive organs and some enzymes in broiler and egg type chicks after hatching. Br Poult Sci 34:523-532.

Noy Y, Sklan D 1995 Digestion and absorption in young chicks. Poult Sci 74:366-373.

Overland M, Tokach MD, Cornelius SG 1993 Lecithin in swine diets. I. Weanling pigs. J Anim Sci 71:1187-1193.

Polin D 1980 Increased absorption of tallow with lecithin. Poult Sci 59:1652.

Rabie MH, Szilagyi M 1998 Effects of L-carnitine supplementation of diets differing in energy levels on performance, abdominal fat content, and yield and composition of edible meat of broilers. Br J Nutr 80:391-400.

Sanz M 1999 Higher lipid accumulation in broilers fed on saturated fats than in those fed on unsaturated fats. Br Poult Sci 40:95-101.

Smulikowa S, Chibowska M, Alloui O, Minorska A 1999 Studies on feeding value for chickens of raw and hydrolized rapeseed lecithin. Oil Crops XIV: 348-357.

Soares M, Lopez-Bote CJ 2002 Effects of dietary lecithin and fat unsaturation on nutrient utilization in weaned piglets. Anim Feed Sci Tech 95:169-177.

Vila B, Esteve-Garcia E 1996 Studies on acid oils and fatty acids for chickens. Rate of inclusion and degree of saturation on fat digestibility and metabolizable energy of acid oils. Br Poult Sci 37:105-117.

Waewaree B 2016 Evaluation of dietary lysophospholipids for broilers chickens and laying hens. Thesis of Seoul National University.

Wiseman J, Salvador F 1989 Influence of age, chemical composition and rate of inclusion on the apparent metabolizable energy value of fats fed to broilers. Poult Sci 30:653-662.

Zobac P, Kumprecht, I, Prokop V, Cmolik J 1998 Use of rapeseed meal and lecithin slops in diets for broiler chickens. Czech J Anim Sci 43(11):511-519.

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