Effect of Dietary Phospholipids on Performance, Intestinal morphology and Fat Digestibility in Broiler Chicks

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Abstract

The experiment was conducted to evaluate the effect of phospholipid (Lecithin) supplementation on growth performance, intestinal morphology and fat digestibility of broilers. A total of 360 one-day-old mix sexed broiler chicks (Ross 308) were randomly allocated to 6 dietary treatments, with 5 replicates and with12 chicks in each replicate. Experimental diets included of: A (basal diet without soybean oil); B (basal diet + soybean oil); C (basal diet without soybean oil + 2 g/kg phospholipid; D (basal diet + soybean oil + 2 g/kg phospholipid); E (basal diet without soybean oil + 2 g/kg phospholipid minus 100 kcal/kg ME); F (basal diet + soybean oil + 2 g/kg phospholipid minus 100 kcal/kg ME). Body weight and weight gain of broilers significantly increased when they fed on B treatment ($P<0.05$); while, feed intake and feed conversion ratio significantly increased in A treatment ($P<0.05$). Abdominal fat was significantly decreased when the birds fed on D and E treatments ($P<0.05$). The fat digestibility in birds received F treatment was significantly higher than other diets ($P<0.05$). The villous height to crypt depth in jejunum and ileum of broilers fed on F treatment significantly higher than other diets ($P<0.05$). In conclusion, supplementation of phospholipid into broilers diet enhanced fat digestibility, villous height to crypt depth ratio of ileum and jejunum at 42 days of age. Additionally, feeding broilers with diet contain soybean oil improved feed intake (FI), body weight (BW) and weight gain (WG) ($P<0.05$); although, lowest feed conversion ratio (FCR) was obtained in basal diet + soybean oil + 2 g/kg phospholipid ($P<0.05$).

Keywords: Broiler; Phospholipid; Performance; Digestibility; Intestinal morphology; Carcass weight

Introduction

Animal fats and vegetable oils are usually added in poultry diets to increase their energy concentration so that growth performance can be improved and industry standards can be achieved (Blanch et al., 1996). The problem of fat digestion is that this process takes place in an aqueous environment, as in gastrointestinal tract, although fats are not water-soluble. This process is naturally mediated by emulsifiers, such as bile salts. In young birds, the assimilation of dietary fats is limited because they have a reduced capacity to produce and secrete bile salts and lipase until their gastrointestinal tract matures (10–14 days of age) (Noy and Sklan, 1995). This limitation causes an inability to form mixed micelles in the intestinal lumen which further decreases fat digestion and absorption of nutrients (Lesson and Atteh, 1983).

Emulsifiers such as phospholipid may aid in fat emulsification optimizing lipase activity and fatty acid incorporation into micelles. Therefore, fat digestion and absorption in young birds could be improved carrying out a positive effect on growth performance throughout production.

Phospholipids have a significant function in the metabolism of animals, particularly in lipid metabolism. In general, plant feedstuffs do not contain high amounts of phospholipids. The most important phospholipids are including phosphatidylcholine, phosphatidylinositol and phosphatidylcholine ethanol amine. Hertramp (2001) claimed that nutrient digestibility in poultry improved by feeding diets enriched with lecithin. Supplementation of lecithin improves growth performance of broiler chickens (Emmert et al., 1996; Huang et al., 2007). Other research reports that the addition of lecithin into broiler diets has no positive effects on growth performance (Blanch et al., 1996; Azman and Siftici, 2004). These contrasts may be associated with an interaction between the type of fat and (or) the use of external emulsifiers. Studies investigating the effect of dietary lecithin on performance of chicken are scarce and limited. This study was designed to assess the effects of dietary phospholipid in commercial diets and low energy diet on growth performance, fat digestibility and gut development in broiler chicks.

Materials and methods

Experimental design, diets and management

Three hundred and sixty one-day-old unsexed broiler chicks (Ross 308) were weighed and randomly divided into 6 dietary treatments with 5 replicate and 12 chicks in each. The temperature was 35^{o}C at the arrival time till first week, and then gradually decreased 2.5 ^{o}C in each week and kept 25 ^{o}C constantly. The lighting program was 23L: 1D hour in rearing phases. The experiment was conducted in a completely randomized design. Feed and water were provided *ad libitum*. All nutrients in diets were formulated based on Ross 308 recommendation (Table 1, 2 and 3). Experimental diets included of: A) basal diet without soybean oil; B) basal diet + soybean oil; C) basal diet without soybean oil + 2 g/kg phospholipid; D) basal diet + soybean oil + 2 g/kg phospholipid; E) basal diet without soybean oil + 2 g /kg phospholipid minus 100 kcal/kg ME; F) basal diet + soybean oil + 2 g/kg phospholipid minus 100 kcal/kg ME. The diets in mash form were provided in four phases: starter (1-14 d), grower (14-28 d) and finisher (28-42 d). The phospholipid (Deoiled Lecithin, 97% Lecithin) that added to diets was provided from Berg and Schmid Sagetechnik Company.

At the end of each rearing phase (14, 28 and 42 d), BW, FI and FCR of broilers were measured. All the pens were check twice a day and the birds that died were collected and weighed for correction of FI and FCR in each phase.

Carcass traits

At the end of experiment (42 d), two birds with body weight similar to mean body weight of their groups selected, feed was withdrawn before weighing and they were slaughtered, weight of carcass, abdominal fat, liver, pancreas, gizzard, heart, cecum, bursa of Fabricius, spleen, weight and length of intestine were measured and calculated based on live weight percentage.

Intestinal morphology

At 42 days of age, the sample of ileum and jejunum of the slaughtered birds were provided and rinsed with buffered saline solution, then 2 cm of each segment was kept in 10% buffered formaldehyde solution and after 24 h the solution was changed and the samples fixed in saline solution for histomorphological measurements (Min et al., 2016). Villous height was clarified from the top of the villous to crypt junction; also, crypt depth was measured from bottom of villous to the crypt. The ratio of villous height and crypt depth was calculated (Tako et al., 2004). Morphological studies were performed on a light microscopic (Olympus CX31, Tokyo, Japan).

Table 1. Ingredients and composition of the diet in starter period (1-14 d)

Ingredients (%)	A	B	C	D	E	F
Corn	60.88	54.8	60.68	54.6	57.38	51.3
Soybean meal	34.5	35.7	34.5	35.7	35.2	36.4
Phospholipid	-	-	0.2	0.2	0.2	0.2
Soybean oil	-	2	-	2	-	2
Dicalcium phosphate	2	2	2	2	2	2
Calcium carbonate	1.2	1.2	1.2	1.2	1.2	1.2
Mineral supplement	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin Supplement	0.25	0.25	0.25	0.25	0.25	0.25
DL-methionine	0.35	0.35	0.35	0.35	0.35	0.35
L-lysine	0.27	0.27	0.27	0.27	0.27	0.27
L-threonine	0.05	0.05	0.05	0.05	0.05	0.05
Salt	0.25	0.25	0.25	0.25	0.25	0.24
Sodium bentonite	-	2.88	-	2.88	2.6	5.48
Calculated chemical composition						
Metabolizable energy (Kcal/kg)	2833	2836	2833	2836	2738	2741
Protein %	21.04	21.04	21.04	21.04	21.04	21.04
Lysine %	1.36	1.36	1.36	1.36	1.37	1.37
Methionine %	0.69	0.69	0.69	0.69	0.69	0.69
Methionine+Cystine %	1.02	1.02	1.02	1.02	1.02	1.02
Calcium %	1.05	1.05	1.05	1.05	1.05	1.05
Available phosphorous %	0.49	0.49	0.49	0.49	0.49	0.49

Each 2.5 kg of vitamin supplemets contained: Vitamin A, 12000000 IU; Vitamin D3, 5000000 IU; Vitamin E, 75000 IU; Vitamin K, 3000 mg; Riboflavin, 8000 mg; Vitamin B12, 125000 mg; Pantotenic acid, 13000 mg; Nicotinic acid, 55000 mg; Folic acid, 2000 mg; Cholin chloride, 18000 mg. Each 2.5 kg of mineral supplement contained: Mg, 56 mg; Fe, 30000 mg; Cu, 4000 mg, Zn, 50000 mg; Se, 150 mg; Mn, 40000 mg; I, 1250 mg A: Basal diet without soybean oil., B: Basal diet+soybean oil., C: Basal diet without soybean oil+2 g/ kg phospholipid., D: Basal diet+soybean oil+2 g/kg phospholipid., E: Basal diet without oil+ 2 g/kg phospholipid minus 100 kilocalories of energy., F: Basal diet+soybean oil+2 g/kg phospholipid minus 100 kilocalories energy. a-b: Values in the same column not sharing common superscript differ significantly ($P \leq 0.05$).

Table 2. Ingredient and composition of the diet in grower period (14-28 d)

Ingredients (%)	A	B	C	D	E	F
Corn	66.41	60.61	66.21	60.41	63.11	57.01
Soybean meal	29.5	30.6	29.5	30.6	30.1	31.3
Phospholipid	-	-	0.2	0.2	0.2	0.2
Soybean oil	-	2	-	2	-	2
Dicalcium phosphate	1.7	1.7	1.7	1.7	1.7	1.7
Calcium carbonate	1.05	1.05	1.05	1.05	1.05	1.05
Mineral premix	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25
DL-methionine	0.3	0.3	0.3	0.3	0.3	0.3
L-lysine	0.25	0.25	0.25	0.25	0.25	0.25
L-threonine	0.04	0.04	0.04	0.04	0.04	0.04
Salt	0.25	0.25	0.25	0.25	0.25	0.25
Sodium bentonite	-	2.7	-	2.7	2.5	5.4
Calculated chemical composition						
Metabolizable energy (Kcal/kg)	2910	2914	2910	2914	2810	2814
Protein %	19.25	19.24	19.25	19.24	19.25	19.24
Lysine %	1.20	1.22	1.20	1.22	1.22	1.24
Methionine %	0.62	0.61	0.62	0.61	0.62	0.61
Methionine+Cystine %	0.92	0.92	0.92	0.92	0.92	0.92
Calcium %	0.90	0.90	0.90	0.90	0.90	0.91
Available phosphorous %	0.45	0.44	0.45	0.44	0.44	0.44

Each 2.5 kg of vitamin supplemets contained: Vitamin A, 12000000 IU; Vitamin D3, 5000000 IU; Vitamin E, 75000 IU; Vitamin K, 3000 mg; Riboflavin, 8000 mg; Vitamin B12, 125000 mg; Pantotenic acid, 13000 mg; Nicotinic acid, 55000 mg; Folic acid, 2000 mg; Cholin chloride, 18000 mg. Each 2.5 kg of mineral supplement contained: Mg, 56 mg; Fe, 30000 mg; Cu, 4000 mg, Zn, 50000 mg; Se, 150 mg; Mn, 40000 mg; I, 1250 mg A: Basal diet without soybean oil., B: Basal diet+soybean oil., C: Basal diet without soybean oil+2 g/ kg phospholipid., D: Basal diet+soybean oil+2 g/kg phospholipid., E: Basal diet without oil+ 2 g/kg phospholipid minus 100 kilocalories of energy., F: Basal diet+soybean oil+2 g/kg phospholipid minus 100 kilocalories energy. a-b: Values in the same column not sharing common superscript differ significantly ($P \leq 0.05$).

Table 3. Ingredient and composition of the diet in finisher period (28-42 d)

Ingredients (%)	A	B	C	D	E	F
Corn	71.18	65.18	70.98	64.98	67.68	61.38
Soybean meal	25	26.2	25	26.2	25.6	26.9
Phospholipid	-	-	0.2	0.2	0.2	0.2
Soybean oil	-	2	-	2	-	2
Dicalcium phosphate	1.6	1.6	1.6	1.6	1.6	1.6
Calcium carbonate	1	1	1	1	1	1
Mineral supplement	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin Supplement	0.25	0.25	0.25	0.25	0.25	0.25
DL-methionine	0.26	0.26	0.26	0.26	0.26	0.26
L-lysine	0.21	0.21	0.21	0.21	0.21	0.21
L-threonine	-	-	-	-	-	-
Salt	0.25	0.25	0.25	0.25	0.25	0.25
Sodium bentonite	-	2.8	-	2.8	2.7	5.7
Calculated chemical composition						
Metabolizable energy (Kcal/kg)	2960	2964	2960	2964	2860	2860
Protein %	17.61	17.61	17.61	17.61	17.60	17.60
Lysine %	1.06	1.08	1.06	1.08	1.069	1.092
Methionine %	0.56	0.55	0.56	0.55	0.55	0.55
Methionine+Cystine %	0.84	0.83	0.84	0.83	0.83	0.83
Calcium %	0.85	0.85	0.85	0.85	0.85	0.85
Available phosphorous %	0.42	0.42	0.42	0.42	0.42	0.42

Each 2.5 kg of vitamin supplemets contained: Vitamin A, 12000000 IU; Vitamin D3, 5000000 IU; Vitamin E, 75000 IU; Vitamin K, 3000 mg; Riboflavin, 8000 mg; Vitamin B12, 125000 mg; Pantotenic acid, 13000 mg; Nicotinic acid, 55000 mg; Folic acid, 2000 mg; Cholin chloride, 18000 mg. Each 2.5 kg of mineral supplement contained: Mg, 56 mg; Fe, 30000 mg; Cu, 4000 mg, Zn, 50000 mg; Se, 150 mg; Mn, 40000 mg; I, 1250 mg A: Basal diet without soybean oil., B: Basal diet+soybean oil., C: Basal diet without soybean oil+2 g/ kg phospholipid., D: Basal diet+soybean oil+2 g/kg phospholipid., E: Basal diet without oil+ 2 g/kg phospholipid minus 100 kilocalories of energy., F: Basal diet+soybean oil+2 g/kg phospholipid minus 100 kilocalories energy. a-b: Values in the same column not sharing common superscript differ significantly ($P \leq 0.05$).

Fat digestibility

The acid insoluble ash (AIA) of the feed and of the excreta was measured using the procedure of Van Keulen and Yang (1977) as adopted by Atkinson et al (1984) for high fat content diets.

From day 38 to 42, broilers were fed diets 0.2% AIA as an internal marker to determine the fat digestibility (Fenton and Fenton, 1979), and ether extract was determined by AOAC method (1994). At d 42, the fecal samples were collected for 24 h, pooled in a cage and then stored at -20^{o}C for determination of fat digestibility. Then samples were dried in an oven for 72 h at 55^{o}C. The following equation was used for calculation of fat digestibility:

Digestibility (%) = 100- (marker in feed/marker in feces)×(nutrient in feces/marker in feed)

Statistical analysis

The obtained data were analyzed in a completely randomized design using the general linear model (GLM) procedure of SAS software (2008). Significant differences among diets were separated by LSD means test at the probability of $P<0.05$.

Results

Performance

The effects of phospholipid on performance parameters are presented in Table 4. Feed intake of broilers in overall rearing phase in C and D treatments significantly differ from control group, and was lower compare to other treatments ($P<0.05$). Body weight and weight gain in B treatment was higher compare to other treatments ($P<0.05$). FCR in overall rearing phase was lower in B, C and D treatments and significantly differ from other treatments ($P<0.05$).

Carcass traits and lymphoid organs

The effects of phospholipid on carcass traits and lymphoid organs are summarized in Table 5. No differences were observed among the experimental diets regarding the weight of carcass, abdominal fat, heart,

gizzard, proventriculus, pancreas and spleen. Abdominal fat weight was numerically increased in D and E treatments (P>0.05). The highest liver weight was obtained in E treatment (P<0.05). Lowest heart, gizzard and proventriculus weights was obtained in B treatment (P>0.05), and pancreas weight was increased in E treatment (P>0.05).
No significant differences was observed in spleen weight (P>0.05); the weight of bursa of Fabricius was significantly decreased in C treatment compare to control group and D treatment (P<0.05).

Fat digestibility

Fat digestibility is significantly affected by phospholipid. The lowest fat digestibility was observed in diet without soybean oil + phospholipids (E treatment), and highest fat digestibility was gained in F treatment (P<0.05).

Small intestine weight, length, and morphology

The effects of phospholipid on intestine weight and length are presented at Table 6. At 42 days of age, the length of jejunum and cecum significantly increased in F treatment (P<0.05), ileum length significantly increased in C treatment (P<0.05), and duodenum length insignificantly increased in E treatment (P>0.05). Weights of duodenum, jejunum and cecum numerically increased in E treatment (P>0.05), while ileum weight significantly increased in E treatment (P<0.05).

No similar trend was observed in morphology of ileum and jejunum at 42 days of age (Table 7). The villous height and villous height to crypt depth ratio in ileum significantly increased in C treatment (P<0.05), and lowest crypt depth was observed in F treatment (P<0.05). The villous height and villous height to crypt depth ratio of jejunum significantly increased by F treatment (P<0.05), and lowest crypt of jejunum was observed in E treatment (P<0.05).

Table 4. Effect of dietary phospholipids on growth performance of broiler chicks in whole period (0-42 d)

Experimental diets	Feed intake (g/d)	Body weight (g)	Weight gain (g/d)	FCR[1] (g/g)
A	101.2[a]	2106.95[b]	49.3[d]	2.06[a]
B	98.2[a]	2287.42[a]	53.6[a]	1.85[bc]
C	90.7[b]	2100.65[b]	49.2[b]	1.84[bc]
D	88.2[b]	2146.00[b]	50.2[b]	1.76[c]
E	98.1[a]	2089.60[b]	48.9[b]	2.01[a]
F	97.0[a]	2186.80[ab]	51.2[b]	1.90[b]
SEM[2]	1.5	18.64	0.44	0.02

1: Feed conversion ratio. 2: Standard error of mean. A: Basal diet without soybean oil., B: Basal diet + soybean oil., C: Basal diet without soybean oil + 2 g/kg phospholipid., D: Basal diet + soybean oil + 2 g/kg phospholipid., E: Basal diet without oil + 2 g/kg phospholipid minus 100 kilocalories of energy., F: Basal diet + soybean oil + 2 g/kg phospholipid minus 100 kilocalories energy. a-b: Values in the same column not sharing common superscript differ significantly (P≤0.05).

Table 5. Effect of dietary phospholipids on carcass traits and lymphoid organs of broiler at 42 d (Live percentage weight)

Experimental diet	Carcass	Abdominal fat	Liver	Heart	Gizzard	Proventriculus	Pancreas	Bursa of Fabricius	Spleen
A	74.89	1.23	2.45 [ab]	0.53	1.83	0.49	1.05	0.069 [a]	0.115
B	73.88	1.17	2.42 [ab]	0.48	1.60	0.44	1.05	0.062 [ab]	0.117
C	74.79	1.08	2.54 [ab]	0.51	1.71	0.45	1.06	0.055 [b]	0.119
D	73.07	0.90	2.34 [b]	0.49	1.72	0.46	1.03	0.067 [a]	0.124
E	73.27	0.92	2.69 [a]	0.51	1.84	0.47	1.12	0.061 [ab]	0.119
F	74.59	1.07	2.38 [b]	0.53	1.76	0.44	1.08	0.062 [ab]	0.111
SEM	0.48	0.05	0.04	0.01	0.03	0.01	0.02	0.001	0.004

SEM: Standard error of mean., A: Basal diet without soybean oil., B: Basal diet+soybean oil., C: Basal diet without soybean oil+2 g/kg phospholipid., D: Basal diet + soybean oil + 2 g/kg phospholipid., E: Basal diet without oil + 2 g/kg phospholipid minus 100 kilocalories of energy., F: Basal diet + soybean oil + 2 g/kg phospholipid minus 100 kilocalories energy., a-b: Values in the same column not sharing common superscript differ significantly (P≤0.05).

Table 6. Effect of dietary phospholipids on length and relative weight of intestine at 42 d

Experimental diets	Length (cm)				Weight (Live weight percentage)			
	Duodenum	Jejunum	Ileum	Cecum	Duodenum	Jejunum	Ileum	Cecum
A	34.60	84.50 [b]	79.60 [b]	39.30 [ab]	0.78	1.98	1.17 [b]	0.93
B	35.70	87.80 [ab]	88.70 [a]	39.90 [ab]	0.77	1.96	1.38 [ab]	0.84
C	35.50	88.30 [ab]	90.2 [a]	39.10 [ab]	0.79	1.98	1.36 [ab]	0.89
D	34.20	84.80 [ab]	84.30 [ab]	38.40 [b]	0.75	1.73	1.18 [b]	0.95
E	37.00	89.80 [ab]	89.80 [a]	38.80 [ab]	0.82	2.05	1.46 [a]	0.99
F	37.00	92.60 [a]	88.25 [ab]	42.5 [a]	0.81	1.87	1.40 [ab]	0.88
SEM [1]	0.5	1.2	1.3	0.6	0.01	0.05	0.04	0.03

Table 7. Effect of dietary phospholipids on villus height, crypt depth and villus height to crypt depth ratio of broiler chicks in Jejunum and Ileum of broiler chick at 42 d

Experimental diets	Ileum			Jejunum		
	Villus height (µm)	Crypt depth (µm)	Villus height to crypt depth	Villus height (µm)	Crypt depth (µm)	Villus height to crypt depth
A	420^{b}	170^{ab}	2.89^{ab}	730^{c}	320^{a}	2.58^{c}
B	530^{ab}	210^{a}	2.61^{b}	830^{b}	230^{ab}	3.85^{ab}
C	560^{a}	160^{ab}	3.69^{a}	880^{b}	270^{ab}	2.46^{abc}
D	490^{ab}	180^{ab}	2.81^{ab}	780^{bc}	280^{ab}	2.80^{bc}
E	420^{b}	160^{ab}	2.65^{b}	590^{d}	210^{b}	3.05^{abc}
F	430^{b}	130^{b}	3.28^{ab}	1007^{a}	280^{ab}	3.93^{a}
SEM [1]	0.02	0.01	0.15	0.03	0.01	0.2

1: Standard error of mean. A: Basal diet without soybean oil; B: Basal diet+soybean oil; C: Basal diet without soybean oil+2 g/kg phospholipid; D: Basal diet+soybean oil+2 g/kg phospholipid; E: Basal diet without oil+ 2 g/kg phospholipid minus 100 kilocalories of energy; F: Basal diet+soybean oil+2 g/kg phospholipid minus 100 kilocalories energy. a-b: Values in the same column not sharing common superscript differ significantly ($P \leq 0.05$).

Discussion

Animal fats and vegetable oils are usually added in poultry diets to increase their energy concentration so that growth performance can be improved and industry standards can be achieved (Blanch et al., 1996, Salehifar et al., 2017). In the present study feeding of phospholipids was attempted to see its effect on growth performance, fat digestibility and gut development in broiler chicks

Performance

At 42 days of age broilers fed supplemented with phospholipids, the body weight and weight gain was not significantly increased ($P>0.05$). The findings of Emmert et al., (1996) demonstrated that broilers fed diet supplemented with choline or deioled lecithin had higher feed intake, which is not confirm present finding. Zobac et al., (1998) found that body weight of broilers at 21 day old increased by adding lecithin. Accordance with present results, Azman and Siftici (2004) indicated that body weight of birds was not affected with lecithin supplementation at 21 and 35 days of age.

In contrast, San Tan et al. (2016) observed that body weight of birds fed diet contains rice bran oil with emulsifier were significantly greater than control group from week 3 to 5. Also, they reported that broilers fed with diets contain rice bran oil with or without emulsifier had similar FCR except for week 5. Dierick and Decuypere (2004) recommended that the contradictory effect of exogenous emulsifier on growth performance could because of saturation of dietary fat that used. Roy et al. (2010) reported that with exogenous emulsifier body weight, feed intake and FCR improved in broilers. The positive effects of emulsifier on growth performance might be due to improved palatability which increases feed and energy intake (Cho et al., 2012).

As observed in present experiment, broilers fed diet with and without soybean oil had more feed intake compare to other treatments to gain their nutrient and energy requirement. In general broilers had the ability to regulate their feed intake based on the energy levels of the diet. Roy et al. (2010) revealed that administration of exogenous emulsifier in diets supplemented with fat, improved growth performance of broilers which is confirm the results of present study.

should be mentioned that the supplementation of emulsifier in broiler diet in order to improve growth performance and nutrient digestibility is more effective in early stage of rearing phase (0-42 days), because secretion and activity of lipase in young chickens is not sufficient and will increase between 40 and 45 days of age (Krogdahl and Sell, 1989). Also, synthesis and circulation of bile salts is still low in young birds (Serafin and Nesheim, 1970), and bile salts supplementation to diets improved the fat absorption and growth of chickens (Polin, 1980; Kussaibati et al., 1982). It seems that discrepancies in obtained results could be related to the type of emulsifier and basal diet that used. In addition, lysophospholipids are powerful surfactants and improved mixing of digesta, reduce the size of the emulsion droplet, and promote the enzyme across to lipids in the gastrointestinal tract.

Carcass traits and lymphoid organs

As mentioned previously, weights of liver and bursa of Fabricius affected by experimental diets ($P<0.05$). The findings of Chao et al (2012) supported the obtained result; they indicated that inclusion of 0.05% sodium

steroyl-2-lactylate had less effect on carcass yield when added to diets of 150 kcal/kg less than the commercial suggestion. Also, Guerreiro et al., (2011) did not observe effect of emulsifier on carcass traits of broiler chicks.

Diets with or without soybean oil plus phospholipids and minus 100 kcal energy increased abdominal fat cavity and liver weight of broilers (P>0.05). In agreement with obtained results, Guerreiro et al., (2011) did not observe any differences in carcass traits of broilers fed with emulsifier supplementation.

The current study also found an increase in pancreas weight of the group that fed on diet without oil plus phospholipid, which was accordance to Raju et al., (2011), who observed that pancreas weight of broilers increased with 0.5 g/kg lysolecithin. The increase of relative weight of pancreas may promote the hydrolysis of fats in diet (Boontiam et al., 2016). In birds liver has a vital role in lipid metabolism of the body, and 95% of the de novo fatty acid synthesis takes place in liver (Theil and Lauridsen, 2007). Current results are in line with the findings of Huang et al (2007), who observed that birds fed diets supplemented with lecithin had better liver weight.

Lymphoid organs

Dietary supplementation of phospholipids had no significant effect on spleen weight, whereas weight of bursa of Fabricius significantly decreased (P<0.05). In consistent with this finding, Cho et al. (2012) found that inclusion of 0.05% sodium steroyl-2-lactylate could enhance spleen weight. In experiment that Zhao and Kim (2017) conducted, relative weight of spleen and bursa of Fabricius of broilers were not affected by reduced energy level and lysophospholipid supplementation. Siyal et al. (2017) indicated that relative weights of bursa of Fabricius and spleen were not affected by soy lecithin during days 21 and 42, which coincided with the findings of present study. Wang et al. (2016) reported that relative weight of spleen and bursa of Fabricius of broilers did not affect by emulsifier and carbohydrase inclusion in broiler diet.

Fat digestibility

It is worth nothing that adding soybean oil plus phospholipids minus 100 kcal (F treatment) significantly enhanced fat digestibility (P<0.05); while, diet without oil plus phospholipids minus 100 kcal (E treatment) significantly decreased fat digestibility (P<0.05). Similar to obtained results, Soares and Lopez-Bote (2002) reported that adding lecithin in piglets diet enhanced apparent digestibility of unsaturated fatty acids more than saturated fatty acids in their diets. Zhao et al. (2015) reported that in weanling pigs fed a low energy diet that used tallow as fat source, nutrient digestibility improved by lysophospholipid.

Schwarzer and Adams (1996) observed a slight improvement in fat digestibility when lysophospholipid were added to broiler diets, which support the obtained results. Also, Zhang et al. (2011) stated that the use of lysophosphatidylcholine in broiler diets significantly improved apparent digestibility of fatty acids as C16:0, C18:1 n9 and C18:1 n7 from 14 to 17 days and C18:2 and C18:3 n 3 from 35 to 28 days.

Contrast with our results, Overland et al., (1995) found no effect of soylecithin on digestibility of lard; while, Jones et al., (1992) stated a positive effect of lecithin on digestibility of lard. Contrary, San Tan et al., (2016) observed that fat digestibility of rice bran oil and rice bran oil plus emulsifier were not significantly different in their experiment.

The improvement in role of phospholipids in fat digestion is their emulsifying traits and micelle formation in digestive tract (Schwarzer and Adams, 1996). The fat source that used in broiler diets strongly affected the nutrient digestibility (Jansen et al., 2015). These contradiction results may be because of differences in basal diets, source and amount of fat administration, structure and amount of emulsifier that added to diets (Zhang et al., 2011).

Small intestine morphology

The morphology of intestine is one of the important parameters to determine gut health. Changes in intestinal morphology such as decreased villous height or increased crypt depth have been considered to cause tissue damage induced by involving pathogens (Nabuurs et al., 1993). Similarly, Boontiam et al. (2016) demonstrated that jejunum villous height was significantly increased by adding 0.05% lysophospholipid in broiler diet, so the surface area of the epithelial cells increases and more nutrient will be absorbed. In recent study, crypt depth of jejunum in diet free of oil and with phospholipid significantly decreased, which is similar to findings of Boontiam et al. (2016). The diminished crypt depth shows the lower rate of epithelial cell destruction, inflammation, and sloughing of the intestinal part from bacterial infections (Yason et al., 1987).

Totally, the enhancement of intestinal mucosa may have primary influences on changes of intestine morphology, absorptive capacity, and protective mechanism and finally effect on bird performance and immunity (Boontiam et al., 2016). In terms of gross anatomy, broilers fed phospholipid had longer and heavier small intestine.

In contrast, Maisonnier et al. (2003) showed that intestinal weight of broiler fed exogenous emulsifier was lower than group without emulsifier. Overall, supplementation of phospholipid in broilers diet improved carcass weight, fat digestibility, villous height to crypt depth ratio in ileum and jejunum. Additionally, the FI, BW and WG

of broilers fed on diets contain soybean oil was higher than other treatments (P<0.05), and FCR of broilers decreased by feeding basal diet + soybean oil + 2 g/kg phospholipid (P<0.05).

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