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Effect of Dietary Supplementation of Some Emulsifiers on Growth Performance, Carcass Traits, Lipid Peroxidation and Some Nutrients Digestibility in Broiler Chickens

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ABSTRACT

For Five weeks feeding trail, one hundred and eighty one day old chicks were used to investigate the effect of dietary supplementation of some emulsifiers on growth performance, carcass traits in broiler chickens and some nutrients digestibility in broiler. The birds were randomly divided into Six groups, each group were divided into Three replicate (Ten birds per replicate) and fed the experimental diets; group1 (G1) fed on the basal diet without additives as control, group 2 (G2) fed basal diet with bile acids(Bas), group 3 (G3) fed basal diet with Bile acids and Lecithin (L), group 4 (G4) fed basal diet with bile acids and polyethylene glycol ricinoleate (PGR), group 5 (G5) fed basal diet with lecithin and group 6 (G6) fed basal diet with polyethylene glycol ricinoleate. The results showed nonsignificant ($p \geq 0.05$) differences in final body weight, total weight gain and total feed conversion ratio between all experimental groups but the results of total feed intake showed significant ($p<0.05$) increase in bile, bile with lecithin and lecithin supplemented groups compared with the control one. Liver index showed significant ($p<0.05$) increase in bile group while bile with PGR group showed significant ($p<0.05$) decrease compared with the control one. Abdominal fat showed significant ($p<0.05$) increase in bile and bile with PGR groups. The obtained results of lipid peroxidation (malondialdehyde content) in both liver and breast muscle meat showed nonsignificant ($p \geq 0.05$) differences among all experimental groups. Poly unsaturated fatty acid content in meat showed nonsignificant ($p \geq 0.05$) difference between all experimental groups but there was a numerical increase in all treated groups compared with the control one. The results of dry matter, protein and fat digestibility showed nonsignificant ($p \geq 0.05$) differences between all experimental groups.

Key Words: Broilers, bile acids, lecithin, polyethylene glycol ricinioleate, performance, carcass traits, nutrients digestibility

1. Introduction

Worldwide animal production increasing in the last years, caused mainly by the growing in global population, put in risk the availability and the supply of traditional ingredients included in broiler feeding Viñado et al. (2019). Fats and oils are important energy sources in feed formulation and due to their high energy density. In recent years, because of the ever-increasing energy costs, there is greater interest in maximizing the use supplemental fats as nutritionists strive to increase the dietary energy density to meet the requirements of high-performing contemporary birds Maertens et al. (2015) and Ravindran et al. (2016). Recent trend in broiler production aimed to provide rations containing feed additives to improve efficiency and get maximum returns in shortest possible time Srinivasan et al. (2020).

Emulsifiers are the substances either natural as soy-lecithin, milk derived casein, lysophatidylcholine or lysolecithin and bile acids, or synthetic as glycerol polyethylene glycol ricinoleate, and sodium stearoyl-2-lactylate which can stabilize the mixture of two products such as oil and water that do not mix together and prevents the coalescence of the globules of the dispersed phase and using exogenous emulsifiers in broiler diets must be looked into because feeding of nutrient dense diets containing added fat is almost inevitable to exploit the full growth potential of the high yielding broiler strains and it`s the mode of action depends mainly on increasing the active surface of fats, allowing the action of lipase enzyme, which hydrolyze triglyceride molecules into monoglycerides and fatty acids and favor the formation of micelles consisting of lipolysis products Roy et al. (2010), Guerreiro Neto et al. (2011) and Upadhaya et al. (2019). The efficacy of emulsifying agents can be used with different vegetable oils and various levels of metabolisable energy. Siyal et al. (2017,b).

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Bile acids are intended for use in animal feed as a novel feed additive to enhance fat absorption by its principal role is emulsification, and thus facilitation of the absorption of lipids as well as lipid-soluble matters (Liu et al., 2010). Soy lecithin is the by-product of soybean oil refinery which is available commercially and can be incorporated in the diet as an alternative source of energy. Soy lecithin is also suitable for improving antioxidant status and has ability to protect against oxidative stress (Siyal et al., 2017,a). Polyethylene glycol ricinoleate founded to be an effective synthetic emulsifier and considered as a feed additive component in the dietary regimen of high-yielding broiler chickens for augmenting nutrient utilization and feed conversion in broilers (Roy et al., 2010).

2. Material and methods

2.1. Birds, experimental design and feeding program

A total of one hundred and eighty one day old commercial Ross 308 chicks of mixed sex were randomly allotted into 6 groups; each group was sub-divided into 3 replicates (10 chicks/ replicate). The chicks were fed on corn-soybean meal-based diets for five weeks in all growth stages, starter (first two weeks of age) and grower till the end of the experiment. The emulsifiers used are: emulsifiers 1 was Runeon® produced by Shandong Longchang Animal Health Product Co Ltd. and imported by Aldakhlyia Poultry Company and consists of deoxycholic acid: 231g, chenodeoxycholic acid: 66 g and corn starch up to 1 kg, it was added according to the manufacture recommendation (500g/ton), emulsifier 2 was Bergapur® produced by Berg + Schmidt Company and imported by Profarm Company and consists of Deoiled lecithin, 97% (pure lecithin). The product was added according to the manufacture recommendation (500g/ton) and emulsifier 3 was Volamel Extra® produced by Nukamel N.V. (Olen, Belgium) and imported by Aldakhlyia Poultry Company and consists of 20% polyethylene glycol riconoleate (PGR) and added according to the manufacture recommendation (500g/ton). The basal diet was formulated to meet the requirements of growing Ross chicks according to the breed manual recommendation of Ross 308 (2019). The chemical analysis of the basal diets was calculated according to the table of NRC (1994). The 1st group of chicks was considered as a control group and fed on basal diet in the starter and grower rations, while the 2nd group was fed on basal diet supplemented with bile acids, the 3rd group was fed on basal diet supplemented with bile acids and lecithin, the 4th group was fed on diet supplemented with bile acids and PGR, the 5th group was fed on basal diet supplemented with lecithin and the 6th group was fed on basal diet supplemented with PGR.

2.2. Measurements

2.2.1. Growth measurement:

The total body weight, weight gain, feed intake and feed conversion ratio were calculated.

2.2.2. Evaluation of carcass traits

At the end of the experimental period, 3 birds from each dietary treatment were randomly taken, fastened for 6 hours then weighed and slaughtered to complete bleeding then eviscerated, and the weight of edibles (liver), and nonedible parts (abdominal fat) were measured. The dressing percentage was calculated.

2.2.3. Measurement of Malondialdehyde content (lipid peroxidation)

Malondialdehyde was estimated by colorimetric method according to Ohkawa et al. (1979) by using Biodiagnostic kits.

Sample collection

At the end of the experimental period, 3 birds from each dietary treatment were randomly taken then slaughtered and the liver and part of the breast muscle meat of each hen were separately frozen till the MDA analysis.

Principle:

Thiobarbituric acid (TBA) reacts with Malondialdehyde (MDA) in acidic media at temperature of 95Co for 30 min to form thiobarbituric acid reactive product the absorbance of the resultant pink product can be measured at 534 nm.

2.2.4. Poly unsaturated fatty acids content in meat

Poly unsaturated fatty acids in broiler right breast meat samples of the experimental groups were estimated according to AOAC 1990 (page 831).

Lipid extraction was originally described by Folch et al. (1957) chloroform-methanol reagents. For methylenation, a method including the combination with sodium methoxide (NaOCH3) will be explained, followed by an acid catalyzed method with boron trifloride methanol solution (BE3 /MeOH). All lipid fractions (free fatty acids) will be estrified by using this combined method Nuernberg et al. (2007).

2.2.5. digestibility determination

At the end of the experiment digestibility trials were carried out to determine the apparent digestibility coefficients of different nutrients.

Digestibility can be determined by accurately measuring feed intake and fecal output.

Sample collection

At the end of experiment, 3 birds from each treatment were taken and each was put in separate cage which allowed a complete separation between each group and fastened overnight. The excreta were quantitatively collected for 3 successive days during which both feed consumption and fecal matter data were also recorded.

The excreta were dried in hot air oven at 60 ^{o}C for 3 days then at 105 ^{o}C for 3 hours, then finally ground and stored until chemical analysis for determination of nutrients was performed.

Fecal nitrogen determination

The fecal nitrogen was determined following the procedures outlined by Jakobsen et al. (1960).

Determination of dry matter and crude nutrients

Analytical dry matter (DM) was determined by oven-drying at 105oC for at least 3 hrs. and constant weight was obtained AOAC, (1985).

Table (1) Ingredient composition (%) and the calculated analysis (%) of the experimental diets

Item	Starter diet (1-14 days)	Grower (15 -35 days)
Yellow corn, ground	**52.4**	**54.7**
Soybean meal (44% CP)	**34.24**	**31.6**
Corn gluten (60% CP)	**5.8**	**5.45**
Soybean oil	**3**	**4.05**
Ground limestone	**1.53**	**1.4**
Mono calcium phosphate	**1.4**	**1.32**
L-Lysine	**0.35**	**0.27**
DL-Methionine	**0.2**	**0.13**
L-Threonine	**0.03**	**0.03**
Sodium bicarbonate	**0.2**	**0.2**
Sodium chloride	**0.25**	**0.25**
Choline chloride	**0.1**	**0.1**
Antimycotoxin	**0.1**	**0.1**
Anticoccidial	**0.05**	**0.05**
Anticolstridial	**0.05**	**0.05**
Premix	**0.3**	**0.3**
Calculated analysis of the basal diets %		
Crude Protein %	**22.76**	**21.55**
ME (Kcal /kg)	**3000**	**3097**
Cal/protein ratio	**131.8**	**143.71**
Calcium%	**0.96**	**0.88**
Available P%	**0.48**	**0.49**
Ether extract %	**5.3**	**6.4**
Lysine%	**1.45**	**1.25**
Methionine %	**0.57**	**0.52**

Vitamins and minerals premix was Hy-mix® produced by Misr feed additives company and composed of (per 3 kg) vitamin A 12000000 IU, vitamin D3 4000000 IU, vitamin E 60000 mg, vitamin K3 3000 mg, vitamin B1 2000 mg, vitamin B2 6500 mg, vitamin B6 5000 mg, vitamin B12 20 mg, niacin 45000 mg, biotin75 mg, folic acid 2000 mg, pantothenic acid 12000 mg, choline chloride 1000 g manganese 100 g, zinc 80 g, iron 45 g, iodine 1g,copper 10 g. , selenium 0.2 g and cobalt 0.1 g.

Monocalcium phosphate was Hi-phos 23, containing 22.7% phosphorus and 17% calcium produced by Rotem Kimyevi Madder SAN.VETIC A.S.

Lysine-HCL was L-lysine monohydrochloride 98.5% pure, produced by Archer Daniels Midland Company, USA.

DL-Methionine was Met Amino, DL methionine grade 99%, produced by Evonik Degussa Antwerpen.

Choline chloride was Havay®,choline chloride 60% produced by GHW Vietnam Chemical Co., Ltd.

Antimycotoxin feed additive was AG- BOND, USA and composed of HASCS Aluminum calcium silicate 100%.

Anticlostridial feed additive was licomix 44 premix® produced by Zeotis Suzhou manufacturing Co. Ltd , China. Consists of 44 g lincomycin and soya hulls as carrier. **Anticoccidial drug** was Maduramix produced by Delta Vet Trading Company.

While crude protein of feed samples was determined by using Kjeldahl method according to Singh and Pradhan (1981). Crude fiber was determined according to AOAC (2000); method 950.02). Moreover ether extract was determined according to Bligh and Dyer (1959) technique as modified by Hanson and Olly (1963). Finally ash contents of feed and fecal samples were determined by incineration at 550Co for 6 hrs. in muffle furnace according to AOAC (1985).

Samples of feed and feces were dried then kept for chemical analysis (calcium and phosphorus) and nutrient digestibility was calculated according to the following formula:

Nutrient digestibility = 100 – (100x % acid insoluble ash in feed / % acid insoluble ash in feces) x % nutrient in feces / % nutrient in feed) Goddard and Mclean (2001).

2.2.6. Statistical analysis

Data obtained in this work were statistically analyzed for analysis of variance (ANOVA) and Duncan's multiple range tests using the SPSS programming tool (IBM SPSS. 20) to assess significant differences.

3.**Results**

3.1. growth performance

The results of the final body weight gain showed nonsignificant ($p \geq 0.05$) differences among all experimental groups but showed numerical increase by 2.1%, 0.79% and 3.5% in bile, bile with lecithin and lecithin supplemented groups respectively compared with the control one.

The results of the total body weight gain showed nonsignificant ($p \geq 0.05$) differences among all experimental groups but showed numerical increase by 2.1%, 0.79% and 3.5% in bile, bile with lecithin and lecithin supplemented groups respectively compared with the control one.

The results of the total body weight gain showed nonsignificant ($p \geq 0.05$) differences among all experimental groups but showed numerical increase by 2.1%, 0.79% and 3.5% in bile, bile with lecithin and lecithin supplemented groups respectively compared with the control one.

Total feed intake showed significant ($p<0.05$) increase in bile, bile with lecithin and lecithin supplemented groups by 1.24%, 1.18%, 0.12% and 1.46% respectively compared with the control one while both PGR supplemented groups showed nonsignificant ($p \geq 0.05$) difference compared with the control one but PGR with bile showed numerical increase by 0.12%.

Total feed conversion ratio showed that there was nonsignificant ($p \geq 0.05$) difference between all experimental groups at the end of the experiment but there was a numerical decrease in bile and L supplemented groups (groups2&4) by 0.67% and 2.01% respectively, compared with the control group while both bile with lecithin group and PGR group were the same TFCR as the control one.

3.2. Carcass traits

The present results of dressing % showed nonsignificant ($p \geq 0.05$) differences between all experimental groups but there was a numerical increase in PGR supplemented groups (4&6 groups) by 3.25% and 5.28% and bile supplemented group had a numerical decrease by 2.5% than the control one while lecithin supplementation with or without bile had a negligible effect on dressing %. Liver index in this experiment showed significant differences between the experimental groups where the bile supplemented group showed significant ($p<0.05$) increase by 26.8% compared with the control one and the bile with PGR group showed significant ($p<0.05$) decrease by 19.4% than the control one while the other groups showed nonsignificant ($p \geq 0.05$) difference but with numerical increased liver index in lecithin supplemented group by 14.5% and numerical decrease in PGR supplemented group by 16.5% compared with the control one. Regarding to abdominal fat content, there was a significant ($p<0.05$) increase in both bile and bile with PGR supplemented groups by 34% and 20.7%, while the other supplemented groups showed nonsignificant ($p \geq 0.05$) differences compared with the control one but showed a numerical increase in L supplemented group by 20.1% and numerical decrease in bile with lecithin group by 36% compared with the control one.

3.3. lipid peroxidation

Effect of dietary supplementation of some emulsifiers on lipid peroxidation (malondialdehyde content) in meat and liver tissues in different groups at the end of the experiment is summarized in Table (4). The obtained results of MDA content in both liver and breast muscle meat showed nonsignificant ($p \geq 0.05$) differences among all experimental groups but there was a numerical decrease in MDA content in liver in both bile and bile with lecithin supplemented groups (groups 2 and 3) by 5.6% and 4.95% and there was a numerical decrease in MDA content in muscle in PGR supplemented groups (groups 4 and 6) by 2.5% and 5.6%.

3.4. Poly unsaturated fatty acids content in meat

The effect of dietary supplementation of some emulsifiers on broiler meat content of poly unsaturated fatty acids is explained in Table (٤). The present results showed that there was nonsignificant ($p \geq 0.05$) difference between all experimental groups but there was a numerical increase in all treated groups compared with the control one by 95.1%, 105.9%, 114.9%, 104% and 181.2% respectively.

3.5. Some nutrients digestibility

Effect of dietary supplementation of some emulsifiers on some nutrients digestibility in different groups at the end of the experiment is summarized in Table (5).

3.5.1. Fat digestibility

The results of fat digestibility at the end of the experiment showed nonsignificant ($p \geq 0.05$) differences between all experimental groups but there is a numerical increase in ether extract digestibility in lecithin supplemented groups and PGR supplemented groups (groups 3, 4, 5 and 6) by 1%, 2.7%, 1% and 3.3% respectively.

3.5.2. Protein digestibility

The results of protein digestibility showed nonsignificant ($p \geq 0.05$) differences between all experimental groups but there was numerical increase in protein digestibility in emulsifiers treated groups than the control one by 3.7%, 3.3%, 6%, 2% and 3% respectively

3.5.3. Dry matter digestibility

The results of dry matter digestibility showed nonsignificant ($p<0.05$) differences between all experimental groups but there was a numerical increase in emulsifiers treated groups than the control one by 4.3%, 6.3%, 8.3%, 6.3% and 5.9% respectively.

Table (2) Effect of dietary supplementation of some emulsifiers on broiler`s performance

Item	G 1 (control)	G 2 (BAs)	G 3 (BAs + L)	G 4 (BAs + PGR)	G 5 (L)	G 6 (PGR)
Initial weight (g)	47.97±0.33a	47.80±0.36a	47.93±0.30a	47.90±0.31a	47.93±0.28a	47.80±0.35a
Final weight (g)	2100.55±36.53a	2144.9±46.58a	2117.2±36.58a	2060.8±42.36a	2174.1±44.75a	2093.3±42.83a
TWG (g)	2052.7±36.23a	2096.4±46.16a	2068.96±36.33a	2012.3±42.15a	2125.5±44.54a	2045.3±42.52a
TFI (g)	3028.17±7.46b	3065.80±4.42a	3063.83±2.29a	3031.20±10.53b	3072.40±3.74a	3022.53±1.77b
TFCR (%)	1.49±0.026a	1.48±0.032a	1.49±0.026a	1.52±0.027a	1.46±0.03a	1.49±0.038a

Values are expressed as means ±standard error. Mean values with different letters in the same row differ significantly at P <0.05

Table (3): Effect of dietary supplementation of some emulsifiers on carcass traits of broilers

Group / items	G 1 (control)	G 2 (BAs)	G 3 (BAs + L)	G 4 (BAs+PGR)	G 5 (L)	G 6 (PGR)
Dressing %	72.91±0.37a	71.12±1.13a	73.31±1.39a	75.28±0.87a	72.35±0.37a	76.76±2.89a
Liver % (g)	3.1±0.20bc	3.93±0.24a	3.1±0.06bc	2.5±0.15d	3.55±0.19ab	2.68±0.13cd
Abd. Fat %	1.64±0.09ab	2.13±0.46a	1.05±0.23b	1.98±0.08a	1.79±0.23ab	1.65±0.04ab

Values are expressed as means ±standard error. Mean values with different letters in the same row differ significantly at P <0.05

Table (4): Effect of dietary supplementation of some emulsifiers on lipid peroxidation of broiler`s liver and meat tissues and meat content of poly unsaturated fatty acids

Group / Items	G 1 (control)	G 2 (BAs)	G 3 (BAs + L)	G 4 (BAs+PGR)	G 5 (L)	G 6 (PGR)
MDA (n.mol/g) Liver	8.08±1.25a	7.63±0.66a	7.68±0.44a	8.93±0.75a	9.95±1.82a	9.9±1.12a
MDA (n.mol/g) Muscle	11.25±2.73a	12.98±3.46a	12.22±1.52a	10.97±0.64a	11.73±2.20a	10.62±1.12a
PUFA (g/100g muscle)	1.01±0.60a	1.97±0.91a	2.08±0.19a	2.17±0.11a	2.06±0.73a	2.84±0.28a

Values are expressed as means ±standard error. Mean values with different letters in the same row differ significantly at P <0.05

Table (5): Effect of dietary supplementation of some emulsifiers on some nutrients digestibility

Group / Items	G 1 (control)	G 2 (BAs)	G 3 (BAs + L)	G 4 (BAs+PGR)	G 5 (L)	G 6 (PGR)
Fat%	91±2.52a	90±2.00a	92±2.31a	93.67±1.45a	92±2.31a	94.33±1.20a
CP%	79±0.58a	82.67±0.33a	82.33±1.20a	85±2.08a	81±2.08a	82±1.33a
Dry matter %	71.67±0.33a	76±1.00a	78±2.08a	80±2.00a	78±2.08a	77.33±2.60a

Values are expressed as means ±standard error. Mean values with different letters in the same row differ significantly at P <0.05

4.Discussion:

The obtained results explained in Table (2) including BWG and FCR showed nonsignificant (p≥0.05) differences between all experimental groups, these nonsignificant (p≥0.05) results may be regarded as explained by Pantaya et al. (2020) and Cho et al. (2012) who explained this to the composition of feed between treatments had the same composition so it did not cause differences in body weight gain and emulsifier in low-density diets can partially improve growth performance while the present experiment was performed on standard basal diets. The supplementation of bile acids in this experiment didn`t produce significant (P<0.05) effect may be regarded to Krogdahl (1985) who demonstrated that the recirculation of bile is poor in newly hatched chickens. Cheah et al. (2017) demonstrated that the effect of emulsifier on broiler performance was dependent on the ME level used in the diet formulations and ages of the bird. The inconsistent effect of exogenous emulsifiers on growth performance may be due to the degree of saturation of the dietary fat used and some of the components in natural bile acids act synergistically and elicit an effect which not seen in the synthetic or purified bile acids (Dierick and Decuypere, 2004; Lai et al., 2018,a). In addition to Karimi et al. (2011) demonstrated that bovine bile powder has no effects on performance and for better results this must be associated with a multi enzyme in broiler diets. Furthermore San Tan et al. (2016) reported that supplementation with exogenous emulsifier based on PGR could be beneficial for birds fed diets containing high unsaturated: saturated fatty acid ratio. Also Zaefarian et al. (2015) suggested that the effectiveness of emulsifier was probably within a short period and thus the increased AME may not be sufficient to affect broilers performance.

The obtained results of the performance are in line with Rezaeipour et al. (2016) and Lai et al. (2018,b) who recorded that the supplementation of bile acids had nonsignificant (p≥0.05) effects on growth performance parameters. Also agree with Azman and Ceftci (2004); Viñado et al. (2019); Vinado et al. (2020) and Shen et al. (2021) who found that the inclusion of lecithin did not induce any significant (p≥0.05) effects of broiler growth performances. In addition agree with Kaczmarek et al. (2015) and San Tan et al. (2016) who demonstrated that the PGR supplementation had a negligible effect on broiler performance.

The differences in the results may due to the differences in application of either the types or the amount of emulsifiers used or basal diet structure or source and amount and degree of saturation of dietary fat (Dierick and Decuypere, 2004; Zhang et al. 2011; Zavareie and Toghyani, 2018; Arshad et al., 2020).

The obtained results of the performance disagree with Piekarski et al. (2016) who reported that the chenodeoxycholic acid had a significant ($p \geq 0.05$) reduction of feed intake and body weight compared to the control while Kamran et al. (2020) who reported that PGR had positive effect on broiler performance. Also, Bontempo et al. (2016) demonstrated that the emulsifier supplementation in broiler diets consisting of oleic acid in combination with glycerol polyethylene glycol ricinoleate had a positive effect on growth performance.

The major goals of the poultry industry are to increase the carcass yield and to reduce carcass fatness, mainly the abdominal fat pad is considered one of the important carcass traits and is a problem in modern broiler strains (Fouad and El-Senousey, 2014; Rezaeipour et al., 2016). The accumulation of the abdominal fat in poultry may be as a result of the balance between the fat absorbed from the diet, the endogenous synthesis of fat (lipogenesis) and the catabolism of fat by β-oxidation (lipolysis) (San Tan et al., 2016). The increase in liver weight regarded to the increase in lipid metabolism in the liver as a result of soybean oil and emulsifiers supplementation (Zosangpuii et al. 2015).

Furthermore, Upadhaya et al. (2017) reported that the increase in liver weight may be due to the increase in metabolic activity related to improved fat digestibility, while Ge et al. (2019) reported that the increased liver may be associated with increased hepatic fat deposition and bile acids could alleviate high energy-induced adverse effects on hepatic fat deposition and liver index.

On the other hand, the reduced liver index in PGR supplemented groups may be attributed to Arshad et al. (2020) who reported that the liver is a principal organ for detoxification and bile production, and its size is directly associated with functional load. Also Roy et al. (2010) reported that the liver fat concentration in the PGR supplemented groups suggestive of an efficient and rapid removal rate of lipids from the liver.

The present results are in line with Etop et al. (2020) who reported that liver was significantly improved in broilers fed diets supplemented with 100g & 150g bile acid per ton feed. Furthermore the results are in line with Huang et al. (2007); Mahmoodi et al. (2016) and Zavareie & Toghyani (2018) who observed that birds fed diets supplemented with lecithin had better liver weight and agree with Alzawqari et al. (2016) reported that DBA in the diets did not affect carcass dressing% or breast muscle. Guerreiro-Neto et al. (2011) Mahmoodi et al. (2016) reported that lecithin supplementation had non-significant ($p \geq 0.05$) effect on carcass traits of broiler. Also, Huang et al. (2008) conducted that the percentage of abdominal fat was not significantly ($p \geq 0.05$) affected by soy-lecithin. The present results are supported by Saleh et al. (2020) reported that breast muscle and heart were not affected addition of PGR emulsifier. Furthermore, Roy et al. (2010); Upadhaya et al. (2017); Kamran et al. (2020) and Srinivasan et al. (2020) demonstrated that there is no significant difference ($p \geq 0.05$) was noticed in dressing percentage, breast meat yield and carcass parameters.

On the other, hand the present results disagree with Etop et al. (2020) who reported that dressing % was significantly improved ($P<0.05$) for broilers fed diets supplemented with 100g & 150g bile acids/ton feed.. Also the present results disagree with Bontempo et al. (2016) who demonstrated that the emulsifier supplementation in broiler diets consisting of oleic acid in combination with glycerol polyethylene glycol ricinoleate had a positive effect carcass dressing.

The results concerning to abdominal fat content disagree with Ge et al. (2019) and Lai et al. (2018,a) who reported that bile acids decreased the abdominal fat content and disagree with Rezaeipour et al. (2016) who reported that abdominal fat not affected by dietary supplementation with bovine bile salt powder. In addition, the results disagree with Shen et al. (2021) who reported significant ($p<0.05$) decrease in abdominal fat content in broilers in lecithin supplemented groups compared with the control.

Regarding to liver index the present results disagree with Parsaie et al. (2007) who reported that bile acids supplementation in broiler reduced the weight of the liver with consideration they depend on wheat-based diets also disagree with Arshad et al. (2020) and Ge et al. (2019) who reported a significant ($p<0.05$) decrease in liver weight due to dietary cholic acid while Rezaeipour et al. (2016) reported that liver index not affected by dietary supplementation with bovine bile salt powder. In addition disagree with Huang et al. (2007) and Zavareie & Toghyani (2018) who observed that birds when fed diets supplemented with lecithin had better liver weight while Saleh et al. (2020) reported that liver index were not affected addition of PGR. Furthermore, disagree with Siyal et al. (2017,a) who reported that L decrease gizzared weight while Etop et al. (2020) reported that gizzard was improved in broilers fed diets supplemented with 100g & 150g bile acid.

Several feed additives such as emulsifiers and antioxidants in poultry diets has been recognized as an effective strategy to alleviate the impaired effects induced by oxidants on broiler performance, oxidative stress is harmful to animals that may alleviate their immune response and affects their performance by generating reactive oxygen species (Siyal et al., 2017,a). The supplementation of soy lecithin improved meat quality and its stability substantially against oxidative deterioration during refrigerated storage condition by lowering TBA (Nagargoje et al., 2016).

Brewer et al. (1992) assessed that the TBARS value is fresh broiler meat in the range of 0.2 mg malondialdehyde (MDA)/kg or less, and that 4.0 mg MDA/kg or more is rancid. In this experiment the effect of the supplementation of bile acids and exogenous emulsifiers had no significant ($p \geq 0.05$) effect on malondehyde content in liver and meat and according to Nagargoje et al. (2016) the present results are all within the normal range because the values are less than 0.2 mg MDA/kg.

The present results agree with An et al. (2020) who reported that the supplementation of exogenous emulsifier in broiler feed was considered to have no significant ($p \geq 0.05$) effect on TBARS value. On the other hand, the present results disagree with Boulos et al. (2011), Dani Preetha (2011), Nagargoje et al. (2016) and Siyal et al. (2017,a) who reported that lecithin had significantly decreased hepatic malondialdehyde values. Also disagree with Saleh et al. (2020) who reported that liver TBARs was nonsignificantly ($p \geq 0.05$) decreased by synthetic emulsifier supplementation.

In all species, meat fatty acid composition can be changed via the diet, more easily in single-stomached pigs and poultry where the linoleic, α-linolenic and long-chain polyunsaturated fatty acid content responds quickly to raised dietary concentrations (Wood and Enser 1997).

Poultry products have become the primary source of long-chain polyunsaturated fatty acids, with one of the most effective solutions being to increase the accretion of PUFAs in chicken products via the adjustment of fatty acids in poultry diets and enhancing polyunsaturated fatty acid content of poultry meats can be associated with chemical oxidative stability and loss of sensory quality Interest on the enrichment of poultry meat with n-3 fatty acids has increased given its important role in human health. Recently there is shift from quantity production to quality production (Shunthwal and Sheoran, 2017; Mu and Kitts, 2018; Alagawany et al., 2019). The emulsifier supplementation in broiler ration can help to dissolve the free fatty acids which are hardly soluble in bile salt micelle alone and thereby increases the digestibility and deposition of fatty acid in the body tissue (Roy et al., 2010).

The present results agree with Saleh et al. (2020) who reported that, poly unsaturated fatty acids content in broiler meat were not significantly affected by addition of emulsifier.

Each type of exogenous emulsifier used in broiler feed may have different influence on intestinal digestion and energy digestibility with the addition of emulsifiers in broilers may vary according to the composition and proportion of the fat source in the feed (Jones et al., 1992 and Zaefarian et al., 2015). The action of fat emulsifier as an emulsifying agent for dietary fat produce better formation of emulsion droplets in the gut which leads to a higher degree of lipolysis of triglycerides so absorption of fat can be enhanced (Cho et al., 2012; Drazbo et al., 2018). The emulsifiers are reported to increase the integration of micelles formation in the gut lumen, which in turn increases the fat digestibility (Zhao et al., 2015). The dietary addition of emulsifiers not only favors fat digestibility but also increases the digestion of other nutrients because dietary lipids could cover other nutrients lowering their digestion Zhang et al. (2011).

It is reported that the exogenous emulsifiers alone do not support proper fat digestion in poultry and lecithin as an exogenous emulsifier in the ration did not notably improve the intestinal fat assimilation and the apparent metabolizable energy of dietary fats because of the effectiveness of emulsifier was probably within a short period and thus the increased AME may not be sufficient to affect broilers performance (Azman and Ceftci, 2004; Zaefarian et al., 2015; Serpunja and Kim, 2018).

Compared to lecithin, PGR is more hydrophilic and dissolves more free fatty acids, which are largely insoluble in bile salt micelles alone and respectively increases the digestibility of saturated fatty acids and may specifically enhance the activities of digestive enzymes and fat absorption, which may improve the biological values of increased energy density diets (Zaefarian et al., 2015; Yin et al., 2018).

The results of this study agree with Lammasak et al. (2018) who reported no significant ($p \geq 0.05$) effects were observed in dry matter, crude protein and ether extract when used porcine bile powder. In addition the present results agree with Liu et al. (2020) who reported that there was no significant ($p \geq 0.05$) influences were observed on the nutrient digestibility parameters; whereas, there have numerical increasing tendency on the fat digestibility in the broilers fed with lecithin supplemented diets. Also the present results agree with Arshad et al. (2020) who reported that bile acids had no effect on fat digestibility. Furthermore Huang et al. (2007) reported that the lecithin in diet containing soybean oil had no effects observed in apparent dry matter, crude protein and ether extract digestibility. Also agree with San Tan et al. (2016) who reported that the fat digestibility was not affected by using PGR as emulsifier when used rice bran oil.

The contradiction results with the present results may be because of the differences in basal diets, structure and amount of emulsifier, the source and amount of fat used and the level of dietary fat may also influence the effectiveness of exogenous emulsifier in aiding digestion (Zhang et al., 2011; Zosangpuii et al., 2015).

On the other hand the present results disagree with Alzawqari et al. (2010) who reported a linear increase ($P < 0.05$) in fat digestibility with DOB. Furthermore disagree with Arif et al. (2016) who reported that fat emulsifier (lecithin) significantly improved ($p<0.05$) dry matter and ether extract digestibility. Also disagree with Roy et al. (2010) and Kaczmarek et al. (2015) and who reported that supplementation with PGR on broiler chickens improved fat digestibility. Furthermore disagree with Saleh et al. (2020) who investigated that both protein and lipids utilization were increased by emulsifier supplementation. In addition disagree with Upadhaya et al. (2017) and Kamran et al. (2020) who demonstrated that PGR showed higher DM and crude fat digestiblities when PGR was supplemented at a higher level.

5. Conclusion

From the results of the study it could be concluded that the dietary supplementation of bile acids and lecithin in broilers improved body weight, weight gain and feed conversion ratio and also improved economic efficiency and European production efficiency factor.

Use of emulsifiers (bile acids, lecithin and polyethylene glycol ricinoleate) improved dressing%, poly unsaturated fatty acids content in meat and some nutrients digestibility.

References

Alagawany, M.; Elnesr, S.S.; Farag, M.R.; Abd El-Hack, M.E.; Khafaga, A.F.; Taha, A.E.; Tiwari, R.; Yatoo, M.; Bhatt, P.; Khurana, S.K. and Dhama, K. (2019). Omega-3 and Omega-6 fatty acids in poultry nutrition: Effect on production performance and health. Animals, 9; 573.

Alzawqari, M.; Kermanshahi, H.H. and Moghaddam, H. (2010). The effect of glycine and desiccated ox bile supplementation on performance, fat digestibility, blood chemistry and ileal digesta viscosity of broiler chickens. Global Veterineria, 5 (3):187-194.

Alzawqari, M.H.; Al-Baadani, H.H.; Alhidary, I. B.; Al-Owaimer, A.N. and Abudabos, A.M. (2016). Effect of taurine and bile acid supplementation and their interaction on performance, serum components, ileal viscosity and carcass characteristics of broiler chickens. South Africa Journal of Animal Science, 46 (4).

An, J.S.; Yun, W.; Lee, J.H.; Oh, H.J.; Kim, T.H.; Cho, E.A.; Kim, G.M.; Kim, K.H.; Lee, S.D. and Cho, J.H. (2020). Effects of exogenous emulsifier supplementation on growth performance, energy digestibility, and meat quality in broilers. Journal of Animal Science Technology, 62(1):43-51.

AOAC (1985). Official Methods of Analysis. 14th Edition, Association of Official Analytical Chemists, Washington DC, No. 43.292. 7.001, 7.009, 7.006.

AOAC (1990). Official Methods of Analysis of the Association of Chemists. Analysis of the Association of Chemists, Washington, DC., pp: 223-225, 992-995.

AOAC (2000). Official Methods of Analysis 942.05. Animal feed chapter 4 p. 5.

Arif, M.; Abbas, M. T.; Saeed, M.; Reyad-ul-ferdous, M.; Hassan, M. A.; Arain, M. A. and Rehman, A. (2016). Emulsifier Effect on Fat Utilization in Broiler Chicken . Asian Journal of Animal Veterinary Advances, 11 (3): 158-167.

Arshad, M.A.; Bhatti, S.A.; Hassan, I.; Rahman, M.A. and Rehman, M.S. (2020). Effects of Bile Acids and Lipase Supplementation in Low-Energy Diets on Growth Performance, Fat Digestibility and Meat Quality in Broiler Chickens. Journal of Brazilian Poultry Science, 22 (2).

Azman, M.A. and Ciftci, M. (2004). Effects of replacing dietary fat with lecithin on broiler chicken zootechnical performance. Revue de Medecine Veterinaire, 155 (8-9): 445-448.

Bligh, E.G. and Dyer, W.J. (1959). A rapid method of total lipid extraction and purification. Canadian Journal of Biochemistry and Physiology, 37(8):911-7.

Bontempo, V.; Comi, M. and Jiang, X.R. (2016). The effects of a novel synthetic emulsifier product on growth performance of chickens for fattening and weaned piglets. Animals, 10(4):592-597.

Boulos N.Z.; Abdel-Khalek, A.M.; Selim, N.A.,;Shabaan, M.; Radwan, N. L. and Mobarez, S.M. (2011). Improving the utilization of dry fat in broiler diets during summer season. Proceeding of the Egg Meat Symposia 2011. September 4–8, Leipzig, Germany.

Brewer, M.S.; Ikins, W.I.Z. and Harbers, C.A.Z. (1992). TBA values, sensory characteristics, and volatiles in ground pork during long term frozen storage: effects of packaging. Journal of Food Science, 57:558–63.

Cheah, Y. S.; Loh, T. C.; Akit, H. and Kimkool, S. 2017. Growth performance, abdominal fat and fat digestibility in broiler chicken fed with synthetic emulsifier and natural biosurfactant. Indian Journal of Animal Sciences, Vol.87 No.4 pp.464-472.

Cho, J.H.; Zhao, P.Y. and Kim, I.H. (2012). Effects of emulsifier and multi-enzyme in different energy density diet on growth performance, blood profiles, and relative organ weight in broiler chickens. Journal of Agriculture Science, 4 (10):161-168.

Dani Preetha, S.A (2011). Quality characteristics of fresh and stored meat as influenced by supplementation of soy acid oil and crude soy lecithin alone or in combination in Ven Cobb broiler diet. M.V.Sc thesis submitted to Indira Gandhi Krishi Vishwavidyalaya, Raipur, India.

Dierick, N.A and Decuypere, J.A. (2004). Influence of lipase and/or emulsifier addition on the ileal and faecal nutrient digestibility in growing pigs fed diets containing 4% animal fat. Journal of Science Food Agriculture, 84:1443-1450.

Drażbo, A.; Kozłowski, K. and Croes, E. (2018). The effect of emulsifier on growth performance and fat digestibility in turkeys. Annals of Animal Science, 19(2) 421-431.

Etop, S,C, ; Nwaoru, C.E.; Oshibanjo, D.O and Ukpong, A.C. (2020). Synergistic effects of dietary supplemental bile acids on performance and carcass characteristics of selected breeds of broiler chickens. Global Journal of Agriculture Research, 8 (1);19-25.

Folch, J.; Lees, M. and Sloane, G.H. (1957). A simple method for the isolation and purification of total lipids from animal tissues. Journal of Biological Chemistry, 226, 497-509.

Fouad, A.M. and El-Senousey, H.K. (2014). Nutritional Factors Affecting Abdominal Fat Deposition in Poultry. Asian-Australasian Journal of Animal Sciences. 27(7): 1057-1068.

Ge, X.K.; Wang, A.A.; Ying, Z.X.; Zhang, L.G.; Su, W.P.; Cheng, K.; Feng, C.C.; Zhou, Y.M.; Zhang, L.L. and Wang, T. (2019). Effects of diets with different energy and bile acids levels on growth performance and lipid metabolism in broilers. Poultry Science, 98 (2): 887–895.

Goddard, J.S. and McLean, E. (2001). Acid-insoluble ash as an inert reference material for digestibility studies in tilapia, Oreochromis aureus. Aquaculture, 194, 93– 98.

Guerreiro Neto, A.C.; Pezzato, A.C.; Sartori, J.R.; Mori, C.; Cruz, V.C.; Fascina, V.B.; Pinheiro, D.F.; Madeira, L.A. and Gonçalvez, J.C. (2011). Emulsifier in broiler diets containing different fat sources. Brazilian Journal of Poultry Science;13 (2).

Hansen, R.J. and Walzem, R.L. (1993). Avian fatty liver hemorrhagic syndrome: a comparative review. Advanced Veterinary Science Comparative Medicine, 37:451-68

Huang, J.; Yang, D. and Wang, T. (2007). Effects of replacing soy-oil with soy-lecithin on growth performance, nutrient utilization and serum parameters of broilers fed corn-based diets. Asian Australian Journal of Animal Science, 20 (12).

Huang, J.; Yang, D.; Gao, S. and Wang, T. (2008). Effects of soy-lecithin on lipid metabolism and hepatic expression of lipogenic genes in broiler chickens. Livestock Science, 118, (1–2): 53-60.

Jakobsen, P.E.S.; Kisston, G. and Nielson (1960). "Furgmed Fjerbarge" digestibility trials with poultry 322. Bertning Fra Forsge Laboratoriet udigivet, statens.

Jones, D.B; Hancock, J.D.; Harmon, D.L and Walker, C.E. (1992). Effects of exogenous emulsifiers and fat sources on nutrient digestibility, serum lipids, and growth performance in weanling pigs. Journal of Animal Science, 70:3473-3482.

Kaczmarek, S.A.; Bochenek, M.; Samuelsson, A. and Rutkowski, A. (2015). Effects of glyceryl polyethylene glycol ricinoleate on nutrient utilisation and performance of broiler chickens. Archives. Animal Nutrition; 69 (4): 285-296.

Kamran, J.; Mehmood, S.; Mahmud, A. and Saima, (2020). Effect of fat sources and emulsifier levels in broiler diets on performance, nutrient digestibility, and carcass parameters. Brazilian Journal of Poultry Science, 22 (1).

Karimi, K., Esmaeilpour, V., Rezaeipour, V. (2011) Effects of bovine bile powder and enzyme treatment on performance of broilers fed high lipid diets. In: European Federation of Animal Science (EAAP) – 62nd annual meeting. Stavanger, Norway, 29 August – 2 September. The Netherlands: Wageningen Academic Publishers.

Krogdahl, A. (1985). Digestion and absorption of lipids in poultry. The Journal of Nutrition; 115, (5) : 675–685.

Lai, W.; Huang, W.; Dong, B.; Cao, A.; Zhang, W.; Li, J.; Wu, H. and Zhang, L. (2018, a). Effects of dietary supplemental bile acids on performance, carcass characteristics, serum lipid metabolites and intestinal enzyme activities of broiler chickens. Poultry Science; 1;97(1):196-202.

Lai, W.; Cao, A.; Li, J.; Zhang, W. and Zhang, L. (2018, b). Effect of high dose of bile acids supplementation in broiler feed on growth performance, clinical blood metabolites, and organ development. Journal of Applied Poultry Research, 27, (4): 532–539.

Lammasak, K.; Kijparkorn, S. and Angkanaporn, K. (2018). Porcine bile powder supplementation of a high fat broiler diet in relation to growth performance and nutrient digestion. Animal Production Science, 59(7): 1310-1317.

Liu, J.; Yang, Y.; Wang, J.; Fu, G. and Li, Y. (2010). Nutritive peculiarity of bile acid and its application in poultry production. China Animal Husbandry & Veterinary Medicine. 2010-01.

Liu, X.; Yoon, S.B. and Kim, I.H. (2020). Growth Performance, Nutrient Digestibility, Blood Profiles, Excreta microbial counts, meat quality and organ weight on broilers fed with de-oiled lecithin emulsifier. Animals, 10(3), 478.

Maertens, L.; Leleu, S.; Rovers, M.; Segers, L. and Delezie, E. (2015). The addition of a nutritional emulsifier improves broiler performance in an energy diluted diet. 20th European Symposium on Poultry Nutrition | 24–27 August . Prague, Czech Republic. P-044 (ID 168).

Mahmoodi, P.; Hasan, A.; Hosna Hajati, H. and Javadi, M. (2016). Effects of soy-lecithin, soy-oil and tallow on performance and expression of SREBP-1 gene in broiler chickens. Pizhūhishhā-yi ʻulum-i dāmī-i Īrān; 7-3 (11).. 294-304.

Mu, K. and Kitts, D. (2018). Use of soy lecithin to improve nutritional quality of poultry meats and its effect on stability and sensory attributes. Nutrition and Food Science, 8:4.

Nagargoje, S.B.; Dhumal, M.V.; Nikam, M.G and Khose, K.K. (2016). Effect of crude soy lecithin with or without lipase on performance and carcass traits, meat keeping quality and economics of broiler chicken. International Journal of Livestock, 6(12).

NRC. (1994). Nutrient Requirements of Poultry. 9thed, National Academy Press, Washington, DC.

Nuernberg, K., Dannenberger, D., Ender, K., and Nuernberg, G. (2007). Comparison of different methylation methods for the analysis of conjugated linoleic acid isomers by silver ion HPLC in beef lipids. Journal of Agriculture and Food Chemistry, 55: 598–602.

Pantaya, D.; Widayanti, A.; Jadmiko, P. and Utami, M.D. (2020). Effect of bile acid supplementation in broiler feed on performance, carcass, cholesterol, triglycerides and blood glucose. IOP Conference Series: Earth and Environmental Science, 411, 2nd Int. Conference on Food and Agriculture. Bali Nusa Dua Convention Center, Bali, Indonesia.

Parsaie, S.; Shariatmadari, F.; Zamiri, M.J. and Khajeh, K. (2007). Influence of wheat based diets supplemented with xylanase, bile acid and antibiotics on performance, digestive tract measurements and gut morphology of broilers compared with a maize-based diet. British Poultry Science, 48 (5), 594-600.

Piekarski, A.; Decuypere, E.; Buyse, J. and Dridi, S. (2016). Chenodeoxycholic acid reduces feed intake and modulates the expression of hypothalamic neuropeptides and hepatic lipogenic genes in broiler chickens. General and Comparative Endocrinology, 1;229:74-83.

Ravindran, V.; Tancharoenrat, P.; Zaefarian, F. and Ravindran, G. (2016). Fats in poultry nutrition: Digestive physiology and factors influencing their utilization. Animal Feed Science and Technology. 213:1-21.

Rezaeipour, V.; Alinejad, H. And Asadzadeh, S. (2016). Growth performance, carcass characteristics and blood metabolites of broiler chickens fed diets formulated on total or digestible amino acids basis with bovine bile salts powder and soybean oil. Journal of Central European Agriculture, 17(2), 272-28.

Roy, A.; Haldar, S.; Mondal, S. and Ghosh, T. (2010). Effects of Supplemental Exogenous Emulsifier on Performance, Nutrient Metabolism, and Serum Lipid Profile in Broiler Chickens Veterinary Medicine International.; 2010,:9.

Saleh, A.A.; Amber, K.A.; Mousa, M.M.; Nada, A.; Awad, W.; Dawood, M.; Abd El- Moneim, A.; Ebeid, T. and Abdel-Daim, M.M. (2020). A Mixture of Exogenous Emulsifiers Increased the Acceptance of Broilers to Low Energy Diets: Growth Performance, Blood Chemistry, and Fatty Acids Traits. Animals, 10, 437.

San Tan, H.; Zulkifli, I.; Farjam, A.; Goh, Y.; Croes, E.; Partha, S. and Tee, A. (2016). Effect of exogenous emulsifier on growth performance, fat digestibility, apparent metabolisable energy in broiler chickens. Journal of Biochemistry and Micobiology, 4(1): 7-10.

Serpunja, S. and Kim, I.H. (2018).The effect of sodium stearoyl-2-lactylate (80%) and tween 20 (20%) supplementation in low-energy density diets on growth performance, nutrient digestibility, meat quality, relative organ weight, serum lipid profiles, and excreta microbiota in broilers. Poultry Science, 98:269–175.

Shen, Y.; Zhang,S. Zhao, X and Shi, S. (2021). Evaluation of a lecithin supplementation on growth performance, meat quality, lipid metabolism, and cecum microbiota of broilers. Animals, 11(9): 2537.

Shunthwal, J. and Sheoran, N. (2017). Influence of linseed oil feeding on performance and fatty acid composition of muscles in broiler chicks. Journal of Pharma Innovation; 6(11): 268-273.

Singh, R. and Pradhan, k. (1981). Forage evaluation. Allied publisher Put. Ltd., New Delhi, India; 225-260.

Siyal, F. A.; Abd El-Hack, M. A.; Alagawany, M.; Wang, C.; Wan, X.; He, J.; Wang, M.; Zhang, L.; Zhong, X.; Wang, T. and Dhama, K. (2017,a). Effect of Soy Lecithin on Growth Performance, Nutrient Digestibility and Hepatic Antioxidant Parameters of Broiler Chickens. International Journal of Pharmacology; 13 (4): 396-402.

Siyal, F. A.; Babazadeh, D; Wang, C. and Arain, M. A. (2017,b). Emulsifiers in the poultry industry. World's Poultry Science Journal Volume 73, (3):611-620.

Srinivasan, G.; Arul, N.; Thanaseelaan, V.; Ruba, A. and Chauhan, S. (2020). Effect of Emulsifier in Low Energy Ration Containing Rice bran oil on Growth Performance of Broiler Chickens. Journal of Current Microbiology Applied Sciences. 9(6): 1117-1123.

Upadhaya, S.; Lee, J.S.; Jung, K.J. and Kim, I.H. (2017). Influence of emulsifier blends having different hydrophilic-lipophilic balance value on growth performance, nutrient digestibility, serum lipid profiles, and meat quality of broilers. Poultry Science, 97(1).

Upadhaya, S.D.; Yun, K.S.; Zhao, P.Y.; Lee, I.S. and Kim, I.H. (2019) Emulsifier as a Feed Additive in Poultry and Pigs Animal Nutrition and Feed Technology. 19 (2):323- 336.

Viñado, A.; Castillejos, L.; Rodriguez-Sanchez, R. and Barroeta, A. C. (2019) Crude soybean lecithin as alternative energy source for broiler chicken diets. Poultry Science; 98, (11): 5601–5612.

Viñado, A.; Castillejos L. and Barroeta, A.C. (2020). Soybean lecithin as an alternative energy source for grower and finisher broiler chickens: impact on performance, fatty acid digestibility, gut health, and abdominal fat saturation degree. Poultry Science, 99(11):5653-5662.

Wood, J.D. and Enser, M. (1997). Factors influencing fatty acids in meat and the role of antioxidants in improving meat quality. 1997. British Journal of Nutrition,78(1): S49-S60.

Yin, J.; Min, H. and Kim, H. (2018). Effects of supplemental glycerol polyethylene glycol ricinoleate in different energy density diets on the growth performance, blood profiles, nutrient utilization, and excreta gas emission of broilers. Korean Journal of Agricultural Science. Vol.45 .(2) p. 219 – 228.

Zaefarian, F; Romero, L.F. and Ravindran, V. (2015). Influence of high dose of phytase and an emulsifier on performance, apparent metabolisable energy and nitrogen retention in broilers fed on diets containing soyoil or tallow. British Poultry Science, 56(5):590-597.

Zavareie, H. N. and Toghyani, M. (2018). Effect of dietary phospholipids on performance, intestinal morphology and fat digestibility in broiler chicks. Journal of Livestock Science. 9: 107-115.

Zhao, P.Y.; Li, H.L.; Hossain, M.M. and Kim, I.H. (2015) Effect of emulsifier (lysophospholipids) on growth performance, nutrient digestibility and blood profile in weanling pigs, Animal Feed Science Technology, 207, 190–195.

Zhang, B.; Haitao, L.; Zhao, D.; Guoa, Y. and Barri, A. (2011). Effect of fat type and lysophosphatidylcholine addition to broiler diets on performance, apparent digestibility of fatty acids, and apparent metabolizable energy content. Animal Feed Science and Technology, 163: 177-184.