Indian J. Anim. Nutr. 2025. 42 (3): 429-437
doi: 10.56093/IJAN.v42i3.14

Indian Journal of
Animal Nutrition

Effect of Supplementing Feed Emulsifier on the Digestibility of Energy and Performance of Broiler Chicken Fed Sub-Optimal Levels of Metabolizable Energy

S.V. Rama Rao[1]*, K. Nagaraja Kumari, S. Anusha [2,] T. Srilatha[3], S. Sai Pavan[2] and D. Nagalakshmi[3]
[1]ICAR-Directorate of Poultry Research, Rajendranagar, Hyderabad-500030, Telangana, India
[2]Sri Ramadhootha Poultry Research Farm Pvt Ltd, Hyderabad, India
[3]PVNR Telangana Veterinary University, Hyderabad, 500 030, Telangana, India
* Correspondence: svramarao1@gmail.com

ABSTRACT

Feed emulsifier (FE) improves the digestibility of the feed, thereby reducing dietary nutrient requirements. An experiment was conducted to study the effect of supplementing graded concentrations of FE on the growth performance, carcass traits, and ileal digestibility of energy in broiler chicken (1- 42d of age) fed sub-optimal levels (less 100 kcal/kg) of metabolizable energy (ME). Broiler male chicks (n=1250; Cobb-430) at day old were randomly allotted to five dietary groups, each with 10 replicates having 25 broiler chicks in each pen. Maize-soybean meal-based diet with the recommended concentrations of nutrients (control diet, CD) was prepared. A basal diet (BD) with sub-optimal concentrations of ME was prepared. A commercial FE (combination of equal concentration of 5% lyso-phosphatidyl choline and phosphatidylcholine) was supplemented to the BD at four graded concentrations (0, 100, 200, and 300g/ton). All the diets were fed *ad libitum* from day 1 to 42d of age. The performance data indicated a trend of linear (P =0.056) increase in feed efficiency with the dose of FE. Contrast analysis revealed that the FE at the highest concentration (300g/ton) was comparable to that of the control group. The breast meat weight was reduced in groups fed the BD. The ileal digestibility of energy improved with the emulsifier supplementation (100 or 200g/ton) compared to those fed the CD. Based on the results, it is concluded that supplementation of the feed emulsifier (300g/ton) could reduce the dietary requirement of ME (by 100 kcal/kg) in the broiler chicken diet without affecting feed efficiency and carcass traits. The beneficial effects of feed emulsifier may partly be associated with the increased ileal digestibility of dietary energy.

KEYWORDS: Broiler chicken, Carcass parameters, Emulsifier, Energy digestibility Performance.

Article received: 23 July 2025; Article accepted: 23 September 2025

INTRODUCTION

Broiler production is one of the most dynamic and fastest-growing segments in the animal husbandry sector. The broiler industry has taken a quantum leap in growth to meet the dietary protein requirement of the growing population. Fast-growing modern broilers need high-density diets to achieve the expected body weight as per their genetic potential. Modern broilers require high-density diets, and to meet their energy requirements, fats/ oils and concentrated sources of energy are included in the diet (Guerreiro Neto et al., 2011). Digestion and assimilation of dietary fat are limited in young chicks due to limitations in the production of bile and lipase, which are not adequate for assimilating dietary fats (Ghazalah, 2019; Siyal et al., 2017). However, supplementation of oil in poultry diets also adds cost to broiler production. Minimizing feed costs in poultry production requires new research on strategies to reduce the ME requirement without compromising the performance and health of the birds (Brickett et al., 2007).

Supplementation of exogenous feed emulsifiers has been suggested to overcome the physiological limitations of the digestive system during the early age of chicken and reduce the fat globule size into smaller micelles, thereby increasing the surface area for enzymatic action and digestion of fat and other associated nutrients (Gholami et al., 2024; Jala et al., 2024). The beneficial effect of emulsifiers in poultry has been attributed to their ability to improve dietary ME and enhance lipid metabolism (Wang et al., 2020). Emulsifier supplementation in broiler chicken diet reported to increase digestibility of energy and other nutrients (Ahmadi-Sefat et al., 2022). The improved energy digestibility with the feed emulsifier may allow for the reduction of energy requirement in the diet while maintaining the same level of performance (Khonyoung et al., 2015; Majdolhosseini et al., 2019). It is also reported that the effect of feed emulsifier on performance and nutrient digestibility was reported to be higher in diets containing lower concentrations of energy and other nutrients (Ahmadi-Sefat et al., 2022). Therefore, supplementation of feed emulsifier was reported to sustain the performance of birds fed sub-optimal concentrations of energy (Majdolhosseini et al., 2019; Haetinger et al., 2021; Nemati et al., 2021). Hence, the present study was conducted to evaluate the effect of supplementing graded concentrations of emulsifiers on the energy digestibility and performance of broiler chickens fed low-energy diets.

MATERIALS AND METHODS

Birds, experimental groups, and management

Bird handling, management, and the experimental protocol were approved by the Institute's Animal Ethics Committee (Indian Council of Agricultural Research-Directorate of Poultry Research, India (IAEC/DPR/18/10 dated 29th September 2018/ CPCSEA). Day-old broiler (*Cobb* 430, Venkateswara Hatcheries, Pvt. Ltd, Hyderabad) male chicks (n=1250) were procured and randomly distributed into five treatment groups. Each treatment was allotted to 10 replicates with 25 chicks in each replicate. Birds were maintained in floor pens in an open-sided house with a floor space of 1.1ft^2 per bird. The house's recorded maximum and minimum temperature, humidity, and temperature humidity index were 23.8-28.9^{o}C, 35.2-38.6^{o}C, and 62.8-76.4%, respectively. Brooding was provided with incandescent bulbs and additional heat was provided with coal to provide about 37^{o}C at bird level during the first week. Subsequently, the temperature was gradually reduced to the ambient temperature at day 21, after which the birds were reared at the ambient temperature.

Feeding regimen and performance

A three-phase feeding regime (pre-starter: 1 to 14 days, starter: 15-28 days, and finisher: 29 to 42 days) was followed. Maize-soybean meal-based control diets (CD) were provided *ad libitum* from 1-42 days. Metabolizable energy (ME) and crude protein levels in pre-starter, starter, and finisher diets were 2950, 3050, and 3150 kcal/kg and 22.5, 21.5, and 19%, (Cobb 400 Management Guide) respectively (Table 1). Another set of low ME (-0.42 MJ/kg) basal diets (BD) was prepared with similar concentrations of protein and essential amino acids. The concentrations of essential amino acids, calcium, and available phosphorus were maintained uniformly in all the diets in each phase. The levels of maize and soybean meal were altered to arrive at the desired concentrations of nutrients in the BD. The feed emulsifier was procured from a commercial source (Varsha Group, Bangalore, Karnataka) containing a mixture of lysophosphatidyl choline (5%) and phosphatidyl choline (5%). The BD was supplemented with feed emulsifier at graded concentrations, i.e., 0, 100, 200, and 300 g/ton. Each test diet, along with the CD, was randomly assigned to 10 replicate pens (201×122 cm) and fed *ad libitum* from day 1 to 42. Feed intake (FI) and body weight (BW) were recorded per pen at the end of each phase, and feed efficiency (FE) was calculated as body weight gain (BWG)/FI. Immunization against Newcastle disease (ND) with live attenuated strain (Lasota, 7 and 28 days), and infectious bursal disease (IBD) with live attenuated strain (intermediate) was carried out at 14 days of age.

Table 1. Ingredient and nutrient composition of diets (g/kg) fed to broilers (0-42 days)

Ingredient	Pre-starter (1-14d)		Stater (15-28d)		Finisher (29-42d)	
	CD	BD	CD	BD	CD	BD
Maize	556.11	493.00	603.23	539.83	631.53	568.34
Oil-Veg	23.75	23.70	31.19	31.20	42.13	42.10
Soya DOC 45%	384.50	373.51	331.67	320.66	293.23	282.23
Salt	4.200	4.146	4.215	4.161	4.227	4.173
Dicalcium Phosphate	11.30	11.00	7.17	6.92	6.53	6.28
Phytase 5000	0.100	0.100	0.100	0.100	0.100	0.100
Limestone powder	12.84	12.91	15.73	15.74	15.84	15.84
DL-Methionine	2.591	2.447	2.391	2.246	2.180	2.035
L-Lysine HCl	1.769	1.446	1.471	1.146	1.391	1.067
Premix[#]	2.85	2.85	2.85	2.85	2.85	2.85
Deoiled Rice Bran	0.00	74.89	0.00	75.15	0.00	74.98
Nutrient (g/kg)						
Metabolizable energy, kcal/kg	2950	2850	3050	2950	3150	3050
Crude protein, g/kg	225.0	225.0	205.0	205.0	190.0	190.0
Crude protein, g/kg[##]	221.5	219.8	198.5	199.1	188.8	189.2
Dig. Lysine, g/kg	12.50	12.50	11.00	11.00	10.00	10.00
Dig. Methionine, g/kg	5.70	5.70	5.28	5.28	4.90	4.90
Dig. Arginine, g/kg	13.82	14.02	12.39	12.59	11.33	11.53
Dig. Tryptophan, g/kg	2.56	2.59	2.28	2.31	2.07	2.10
Dig. Threonine, g/kg	7.80	7.94	7.12	7.26	6.61	6.75
Calcium, g/kg	9.40	9.40	9.00	9.00	8.80	8.80
Calcium, g/kg[##]	9.56	9.61	9.05	9.12	8.95	8.86
Available Phosphorus, g/kg	4.50	4.50	4.00	4.00	3.80	3.80
Total phosphorus, g/kg[##]	7.21	7.26	6.52	6.67	6.32	6.18
Sodium, g/kg	1.80	1.80	1.80	1.80	1.80	1.80

CD control diet; BD low energy basal diet
[#] retinol acetate 2.75 mg, cholecalciferol 0.03 mg, á tocopherol 10 mg, thiamin 1 mg, pyridoxine 2 mg, cyanocobalamine 0.01 mg, niacin 15 mg, pantothenic acid 10 mg, riboflavin 10 mg, biotin 0.08 mg, menadione 2 mg, choline 650 mg, copper 8 mg, iron 45 mg, manganese 80 mg, zinc 60 mg, selenium 0.18 mg monensin sodium 50 mg and hydrated sodium calcium aluminosilicate 800 mg
[##] analysed values

Carcass traits

The carcass traits, including ready-to-cook yield (RTC) and relative weights of breast meat, liver, and abdominal fat, were recorded by slaughtering two birds per replicate at day 42. The weights of the carcass variables were expressed as g per kg pre-slaughter live weight of the respective bird.

Ileal digestibility of energy

The apparent ileal digestibility of energy was studied by using Cr_2O_3 as an indigestible marker (0.3% in the diet) (Ravindran et al., 2005). The indicator-supplemented diets were fed *ad libitum* to all the birds in each pen from day 36 to 42. On day 42, five birds in each pen were slaughtered by cervical dislocation after exposure to chloroform for the collection of ileal digesta. The total digesta from the entire ileum, i.e., segment of the small intestine from Meckel's diverticulum to the ileocecal junction, was collected. The digesta was rinsed out of each segment (without squeezing) with demineralized water (4°C) into separate stainless-steel containers. The digesta was pooled per pen and stored at -20°C. Subsequently, the digesta was thawed to room temperature and dried at 70 °C in a forced air oven for 48 hours till the moisture concentration reached about 10% and ground to pass through a 1 mm screen (Cyclotec™ 1093 Sample Mill, FOSS Analytical, Hilleroed, Denmark). Experimental feeds and ileal digesta samples were analysed for gross energy and Cr_2O_3. The gross energy was estimated with an

Adiabatic Bomb Calorimeter (S No 219, CAT. No – CC.01/M3, Toshniwal Brothers (Delhi) Pvt. Ltd, New Delhi, India) using benzoic acid for estimation of energy equivalence of the bomb. The nitrogen (crude protein) content was estimated with Kjeldahl method and Cr_2O_3 content was determined by wet destruction with a mixture of $HNO_3/HClO_4$ (1:1). The absorption of the hexavalent Cr atom, measured at a wavelength of 357.8 nm, is proportional to the Cr_2O_3 concentration in the sample. The following formula was used to calculate the digestibility of energy and nitrogen in different groups.

AIDE (%) = 100-[100 X (Cr_2O_3 diet/ Cr_2O_3digesta) x (Nutrient in digesta/Nutrient in diet)]

Statistical analysis

The data on the effect of emulsifier supplementation on performance and slaughter variables were analysed using a one-way analysis of variance using the GLM procedures available in SPSS (2008). Orthogonal polynomial contrast was performed to study the linear and quadratic effects of emulsifier dose. A simple contrast analysis was performed to compare individual groups with the control and basal diets. For all analyses, the difference between treatment means was considered to be significant when P<0.05, whereas a trend was considered to exist if 0.05 £ P £ 0.10. Further, the response in the dependent variables with change in the concentration of feed emulsifier concentration in BD fed groups was fitted by the polynomial equation in the form of $Y=a+bx+cx^2$ to know the trend in the dependent variable in relation to the emulsifier concentration.

RESULTS AND DISCUSSION

Performance

The regression analysis indicated that the performance variables (BWG and FI) were not affected (P>0.05) by supplementation of the feed emulsifier to the BD (low ME diets, Table 2) during different phases or overall experiment (1-42d). The FE during 1-42d of age showed a trend of linearity (P = 0.056) with the dose of the emulsifier in the BD. The contrast analysis indicated a significant reduction in BWG and FE during the pre-starter phase with a reduction in dietary ME (BD) compared to those fed the CD. However, supplementation of the emulsifier to the BD failed to exhibit any response in the performance parameters during the pre-starter phase compared to those fed the BD (2 vs 3, 4 or 5). The reduction of ME or supplementation of the emulsifier to the low-ME BD did not show any effect on BWG or FE in broilers during the starter or finisher phases compared to those fed the CD. Similarly, during the overall experiment period, the BWG was not affected by dietary treatments compared to the control group. The FE during 1-42d of age reduced significantly in broilers fed the BD compared to those fed the CD (1 vs 2). Supplementation of emulsifier at 100 or 200g showed a trend of improvement (P = 0.077 and 0.062, respectively) in FE (1 vs 3 and 4), the FE in groups fed 300g emulsifier was significantly higher than those fed the BD (2 vs 5) and the FE in the later groups was similar to those fed the CD which had the standard energy levels.

Table 2. Effect of supplementing graded concentrations of feed emulsifier (EMR) on the performance of broilers fed standard and low ME diets

Treat	Pre-starter (1-14d)		Starter (15-28d)		Finisher (29-42d)		Overall (1-42d)	
	BWG	FE	BWG	FE	BWG	FE	BWG	FE
	g	FI/BWG	g	FI/BWG	g	FI/BWG	g	FI/BWG
1. CD	480.3	1.108	1201	1.546	1106	2.080	2787	1.680
2. BD	461.2	1.147	1177	1.557	1090	2.124	2728	1.713
3. BD+100 EMR	462.4	1.140	1184	1.550	1104	2.100	2751	1.701
4. BD+200 EMR	458.8	1.153	1187	1.549	1101	2.100	2746	1.702
5. BD+300 EMR	459.5	1.150	1190	1.543	1109	2.068	2759	1.688
SEM	4.316	0.0033	11.25	0.0029	23.25	0.0062	26.45	0.0091
P-value								
Linear	0.673	0.273	0.394	0.105	0.582	0.133	0.458	0.056
Quadratic	0.914	0.529	0.689	0.272	0.854	0.325	0.749	0.163
Simple contrast								
1 vs 2	0.003	0.001	0.142	0.249	0.616	0.264	0.119	0.007
1 vs 3	0.005	0.001	0.308	0.655	0.945	0.608	0.337	0.077
1 vs 4	0.001	0.001	0.384	0.760	0.858	0.622	0.276	0.062
1 vs 5	0.001	0.001	0.517	0.768	0.938	0.760	0.455	0.525
2 vs 3	0.845	0.314	0.647	0.423	0.655	0.506	0.550	0.342
2 vs 4	0.727	0.284	0.545	0.338	0.738	0.492	0.637	0.392
2 vs 5	0.800	0.624	0.409	0.107	0.547	0.125	0.421	0.046

CD control diets having the recommended levels of energy; BD low energy basal diet having -0.42 MJ/kg; BWG body weight gain; FE feed efficiency; SEM standard error mean; N number of replications; P probability

*g emulsifier/ton diet in pre-starter, starter and finisher phases, respectively

The data of the current study suggest that the reduction of dietary ME (100 kcal/kg) reduced the broiler performance (feed efficiency) compared to those fed the energy-adequate CD. Supplementation of feed emulsifier at the rate of 300g/ton sustained the performance of broilers fed the low-ME basal diet similar to those fed the CD. In line with the current findings, a few authors (Bontempo et al., 2018; Kulkarni et al., 2019) and our recent study (Rama Rao et al., 2023) reported significant improvement in BWG, FE, and performance index in broilers fed diets supplemented with feed emulsifier. The improved broiler performance with emulsifier supplementation was attributed to the increased FI and fat assimilation (Kamran et al., 2020; Haetinger et al., 2021). The ileal digestibility data from the current study and our previous findings (Rama Rao et al., 2023) also indicate that feed emulsifiers significantly improve the ileal digestibility of energy and/or N compared to those fed the NC. Increased digestion and absorption of nutrients (fat and energy) with emulsifier supplementation were also reported in the literature (Zhang et al., 2011; Maertens et al. 2015; Ji Seon An et al., 2020; Rama Rao et al., 2023). Significant reduction in the gut viscosity with emulsifier supplementation (Jalal et al., 2024; Gholami et al., 2024), might also be another mode of action of emulsifier to improve bird performance. The data of the current study also further suggested the possibility of maintaining the broiler performance on diets containing reduced dietary ME with feed emulsifier supplementation at par with the performance of broilers fed the energy-adequate CD.

Though the protein digestibility was not estimated in the current study, the published literature indicated a significant improvement in protein and lipid digestibility in broilers fed diets supplemented with feed emulsifier (Saleh et al., 2020; Haetinger et al., 2021). The improvement in nutrient digestibility might be due to an increase in intestinal villi development (Brautigan et al., 2017; Chen et al., 2019; Gazhalah et al., 2021), besides a reduction in fat globular size (San Tan et al., 2016) with emulsifier supplementation.

Contrary to the present findings, Azman and Ciftci (2004) reported a lack of significant improvement in the performance of broilers fed diets supplemented with feed emulsifiers. Soya lecithin was used as a substitute for soybean oil by Azman and Ciftci (2004), who found similar weight gain in broilers compared to that of soybean oils without influencing fat assimilation. The feed emulsifier used in the current study had lysophosphatidylcholine and phosphatidylcholine, which are potent emulsifiers capable of increasing the digestibility of saturated fatty acids. The improved performance observed in the current study could be attributed to the emulsification potential of these two compounds. Results of Gazhalah et al. (2021) demonstrated that the combination of lysolecithin, synthetic emulsifier, and monoglycerides significantly improved the BWG and FE in broiler chicken compared to those fed diets without emulsifier. It is worth noting that the improved ileal digestibility of energy (probably due to fat hydrolysis) was observed in the current study with emulsifier supplementation, demonstrating the probable reason for the improved performance in broilers fed low-ME diets with emulsifier supplementation.

The contrast analysis demonstrated that the performance of broilers fed 300 g/ton emulsifier was significantly higher than that of those fed the low-energy diet, and the FE in 300 g/ton group was similar to that of those fed the CD diet, which implies that dietary supplementation of emulsifiers could reduce the dietary requirement of ME. The FE in groups fed the lower concentrations of emulsifier (100 and 200g/ton) was intermediate. Similarly, Chen et al. (2019) also reported that 250g emulsifier (lysolecithin)/kg diet was optimum for growth performance, and they concluded that the supplementation dose should be recommended according to dietary energy levels. At the reduced dietary ME level (-.42 MJ/kg), a concentration of 300 g/ton diet gave similar performance compared to those fed the CD, which received the recommended levels of energy. Similar to the current findings, few recent studies (Ahmadi-Sefat et al., 2022; Gholami et al., 2024) reported the possibility of reducing dietary energy up to 0.42 MJ/kg diet with the feed emulsifier supplementation without affecting the broiler performance.

Carcass traits

The relative weight of the gizzard was not affected ($P>0.05$) with the emulsifier supplementation to the BD (Table 3). However, supplementation of emulsifier to the BD non-linearly ($P<0.05$) increased the RTC yield, and linearly increased the breast meat weight (BE), and reduced ($P<0.05$) the abdominal fat and liver weight. The contrast analysis indicated that most carcass variables (except BM) were unaffected by the reduction in dietary ME (0.42 MJ) compared to those fed the CD. The BM weight reduced significantly (P<0.05) in broilers fed the BD compared to those fed the CD. Similarly, supplementation of the emulsifier did not affect the carcass variables, except for abdominal fat. The abdominal fat was significantly reduced with the emulsifier at 300g/ton compared to those fed the CD. The contrast analysis also indicated that the emulsifier supplementation to the BD at 200g and 300g/ton, respectively, increased RTC weight and reduced abdominal fat weight.

Table 3. Effect of supplementing graded concentrations of feed emulsifier (EMR) on slaughter variables (g/kg live weight) and energy retention coefficient in broilers fed standard and low ME diets

Treat	RTC	BM	Abd fat	Liver	Gizzard	Energy digestibility coefficient
1. CD	801.0	273.9	10.72	17.27	14.46	0.723
2. BD	783.6	253.7	11.57	17.66	15.92	0.715
3. BD+100 EMR	780.5	268.4	9.71	18.62	15.21	0.773
4. BD+200 EMR	796.2	264.4	10.95	18.26	15.21	0.774
5. BD+300 EMR	790.7	271.9	7.50	16.58	15.41	0.757
SEM	5.179	5.518	0.772	0.722	0.641	1.342
P-value						
Linear	0.591	0.042	0.007	0.249	0.603	0.069
Quadratic	0.011	0.056	0.018	0.018	0.684	0.185
Simple contrast						
1 vs 2	0.337	0.015	0.435	0.704	0.114	0.946
1 vs 3	0.165	0.800	0.364	0.195	0.413	0.034
1 vs 4	0.457	0.229	0.834	0.338	0.413	0.036
1 vs 5	0.168	0.479	0.005	0.499	0.298	0.061
2 vs 3	0.105	0.646	0.120	0.325	0.451	0.027
2 vs 4	0.027	0.615	0.594	0.536	0.451	0.021
2 vs 5	0.681	0.067	0.001	0.262	0.591	0.013

CD control diets having the recommended levels of energy; BD low energy basal diet having -0.42 MJ/kg; RTC ready to cook yield; BM breast meat; AF Abdominal fat; SEM standard error mean; N number of replications; P probability

*g emulsifier/Ton diet in pre-starter, starter, and finisher phases, respectively

Energy digestibility

The regression analysis indicated that there was no significant (P>0.05) effect of emulsifier supplementation to the BD on energy digestibility compared to those fed the BD without the emulsifier (Table 3). The contrast analysis between CD and BD indicated no significant effect of dietary ME on the ileal digestibility of energy. However, supplementation of the emulsifier at 100 or 200g/ton significantly improved energy digestibility compared to BD or CD.

In the present study, the relative weight of BM reduced significantly with a reduction in dietary ME. Supplementation of the feed emulsifier improved the breast meat yield similar to those fed the CD. The improvement in meat yields and FE with the emulsifier supplementation to the low-ME basal diet (LF) could be due to the significant improvement in the ileal energy digestibility with emulsifier supplementation. Significant reduction in fat deposition in the abdominal area in broilers fed the highest concentration of feed emulsifier (300 g/ton) also suggests the higher utilization of dietary fat with emulsifier supplementation. Similar to these findings, significant improvements in the carcass traits were reported in broilers fed emulsifier-supplemented diets (Ghazalah et al., 2021). The improvement in energy digestibility may be the probable reason for the improved meat yields in broiler chicken as reported by Ji Seon An et al. (2020).

CONCLUSIONS

Based on the results, it is concluded that emulsifier supplementation (300g/ton) could sustain the performance and meat yield in broilers fed a low-energy diet (-.42 MJ/kg). The improved performance in broilers fed low-energy diets supplemented with the feed emulsifier was associated with increased ileal digestibility of energy.

REFERENCES

Ahmadi-Sefat, A.A., Kamran Taherpour, Hossein Ali Ghasemiy Mohammad Akbari Gharaei,Hassan Shirzadi, and Farhad Rostami. 2022. Effects of an emulsifier blend supplementation on growth performance, nutrient digestibility, intestinal morphology, and muscle fatty acid profile of broiler chickens fed with different levels of energy and protein. Poultry Science. 101: 102145

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

Bontempo, V., Comi, M., Jiang, X.R., Rebucci, R., Caprarulo, V. and Giromini, C. 2018. Evaluation of a synthetic emulsifier product supplementation on broiler chicks. Animal Feed Science and Technology. 240: 157-64.

Brautigan, D.L., Li, R., Kubicka, E., Turner, S.D., Garcia, J.S., Weintraut, M.L. and Wong, E.A. 2017. Lysolecithin as feed additive enhances collagen expression and villus length in the jejunum of broiler chickens. Poultry Science. 96: 2889–2898.

Brickett, K.E., Dahiya, J.P., Classen, H.L. and Gomis, S. 2007. Influence of Dietary Nutrient Density, Feed Form, and Lighting on Growth and Meat Yield of Broiler Chickens. Poultry Science. 86: 2172-2181.

Chen, C., Jung, B. and Kim, W.K. 2019. Effects of lysophospholipid on growth performance, carcass yield, intestinal development, and bone quality in broilers. Poultry Science. 98: 3902–3913.

Ghazalah, A., Abd-Elsamee, M., Ibrahim, M., Abdelgayed, S.S., Abdelkader, M. and Gonzalez-Sanchez, D. 2021. Effects of a combination of lysolecithin, synthetic emulsifier, and monoglycerides on growth performance, intestinal morphology, and selected carcass traits in broilers fed low-energy diets. Animals. 11(11): 3037.

Gholami, M., Hassan Shirzadi, Enayat Rahmatnejad, Kamran Taherpour, AlinaghiShokri and AliKhatibjoo. 2024. Effect of emulsifier on growth performance, nutrient digestibility, intestinal morphology, faecal microbiology and blood biochemistry of broiler chickens fed low-energy diets. Veterinary Medical Sciences. 10: e1437.

Guerreiro Neto, A.C., Pezzato, A.C., Sartori, Jr, 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: 119-125.

Haetinger, V.S., Dalmoro, Y.K., Godoy, G.L., Lang, M.B., De Souza, O.F. and Aristimunha, P. 2021. Optimizing cost, growth performance, and nutrient absorption with a bioemulsifier based on lysophospholipids for broiler chickens. Poultry Science. 100: 101025.

Jalal, M.P., Sharifi, S.D., Honarbakhsh, S. and Rouhanipour, H. 2024. Effects of low-energy diets supplemented with emulsifier on growth performance, nutrient digestibility, and intestinal morphology of broiler chickens. Livestock Science. 289: 105581

Kamran, J., Mehmood, S., Rahman, M.A., Mahmud, A., Hussain, M., Rehman, A., Khalil, S. and Qamar, S.H. 2020. Effect of fat sources and emulsifier supplementation in broiler starter, grower and finisher diets on performance, nutrient digestibility, and carcass parameters. Brazilian Journal of Poultry Science. 22: 1-10.

Khonyoung, D., Yamauchi, K. and Suzuki, K. 2015. Influence of dietary fat sources and lysolecithin on growth performance, visceral organ size, and histological intestinal alteration in broiler chickens. Livestock Sciences. 176: 111–120.

Kulkarni, R.C., Dingore, A.D., Durge, S.M., Dinani, O.P. and Amrutkar, S.A, 2019. Supplementation of different emulsifiers on performance of broilers. Journal of Entomology and Zoology Studies. 7(5): 25-29.

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. In 20th European Symposium on Poultry Nutrition, Prague, Czech Republicp 44.

Majdolhosseini, L., Ghasemi, H.A., Hajkhodadadi, I. and Moradi, M.H. 2019. Nutritional and physiological responses of broiler chickens to dietary supplementation with de-oiled soyabean lecithin at different metabolisable energy levels and various fat sources. British Journal of Nutrition. 122: 863–872.

Nemati, M., Ghasemi, H.A., Hajkhodadadi, I. and Moradi, M.H. 2021. De-oiled soy lecithin positively influenced growth performance, nutrient digestibility, histological intestinal alteration, and antioxidant status in turkeys fed with low energy diets. British Poultry Science. 62**:** 858–867.

Rama Rao, S.V., Nagaraja Kumari, K., Raju, M.V.L.N., Prakash, B., Paul, S.S. and Santosh Phani, K.P. 2023. Feed emulsifier improves the performance and nutrient digestibility in broiler chicken fed diets without antibiotic growth promoter. British Poultry Science. 64: 745-750.

Ravindran, V., Hew, L.I., Ravindran, G. and Bryden, W.L. 2005. Apparent ileal digestibility of amino acids in dietary ingredients for broiler chickens. Animal Science. 81: 85–97.

Saleh, A.A., Amber, K.A., Mousa, M.M., Nada, A.L., Awad, W., Dawood, M.A.O., Abd El-Moneim, A.E.M.E., Ebeid, T.A. 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: 473

San Tan, H., Zulkifli, I., Farjam, A.S., Goh, Y.M., Croes, E. and Partha, S.K. 2016. Effect of exogenous emulsifier on growth performance, fat digestibility, apparent metabolisable energy in broiler chickens. Journal of Biochemistry Microbiology and Biotechnology. 31: 7-10.

Siyal, F.A., Babazadeh, D., Wang, C., Arain, M.A., Saeed, M., Ayasan, T., Zhang. L. and Wang, T. 2017. Emulsifiers in the poultry industry. World's Poultry Science Journal. 73: 611-620.

Siyal, F.A., Abd, E.L.-Hack, M.E., Alagawany, M., Wang, C., Wan, X. and He, J. 2017. Effect of soy lecithin on growth performance, nutrient digestibility and hepatic antioxidant parameters of broiler chickens. International Journal of Pharmacology. 13: 396-402.

SPSS, Statistical Packages for Social Sciences, version 17.0. SPSS Inc., Illinois (2008).

Wang, J., Choi, H. and Kim, W.K. 2020. Effects of dietary energy level and 1,3-diacylglycerol on growth performance and carcass yield in broilers. Journal of Applied Poultry Research. 29: 665–672.

Zhang, B., Haitao, L., Zhao, D., Guo, 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.