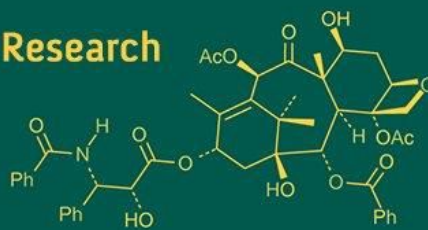
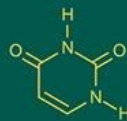
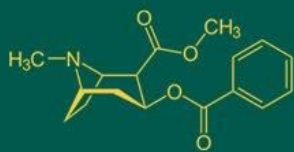


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
 ISSN Online: 2617-4707
 NAAS Rating (2025): 5.29
 IJABR 2025; 9(12): 1378-1383
www.biochemjournal.com
 Received: 23-09-2025
 Accepted: 25-10-2025

Hetal M Patel
 Department of Animal
 Nutrition, College of
 Veterinary Science & A.H.,
 KU, Navsari, Gujarat, India

VR Patel
 Department of Animal
 Nutrition, College of
 Veterinary Science & A.H.,
 KU, Navsari, Gujarat, India

YD Padheriya
 Department of Animal
 Nutrition, College of
 Veterinary Science & A.H.,
 KU, Navsari, Gujarat, India

JK Movaliya
 Department of Animal
 Nutrition, College of
 Veterinary Science & A.H.,
 KU, Navsari, Gujarat, India

AI Vohra
 Department of Animal
 Nutrition, College of
 Veterinary Science & A.H.,
 KU, Navsari, Gujarat, India

Corresponding Author:
VR Patel
 Department of Animal
 Nutrition, College of
 Veterinary Science & A.H.,
 KU, Navsari, Gujarat, India

Effect of lysophospholipid and sophorolipid supplementation on blood biochemical and antioxidant status in broiler chicken

Hetal M Patel, VR Patel, YD Padheriya, JK Movaliya and AI Vohra

DOI: <https://www.doi.org/10.33545/26174693.2025.v9.i12q.6848>

Abstract

The experiment was carried out in total of one hundred and sixty (n-160) day old broiler chicks of Vencobb-400 strain for a period of 5 weeks (2nd to 6th). Chicks were randomly assigned into four homogenous groups (10 chicks/replicate) on the basis of their live body weight. All the birds were fed on standard diet formulated as per (BIS, 2024). The four dietary treatments were control were offer with basal diet (T₁) other are supplemented with Lysophospholipid and Sophorolipid at 7.5 and 12; 12.5 and 20 and 17.5 and 28 mg/kg, respectively in T₂, T₃ and T₄. Blood collection was doing randomly from eight birds of each group (two birds/replicate) at the end of 6th week. All the major haematological parameters were in normal range and serum parameters were also in normal range except glucose and albumin hence, it was indicated that supplementation of LPL and SPL did not affect health status of birds. Glucose and albumin were significantly increased among different treatment groups and was highest in T₄ treatment group. Haematological parameters like Hb, RBCs, PCV, MCV, MCHC, TLCs, lymphocytes and monocytes did not show any significant ($p > 0.05$) differences between treatment groups. Supplementation of LPL and SPL improved antioxidant status by increasing SOD, GpX activity and decreased activity of MDA ($P < 0.05$) which strongly indicates that the birds were protected from stress.

Keywords: Lysophospholipid, Sophorolipid, Broilers, Haematology, Blood, Antioxidants

1. Introduction

The cost-effective production of the broiler business depends on increasing dietary fat consumption. By providing vital fatty acids and vitamins, may increase energy availability, feed efficiency, health status and carcass quality (Ravindran *et al.*, 2016) [31]. For effective utilization of fats from diet, micelle production and process of emulsification are very crucial. Therefore, externally sourced emulsifier supplementation is alternative to accomplish this (Iqbal and Hussain, 2009) [16]. A class of chemicals known as emulsifying agents makes it possible for water in oil or oil in water to disperse uniformly as an emulsion. Emulsifiers are crucial because they break down dietary lipids into smaller droplets, which encourages the formation of micelle-like structures makes it easier for the body to absorb (Melegy *et al.*, 2010) [23]. Numerous emulsifiers have developed to enhance broiler chicken development and nutrient digestion; however, public health concerns it is necessary to understand emulsifiers' toxicity and biodegradability (Upadhaya *et al.*, 2018) [38]. Lysophospholipid (LPL) is a class of membrane lipids exhibits greater stability in the aqueous environment of the gastrointestinal tract and have efficient bio stimulant emulsifying qualities (Joshi *et al.*, 2006) [18]. Furthermore, SPL might have a number of special effects, such as collagen neogenesis, fibroblast activation and immune regulation (Hardin *et al.*, 2007) [14]. Therefore, the study was carried out to evaluate potential of Lysophospholipid (LPL) and Sophorolipid (SPL) as an exogenous surfactant on blood biochemical status of broilers.

2. Materials and Methods

2.1 Location

The experiment was carried out for a period of 5 week (2nd to 6th week) at Poultry farm, Department of Livestock Farm Complex, College of Veterinary Science and Animal Husbandry, Kamdhenu University, Navsari, Gujarat. The analytical work was carried out in

the Department of Animal Nutrition. Geographically, the experimental location is 9 meters above sea level with subtropical climatic conditions.

2.2 Treatment groups and feeding standards

A total of one hundred and sixty (160) a seven day - old broiler chicks of Vencobb-400 strain were used as experimental birds. Experimental chicks were weighed individually and randomly assigned into four homogenous groups on the basis of their live body weight. Each group (40 chicks) comprised of 4 replicates (10 chicks/ replica). All the birds were fed on standard diet formulated as per BIS (2007). The control group was fed basal diet (T₁), where Lysophospholipid and Sophorolipid at 7.5, 12 mg/kg, 12.5, 20 mg/kg and 17.5, 28 mg/kg of feed were supplemented respectively in T₂, T₃ and T₄.

2.3 Measures of Traits

- **Feed intake:** Weighed quantity of feed offer twice a day and leftover was collected in next early morning and weighed. The difference was considered as amount of feed ingested.
- **Blood sampling:** Blood was collected early in the morning from the wing vein using clean, sterilized needles into two separate clean and dry test tubes for hematological and serum biochemical analysis. The first tube containing EDTA was used for estimation of hematological assay. In the second tube, blood was collected without anticoagulant and was allowed to clot for 1 h at room temperature (25°C) and then centrifuged at 2000 rpm for 15 minutes to harvest serum. The clear, non-hemolysed serum was then taken into a set of clean, dry, eppendorf tubes and stored at -40°C for further analysis.

3. Results and Discussion

3.1 Feed Intake

Table 3.1: Voluntary feed intake of broiler chickens with dietary LPL and SPL supplementation.

Parameters	Treatment Groups				SEM	F- Value	P-Value
	T ₁	T ₂	T ₃	T ₄			
Total Feed Intake (g)	4175.62±118.36	4177.72±252.16	4280.83±24.09	4231.50±188.33	76.208	0.088	0.965
Average Daily Feed Intake (g)	119.30±3.38	119.36±7.20	122.31±0.69	120.90±5.38	2.177	0.089	0.965

The voluntary feed intake was recorded as total feed intake (g) and average daily feed intake (g) are presented in Table 3.1. There was non-significant ($p>0.05$) difference observed in feed intake (g) among the treatment groups. Many researchers are in agreement with present findings on supplementation of various emulsifiers in combination of alone with various doses (Movagharnejad *et al.*, 2020; Ko *et al.*, 2023 and Ani *et al.*, 2024) [26, 20]. The results indicates that palatability of feed was unaffected on emulsifier supplementation; however, the level of energy, requirements, growth rate, type and composition of emulsifier, its dose rate, level and types of other incorporated nutrients/ additives, methods of formulation and forms of feed are factors can be associated with voluntary feed intake by chickens.

3.2 Haematological parameters

Blood is a biological connective tissue primarily comprising of fluid portion and plasma in which major blood components (erythrocytes, leukocytes and thrombocytes) remain suspended. Blood represents a means of assessing clinical and nutritional health position of animals in feeding trials and the haematological variables most commonly in nutritional studies include PCV, RBC, Hb, mean corpuscular haemoglobin concentration (MCHC), Mean corpuscular volume (MCV) and clotting time (Osho *et al.*, 2014) [29]. In this experiment, blood was collected at end of the experiment (42nd days) for the analysis of hematological parameters. The findings of different hematological indices of treatment groups are presented in Table 3.2.

The concentration of Hb, MCV, MCH, MCHC and monocytes did not display any significant changes among the different groups. All the haematological parameters found in present study were in normal range and reflected that inclusion of Lysophospholipid and Sophorolipid does not affect health status of birds.

Similar to present results, Ani *et al.* (2024) [2] reported that dietary incorporation of lysolecithin induced no linear or

quadratic effects ($p>0.05$) on all haemato-biochemistry attributes in broiler chickens. Our findings were supported by Cho *et al.* (2012) [6] and Mohammadigheisar *et al.* (2018) [24], who observed that broilers fed diets supplemented with emulsifiers and lysolecithin in varying calorie diets did not exhibit any appreciable changes in their haematology attributes. There were no significant differences observed in blood total protein, total albumin, triglyceride, cholesterol, HDL and LDL levels ($p>0.05$) of broiler chickens fed an emulsifier-supplemented with or without low energy feed (Gholami *et al.*, 2024) [13]. Our findings are further supported by Singh *et al.* (2023) [134], who documented no dietary influence on the blood biochemistry and haematology of the broilers fed emulsifier at different energy levels. Kothare *et al.* (2021) [121] noticed no significant ($p>0.05$) effect of dietary energy levels and multi-enzymes between treatments on any of the haematological measures in broiler chickens. Consequently, the findings of Cowieson and Adeola (2005) [7] indicate the absence of any significant interaction between multi-enzyme supplementation and dietary energy levels. The current experimental findings are in agreement with the findings of Saleh *et al.* (2020) [32] who reported no significant ($p>0.05$) change for the total protein and albumin levels among treatment groups supplemented with multi-enzyme with different energy level (ME: 3151 and 3102 Kcal/Kg) diets. Alike to these, Attia *et al.* (2018) [3] noticed no significant ($p>0.05$) effect in broiler birds fed various levels of multi enzymes on the level of total protein, albumin and globulin in standard and low-density diets. However, contrary to the present findings, Abudabos (2012) [1] demonstrated significant increase in concentration of total protein in broiler birds fed different levels energy and multi-enzyme. Similarly, Sanhoury and Ahmed (2017) [33] also observed significantly ($p<0.01$) increased levels of total protein and globulin with multi-enzyme supplementation in broiler birds.

Table 3.2: Hematological indices of broiler chickens with dietary LPL and SPL supplementation.

Parameters	Treatment Groups				SEM	F- Value	P-Value
	T ₁	T ₂	T ₃	T ₄			
Hb(g/dl)	8.90±0.29	9.31±0.35	9.21±0.38	9.83±0.47	0.191	1.042	0.389
RBCs (*10 ⁶ /μl)	2.60±0.16	2.83±0.26	2.60±0.14	2.83±0.25	0.104	0.404	0.751
PCV (%)	29.44±2.16	31.94±2.22	32.08±2.41	33.89±2.64	1.162	0.594	0.624
MCV (fl)	117.59±12.44	118.93±12.64	126.23±12.70	124.55±12.39	5.999	0.112	0.952
MCH (pg)	35.12±2.32	34.46±2.75	36.21±2.60	37.55±5.14	1.630	0.158	0.924
MCHC (g/dl)	31.59±2.94	29.88±1.87	29.85±2.48	30.39±2.88	1.233	0.099	0.960
Monocytes	4.37±0.59	4.00±0.65	4.75±0.52	5.00±0.65	0.298	0.514	0.676
TLCs (*10 ³ /μl)	2.37±0.16	2.45±0.16	2.63±0.11	2.42±0.18	0.078	0.518	0.673
Lymphocytes (%)	71.00±1.99	70.00±1.78	72.00±1.90	71.50±1.99	0.922	0.198	0.897

3.3 Blood biochemical parameters

Data pertaining to blood biochemical parameters in broiler chicken are presented in table 3.3.

The results revealed significant differences for glucose and albumin level while comparable findings were observed for ALT(U/L), AST(U/L), uric acid (mg/dl), total protein (g/dl), globulin (g/dl), total cholesterol (mg/dl) and triglyceride (mg/dl) levels. Serum glucose level and albumin was found highest in T₄ and T₃ group, respectively. The levels of the serum parameters are related to broilers' health status, and they are good indicators of their nutritional conditions.

In agreement to present findings, Park *et al.* (2018) [30] inferred that inclusion of lysolecithin did not affect serum total cholesterol, triglyceride, or free fatty acid concentrations. Similarly, serum total cholesterol, triglyceride, and HDL cholesterol levels of broiler chicken fed diets containing vegetable oil or animal fat were not affected by emulsifier supplementation (Lysophospholipid and Lipase enzyme supplementation to low metabolizable energy diets) as observed by Movagharnejad *et al.* (2020) [26]. Alike, Cai *et al.* (2024) [5] concluded that the differences in calorie content or the inclusion of LPC in the meals had no effect on the serum concentrations of TG, TC, and AST on day 21 ($p > 0.05$). In the same way, Eid *et al.* (2025) [10] reported that discrete dietary supplementation of LPL at the level of 0.5 or 1g did not change the levels of AST, ALT, creatinine, LDL-cholesterol, and triglycerides parameters compared to the control group (-DEX).

On the other hand, Cho *et al.* (2012) [6] reported that broiler chickens fed with diet containing 0.05% emulsifier (sodium stearoyl-2-lactylate) had lower serum triglycerides than those fed with high-energy diets without emulsifier. They assume that the effect on lipid metabolites may depend on fat sources and emulsifier types. Similarly, Zhao and Kim (2017) [41] showed that LPC supplementation on day 14 decreased the TG levels. Because dietary fat is absorbed and metabolized more quickly in broilers given LPC, their serum levels of TG and NEFA may be lower. Furthermore, Eid *et al.* (2025) [10] reported that discrete LPL dietary supplementation at 0.5 or 1g did not change the levels of AST, ALT, creatinine, LDL-cholesterol, and triglycerides parameters compared to the control group (-DEX). Additionally, Kamran (2020) [19] have indicated that broilers fed diets containing emulsifiers or emulsifiers with lipase did not alter in the levels of cholesterol, glucose, and triglycerides.

In partial agreement, Mohiti-Asli *et al.* (2025) [25] reported that dietary supplementation with LP in broilers significantly reduced serum triglyceride (TG), total cholesterol, and low-density lipoprotein cholesterol (LDL-C) concentrations, while significantly increasing high-density lipoprotein cholesterol (HDL-C) levels by day 42, compared with birds fed non-supplemented diets ($p < 0.05$). This suggests that chylomicrons were either released into the serum more slowly or removed from the blood more quickly (Jones *et al.*, 1992) [17], which is indicative of better hepatic lipid metabolism (Tompkins and Parkin, 1980) [37]. Moreover, they specified that emulsifiers break down triglycerides for enhanced energy utilization. Based on these findings, it can be concluded that emulsifier supplementation effectively reduced blood triglyceride levels as birds aged, likely by enhancing energy utilization. Emulsifiers could also reduce cholesterol and triglyceride levels by stabilizing the phospholipid coating of portomicrons as suggested by Jones *et al.* (1992) [17]. This could in turn decrease the release rate of cholesterol and triglycerides (sequestered in the portomicron interior) into the blood; hence, low levels can be observed.

Consistent with the observed increase in glucose concentration in the T₃ group, Eiler (2004) [11] suggested that improvements in blood glucose levels reflect enhanced glucose uptake and utilization, thereby promoting metabolic activity in hepatocytes. In contrast, Cai *et al.* (2024) [5] reported that dietary lysophospholipid inclusion had no significant effect on serum glucose levels.

Nasr *et al.* (2017) [27] suggested that serum biochemical parameters serve as fundamental indicators of oxidative stress, as reflected by alterations in blood biochemistry. The present findings may be attributed to the complex metabolic effects of emulsifiers, which vary according to dosage, mode of supplementation, and individual physiological differences. Some studies are partially consistent with the current results, as Oketch *et al.* (2022) [28] reported no significant dietary effects of emulsifier supplementation on total cholesterol and triglyceride levels at day 21. However, by day 35, marginal reductions in total blood cholesterol and triglyceride concentrations ($p = 0.076$ and $p = 0.095$, respectively) were observed in broilers fed emulsifier-supplemented NCL and PCL diets. These findings suggest that serum lipid fractions may be more susceptible to the effects of emulsifier supplementation over time.

Table 3.3: Blood biochemical status in broiler chickens with dietary LPL and SPL supplementation.

Parameters	Treatment Groups				SEM	F- Value	P-Value
	T ₁	T ₂	T ₃	T ₄			
ALT(U/L)	5.09±0.42	4.52±0.59	4.97±0.60	4.23±0.50	0.261	0.559	0.646
AST(U/L)	217.05±2.07	222.50±3.06	215.19±3.46	219.01±3.65	1.563	1.001	0.407
Glucose (mg/dl)	89.24±3.90 ^c	102.68±4.46 ^b	106.30±5.15 ^{ab}	110.13±4.72 ^a	2.596	3.929	0.019
Uric acid (mg/dl)	4.54±0.45	4.54±0.45	4.82±0.30	4.53±0.23	0.179	0.146	0.932
Total protein (g/dl)	3.29±0.29	3.84±0.33	3.92±0.22	3.8650±0.22	0.135	1.183	0.334
Albumin (g/dl)	1.22±0.05 ^b	1.61±0.21 ^{ab}	1.63±0.10 ^{ab}	1.71±0.13 ^a	0.074	2.491	0.041
Globulin (g/dl)	2.07±0.30	2.23±0.35	2.29±0.30	2.15±0.17	0.138	0.106	0.956
Total cholesterol (mg/dl)	216.03±12.15	202.86±12.07	197.39±7.07	187.82±3.94	4.860	1.546	0.224
Triglyceride (mg/dl)	110.26±7.62	100.53±8.15	117.87±8.08	122.27±6.20	3.884	1.591	0.214

^{abc}Means with different superscript in a row differ significantly ($p < 0.05$).

3.4 Serum antioxidant status

Serum superoxide dismutase (SOD) and glutathione peroxidase (GPx) activities, malondialdehyde (MDA), and total antioxidant capacity (TAC) are widely used indicators of oxidative status in animals. SOD, a copper- and zinc-dependent enzyme, mitigates superoxide (O_2^-) accumulation, which can generate hydroxyl radicals or peroxynitrite, contributing to oxidative stress. In the present study (Table 3.4), dietary treatments significantly influenced serum antioxidant parameters, except for TAC. SOD and GPx activities increased significantly ($p < 0.05$), whereas MDA levels decreased ($p < 0.05$), reflecting an improved antioxidant status in broilers. The level of MDA (ng/ml) was 77.01±3.58, 62.00±3.11, 62.52±2.42 and 52.59±3.65, respectively in T₁ to T₄ dietary treatment groups. SOD (ng/ml) mean value was 0.62±0.02, 0.77±0.03, 0.80±0.06 and 0.86±0.04, respectively in T₁ to T₄ dietary treatment groups and GPx (ng/ml) concentration was 0.56±0.06, 0.69±0.06, 0.74±0.05 and 0.78±0.07, respectively in T₁ to T₄ dietary treatment groups.

Consistent with the present findings, Cai *et al.* (2024) [5] reported a significant reduction in malondialdehyde (MDA) concentration in broilers fed lysophosphatidylcholine (LPC)-supplemented diets ($p < 0.01$). However, LPC inclusion had a nonsignificant effect on hepatic superoxide dismutase (SOD) and glutathione peroxidase (GPx) activities on day 42 ($p > 0.05$). Notably, there was a significant interaction between dietary energy content and LPC with respect to liver MDA levels ($p < 0.05$), indicating that broilers fed low-metabolizable-energy diets were more responsive to LPC's effect on MDA. MDA, a product of lipid peroxidation, is commonly used as an indicator of oxidative stress because it reflects hepatocyte damage and negatively impacts cellular membrane composition and

function (Lu, 2015; Deng *et al.*, 2019; Ayala *et al.*, 2014) [22, 9, 4].

Previous studies support the antioxidant-enhancing effects of lecithin and LPL supplementation. Zangeneh *et al.* (2018) [40] observed improved oxidative balance in broilers, evidenced by increased TAC, GPx, and SOD activities alongside decreased MDA levels. Wu *et al.* (2022) observed reduced serum MDA and elevated hepatic GPx in goslings supplemented with 100 mg/kg soybean lecithin for 32 days. Conversely, Surai *et al.* (2018) [36] reported that including 0.5 g/kg LPL in breeder diets produced offspring with lower hepatic SOD ($p < 0.01$), suggesting improved antioxidant status in the hens. Furthermore, El-Katcha *et al.* (2021) [12] demonstrated that supplementing 0.05% lysolecithin to 60-day-old ducks increased GPx activity, aligning with the current study's results. Ani *et al.* (2024) [2] reported that dietary lysolecithin at 300-400 g/100 kg significantly decreased malondialdehyde (MDA; linear $p = 0.003$) while increasing superoxide dismutase (SOD; linear $p < 0.001$), glutathione peroxidase (GPx; quadratic $p < 0.001$), and glutathione (linear $p < 0.001$) in broilers, suggesting a protective role against oxidative stress.

The antioxidant effect of lysolecithin is attributed to its composition, which includes amino-alcohol phospholipids and tocopherols (γ , α , and δ). Sun *et al.* (2018) [35] suggested that the polar head groups of phospholipids, such as amino and choline groups, facilitate their use as lipophilic antioxidants, enhancing the capacity to counteract oxidative stress. Consistently, Das and Vasudevan (2006) [8] reported that lysolecithin exhibits antioxidant and neuroprotective properties, helping reduce liver damage, improve oxidative resistance, and increase the stability of oils and fats due to its phospholipid content. The efficacy of emulsifiers as antioxidants may depend on the type of oil, its tocopherol content, and fatty acid composition (Ilyas *et al.*, 2016) [15].

Table 3.4: Serum Antioxidant status in broilers chicken with dietary LPL and SPL supplementation.

Parameters	Treatment Groups				SEM	F- Value	P-Value
	T ₁	T ₂	T ₃	T ₄			
MDA (ng/ml)	77.01±3.58 ^a	62.00±3.11 ^b	62.52±2.42 ^b	52.59±3.65 ^c	2.193	9.748	0.000
SOD (ng/ml)	0.62±0.02 ^b	0.77±0.03 ^a	0.80±0.06 ^a	0.86±0.04 ^a	0.026	6.276	0.002
GpX (ng/ml)	0.56±0.06 ^b	0.69±0.06 ^{ab}	0.74±0.05 ^a	0.78±0.07 ^a	0.032	2.769	0.050
TAS (ng/ml)	1.07±0.11	1.11±0.23	1.22±0.25	1.28±0.17	0.096	0.237	0.870

^{abc}Means with different superscript in a row differ significantly ($p < 0.05$).

Conclusion

The present study demonstrated that dietary supplementation with lysophospholipid (LPL) and sphorolipid (SPL) had no adverse effects on hematological parameters in broiler chickens. Serum biochemical analysis revealed that glucose and albumin concentrations were

significantly increased with emulsifier supplementation, while other parameters remained unaffected. Furthermore, the antioxidant status of the birds was significantly improved, as evidenced by reduced malondialdehyde (MDA) levels and increased activities of superoxide dismutase (SOD) and glutathione peroxidase (GPx) in LPL-

and SPL-supplemented diets. These findings indicate that LPL and SPL supplementation can improve antioxidant defense and overall physiological status in broilers.

Declarations

The permission for animal experiments was granted by the institutional Animal Ethics Committee (IAEC: 142/VCN/2025).

Funding

The research grant was received from the project of Kamdhenu University, Gandhinagar.

References

- Abudabos AM. Effect of enzyme supplementation to normal and low-density broiler diets based on corn soybean meal. *Asian Journal of Animal and Veterinary Advances*. 2012;7(2):139-148.
- Ani AO, Onodugo MO, Ogwuegbu MC, Udeh VC, Mthiyane DMN. Influence of dietary lysolecithin on growth performance, nutrient digestibility, haemato-biochemistry, and oxidative status of broiler birds. *Tropical Animal Health and Production*. 2024;56(8):271-282.
- Attia YA, Abd El-Hamid AE, Abdallah AA, Berikaa MA, El-Gandy MF, Sahin K, Abou-Shehema BM. Effect of betaine, vitamin C and vitamin E on egg quality, hatchability, and markers of liver and renal functions in dual-purpose breeding hens exposed to chronic heat stress. *European Poultry Science*. 2018;82:1-12.
- Ayala A, Muñoz MF, Argüelles S. Lipid peroxidation: production, metabolism, and signaling mechanisms of malondialdehyde and 4-hydroxy-2-nonenal. *Oxidative Medicine and Cellular Longevity*. 2014;2014:360-438.
- Cai Y, Gao L, Song B, Song Z. Lysolecithins improved growth performance, nutrient digestibility, immunity, and antioxidant ability in broiler chickens. *Animal Bioscience*. 2024;37(8):1408-1420.
- Cho JH, Zhao P, Kim IH. 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 Agricultural Science*. 2012;4(10):161-168.
- Cowieson AJ, Adeola O. Carbohydrates, protease and phytase have an additive beneficial effect in nutritionally marginal diets for broiler chicks. *Poultry Science*. 2005;84(12):1860-1867.
- Das SK, Vasudevan D. Effect of lecithin in the treatment of ethanol-mediated free radical induced hepatotoxicity. *Indian Journal of Clinical Biochemistry*. 2006;21(1):62-69.
- Deng S, Fu A, Junaid M, Wang Y, Yin Q, Fu C, Pei DS. Nitrogen-doped graphene quantum dots perturb redox-sensitive systems via selective inhibition of antioxidant enzyme activities in zebrafish. *Biomaterials*. 2019;206:61-72.
- Eid Y, El-Soud SA, Gamel MZ, El-Kassas S, Azzam MM, Di Cerbo A, Kirrella AA. Dietary lysophospholipids enhance broiler performance, immune response, meat quality, and mitigate oxidative stress. *Frontiers in Immunology*. 2025;16:1572314.
- Eiler H. Endocrine glands. In: Reece WO, editor. *Dukes' Physiology of Domestic Animals*. 12th ed. Ithaca (NY): Comstock Publishing; 2004. p. 621-669.
- El-Katcha MI, Soltan MA, Shewita R, Abdo SE, Sanad AS, Tufarelli V, El-Naggar K. Dietary fiber and lysolecithin supplementation in growing ducks: effects on performance, immune response, intestinal morphology and lipid metabolism-regulating genes. *Animals*. 2021;11(10):2873-2889.
- Gholami M, Shirzadi H, Taherpour K, Rahmatnejad E, Shokri A, Khatibjoo A. Effect of emulsifier on growth performance, nutrient digestibility, intestinal morphology, faecal microbiology and blood biochemistry of broiler chickens fed low-energy diets. *Veterinary Medicine and Science*. 2024;10(3):1437-1450.
- Hardin R, Pierre J, Schulze R, Mueller CM, Fu SL, Wallner SR, Bluth MH. Sphorolipids improve sepsis survival: effects of dosing and derivatives. *Journal of Surgical Research*. 2007;142(2):314-319.
- Ilyas M, Arshad MU, Basra SMA. Toxicological assessment of aqueous extracts of leaves and seeds of *Moringa oleifera* on blood biochemical profile of rats. *International Journal of Agriculture and Biology*. 2016;18:1263-1270.
- Iqbal J, Hussain MM. Intestinal lipid absorption. *American Journal of Physiology - Endocrinology and Metabolism*. 2009;296(6):1183-1194.
- Jones DB, Hancock JD, Harmon DL, Walker CE. Effects of exogenous emulsifiers and fat sources on nutrient digestibility, serum lipids, and growth performance in weanling pigs. *Journal of Animal Science*. 1992;70(11):3473-3482.
- Joshi A, Paratkar SG, Thorat BN. Modification of lecithin by physical, chemical and enzymatic methods. *European Journal of Lipid Science and Technology*. 2006;108(4):363-373.
- Kamran J, Mehmood S, Rahman M, Mahmud A, Hussain M, Rehman A. 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*. 2020;22:eRBCA20201285.
- Ko H, Wang J, Chiu JWC, Kim WK. Effects of metabolizable energy and emulsifier supplementation on growth performance, nutrient digestibility, body composition, and carcass yield in broilers. *Poultry Science*. 2023;102:102509.
- Kothare A, Wankhede S, Munde V, Sirsat Y, Mogale R. Effect of supplementation of multi-enzyme in low energy diet on carcass traits and hematobiochemical parameters of broiler birds. *Journal of Veterinary Sciences and Animal Husbandry*. 2021;6(3):34-39.
- Lu CH. Application research of substitution of emulsifier for partial oil in the production of broilers [master's thesis]. Nanjing: Nanjing Agricultural University; 2015.
- Melegy T, Khaled NF, El-Bana R, Abdellatif H. Dietary fortification of a natural biosurfactant, lysolecithin in broiler diets. *African Journal of Agricultural Research*. 2010;5(21):2886-2892.
- Mohammadigheisar M, Kim HS, Kim IH. Effect of inclusion of lysolecithin or multi-enzyme in low

- energy diet of broiler chickens. *Journal of Applied Animal Research*. 2018;46(1):1198-1201.
25. Mohiti-Asli M, Ghanaatparast-Rashti M, Sharifi SD, Rouhanipour H, Akbarian P. Effects of lysophospholipid supplementation in diets with different oil sources on broiler performance under heat stress. *Frontiers in Veterinary Science*. 2025;12:1561679.
 26. Movagharnajad M, Kazemi-Fard M, Rezaei M, Teimuri-Yansari A. Effects of lysophospholipid and lipase enzyme supplementation to low metabolizable energy diets on growth performance, intestinal morphology and microbial population in broiler chickens. *Brazilian Journal of Poultry Science*. 2020;22:1-10.
 27. Nasr MA, Ali ESM, Hussein MA. Performance, carcass traits, meat quality and amino acid profile of different Japanese quail strains. *Journal of Food Science and Technology*. 2017;54:4189-4196.
 28. Oketch EO, Lee JW, Yu M, Hong JS, Kim YB, Nawarathne SR, Heo JM. Physiological responses of broiler chickens fed reduced-energy diets supplemented with emulsifiers. *Animal Bioscience*. 2022;35(12):1929-1942.
 29. Osho IB, Akindahunsi A, Igbanan FA, Adekunle DJ. Effect of orally administered bitter leaf (*Vernonia amygdalina*) extract on growth performance and haematological parameters of broiler chicken. *Journal of Veterinary Medicine and Animal Health*. 2014;6(10):251-256.
 30. Park JH, Nguyen DH, Kim IH. Effects of exogenous lysolecithin emulsifier supplementation on growth performance, nutrient digestibility, and blood lipid profiles of broiler chickens. *Journal of Poultry Science*. 2018;55(3):190-194.
 31. Ravindran V, Tancharoenrat P, Zaefarian F, Ravindran G. Fats in poultry nutrition: digestive physiology and factors influencing their utilisation. *Animal Feed Science and Technology*. 2016;213:1-21.
 32. Saleh AA, Amber KA, Mousa MM, Nada A, Awad W, Dawood M, Abd El-Moneim A, Ebeid T, Abdel-Daim MM. A mixture of exogenous emulsifiers increased acceptance of broilers to low energy diets. *Animals*. 2020;10:437-452.
 33. Sanhoury MHS, Ahmed AMH. Broiler performance, enzyme activity and histological observations affected by multi-enzymes complex (Zado®). *Egyptian Journal of Nutrition and Feeds*. 2017;20(2):309-320.
 34. Singh PK, Shekhar A, Kumar K, Kumar S, Kumar P, Ganguly B. Comparative efficacy of synthetic and herbal emulsifiers in broiler chicken fed energy-restricted diet. *Indian Journal of Animal Sciences*. 2023;93(4):359-365.
 35. Sun N, Chen J, Wang D, Lin S. Advances in food-derived phospholipids: sources, molecular species, structures and biological activities. *Trends in Food Science and Technology*. 2018;80:199-211.
 36. Surai PF, Kochish II, Fisinin VI. Glutathione peroxidases in poultry biology: classification and mechanisms of action. *World's Poultry Science Journal*. 2018;74(2):185-198.
 37. Tompkins RK, Parkin LG. Effects of long-term ingestion of soya phospholipids on serum lipids in humans. *American Journal of Surgery*. 1980;140(3):360-364.
 38. Upadhaya SD, Lee JS, Jung KJ, Kim IH. Influence of emulsifier blends with different hydrophilic-lipophilic balance values on growth performance and meat quality of broilers. *Poultry Science*. 2018;97(1):255-261.
 39. Wu H, Wang S, Tian Y, Zhou N, Wu C, Li R, Lu L. Effects of hydroxylated lecithin on growth performance and meat quality in Jiangnan white goslings. *Frontiers in Veterinary Science*. 2022;9:829338.
 40. Zangeneh S, Torki M, Lotfollahian H, Abdolmohammadi A. Effects of dietary lysophospholipids and vitamin C on broiler chickens under heat stress. *Journal of Animal Physiology and Animal Nutrition*. 2018;102:1521-1532.
 41. Zhao PY, Kim IH. Effect of diets with different energy and lysophospholipids levels on performance and body composition in broilers. *Poultry Science*. 2017;96(5):1341-1347.