Full Length Article

INFLUENCE OF GLYCERYL POLYETHYLENE GLYCOL RICINOLEATE (GPEGR) ON PRODUCTION PERFORMANCE OF BROILER CHICKEN

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ABSTRACT

A biological trial was conducted to evaluate the effect of glyceryl polyethylene glycol ricinoleate (GPEGR) supplementation on the production performance in broiler chicken. A total of two hundred day-old broiler chicks were randomly assigned to five dietary treatments containing forty birds in each group with five replicates in each treatment group and thus constituting eight birds per replicate . The control group (C) received basal diet, T_1 group received the basal diet and GPEGR, while the T_2, T_3, and T4 groups received GPEGR-supplemented diets with graded reductions in energy density by 20, 40, and 60 kcal/kg, respectively. All the birds were maintained under uniform and standard managemental conditions with access to ad-libitum feed and water. The study found that the final body weight and average daily gain (ADG) in the T_1 group (1804.99 g and 50.21 g, respectively) were significantly ($P<0.05$) higher than the control group (1662.80 g and 46.16 g, respectively). While the energy reduced diets (T_2, T_3, T_4) supplemented with GPEGR did not show significant improvements in body weight and ADG compared to the control. The cumulative and average daily feed as well as the feed conversion ratio (FCR), showed no significant ($P>0.05$) differences among the groups. It can be concluded that the feeding of GPEGR supplemented diet containing 3000 Kcal per kg enhanced the growth rate in broiler chicken

Keywords: Broiler chicken, Glyceryl Polyethylene glycol ricinoleate (GPEGR), Production performance

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INTRODUCTION

India, as the largest developing country, is experiencing rapid growth in its poultry sector. Over recent decades, there have been significant advancement in nutrition, genetics, and management practices. In the 2022–2023 period, India

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produced a total of 9.77 million tons of poultry meat, marking a 4.5 per cent increase in the commercial poultry population compared to 2012 census. The price of traditional feed components is increasing due to recession, Covid- 19 like epidemics and conflicts. Variety of oil and fats are included in the modern broiler chicken diets for meeting out its high energy demand. The efficient digestion of lipid sources is essential to reduce the expense on feed and wastage. Emulsifiers are also frequently used in the animal production sector to enhance the utilization of lipids. Emulsification products can be either synthetic or natural. Examples of natural emulsifiers include bile, phospholipids, soy lecithin and casein, while synthetic emulsifiers include lysolecithin, glycerol monostearate, glycerol distearate, and sodium stearoy l-2-lactylate.

Glyceryl polyethylene glycol ricinoleate (GPEGR), an exogenous emulsifier was used in this study to assess its influence on production performance of broiler chicken. Glyceryl Polyethylene Glycol Ricinoleate (GPEGR) is a synthetic emulsifier. The lipophilic part of GPEGR molecule consists of glyceryl polyethylene glycol ricinoleate together with fatty acid esters of polyethylene glycol. The hydrophilic part consists of free polyethylene glycol and ethoxylated glycerol. It works good with environment of high water and less fat. These emulsifiers are more useful as the environment in the bird's gut has plenty of water and little oil. The Hydrophilic-Lipophilic Balance (HLB) of this class of emulsifiers can vary from 2.14 to over 16.

MATERIALS AND METHODS

Two hundred day-old broiler chicks were randomly divided into five treatment groups including C (control), T_1, T_2, T_3 and T_4 groups of 40 birds per treatment with each treatment having 5 replicates constituting 8 birds in each replicate. The standard basal diet is kept as control. The four treatment diets are supplemented with GPEGR @ 30 g/100 Kg diet and the only variation being in the energy content. T_1 group fed with basal diet with supplementation of GPEGR @ 30 g/100 Kg diet having the same energy values as that of control diet while the treatments T_2, T_3 and T_4 had reduced energy content of 20, 40 and 60 kcal per kg less ME respectively.. All the birds were maintained in uniform managemental conditions. Diets were prepared with the standards of Vencobb breed requirement for pre starter, starter and finisher phases (Table 1,2 and 3, respectively). Body weight, cumulative feed in take and feed conversion ratio were calculated at weekly intervals. Individual bird's body weight was measured at every week with calibrated electronic weighing balance to a accuracy of 1.0 g . Feed intake was noted to level of 1.0 g accuracy for individual replicates in a weekly basis. Feed conversion ratio was calculated with the body weight and feed intake data.The data collected on various parameters were statistically analysed using the method of Snedecor and Cochran (1989). The data was subjected for one-way analysis of variance (ANOVA), followed by Duncan's post hoc test, to assess the significance of differences between the control and experimental groups. The analysis was conducted using SPSS software, version 20 (SPSS 20.0).

RESULTS AND DISCUSSION

Body weight

The results of the feeding experiment for the parameters on weekly body weight and average daily gain are summarized in Table 4. The T_1 group fed with basal diet and supplemented with Glyceryl polyethylene glycol ricinoleate (GPEGR) had significantly (P<0.05) higher final body weight at the end of 5th week than the control group fed with basal diet. However, the differences was not significant (P>0.05) among control, T_2, T_3 and T_4 groups. Energy reduced and GPEGR supplemented diet groups T_2, T_3 and T_4 groups showed non-significant (P>0.05) increase in final week body weight when comparted with the control group. Average daily gain (ADG) of T_1 group was significantly higher (P<0.05) than the control group. ADG of energy reduced and GPEGR supplemented groups (T_2, T_3 and T_4) though higher than the control group were non-significant (P>0.05) compared to the control group. The improvements in the body weight could be attributed to the improved fat utilization in the groups supplemented with GPEGR by emulsification of fat droplets by GPEGR.

The body weight in the first and second-week in the present study aligned with the results of Kaczmarek *et al.* (2015) wherein they documented non-significant difference in the body weight of broiler chicken with supplementation of GPEGR in low energy diet (0.41 MJ/Kg less apparent metabolizable energy -nitrogen corrected). Yin *et al.* (2018) also reported that similar (P>0.05) bodyweights was observed between the groups supplemented with decreased energy density with GPEGR and decreased energy density diet without GPEGR during 0 to 17 days. Further, Tavares *et al.* (2022) also documented a non-significant difference between the GPEGR supplemented energy reduced diet groups and basal diet group in broiler chicken up to 21 days of age. On the contrary, Cheah *et al.* (2017) and Ganna *et al.* (2022) reported a non-significant difference in final body weight between GPEGR supplemented group and control group

However, Bontempo *et al.* (2018) reported significantly (P<0.05) higher body weight and average daily gain in broiler chicken when the diet was supplemented with GPEGR (387.6 and 1092g in 12^{th} and 22^{nd} day of age, respectively) than the basal diet fed group (378 and 1070 g, respectively). Zulkifli *et al.,* (2019) documented a significant (P<0.05) increase in the body weight of broiler chicken which was supplemented with GPEGR in the diet (457g) than the basal diet group (444g) at two weeks of age. Reported a significant (P<0.05) increase in the body weight of broiler chicken in first, third, fourth, fifth and sixth week of age (169.70, 790.56, 1340.3, 1859, 2432.6g respectively) when supplemented with natural and synthetic emulsifiers combinely than the basal diet fed group (159.87, 707.80, 1124.10, 1574 and 2177g respectively).

Cumulative feed intake

Results of mean cumulative feed intake was presented in Table 5. There was no significant difference (P>0.05) in cumulative feed intake and average daily feed intake in GPEGR fed groups (T_1, T_2, T_3 and T_4) in comparison with the control group. Inspite of energy reduction in T_2, T_3 and T_4 groups, the feed intake was not affected significantly which might be due to the effect of addition of GPEGR which enhanced the energy utilization.

In accordance with the present study, Bontempo *et al.,* (2018) recorded a non-significant (P>0.05) feed intake among the basal diet fed control group and GPEGR fed groups. Kaczmarek *et al.* (2015) also reported a similarity in feed intake of basal diet fed group, basal diet and GPEGR fed group, low energy diet group and GPEGR supplemented low energy diet groups. Amitava Roy *et al.,* (2010) reported similar results which is in consonance with the findings of present study, a non-significant difference in the cumulative feed intake of GPEGR supplemented (1 and 2 per cent of added fat) and basal diet groups. Saleh *et al.,* (2020) also observed that the effect of feeding GPEGR on feed intake was non-significant. Ghazanfari *et al.* (2024) also stated a similar (P>0.05) feed intake between the basal diet group, low energy diet group, low energy diet with emulsifier supplemented group, low energy diet with emulsifier and peppermint oil supplemented group during the starter, grower and finisher phase. Zosangpuii *et al.* (2015) documented similar feed intake among the groups in which ducks supplemented with emulsifier and the group fed with basal diet.

In agreement with this study, Tavares *et al.* (2022), San Tan *et al.* (2016) and Yin *et al.* (2018) reported non-significant impact on feed intake between the emulsifier supplemented group and control group. There was a non-significant difference in feed intakes of GPEGR and GPEGR with bile supplemented groups (Ganna *et al.,* 2022) corroborating with present study's findings.

Whereas, Bontempo *et al.* (2016) reported a significant (P<0.05) increase in average daily feed intake of GPEGR fed broiler chicken, when calculated from 10 to 20 (79.3 vs. 67.8 g), 20 to 34 (144.2 vs. 119.7 g) and 0 to 34 (93.0 vs. 79.3 g) days of age in comparison with the basal diet group. While, Tavares *et al.* (2022) reported significantly (P<0.01) lower feed intake in the emulsifier supplemented group (1052.21 g) in comparison with the control group (1236.33 g) without emulsifier from 0 to 21 days of age. Shekhar *et al.* (2023) also reported significantly lower feed intake in the synthetic emulsifier fed group (2995.13g) than the energy restricted (3 per cent less ME) diet group (3084.04 g).

Feed conversion ratio (FCR)

Results of feed conversion ratio is presented in Table 6. In the present study, there was no significant difference in feed conversion ratio (FCR) observed among the treatment groups during first, second, fourth and fifth week of age. There was significantly ($P<0.05$) higher FCR in GPEGR supplemented low energy (60 kcal less ME) diet group (1.29) (T4) in comparison with the control, T_1, T_2 (20 kcal less ME) and T_3 group (40 kcal less ME) at 3rd week of age . This may be probably attributed to the increased feed intake in the low energy diet (60 kcal/kg low energy) during 3rd week. Even though there was a non-significant difference in final FCR of the emulsifier supplemented T_1, T_2 and T_4 groups (1.56, 1.57 and 1.62) were numerically ($P>0.05$) better than the control group (1.64) which might be due to the improved ether extract digestibility in the emulsifier supplemented groups. The poor FCR in the T_3 group might be due to the increased feed intake due to the higher level of energy reduction.

In agreement with the findings in the present study, Kaczmarek *et al.* (2015) highlighted a similar FCR between the control and low energy diet group during 14 to 35 days of age. In addition, Saleh *et al.* (2020), Ganna *et al.* (2022) and Ghazanfari *et al.* (2024) also reported similar FCR ($P>0.05$) between the basal diet group and low energy diet group supplemented with emulsifier. Bontempo *et al.* (2016) reported a similar FCR ($P>0.05$) from 0 to 34 days of age, between the broiler chicken groups supplemented with GPEGR and basal diet which was in corroboration to our present study. Tavares *et al.* (2022) reported similarity in FCR between the basal diet and emulsifier supplemented reduced energy diet groups from 22 to 42 days of age in agreement with present study. Cheah *et al.* (2017) also documented a similar FCR between the basal diet and GPEGR supplemented groups during 15 to 35 days of age.

Shekhar *et al.* (2023) observed that in broiler chicken, the emulsifier (synthetic and herbal combination) supplemented group had significantly ($P<0.05$) higher FCR (1.66) than the basal diet group (1.92) which was not in agreement with the findings in the present study. Yin *et al.* (2018) observed and reported significantly ($P<0.05$) higher FCR in broiler chicken supplemented with GPEGR in low energy density diet (1.521) than the low energy diet without emulsifier (1.565). Tavares *et al.* (2022) also documented a significant ($P<0.05$) improvement in FCR in emulsifier supplemented reduced energy diet (1.11) group than the basal diet group (1.28) during the age of 0 to 21 days. Cheah *et al.* (2017) reported a significant ($P<0.05$) improvement in FCR in broiler chicken fed with GPEGR (1.02) than the basal diet group at 1 to 14 days of age (1.09).

CONCLUSION

The results of this feeding experiment infers that feeding of GPEGR at 30 g/100 kg without energy reduction in broiler chicken enhanced the growth rate.

Table 1: Ingredients (per cent) and nutrient composition of experimental broiler pre starter ration

INGREDIENTS	BROILER PRE-STARTER				
	C	T1	T2	T3	T4
Maize	56.64	56.61	57.04	57.45	57.87
Soybean meal	37.70	37.70	37.70	37.70	37.70
Rice bran oil	1.98	1.98	1.55	1.14	0.72
Calcite	1.20	1.20	1.20	1.20	1.20
Dicalcium phosphate	0.98	0.98	0.98	0.98	0.98
Salt	0.30	0.30	0.30	0.30	0.30
Sodium bicarbonate	0.10	0.10	0.10	0.10	0.10
Phytase	0.01	0.01	0.01	0.01	0.01
Choline chloride	0.05	0.05	0.05	0.05	0.05
Toxin binder	0.10	0.10	0.10	0.10	0.10
Liver powder1	0.05	0.05	0.05	0.05	0.05
DL-Methionine	0.34	0.34	0.34	0.34	0.34
Lysine	0.20	0.20	0.20	0.20	0.20
Threonine	0.10	0.10	0.10	0.10	0.10
Coccidiostat	0.10	0.10	0.10	0.10	0.10
Vitamin premix2	0.05	0.05	0.05	0.05	0.05
Trace minerals3	0.10	0.10	0.10	0.10	0.10
GPEGR4	0.00	0.03	0.03	0.03	0.03
Total	100	100	100	100	100
Nutrient composition (Calculated values)					
ME Kcal/kg	3000	3000	2980	2960	2940
Crude protein (%)	22.56	22.56	22.60	22.63	22.67
Calcium (%)	0.95	0.95	0.95	0.95	0.95
Available Phosphorus (%)	0.45	0.45	0.45	0.45	0.45

Table 2: Ingredients (per cent) and nutrient composition of experimental broiler starter ration

INGREDIENTS	BROILER PRE-STARTER				
	C	**T1**	**T2**	**T3**	**T4**
Maize	57.79	57.76	58.16	58.59	59.12
Soybean meal	34.00	34.00	34.00	34.00	34.00
Rice bran oil	4.17	4.17	3.77	3.34	2.81
Calcite	1.58	1.58	1.58	1.58	1.58
Dicalcium phosphate	0.97	0.97	0.97	0.97	0.97
Salt	0.29	0.29	0.29	0.29	0.29
Sodium bicarbonate	0.10	0.10	0.10	0.10	0.10
Phytase	0.01	0.01	0.01	0.01	0.01
Choline chloride	0.05	0.05	0.05	0.05	0.05
Toxin binder	0.10	0.10	0.10	0.10	0.10
Liver powder1	0.05	0.05	0.05	0.05	0.05
DL-Methionine	0.34	0.34	0.34	0.34	0.34
Lysine	0.20	0.20	0.20	0.20	0.20
Threonine	0.10	0.10	0.10	0.10	0.10
Coccidiostat	0.10	0.10	0.10	0.10	0.10
Vitamin premix2	0.05	0.05	0.05	0.05	0.05
Trace minerals3	0.10	0.10	0.10	0.10	0.10
GPEGR4	0.00	0.03	0.03	0.03	0.03
Total	100	100	100	100	100
Nutrient composition (Calculated values)					
ME Kcal/kg	3125	3125	3105	3085	3065
Crude protein (%)	20.99	20.99	21.03	21.06	21.10
Calcium (%)	1.07	1.07	1.07	1.07	1.07
Available Phosphorus (%)	0.44	0.44	0.44	0.44	0.44

Table 3: Ingredients (per cent) and nutrient composition of experimental broiler finisher ration

INGREDIENTS	BROILER PRE-FINISHER				
	C	T1	T2	T3	T4
Maize	60.52	60.49	60.89	61.33	61.75
Soybean meal	30.20	30.20	30.20	30.20	30.20
Rice bran oil	5.74	5.74	5.34	4.90	4.48
Calcite	1.25	1.25	1.25	1.25	1.25
Dicalcium phosphate	0.80	0.80	0.80	0.80	0.80
Salt	0.29	0.29	0.29	0.29	0.29
Sodium bicarbonate	0.10	0.10	0.10	0.10	0.10
Phytase	0.01	0.01	0.01	0.01	0.01
Choline chloride	0.05	0.05	0.05	0.05	0.05
Toxin binder	0.10	0.10	0.10	0.10	0.10
Liver powder1	0.05	0.05	0.05	0.05	0.05
DL-Methionine	0.34	0.34	0.34	0.34	0.34
Lysine	0.20	0.20	0.20	0.20	0.20
Threonine	0.10	0.10	0.10	0.10	0.10
Coccidiostat	0.10	0.10	0.10	0.10	0.10
Vitamin premix2	0.05	0.05	0.05	0.05	0.05
Trace minerals3	0.10	0.10	0.10	0.10	0.10
GPEGR4	0.00	0.03	0.03	0.03	0.03
Total	100	100	100	100	100
Nutrient composition (Calculated values)					
ME Kcal/kg	3250	3250	3230	3210	3190
Crude protein (%)	19.52	19.52	19.55	19.59	19.63
Calcium (%)	0.9	0.9	0.9	0.9	0.9
Available Phosphorus (%)	0.4	0.4	0.4	0.4	0.4

Table 4. Effect of feeding GPEGR on body weight (g), and average daily gain (g) in broiler chicken upto five weeks of age (Mean ± SE)

Treatment groups	Body weight in g at weekly intervals						Average Daily Gain (g/d/bird) Upto 35 days
	Day old	I	II	III	IV	V	
Control	47.20±0.71	185.98±2.53	461.20±6.88	873.17±14.97	1259.88±21.44	1662.80a±32.76	46.16a±0.93
T_1	47.42±0.70	182.37±2.89	453.75±6.87	875.75±15.19	1276.13±24.99	1804.99b±35.77	50.21b±1.02
T_2	47.94±0.68	183.40±2.59	455.26±7.24	872.61±14.82	1248.17±26.38	1747.37ab±36.30	48.55ab±1.03
T_3	47.83±0.65	188.10±2.30	459.38±5.65	886.16±13.37	1235.93±19.46	1724.65ab±25.85	47.91ab±0.73
T_4	48.00±0.65	185.81±2.41	459.61±5.24	870.60±13.35	1254.90±10.32	1675.33a±37.82	46.48a±1.07
P value	0.904^{NS}	0.516^{NS}	0.914^{NS}	0.947^{NS}	0.805^{NS}	0.024*	0.024*

^{a,b} **Means in columns bearing different superscripts vary significantly * (P<0.05); ^{NS}: Non-Significant**

Table 5. Effect of feeding GPEGR on cumulative (g/bird) and average daily feed intake (g/d/bird) in broiler chicken up to 5 weeks of age (Mean ± SE)

Treatment groups	Age in weeks					Average Daily Gain (g/d/bird) Upto 35 days
	I	II	III	IV	V	
Control	179.00 ± 2.91	546.80 ± 4.64	1094.60 ± 13.36	1775.32 ± 27.63	2740.30 ± 80.86	78.29 ± 2.31
T_1	174.60 ± 4.26	535.90 ± 6.01	1086.10 ± 15.89	1787.22 ± 25.71	2825.22 ± 92.37	80.72 ± 2.63
T_2	168.60 ± 4.13	534.40 ± 9.08	1092.60 ± 19.48	1822.09 ± 18.02	2729.35 ± 32.86	77.98 ± 0.93
T_3	171.80 ± 2.85	536.40 ± 1.96	1106.00 ± 12.73	1805.99 ± 13.26	2892.58 ± 87.30	82.64 ± 2.49
T_4	177.54 ± 3.67	550.94 ± 6.15	1129.14 ± 21.83	1835.53 ± 24.75	2712.61 ± 78.56	77.50 ± 2.24
P value	0.281^{NS}	0.231^{NS}	0.436^{NS}	0.344^{NS}	0.442^{NS}	0.442^{NS}

^{a,b} **Means in columns bearing different superscripts vary significantly * (P<0.05); ^{NS}: Non-Significant**

Table 6. Effect of feeding GPEGR on feed conversion ratio in broiler chicken upto 5 weeks of age (Mean ± SE)

Treatment groups	Age in weeks				
	I	II	III	IV	V
Control	0.96 ± 0.01	1.18 ± 0.01	1.25a± 0.01	1.40 ± 0.02	1.64 ± 0.03
T_1	0.95 ± 0.01	1.18 ± 0.01	1.24a ± 0.01	1.40 ± 0.01	1.56 ± 0.05
T_2	0.92 ± 0.02	1.17 ± 0.01	1.25a ± 0.01	1.47 ± 0.03	1.57 ± 0.03
T_3	0.91 ± 0.01	1.16 ± 0.01	1.24a ± 0.01	1.46 ± 0.01	1.67 ± 0.05
T_4	0.95 ± 0.02	1.19 ± 0.01	1.29b ± 0.01	1.47 ± 0.03	1.62 ± 0.04
P value	0.388^{NS}	0.575 ^{NS}	0.024*	0.220 ^{NS}	0.422 ^{NS}

^{a,b}Means in columns bearing different superscripts vary significantly * (P<0.05);
^{NS}: Non-Significant;

REFERENCES

Amitava Roy, Sudipto Haldar, Souvik Mondal and Ghosh. (2010). Effects of supplemental exogenous emulsifier on performance, nutrient metabolism, and serum lipid profile in broiler chickens. *Veterinary Medicine International,* 2010(**1**) : 1-9. doi: 10.4061/2010/262604.

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. *Animal*, **10**(4):592-597.

Bontempo, V., Comi, M., Jiang, X.R., Rebucci, R., Caprarulo, V., Giromini, C. and Baldi, A. (2018). Evaluation of a synthetic emulsifier product supplementation on broiler chicks. *Animal Feed Science and Technology,* **240**:157-164.

Cheah, Y., Loh, T., 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*, **87**(4): 464-472.

Ganna, S., Abdel-Latif, M. and Ahmed, H. (2022). Effect of dietary supplementation of some emulsifiers on growth performance, carcass traits, lipid peroxidation and some nutrients digestibility in broiler chickens. *Damanhour Journal of Veterinary Sciences*, **7**(2): 16-23.

Ghazanfari, S., Ghzghapan, A.S. and Honarbakhsh, S. (2024). Effects of peppermint essential oil and artifier on growth performance, carcass characteristics and nutrient digestibilities in broiler chickens fed with low energy diets. *Veterinary and Animal Science*, **24:** 100354.

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

Saleh, A.A., Amber, K.A., Mousa, M.M., Nada, A.L., Awad, W., Dawood, M.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**(3): 437.

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

Shekhar, A., Singh, P. K., Kumar, K., Kumar, S., Kumar, P. and Ganguly, B. (2023). Comparative efficacy of synthetic and herbal emulsifiers in broiler chicken fed energy-restricted diet. *Indian Journal of Animal Sciences*, **93**(4): 359-365.

Snedecor, G.W. and Cochran.W.G.(1989). Statistical methods. 8thEdn., lowa state university press, Ames, USA. lowa - 50010.

Tavares, F.B., de Souza Lima, K.R., Manno, M.C., Barata, Y.M.L., de Oliveira Pinheiro, H.C., Arruda, J.D.C.B. and Faturi, C. (2022). Effect of exogenous emulsifier and different fat sources on the performance, carcass characteristics, nutrient digestibility, and serum lipid profile of broiler chickens. *Brazilian Journal of Veterinary Research and Animal Science,* **59**:e189542-e189542.

Yin, J., Yun, H.M. and Kim, I.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: focus on dietary glycerol polyethylene glycol ricinoleate in broilers. *Korean Journal of Agricultural Science*, **45**(2): 219-228.

Zosangpuii, Z., Patra, A.K. and Samanta, G. (2015). Inclusion of an emulsifier to the diets containing different sources of fats on performances of Khaki Campbell ducks. *Iranian Journal of Veterinary Research*, **16**(2): 156-160.

Zulkifli, I., Tan, H.S., Soleimani, A.F., Goh, Y.M., Croes, E., Partha, S.K. and Tee, A.K. (2019). The effects of glyceryl polyethylene glycol ricinoleate on growth performance, fat digestibility, apparent metabolisable energy, serum lipid profile, meat fatty acid content, and caecal microflora in male broiler chickens. *European Poultry Science/ Archiv für Geflügelkunde*, **83**(274).