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Sources and levels of glycerin for broilers from 22 to 35 days

Verônica Maria Pereira Bernardino*, Paulo Borges Rodrigues, Rilke Tadeu Fonseca de Freitas, Elisangela Minati Gomide, Letícia Makiyama, Rodrigo Silva Bueno, David Henrique de Oliveira and Lucas Januzzi Lara

Animal Sciences Department, Federal University of Lavras (UFLA), Lavras, Minas Gerais, 37200-000, Brazil.

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The aim of this experiment was to evaluate the performance and carcass yield of broilers from 22 to 35 days old, receiving diets with different levels of soybean glycerin (SG) and semipurified glycerin (PURG). A total of 792 male broilers of the Cobb 500 strain, a 4x2+1 factorial arrangement was used designed in randomized blocks by the weight of the birds, with four inclusion levels (17.5, 35.0, 52.5 and 70, 0 g/kg) of two glycerins (SG and PURG) in the diets and one glycerin-free control treatment. Four replicates per treatment of 22 birds were used for each experimental unit. Feed intake and carcass yield were not influenced by the levels and sources of glycerin. There was an interaction between levels and sources of glycerin for the weight gain (WG) where a quadratic effect was observed for the SG and the largest WG obtained with the addition of 35.50 g/kg of SG. There was an interaction between glycerol levels and sources for feed conversion (FC) and a quadratic effect was observed for both sources; the level of 35.5 g/kg of SG promoted a better FC and the level of 39.44 g/kg of PURG promoted the worst FC. For the thigh and drumstick yield (TDY), there was an interaction between levels and sources of glycerin, and the inclusion of 40.21 g/kg of SG provided a lower TDY. There was also interaction for breast yield (BY), where the highest levels of BY were 35.15 g/kg of SG and 43.69 g/kg PURG. The percentage of abdominal fat (AF) was influenced only by the sources of glycerins, where the lowest percentage of AF was promoted by PURG. Regarding the control, the inclusion of 70 g/kg SG provided the worst PG, TDY and BY. In conclusion, the addition of 35.5 g/kg of SG and 70.0 g/kg PURG provides the best performance outcome of birds at 22 to 35 days old, within the evaluated levels.

Key words: Poultry, commercial cuts, glycerol, abdominal fat.

INTRODUCTION

Glycerin is a byproduct of biodiesel production, derived from vegetable oils and animal fats (Rivaldi et al., 2007). According to Swiatkiewicz and Koreleski (2009), from each 1000 kg of biodiesel produced, about 100 kg of glycerin is obtained.

In Brazil there is an increasing production of biodiesel which, according to the National Petroleum Agency (2013), the estimated production of biodiesel for 2012 is 2.72 billion liters. Therefore, there was a production of 272 million liters of crude glycerin only in Brazil. Thus,

*Corresponding author. E-mail: veronicampb@gmail.com .
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Table 1. Ingredient and calculated nutritional composition of the diets (g/kg as fed basis) during the period from 22 to 35 days of age.

Ingredient	Control	Crude glycerin from soybean oil				Semipurified glycerin†			
		17.5	35.0	52.5	70.0	17.5	35.0	52.5	70.0
Corn	617.39	597.48	577.55	556.37	534.60	597.44	577.47	556.77	535.13
Soybean meal	316.02	319.63	323.24	327.08	331.03	319.64	323.26	327.01	330.94
Soybean oil	29.53	29.91	30.29	31.09	32.11	29.80	30.06	30.58	31.42
Glycerin	0.00	17.5	35.00	52.50	70.0	17.50	35.00	52.50	70.00
Dicalcium phosphate	16.47	16.52	16.57	16.63	16.68	16.52	16.57	16.63	16.68
Limestone	8.36	8.32	8.28	7.61	6.63	8.32	8.28	7.87	6.98
Common salt	2.24	2.25	2.26	1.57	0.53	2.25	2.26	1.86	0.92
DL-Methionine	2.23	2.25	2.28	2.31	2.33	2.25	2.28	2.30	2.33
L-Lysine HCl	1.75	1.68	1.62	1.55	1.48	1.68	1.62	1.55	1.48
L-Threonine	0.36	0.35	0.35	0.35	0.34	0.35	0.35	0.35	0.34
Calcium chloride	0.00	0.00	0.00	0.89	2.22	0.00	0.00	0.53	1.73
Sodium bicarbonate	3.61	2.06	0.51	0.00	0.00	2.20	0.80	0.00	0.00
Lasalocid	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Mineral supplement‡	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Vitamin supplement●	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Choline chloride	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Zinc bacitracin	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Calculated nutrient composition (g/kg as fed basis)									
ME (MJ/kg)	12.98	12.98	12.98	12.98	12.98	12.98	12.98	12.98	12.98
Crude protein	197.27	197.27	197.27	197.27	197.27	197.27	197.27	197.27	197.27
Glycerol►	0.00	12.25	24.5	36.75	49.00	13.88	27.76	41.64	55.52
Calcium	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
Available Phosphorus	4.11	4.11	4.11	4.11	4.11	4.11	4.11	4.11	4.11
Sodium	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50
Chlorine	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
Lysine	10.73	10.73	10.73	10.73	10.73	10.73	10.73	10.73	10.73
Methionine + cystine	77.30	77.30	77.30	77.30	77.30	77.30	77.30	77.30	77.30
Threonine	69.70	69.70	69.70	69.70	69.70	69.70	69.70	69.70	69.70
D.E.B (mEq/kg)*	231	231	231	231	231	231	231	231	231

†Semiurified glycerin from soybean oil (GENPA®, Granol Indústria, Comércio e Exportação S/A). ‡Supplied per kg of the diet: Zn, 55 mg; Se, 0.18 mg; I, 0.70 mg; Cu, 10 mg; Mn, 78 mg; Fe, 48 mg. ●Supplied per kg of the diet: folic acid, 0.48 mg; pantothenic acid, 8.7 mg; biotin, 0.018 mg; butylated hydroxytoluene (BHT), 1.5 mg; niacin, 11.1 mg; vitamin A, 6,000 IU; vitamin B1, 0.9 mg; vitamin E, 12.15 IU; vitamin B12, 8.1 µg; vitamin B2, 3.6 mg; vitamin B6, 1.8 mg; vitamin D3, 1,500 IU; vitamin K3, 1.44 mg. ►Glycerol from glycerin supplementation. *Dietary electrolyte balance (D.E.B.) calculated using the equation proposed by Mongin (1981), which correlates the calculated concentrations of sodium, potassium and chloride ($Na^+ + K^+ – Cl^-$). ME: metabolizable energy.

there is a production of glycerin above the market demand, which drives the researchers to seek new uses of this byproduct. Due to the lack of legislation to dispose the glycerin produced in excess, this byproduct can become in this way, an environmental problem.

As crude glycerin may be considered a good source of dietary energy for poultry and pigs (Cerrate et al., 2006; Dozier et al., 2008) it is possible to suggest its inclusion in animal diet, which is a viable and environmentally sustainable alternative to allocate part of this byproduct on the market, as it may prevent the over production from having inadequate destinations and contaminating the environment. Thus, this study aimed to evaluate the performance and carcass yield of broilers from 22 to 35 days old, receiving diets with different levels of crude glycerin derived from soybeans and semipurified glycerin.

MATERIALS AND METHODS

The experiment was conducted at the Poultry Section of the Department of Animal Science, Federal University of Lavras, Lavras - MG, using 792 male broilers of the Cobb 500 strain, in a 4x2 +1 factorial arrangement, with a design in blocks randomized by the weight of the birds, being four levels of inclusion of two glycerins in the diets (17.5, 35.0, 52.5 and 70.0 g/kg diet) and a control treatment without any addition of glycerol. Crude soybean glycerin (SG), and semipurified glycerin - GENPA® (PURG) were used. Diets were formulated to meet nutritional requirements in accordance with recommendations of the Brazilian tables (Rostagno et al., 2005) (Table 1). Due to the high sodium concentration in the

Table 2. Chemical composition of the different glycerin types*.

Parameter	Crude glycerin from soybean oil	Semipurified glycerin from soybean oil‡
Moisture and volatiles (g/kg)	167.5	110.8
Karl Fischer moisture (g/kg)	124.5	101.5
Glycerol (g/kg)	700.0	793.1
Gross energy (MJ//kg)	15.33	15.48
Crude protein (g/kg)	0.3	0.4
Methanol●	181.3	20.6
Sodium (g/kg)	23.8	21.6
Total phosphorus (g/kg)	0.0	0.3
Potassium (g/kg)	0.6	0.9
pH in aqueous solution	6.05	5.72

*Chemical analyses performed by CBO laboratory analyses, Campinas/São Paulo, Brazil. ‡Semipurified glycerin from soybean oil (GENPA®, Granol Indústria, Comércio e Exportação S/A). •Units are mg/L for the glycerin from crude soybean and semi-purified sources and g/kg for the mixed glycerin.

glycerins used, we adjusted the salt in the diet formula, with the necessary corrections for sodium and chlorine, the latter corrected by the addition of calcium chloride. In the formulating diets, we used an average value of corrected apparent metabolic energy for nitrogen for each glycerin (3279 and 3304 kcal/kg of natural matter, respectively), previously determined by Lima et al. (2012). The nutritional composition of the glycerins used was analyzed by CBO Laboratory Analysis (Table 2). We evaluated the performance and carcass yield and cuts of chicken from 22 to 35 days old.

In all, there were nine treatments with four replicates of 22 birds each. The birds were housed in brick shed, divided into boxes of 3 m^2. The floor of each box was covered with wood shavings and each box contained a tubular feeder and drinker a pendulum. The animals were exposed to continuous light, receiving water and ration *ad libitum*.

To evaluate the performance, birds and diets were weighed at the beginning and at the end of the experiment (at 22 and 35 days old) for weight gain, diet intake and feed conversion. The mortality of birds was recorded and considered for the correction of performance data.

At 35 days old, for carcass yield evaluation, two birds per experimental unit, were selected and slaughtered (eight birds per treatment in total) with a weight of approximately 5.0% of the respective box average. The carcass yield was calculated on the weight of the clean carcass and eviscerated without going through the chiller in relation to the fasting body living weight. The chilled carcasses were manually cut into pieces (breast, thigh + drumstick and abdominal fat).

Statistical analysis of the performance variables and carcass yield were performed by the statistical software SAEG (UFV, 2007). The ANOVA of performance data and carcass yield and cuts was conducted, and when significant, sources of glycerin were compared by the Student-Newman-Keuls test and the glycerin levels by regression analysis. The control treatment was compared to the average of treatments with glycerin by the Dunnett's test.

RESULTS AND DISCUSSION

The diet intake was not influenced by the sources nor by the levels of glycerin inclusion (Table 3) and did not differ from the control diet (P>0.05) either. This result is according to Mclea et al. (2011), who at the moment of inclusion of two sources of glycerin (with apparent metabolizable energy values of 3093.11 and 3487.21 kcal/kg of natural matter) and three levels (33.63 and 100 g/kg) for broilers in the period from 7 to 28 days and did not observe any difference in the diet intake. Cerrate et al. (2006) did not observe differences in the diet intake in broilers from 0 to 35 days old fed with 0, 50 and 100 g of glycerin/kg of diet either. Probably, the non-difference in the diet intake observed in the present experiment was due to the fact that the experimental diets are isonutritious; therefore, it can be inferred that the concentration of glycerin in the diet does not interfere in the diet intake, as long as the poultry nutritious requirements are met.

A significant interaction was observed (P<0.05) between the sources and levels of glycerin tested for the weight gain (Table 3), where the quadratic effect of the evaluated levels was observed for the soybean glycerin, and for the semi purified glycerin the levels did not influence the weight gain. The effect of the levels of crude soybean glycerin on the weight gain in the broilers can be expressed by the $Y= -0.0002x^2+0.01423x+1.2119$ (R^2= 0.95) equation, suggesting the best level for dietary inclusion of the soybean glycerin as 35.58 g/kg.

The difference observed in the weight gain in the present experiment was not observed by Mclea et al. (2011), who studied the inclusion of glycerin sources and levels of 33.0, 67.0 and 100.0 g/kg for broilers in the period from 21 to 28 days old. Cerrate et al. (2006) verified that even the inclusion of 50 g/kg of crude glycerin in the diet of broilers in the period from 0 to 35 days old does not alter the weight gain of the birds. However, 100 g/kg of glycerin negatively affected breast weight gain (BWG). Jung and Batal (2011a) included up to 75.0 g/kg of glycerin in the diets of broilers in the period from 16 to 34 days old and did not observe difference in weight gain either.

The worsening in weight gain from 35.58 g/kg of inclusion of the soybean glycerin and the contradictory results to those found by the supracited authors can be

Table 3. Diet intake (kg), weight gain (kg) and feed conversion (kg/kg) of birds fed with diets containing glycerins in different levels in the period from 22 to 35 days old.

Evaluation parameter	Diet intake (kg)				
	Level (g/kg)				
Glycerins	17.5	35.0	52.5	70.0	Average
Soybean [ns]	2.210	2.252	2.260	2.251	2.243
Semipurified [ns]	2.223	2.241	2.230	2.228	2.231
Probability			P>0.05		
Control Treatment			2.192		
Variation Coeficient (%)			3.806		
	Weight gain (kg)				
	Level (g/kg)				
Glycerins	17.5	35.0	52.5	70.0	Average
Soybean [Q]	1.410[A]	1.450[A]	1.453[a]	1.256[B]*	1.392
Semipurified	1.391[A]	1.341[B]	1.396[a]	1.434[A]	1.391
Probability			P<0.05		
Control Treatment			1.433		
Variation Coeficient (%)			4.530		
	Feed conversion (kg)				
	Level (g/kg)				
Glycerins	17.5	35.0	52.5	70.0	Average
Soybean[Q]	1.57[A]	1.55[A]	1.56[a]	1.79[B]*	1.62
Semipurified [Q]	1.60[A]*	1.67[B]*	1.60[A]*	1.56[A]	1.61
Probability			P<0.05		
Control Treatment			1.53		
Variation Coeficient (%)			2.052		

A,B differ through the Student-Newman-Keuls test; * Average differs from the control treatment through the Dunnett test; NS = non-significant; [Q] Quadratic effect.

partially explained by the composition of the evaluated glycerins. For example, the crude glycerin used by Mclea et al. (2011) contained 523 g of glycerol per kilo of crude glycerin; and the crude soybean glycerin used in the present experiment contained 700 g of glycerol per kilo. Possibly, the greater concentration of glycerol in the crude glycerin used in the present work, may have surmounted its metabolization capacity by the animal, promoting a worsening in the performance with higher levels of inclusion. Considering that the glycerol, when not metabolized, needs to be excreted, such process promotes energetic expenditure which can compromise the broilers performance.

In relation to the control treatment, the inclusion of 70 g of crude soybean glycerin/kg of diet was the first treatment which differed ($P<0.05$), promoting a worst weight gain to the birds (Table 3). This result may be due to the ingestion of a greater amount of glycerol than the metabolization capacity of this by the birds.

For the feed conversion, a significant interaction was observed ($P<0.05$) between the sources and levels of the tested glycerins (Table 3), where the quadratic effect was verified in both sources. The effect of the crude soybean glycerin on the feed conversion in the birds from 22 to 35 days old ($Y= 0.0002x^2 - 0.0142x + 1.765$; $R^2=0.94$), allowed a better feed conversion with the inclusion of 35.5 g of this glycerin per kilo of diet, similar to the result obtained for the weight gain. For the purified glycerin, the inclusion of 39.44 g/kg, was the one which promoted the worst conversion ($Y= -0.00009x^2 + 0.0071x + 1.5118$; $R^2= 0.77$). These results differ from those reported by Cerrate et al. (2006), who did not observe difference in the food conversion of broilers in the period from 0 to 35 days old when comparing the inclusion of 25.0 and 50.0 g/kg of glycerin. Simon et al. (1996) also found different results from the ones observed in this work, where the referred authors included up to 25.0 g/kg of pure glycerol in diets of broilers and did not verify difference in the feed conversion until the inclusion of 10.0 g/kg.

In relation to the control treatment, the level of 70 g/kg of crude soybean glycerin and 17.5; 35; 52.5 g/kg of semipurified glycerin showed the worse feed conversion ($P<0.05$) (Table 3). That is, when comparing the soybean glycerin with a diet without glycerin, the inclusion of 70.0 g/kg of this glycerin damages the performance of the birds may be suggested, possibly due to the excess of

Table 4. Carcass yield (%), Thigh + Drumstick yield (%), Breast yield (%) and Abdominal fat (%) of birds fed with diets containing glycerins in different levels in the period from 22 to 35 days old.

Evaluation parameter	Carcass yield (%)				
	Level (g/kg)				
Glycerins	17.5	35.0	52.5	70.0	Average
Soybean	73.48	72.44	73.22	71.85	72.75
Semipurified	72.44	72.44	72.69	73.09	72.67
Probability			NS		
Control Treatment			72.80		
Variation coefficient (%)			1.033		
	Thigh and Drumstick yield (%)				
	Level (g/kg)				
Glicerins	17.5	35.0	52.5	70,0	Average
Soybean [Q]	30.46A	28.96B	29.12[a]	31.81A*	30.09
Semipurified	30.46A	30.31A	29.88[a]	30.35B	30.25
Probability			P<0.05		
Control treatment			29.19		
Variation coefficient (%)			2.818		
	Breast yield (%)				
	Level (g/kg)				
Glycerins	17.5	35.0	52.5	70.0	Average
Soybean [Q]	37.16A	37.38A	37.77[a]	33.12B*	36.36
Semipurified [Q]	37.33A	37.51A	37.99A*	37.19[a]	37.51
Probability			P<0.05		
Control Treatment			37.18		
Variation coefficient (%)			1.124		
	Abdominal fat (%)				
	Level (g/kg)				
Glycerins	17.5	35.0	52.5	70.0	Average
Soybean	1.97	1.85	1.60*	1.78	1.80[a]
Semipurified	1.64*	1.64*	1.54*	1.59*	1.60B
Probability			P<0.05		
Control treatment			2.03		
Variation coefficient (%)			11.890		

A,B differ through Student-Newman-Keuls test; * Average differs from the control treatment through the Dunnett test; NS = non-significant; [Q] Quadratic effect.

glycerol ingested or due to the effect of contaminants present in this byproduct, which in higher levels may be toxic to the animal, as for example, the methanol which is present in the soybean glycerin in the concentration of 181.31 mg/L. An inverse effect was observed for the semipurified glycerin, where the levels below 70 g/kg showed greater feed conversion in relation to the control treatment (P<0.05). The improvement in the feed conversion with the inclusion of 70 g/kg of semipurified glycerin may be partially explained by the low concentration of methanol (20.62 mg/L), which would allow the supply of glycerin levels to be higher in the studied animal. However, the limitation to a higher inclusion of this semipurified glycerin would be the sodium concentration in it.

The inclusion of 35.0 and 70 g/kg of the soybean glycerins and semipurified, respectively, can be noticed by the performance results, allowing a sustainable and environmentally correct fate for the glycerins originating from the production of biodiesel.

For the carcass yield there was no interaction (P>0.05), nor influence of the sources and levels of glycerin (Table 4). No difference (P>0.05) in the yield of the birds fed with the different diets in relation to the control treatment was observed either (Table 4). The same was observed by Cerrate et al. (2006), working with the inclusion of 0; 25.0 and 50.0 g/kg of glycerin. However, these same authors, including 0; 50.0 and 100.0 g/kg of glycerin in another experiment, verified the reduction in the carcass yield with the inclusion of 100.0 g/kg.

A significant interaction was observed (P<0.05) between sources and levels of glycerin for the thigh and drumstick yield (TDY) (Table 4). The levels of soy glycerin provided a quadratic effect of TDY ($Y = 0.0034 \times -0.2734 + 34.2520x^2$, $R^2 = 0.99$), where the lowest TDY was found with 40.21 g/kg inclusion of SG. Results contrary to those of Cerrate et al. (2006), who did not observe any influence of glycerin levels on the yield of the thigh and drumstick. The purified glycerin levels did not influence the TDY (P>0.05).

Only the birds fed with 70.0 g/kg of SG differed from the control treatment in relation to TDY (P<0.05), with poorer outcome. Such result can be justified by the results of weight gain and feed conversion found in this study. Probably, there was saturation of the kinase glycerol enzyme, limiting the use of glycerol by the body, and also the performance of the chickens may have been damaged by the ingestion of high amounts of methanol present in the crude soybean glycerin. This explanation would agree with Doppenberg and Van der Aar (2007), who suggested that there was over 50 g of glycerol per kilogram of feed, as there may be saturation of glycerol kinase.

According to Jung and Batal (2011b), there is variation in the composition of methanol in different glycerins produced from biodiesel, highlighting the importance of analyzing them before feeding the birds, since this alcohol, in higher concentrations, can be harmful to animals.

There was a significant interaction (P<0.05) between levels and sources of glycerin for breast yield, and quadratic effects were observed for both sources (Table 4). A higher breast yield was obtained with the inclusion of 35.15 g/kg of soybean glycerin ($Y = -0.004x^2 + 0.2812 + 33.19x$, $R^2 = 0.90$) and 43.69 g/kg of semi purified glycerin ($Y = -0.0008 + 0.0699x + 36.274x^2$, $R^2 = 0.66$). At levels of 25.0 and 50.0 g of glycerin inclusion per kilo of diet, Cerrate et al. (2006) did not observe difference in breast yield to the levels tested. However, in relation to the glycerin-free diet, the presence of this byproduct showed higher breast yield in broilers.

The addition of 70.0 g/kg of soybean glycerin provided breast yield lower than the control treatment, and including 52.5 g/kg of semi purified glycerin resulted in breast yield higher than the control treatment. These results do not confirm the theory that glycerol could save gluconeogenic amino acids (Cryer and Bartley, 1973) increasing protein retention, resulting in higher breast yield, since the other levels of tested glycerins did not differ from the control treatment, similar to the results of Cerrate et al. (2006) that included 0.0, 50.0 and 100.0 g glycerol/kg and found no difference in breast yield.

The percentage of abdominal fat was only influenced by sources of evaluated glycerins (P <0.05), where the lowest fat percentage was obtained with the use of semipurified glycerin. It could be deduced that the concentration of glycerol does not increase lipogenesis, since the glycerin with the highest percentage of glycerol was the source that provided thinner carcass. The inclusion of 17.5, 35.0 and 70.0 g/kg of soybean glycerin provided percentage of abdominal fat similar to the control treatment, and the level of 52.5 g/kg of soybean glycerin and all levels of the semi purified glycerin presented a lower percentage of abdominal fat in relation to the control treatment.

Conclusion

The addition of 35.5 g/kg of crude soybean glycerin and 70.0 g/kg of purified glycerin gave the best performance results of broilers in the period from 22 to 35 days, within the evaluated levels. The use of glycerin from biodiesel can be applied to the nutrition of broilers achieving good results, since it is considered a contaminant concentration in the byproduct since, at high concentrations they can harm the animal metabolism, resulting in lower animal performance.

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Conflict of Interest

The authors have not declared any conflict of interests.

REFERENCES

National Petroleum Agency (Agência Nacional do Petróleo) (2013). Available at: <http://www.anp.gov.br>.

Cerrate S, Yan F, Wang Z, Coto C, Sacakli P, Waldroup PW (2006). Evaluation of glycerine from biodiesel production as a feed ingredient for broilers. Int. J. Poult. Sci. 5:1001–1007.

Cryer A, Bartley W (1973). Studies on the adaptation of rats to a diet high in glycerol. Int. J. Biochem. 4(21):293-308.

Doppenberg J, Van Der Aar P (2007). Applications of rapeseed meal or-expeller and glycerine in diets for non ruminants. In: Doppenberg J, van der Aar P (eds.), Biofuels Implications for the feed industry. The Netherlands: Wageningen Academic Publishers. pp. 73-88.

Dozier WA, Kerr BJ, Corzo A, Kidd MT, Weber TE, Bregendahl K (2008). Apparent metabolizable energy of glycerin for broiler chickens. Poult. Sci. 87:317–322.

Jung B, Batal AB (2011a). Nutritional and feeding value of crude glycerin for poultry - Part 2. Evaluation of feeding crude glycerin to broilers. J. Appl. Poult. Sci. Res. 20:514-527.

Jung B, Batal AB (2011b). Nutritional and feeding value of crude glycerin for poultry - Part 1. Nutritional value of crude glycerin. J. Appl. Poult. Sci. Res. 20:162-167.

Lima EMC, Rodrigues PB, Alvarenga RR, Bernardino VMP, Makiyama L, Lima RR, Cantarelli VS, Zangerônimo MG (2012). The energy value of biodiesel glycerin products fed to broilers at different ages. J. Anim. Physiol. Anim. Nutr. 5(10):1515-1520.
Mclea L, Ball MEE, Kilpatrick D (2011). The effect of glycerol inclusion on broiler performance and nutrient digestibility. Br. Poult. Sci. 52(3):368-375.
Mongin P (1981): Recent advances in dietary anion-cation balance: application in poultry. Proc. Nutr. Soc. 40:285-294.
Rivaldi JR, Sarroub BF, Fiorilo R, Silva SS (2007). Glicerol de biodíesel. Biotecnol. Ciênc. Desenvolv. 37:44-51.
Rostagno HS, Albino LFT, Donzele JL, Gomes PC, OLIVEIRA RD, Lopes DC, Ferreira AS, Barreto SD (2005). Tabelas brasileiras para aves e suínos: Composição de alimentos e exigências nutricionais. Viçosa: UFV/DZO. P. 186.
SAEG – Sistema de Análises Estatísticas e Genéticas (2007). Versão 9.1. Viçosa, MG Universidade Federal de Viçosa - UFV.
Simon A, Bergner H, Schwabe M (1996). Glycerol-feed ingredient for broiler chickens. Arch. Anim. Nutr. 49:103-112.
Swiatkiewicz S, Koreleski J (2009). Effect of crude glycerin level in the diet of laying hens on egg performance and nutrient utilization. Poult. Sci. 88:615-619.