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Performance and Carcass Yield of Broilers Fed Crude Glycerin at Differing Inclusion Levels

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ABSTRACT

This experiment was conducted to evaluate the effect of crude glycerin at differing inclusion levels on performance and carcass characteristics of broilers and litter moisture. 960 broilers of 21-42 days of age were used in a completely randomized design with six crude glycerin inclusion levels (0, 3, 6, 9, 12, 15%), with eight replicates containing 20 broiler chickens per experimental unit. There was a quadratic effect ($p<0.05$) for weight gain, feed intake and feed:gain ratio from 21 to 42 days of age. Higher levels of crude glycerin in diets increased (40.24%, $p<0.05$) the litter moisture and reduced (6.04%, $p<0.05$) the viability of of the birds. There were no effects ($p>0.05$) on carcass yield, breast, or liver percentages. However, there was an increase (6.17%, $p<0.05$) in leg yield and a decrease in ($p<0,05$, 7.05%) the drumstick yield. For the wing yield and abdominal fat, a quadratic effect ($p<0.05$) was observed. The protein and fat deposition rates, as well as the dry matter content of the carcass, showed a quadratic effect ($p<0.05$) due to the inclusion levels of crude glycerin. Crude glycerin may be used in broiler diets from 21 to 42 days, at up to 6% without harming the performance of the broilers, the yield and carcass quality, litter moisture, and the viability of broilers. It is recommended that crude glycerin can be fed at 5.63% from 21 to 42 days, while for lower feed conversion it is recommended that the level of 3.72% is used.

INTRODUCTION

Poultry farming is of great importance to Brazilian agribusiness, it is responsible for generating millions of jobs. Brazil is ranked as the third largest producer and the largest exporter of chicken meat, with 17.254 million tons produced and 4.099 million tons exported, while having a per capita consumption estimated at 47.8 kg per year (UBABEF, 2015).

Broilers have great potential to convert food into animal protein, but to express this characteristic it is important that their diets adequately provide their nutrient requirements. The use of high quality feed ingredients can result in expensive feed programs. Thus, it is important to study alternative ingredients that can efficiently replace major grains such as corn and soybean meal to reduce feed cost.

Crude glycerin is a biodiesel by-product generated from renewable sources such as vegetable oils or animal fats and can be an alternative ingredient in poultry feeding programs. This ingredient has a high glycerol content, which plays a vital role in animal metabolism (MIN *et al.*, 2010), as main structural component of phospholipids and triglycerides.

Glycerin is a source of gross energy, with values ranging between 3337-6742 kcal kg^{-1} and can be over 99% metabolized by broilers

(Batal & Jung, 2011). Although crude glycerin can be used in poultry diets, some factors must be considered, for instance the methanol residual presence, sodium, potassium and fatty acid profile. These compounds have been demonstrated to affect the performance and carcass characteristics of poultry (Suchý *et al.*, 2011; Min *et al.*, 2010; Cerrate *et al.*, 2006; Sehu *et al.*, 2013).

Crude glycerin supplementation in broilers diets has been widely studied by many researchers. In the study by Jung & Batal (2011), it was observed that crude glycerin can be included up to 10% in diets for broilers without affecting performance parameters, however it is important to quantify the methanol content, as this may compromise bird performance.

According to Abd-Elsamee *et al.* (2010), glycerin supplementation at up to 8% in broiler finisher diets did not affect performance and meat quality. For Cerrate *et al.* (2006), a 10% glycerol utilization impaired the weight gain of broilers, however, the supplementation of 5% did not influence the performance, and the inclusion of crude glycerin at 2.5% improved breast meat yield. Similarly, Sehu *et al.* (2012) observed that the inclusion up to 5% of glycerol at 1-42 days of age did not affect broilers performance or carcass characteristics.

Although several studies have demonstrated the beneficial effects of crude glycerin supplementation on poultry diets, it is necessary for more studies to be conducted that correlate inclusion levels for different phases of broiler rearing. Thus, the aim of this study was to evaluate the performance, carcass yield, the deposition rate of protein and fat, and litter moisture of broilers fed different levels of crude glycerin from 21-42 days of age.

MATERIAL AND METHODS

This study was conducted at the Poultry Sector of the Experimental Station of the State University of the West of Paraná - UNIOESTE, Campus Marechal Cândido Rondon – PR, Brazil. One-day-old Cobb 500 broiler chicks were housed in an experimental shed (20 meters long and 8 meters wide) that consisted of square pens that were 1.76 m2. Each pen (experimental unit - EU) had a tubular feeder, a nipple drinker line, and concrete floors lined with pine shavings. Throughout the experimental period the room temperatures were maintained within the zone of thermal comfort. In the month of April the maximum was 27.2 °C and minimum of 16.8 °C in the month of May the maximum was 24.5 °C and minimum 14.0 °C.

At 21 days of age, broilers were individually weighed and distributed according to weight in a completely randomized design with six treatments of different crude glycerin inclusion levels (0, 3, 6, 9, 12 and 15%) eight replicates per treatment and 20 broilers per experimental unit. The experimental diets were isonitrogenous and isocaloric formulated according to nutritional requirements recommended by Rostagno *et al.* (2011), for 21 to 42 days of age phase (Table 1). The animals received feed and water *ad libitum*, with a continuous 24h lighting program.

Broilers and leftover feed were weighted on day 42 to evaluate feed intake, weight gain, and feed conversion ratio. Mortality was recorded daily and the broilers were weighed and feed intake was recorded for feed conversion calculations.

For litter moisture determination, samples were taken from several points of each experimental unit, avoiding places close to feeders and drinkers. Subsequently, the samples were placed in 105°C ovens for dry matter analysis, according to methodology described by Silva & Queiroz (2002).

At the end of the experimental period (42 days of age), 16 broilers representing the average weight of treatment (±10%), were fasted for six hours and slaughtered for carcass yield determination. The animals were slaughtered according to Normative Instruction N°. 3 of 104 January 17, 2000, of the DSA/MAPA, which establishes the methods of desensitization for 105 humanitarian abatement. The animals were slaughtered for carcass yield determination. During evisceration, liver and fat deposited close to the cloacal, bursa, and gizzard were collected for evaluation of liver relative percentage (% live weight) and abdominal fat percentage, respectively. Carcass yield was determined according to the weight of carcass (without head, feet, and abdominal fat) in relation to live weight. The yield of prime cuts (breast, thigh, drumstick, and wing) were considered as relationship to eviscerated carcass weight.

The determination of the rate of protein and fat deposition and carcass dry matter was performed according to Fraga *et al.* (2008) adapted methodology. The birds selected for processing were slaughtered by cervical dislocation and then plucked. Carcasses were ground in an industrial meat grinder, and samples were taken to perform the pre-drying, pre-degreasing, grinding on ball mill type, and subsequent analysis of dry matter, crude protein and ether extract according to Silva & Queiroz (2002) described methodologies. The deposition rate of protein and fat was measured

Table 1 – Chemical and calculated composition of experimental diets.

Ingredients	0	3	6	9	12	15
Corn	59.06	56.02	52.90	49.36	45.64	42.05
Soybean meal	32.80	33.35	33.88	34.54	35.23	35.88
Crude glicerol	0.00	3.00	6.00	9.00	12.00	15.00
Soy oil	4.40	4.10	3.89	3.85	3.90	3.85
Limestone	1.17	1.17	1.17	1.16	1.16	1.16
Monocalcium phosphate	1.19	1.19	1.19	1.19	1.20	1.20
Salt	0.457	0.265	0.072	0.000	0.000	0.000
DL-Methionine	0.290	0.292	0.296	0.299	0.301	0.304
L-Lysine	0.226	0.217	0.207	0.196	0.179	0.167
L-Threonine	0.067	0.067	0.067	0.066	0.065	0.064
L-Valine	0.041	0.041	0.041	0.039	0.038	0.036
Vitamin[2]	0.100	0.100	0.100	0.100	0.100	0.100
Mineral[1]	0.050	0.050	0.050	0.050	0.050	0.050
Choline chrolide	0.060	0.060	0.060	0.060	0.060	0.060
Coxistac[3]	0.060	0.060	0.060	0.060	0.060	0.060
Surmax 200[4]	0.020	0.020	0.020	0.020	0.020	0.020
Antioxidant[5]	0.005	0.005	0.005	0.005	0.005	0.005
Total	100	100	100	100	100	100
Calculated composition						
EM (kcal kg^{-1})	3.150	3.150	3.150	3.150	3.150	3.150
Crude protein (g kg^{-1})	199.5	199.5	199.5	199.5	199.5	199.5
Calcium (g kg^{-1})	7.60	7.60	7.60	7.60	7.60	7.60
Available phosphorous (g kg^{-1})	3.55	3.55	3.55	3.55	3.55	3.55
Dig lysine (g kg^{-1})	11.31	11.31	11.31	11.31	11.31	11.31
Dig. Met+Cis (g kg^{-1})	8.26	8.26	8.26	8.26	8.26	8.26
Dig. Threonine (g kg^{-1})	7.55	7.55	7.55	7.55	7.55	7.55
Dig. Valine (g kg^{-1})	8.82	8.82	8.82	8.82	8.82	8.82
Sodium (g kg^{-1})	2.00	2.00	2.00	2.48	3.25	4.01
Potassium (g kg^{-1})	7.71	7.73	7.73	7.75	7.77	7.78
Chloride (g kg^{-1})	3.24	3.18	3.11	3.76	4.84	5.92

[1]mineral premix: Mg – 16.0 g; Fe – 100.0 g; Zn – 100.0 g; Cu – 2.0 g, Co – 2.0 g; I – 2.0 g; e vehicle q. s. p. – 1.000 g. [2]vitamin premix: Vit. A – 10.000.000 UI; Vit D3 – 2.000.000 UI; Vit E – 30.000 UI; Vit B1 – 2.0 g; Vit B6 – 4.0 g; Pantothenic ac. – 12.0 g; Biotin – 0.10 g; Vit K3 – 3.0 g; Folic ac. – 1.0 g; Nicotinic ac. – 50.0 g; Vit B12 – 15.000 mcg; Selenium – 0.25 g; e Vehicle q. s. p. – 1.000 g. [3]salinomicine; [4]avilamicine; [5]BHT.

by the comparison between broilers slaughtered at the end of the experimental period and an additional group of five broilers slaughtered at 21 days of age.

The results obtained were subjected to analysis of variance and polynomial regression through SAEG software (Sistema de Análises Estatísticas e Genéticas, version 8.0, Universidade Federal de Viçosa, 2007). The Dunnett's test, at 5% probability, was used to compare the results between control treatment and each crude glycerin inclusion levels.

RESULTS AND DISCUSSION

The increasing crude glycerin inclusion levels on diets for broilers from 21 to 42 days of age, showed a quadratic effect ($p<0.05$) for weight gain (WG), feed intake (FI) and feed conversion ratio (FCR), and linear ($p<0.05$) for litter moisture and viability (Table 2). Analysis of the data was conducted using Dunnett's Test, it was observed that until 9% of crude glycerin inclusion level, the average WG, FI, and FCR were similar to the control treatment (0% inclusion of crude glycerin). Thus, the broilers fed diets containing 12 and 15% of crude glycerin had impaired ($p<0.05$) performance, within 21 to 42 days old.

There was a quadratic effect ($p<0.05$) of crude glycerin inclusion levels in diets for broilers WG from 21 to 42 days of age, an estimated level of 5.63% of crude glycerin was calculated for higher WG. Guerra *et al.* (2011), studying crude glycerin levels of (0, 2, 4, 6, 8 and 10%) within 1-42 days of age, estimated for maximum WG a level of 5.10% of crude glycerin inclusion, similar results were found in this study. The same authors reported that FI was affected up to 6.53% inclusion level, and, in turn, FCR impaired linearly as increasing crude glycerin inclusion levels.

Table 2 – Weight gain, feed intake, feed conversion ratio, litter moisture and viability of broilers from 21 to 42 days of age fed with different inclusion levels of crude glycerin.

Inclusion (%)	WG (g)	FI (g)	FCR (g/g)	LM (%)	Viability (%)
0 (Control)	1782.08	2880.81	1.617	40.18	98.03
3	1758.22	2878.16	1.640	42.19	99.34
6	1761.64	2875.02	1.632	43.42	97.36
9	1796.11	2950.62	1.643	47.47*	98.68
12	1594.17*	2726.74*	1.712*	54.38*	96.05
15	1506.62*	2606.51*	1.732*	56.35*	92.11
Effect	Q	Q	Q	L	L
CV (%)	3.326	2.548	2.152	6.624	5.354

Variable	Estimated level (%)	Estimated level (%)
WG	1675.38 + 37.4084*X – 3.32025*X2 (R2 = 0.90)	5.63
FI	2748.05 + 53.1846*X – 4.23541*X2 (R2 = 0.89)	6.28
FCR	1.64387 - 0.00632042*X – 0.000850493*X2 (R2 = 0.92)	3.72
LM	36.9732 + 1.3095*X (R2 = 0.95)	-
Viability	101.447 – 0.526316*X (R2 = 0.76)	-

WG: weight gain; FI: feed intake; FCR: feed conversion ratio; LM: litter moisture; *Mean differ from control treatment at 5% of significance level by Dunnett test; L: linear effect by regression analysis at 5% of significance level; Q: quadratic effect by regression analysis at 5% of significance level.

In this study the FI also showed a quadratic effect ($p<0.05$), but the estimated level of 6.28% provides higher feed consumption, which is not interesting from the zootechnical point of view, as it could impair broilers FCR. Similarly, Carole *et al.* (2009) reported a FI reduction of broilers fed with 10% crude glycerin diets in 1-35 days period. For Cerrate *et al.* (2006), WG and FI of broilers from 1 to 35 days of age were not affected by 5 and 10% crude glycerin inclusion, however, FCR was increased as the inclusion level of crude glycerine increased. The same authors, in a second trial, found that FCR was not affected by 5% inclusion of crude glycerin.

The optimal FCR was obtained at 3.72% of crude glycerin. These results differ from those obtained by Silva *et al.* (2012), which evaluated the crude glycerin inclusion of 2.5 to 10% levels to broiler diets during the periods of 1-21 and 1-42 days of age, founding no effect of crude glycerin levels on performance parameters.

According to Romano *et al.* (2014) broilers are capable of adequately metabolizing glycerin at up to 7.5%, but at higher levels undesirable metabolic changes may occur. The enzymatic capacity of glycerol transformation in the body is limited, and when its consumption exceeds this capacity, it may not be completely metabolized, as a response, there is an increase in blood levels (Robinson & Newsholme., 1969).

The results found in this study may be related to the physical form of feed, which make it difficult to flow in the feeders due to higher crude glycerin content, causing a direct effect on WG and FCR. High crude glycerin levels may affect the quality of the pellet and feed production, causing a reduction in bird consumption and performance, as reported in a study carried out by Cerrate *et al.* (2006).

The methanol concentration of crude glycerin, is another factor that can be considered a limiting factor in poultry performance because methanol is metabolized in the liver and the accumulation of its metabolites in the body is toxic to animals. Perhaps the high methanol content in the crude glycerin used in the present study may have negatively affected the performance of the animals.

The litter moisture increased ($p<0.05$) as crude glycerin is increased in the diets, according to the regression analysis. The Dunnett's Test shows that for 9, 12, and 15% crude glycerin inclusion levels, litter moisture was higher than the control group ($p<0.05$). Glycerol is a hydrophilic polar substance with a low molecular content, osmotically active and excreted together with water. The increase in water excretion of broilers fed the highest glycerin level is attributed to the effect of reduced reabsorption of water in the large intestine or increased renal excretion (Gianfelici *et al.*, 2011).

Another factor that may be related to increases in litter moisture is the high sodium content present in crude glycerin. According Borsato *et al.* (2010), biodiesel can be obtained from transesterifications reactions of vegetable oils, consisting in a reaction between a triglyceride with an alcohol with a presence of a catalyst, to produce esters and a by-product, the glycerol. The major catalyst used in this process is sodium hydroxide, and therefore the crude glycerin may have high sodium content in its composition. The effect on litter moisture may be related to higher levels of sodium in broilers diets, stating that this response is due to increased consumption of water by the broilers in an attempt to maintain homeostasis (Barros *et al.*, 2004).

The viability of broilers decreased as crude glycerin was increased in the diets, which may be related to higher litter moisture. Waldroup (2007) working with experimental diets containing 0, 5 and 10% glycerol observed that 10% level, produces noticeably more humid excreta.

The crude glycerin inclusion levels in diet did not affect (p>0.05) carcass and breast yield and liver percentage to broilers slaughtered at 42 days of age. But showed an increase (p<0.05) in thigh yield and a decrease (p<0.05) in drumstick yield. For wing yield and abdominal fat, a quadratic effect was observed (p<0.05) for crude glycerin supplementation (Table 3). According to Dunnett's test, only thigh yield and abdominal fat percentage in broilers fed diets containing 15% of crude glycerin differed from the control treatment. Cerrate *et al.* (2006), using diets containing 2.5 or 5% glycerol, reported increased breast yields, suggesting that glycerol can enhance the body water absorption. There was no effect (p>0.05) on liver relative percentage as a function of increasing levels of crude glycerin in diets, corroborating Lin *et al.* (1976), who also found no changes in liver weight in broilers fed diets containing 20% glycerol for three weeks. Evaluating the crude glycerin use for broilers, Suchý *et al.* (2011) found no differences between treatments for carcass yield, noting that tissues and organs development were not affected by glycerol supplementation. According to Abd-Elsamee *et al.* (2010), up to 8% glycerin in diets for broilers in the finisher phase did not affect performance and meat quality. Similarly, Sehu *et al.* (2012) showed that inclusion up to 5% glycerol 1-42 days of age did not affect carcass parameters.

According to the results found for carcass yield, cuts, and abdominal fat, it is believed that increasing levels of crude glycerol do not increase lipogenesis, since the birds that received the highest levels presented the lighter carcasses.

Table 3 – Carcass, breast, thigh, drumstick and wing yield, and liver percentage of broilers at 42 days of age, fed diets with different inclusion levels of crude glycerin.

Inclusion (%)	Carcass (%)	Breast (%)	Thigh (%)	Drumstick (%)	Wing (%)	Liver (%)
0 (Control)	74.16	35.41	13.12	16.03	10.05	2.65
3	74.40	35.74	12.97	15.68	9.84	2.50
6	74.69	35.99	12.93	15.97	9.80	2.51
9	74.82	36.72	13.63	16.21	10.28	2.55
12	74.51	35.83	13.10	14.38	9.76	2.60
15	73.96	34.41	13.93*	14.90	9.66	2.56
Effect	ns	ns	L	L	Q	ns
CV (%)	2.144	7.824	7.102	10.300	5.683	11.070

Variable	Equations	Estimated level (%)
Thigh	$12.6879 + 0.0693963*X$ ($R^2 = 0.55$)	-
Drumstick	$16.3694 - 0.104695*$ ($R^2 = 0.42$)	-
Wing	$9.42956 + 0.145815*X - 0.00884215*X^2$ (R^2=0.46)	8.25

*Mean differ from control treatment at 5% of significance level by Dunnett test; ns: non-significant; L: linear effect by regression analysis at 5% of significance level; Q: quadratic effect by regression analysis at 5% of significance level.

The crude glycerin supplementation in diets for broilers from 21 to 42 days of age showed a quadratic effect (p<0.05) on protein and fat deposition rate and carcass dry matter content (Table 4). By polynomial regression analysis, the estimated level for higher protein deposition rate is 6.25% crude glycerin in diet. For higher fat deposition rate and dry matter content in carcass levels of 4.61 and 4.17% were estimated, respectively. However, by Dunnett's test, a difference was observed (p<0.05) only for fat deposition rate, where levels of 3, 12 and 15% differ from the control treatment.

The protein deposition rate in the present trial were similar to those obtained by Young *et al.* (1964) and Cryer & Hartley (1973), according to these authors glycerol may act as a protein synthesis stimulant. According to Carew & Hill (1964), the fat deposition rate and dry matter content of the carcass are directly correlated, the higher the fat content, the higher the dry matter content of the carcass. This was confirmed in the present study, where the dry matter content and fat deposition rate showed similar behavior, and furthermore, the inverse relationship between fat and protein deposition in carcass was observed.

Table 4 – Protein deposition rate (PDR), fat deposition rate (FDR) and dry matter content of broiler carcasses at 42 days of age, fed diets with different levels of crude glycerin.

Inclusion (%)		PDR (g/day)	FDR (g/day)	Dry Matter (%)
0 (Control)		13.18	9.57	31.22
3		12.57	11.12*	32.60
6		12.65	10.65	32.31
9		12.31	10.14	31.00
12		13.55	7.74*	30.52
15		13.17	6.49*	30.29
Effect		Q	Q	Q
CV (%)		7.836	16.770	5.562
Variable	Equations			Estimated level (%)
PDR	$13.0375 - 0.1356*X + 0.010847*X^2$ ($R^2 = 0.48$)			6.25
FDR	$9.8557 + 0.39672*X - 0.0429991*X^2$ ($R^2 = 0.94$)			4.61
DM	$31.6723 + 0.145356*X - 0.0174299*X^2$ ($R^2 = 0.69$)			4.17

*Mean differ from control treatment at 5% of significance level by Dunnett test; Q: quadratic effect by regression analysis at 5% of significance level.

CONCLUSIONS

The inclusion of crude glycerin in diets for broilers from 21 to 42 days of age, may be performed up to 6% level without negative effects on the performance of the broilers, carcass yield and meat quality, litter moisture and viability of broilers. For higher weight gain, it is recommended 5.63% crude glycerin level inclusion from 21 to 42 days of age, while for better feed conversion it is recommended the level of 3.72%.

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