Effects of dietary glycerol addition on growth performance, carcass traits and fatty acid distribution in cloacal fat in broiler chickens

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SUMMARY

The effects of dietary inclusion of methanol free glycerol as biodiesel by-product at 5% or 10% were examined on weight growth, carcass traits and fatty acid distribution of cloacal fat in broiler chickens. For this aim, a total of 270 one-day-old Ross 308 broiler chickens were randomly divided into 3 equal groups according to the glycerol amounts included into diets [0% (control group fed with basal diets), 5% and 10%] for 42 days. Growth parameters (body weights, weight gains), food consumption and efficiency were weekly evaluated and carcass traits (carcass yield, intestinal pH, relative weights of heart, spleen, liver, stomach, gizzard and cloacal fat) as well as the fatty acid distribution in cloacal fat were determined at the end of the trial. Weight growth was significantly increased in treated birds, particularly in those supplemented with 5% glycerol. The glycerol supplementation has slightly improved food efficiency especially at the 4th week at the level of 5% ($P < 0.05$) and the carcass traits, particularly the relative weights of heart, liver and gizzard ($P < 0.05$). By contrast, cloacal fat composition in fatty acids was not modified by the glycerol dietary inclusion. These results show that glycerol may be incorporated into broiler diets at least at 5% without compromising growth and carcass traits.

Keywords: Broiler, glycerol, dietary supplementation, growth, carcass traits, fatty acids, cloacal fat.

RÉSUMÉ

Effets du glycérol inclus dans les rations alimentaires des poulets de chair sur la croissance, les caractéristiques des carcasses et la composition en acides gras de la graisse cloacale

Les effets de l'addition à 5 % et 10 % dans la ration de glycérol exempt de méthanol sur la croissance, les caractéristiques des carcasses et la composition en acides gras de la graisse cloacale ont été examinés chez les poulets de chair. Pour cela, 270 poussins Ross 308 de 1 jour ont été aléatoirement répartis en 3 groupes égaux en fonction du pourcentage de glycérol ajouté à la ration (0 % (groupe contrôle recevant des rations standards de base) 5 % et 10 %), pendant 42 jours. Les paramètres de croissance (poids vifs et gains de poids), l'ingéré et l'efficacité alimentaires ont été mesurés toutes les semaines puis à la fin de l'essai, les caractéristiques des carcasses (rendement, pH intestinal, poids relatifs du cœur, du foie, de la rate, de l'estomac, du gésier et de la graisse cloacale) ainsi que la distribution des acides gras dans la graisse cloacale ont été analysées. La croissance pondérale a été significativement augmentée chez les oiseaux supplémentés particulièrement chez ceux recevant 5 % de glycérol. L'ajout de glycérol a aussi légèrement amélioré l'efficacité alimentaire surtout lors de la 4ème semaine chez les oiseaux traités avec 5 % ($P < 0.05$) ainsi que les caractéristiques des carcasses, notamment les poids relatifs du cœur, du foie et du gésier ($P < 0.05$). En revanche, la composition en acides gras de la graisse cloacale n'a pas été modifiée. Ces résultats montrent que le glycérol peut être incorporé dans la ration des poulets de chair à au moins un taux de 5 % sans altérer ni la croissance ni les caractéristiques des carcasses.

Mots clés : Poulet, glycérol, supplémentation alimentaire, croissance, caractéristiques des carcasses, acides gras, graisse cloacale.

Introduction

Biodiesel is a product which is obtained from vegetable oils and it has similar physical and chemical properties like as diesel oil. Because of this property it can be used together or substitute with diesel oil. Canola oil is the most preferred oil in biodiesel industry. But some vegetable oils such as soybean, cotton, sunflower and safflower oils and animal oils or even frying oils can also use for achieve biodiesel [1]. There are several ways for obtain biodiesel but in generally biodiesel is obtain from fat acids (vegetable or animal oils) esterase reaction with alcohol (methanol or ethanol) under alkaline catalyse (NaOH or KOH). At the end of reaction two products, biodiesel and glycerine are obtained. Alcohols dissociate from products with evaporation or distillation so glycerine pureness can be reached over 99% [21].

In biodiesel industry, 10% of the total production is glycerine and it can be used in cosmetic, drug and weapon industries after finished to refining process. Usage of glycerine in animal feeds such as an alternative energy source has been got attention in recent studies [4, 7, 10, 17]. Several studies have been evaluated for glycerine addition to animal diets in broiler chickens [4, 7, 19, 20], rat [13, 15], pigs [9-11], dairy cow [3, 5, 18], quails [7] and laying hens [22] in which egg productivity and quality parameters were evaluated during dietary 0, 2.5, 5 and 7.5% glycerine supplementation. No statistically important differences in egg production and egg weight were found between all groups whereas FCR (Food conversion ratio) showed remarkable decreased for 7.5% glycerol dietary addition at the end of the trial. In laying quails [7], live weight, egg production and feed efficiency were not significantly affected by dietary 2.5, 5, 7.5 and 10% glycerol supplementation, but birds supplemented with 10% glycerol exhibited noticeable decreases in albumin height and Haugh unit at the end of experiment. CERATE *et al*. [4] also observed decreases in food intake and in live weights when broilers were supplemented with 10% glycerine into diets while growth performances were not changed when supplementation was below 5% and even a better breast yield as a percent of the dressed carcass was achieved in 2.5% glycerine supplemented broilers compared to the other groups. On the other hand, in another trail [19], it was observed that 5 to 10% glycerol supplementation seems to be beneficial for weight gain, food intake and food conversion ratio and that the plasma glycerol concentrations markedly increased (from 0.65 to 4.36 mmol/L) 2 hours after feeding.

Because of these discrepancies observed in growth performances and carcass traits from broilers supplemented with glycerol, the aim of present study was to examine the effects of dietary supplementation with 5 or 10% methanol free glycerol, as biodiesel by-product, on growth performance, carcass characteristics and intestinal pH in broiler chickens.

Material and Methods

ANIMALS AND PROTOCOL DESIGN

In this experiment, 270 one-day-old male Ross 308 broiler chicks were randomly divided into 3 groups according to the dietary regimen and each group was constituted by 5 subgroups of 18 birds. The experimental protocol was approved by Local Ethics Committee of Ankara University.

In the control group, chickens were fed with basal standard diets based on corn and soybean meal, more specifically with a starter diet [23% crude proteins (CP) and 3100 kcal/kg metabolisable energy (ME)] for the first 14 days long period then with a grower diet [22% crude proteins (CP) and 3150 kcal/kg metabolisable energy (ME)] for the second 14 days long period, and then with a finisher diet [21% crude proteins (CP) and 3200 kcal/kg metabolisable energy (ME)] for the 3rd and the last 14 days long period (Table I). Dietary metabolisable energy was expressed in the National Research Council recommendations for broilers [16]. Birds from the groups 2 and 3 received standard diets supplemented with 5% or 10% glycerol, respectively for the whole experimental period. Feeds were analyzed for crude protein, calcium, and total phosphorous according to the reference methods [2]. Food and water were given *ad libitum*.

The birds were housed in wire-bottomed pens fitted with electrical heaters during the 42 days experimental period. The temperature started at 33°C (from the 1st day to the 3rd day) and was gradually reduced (2-3°C/week) according to normal management practice. Chicks were maintained on a 24 hour constant light schedule until the end of the experiment.

	Starter diet			Grower diet			Finisher Diet		
Ingredients (%)									
Glycerol	0.00	5.00	10.00	0.00	5.00	10.00	0.00	5.00	10.00
Corn	52.33	46.33	40.38	54.13	48.13	42.13	54.80	48.73	42.63
Soybean Meal	32.00	33.05	34.00	31.00	32.00	33.00	31.13	32.20	33.30
Corn Gluten	7.00	7.00	7.00	6.50	6.50	6.50	5.00	5.00	5.00
Vegetable Oil	4.00	4.00	4.00	4.50	4.50	4.50	5.50	5.50	5.50
Limestone	1.00	1.00	1.00	0.90	0.90	0.90	0.90	0.90	0.90
DCP	2.25	2.25	2.25	2.00	2.00	2.00	2.00	2.00	2.00
Salt	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Vitamin Premix[1]	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Mineral Premix[2]	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
DL-Methionine	0.35	0.35	0.35	0.20	0.20	0.20	0.10	0.10	0.10
L-Lysine	0.50	0.45	0.45	0.20	0.20	0.20	0.00	0.00	0.00
Chemical composition									
Dry matter	91.86	91.04	89.45	91.02	89.85	87.85	90.93	90.26	88.68
ME[3]	3107	3106	3107	3152	3153	3153	3201	3201	3200
Crude protein	23.00	23.00	23.00	22.00	22.00	22.00	21.00	21.00	21.00
Ether extract	6.81	6.76	7.36	7.04	7.08	7.87	7.22	8.21	8.60
Crude fiber	8.80	3.65	2.90	3.50	3.75	3.45	3.40	3.50	3.25
Crude ash	6.01	6.26	6.32	5.81	6.36	5.76	5.95	5.84	5.44
Calcium[3]	1.02	1.03	1.03	0.92	0.93	0.93	0.92	0.93	0.93
Available Phosphorus[3]	0.50	0.50	0.50	0.46	0.46	0.46	0.46	0.46	0.46
Met./Cys.[3]	1.13	1.12	1.11	0.96	0.95	0.94	0.82	0.82	0.81
Lysine[3]	1.46	1.44	1.45	1.20	1.21	1.22	1.03	1.04	1.06

ME: metabolisable energy; Met.: methionine; Cys: Cysteine; [1]Vitamin premix provided per kilogram of diet: vitamin A, 15000 IU; vitamin D3, 5000 IU; vitamin E, 50 mg; vitamin K_3, 10 mg; vitamin B_1, 4 mg; vitamin B_2, 8 mg; vitamin B_6, 5mg; vitamin B_{12}, 0.025mg; niacin, 50 mg; pantothenic acid, 20 mg; folic acid, 20 mg; biotin, 0.25 mg; choline, 175 mg. [2]Mineral provided per kilogram of diet: manganese, 100 mg; zinc, 150 mg; iron, 100 mg,; cupper, 20 mg; iodine, 1.5 mg; cobalt, 0.5 mg; selenium, 0.2 mg; molybdenum, 1mg; magnesium, 50 mg. [3]Results have been found out with calculation.

TABLE I: Composition and chemical analysis of the broiler (starter, grower and finisher) diets.

PERFORMANCE, CARCASS TRAITS AND INTESTINAL PH ANALYSES

Body weights were determined by pen on days 1, 7, 14, 21, 28, 35 and 42 and food intakes were measured during each feeding period. The corresponding cumulated body weight gains (from the 1st day to the ith day) and food conversion ratios (expressed as g of consumed food / weight gain in g) were calculated for the whole feeding period (between 1st to 42nd days of experiment).

On the day 42, 3 birds from each pen for which the body weight was closed to the mean value were slaughtered by cervical dislocation. The weight of the edible carcass and the weights of liver, spleen, gizzard, heart, glandular stomach and cloacal fat were recorded and all values were expressed as percentages of the carcass weight for a same bird.

The intestinal (duodeno-jejunal) and caecal contents were collected from 3 other birds from each pen slaughtered on the day 42 and the samples were diluted with deionised water.

FATTY ACID ANALYSIS

Total lipids were extracted from the abdominal fat samples by the method of FOLCH *et al*. [8]. Fat samples (4 g) were homogenized with 80 mL of a 2:1 (v/v) mixture of chloroform-methanol, after which 4 mL 0.88% NaCl was added; the liquid was mixed and left to stand for 2 hours to allow phase separation. The chloroform-methanol extract was evaporated to dryness in a water bath at 50°C under N_2 flow. The lipid extracts were then converted to fatty acid methyl esters by using boron-trifluoride-methylation solution (catalogue no. 3-3021). The Fatty acid methyl esters (FAMEs) were separated and analyzed by Gas Chromatograph (GC) Shimadzu 15-A, equipped with dual Flame Ionisation Detector and a 1.8 m × 3 mm internal diameter packed glass column containing 100/120 Chromosorb WAW coated with 10% SP 2330. The injector and detector temperatures were 225 and 245°C, respectively. Column temperature program was 190oC for 35 min then increasing at 30°C/minute up to 220°C where it was maintained for 5 minutes. Nitrogen at a flow rate of 20 mL/minute was used as the carrier gas.

The fatty acid compositions were identified by the comparison of retention times with known as external standard mixtures, quantified by a Shimadzu Class-VP software system. The results were expressed as percentage distribution of fatty acid methyl esters. All the chemicals used for the gas chromatography analysis procedure were obtained from Supelco Inc. (Bellefonte, PA, U.S.A.).

STATISTICAL ANALYSIS

All data were analyzed by ANOVA using SPSS 11.50 program (Inc., Chicago, II, USA). Significant differences among treatment were determined using Duncan's multiple range tests [6] with a 5% level of probability.

Results

The growth performance and the food intakes in broilers according to the dietary treatments are summarized in the Table II. The body weights and the body weight gains during the first 21 days did not show any statistical variance between all treatment groups, although the growth parameters were numerically increased in birds supplemented with 5% glycerol compared to controls and to birds supplemented with 10% glycerol. Thereafter, the growth performance significantly increased in the 5% glycerol supplemented group compared to the 2 other groups at 21, 28, 35 and 42 days of experiment ($P < 0.01$ to $P < 0.05$). Furthermore, the mean live weights and weight gains cumulated over the whole experimental period were markedly increased in 5% glycerol supplemented broilers ($P < 0.05$). On the other hand, although the differences were not significant among groups, the highest food intakes for the all periods (starter, grower and finisher) were also observed in birds supplemented with 5% glycerol. During the whole experiment, food efficiency was not significantly altered in the glycerol supplemented birds compared to the controls except at the 4th week (between 21 to 28 days) of trail. In this period food conversion ratio was notably depressed in broilers supplemented with 5% glycerol ($P < 0.05$).

As shown in Table III, the carcass traits, the organ weights and the corresponding indices (100 x organ weight / carcass weight) were summarized. No significant difference in carcass yield was evidenced according to the 3 dietary regimens; nevertheless, the highest carcass yield was recorded for birds supplemented with 5% glycerol but differences between the other groups were not statistically significant. The heart ($P < 0.01$) and liver ($P < 0.001$) indices were significantly decreased in birds supplemented with 5% glycerol compared to those receiving 10% glycerol. The same tendency was also noted for the cloacal fat percentages but differences between groups were not significant. By contrast, the relative gizzard weights ($P < 0.05$) and the glandular stomach (not significant, however) were higher in controls than in glycerol supplemented broilers. Finally, although the intestinal pH appeared more acid in supplemented birds, no significant difference was achieved between the 3 experimental groups.

As shown in Table IV, the distribution of fatty acids in cloacal fat has not significantly differed according to the glycerol supplementation. It was observed that the cloacal fat was rich in unsaturated fatty acids, especially in Ω6 fatty acids in all groups. However, as summarized in Table V, it was observed that proportions of some minor saturated (C11, C12, C13, C20 and C21) and monounsaturated (C14:1, C16:1-t and C20:1) fatty acids were slightly decreased in 5% and 10% glycerol supplemented chickens compared to the controls whereas those of other saturated acids (C15, C17 and C24) and of unsaturated acids were weakly (C22:4, and C20:3 at a lesser extend) or significantly (C22:1 and C20:2) increased. Additionally, it was also noted that the percentages of the C15:1, C16:2, C18:3, C22:1, C22:2, C22:3 and C22:6 were enhanced especially in 5% glycerol supplemented birds and that those of the C16:1 (a relatively major monounsaturated) and of the C20:4 were slightly decreased. Nevertheless, except for the C22:1

	Dietary treatments			SEM	*P*
	0%	5%	10%		
Body weights (g)					
Day 1	45.29	44.47	45.07	0.12	NS
Day 7	143.39	154.22	153.17	2.22	NS
Day 14	380.17	400.67	389.54	5.12	NS
Day 21	720.56^{a}	786.72^{c}	750.88^{b}	8.89	< 0.05
Day 28	1191.49^{a}	1315.89^{c}	1247.78^{b}	16.23	< 0.01
Day 35	1679.33^{a}	1831.38^{c}	1755.77^{b}	21.04	< 0.01
Day 42	2193.80^{a}	2378.17^{b}	2259.34^{a}	30.77	< 0.05
Body weight gains (BWG, g)					
BWG_{1-7}	98.10	109.76	108.10	2.25	NS
BWG_{7-14}	236.78	246.44	236.38	3.96	NS
BWG_{14-21}	340.39	386.05	361.34	8.34NS	NS
BWG_{21-28}	470.93^{a}	529.17^{c}	497.90^{b}	7.99	< 0.01
BWG_{28-35}	487.84	515.50	506.99	6.73	NS
BWG_{35-42}	514.47	546.78	503.57	18.57	NS
BWG_{1-42}	2148.51^{a}	2333.70b	2214.27^{ab}	30.82	< 0.05
Food intake (FI, g)					
FI_{1-7}	132.44	131.06	134.72	4.84	NS
FI_{7-14}	328.94	337.28	333.17	4.01	NS
FI_{14-21}	567.67	596.94	582.92	5.68	NS
FI_{21-28}	877.28	884.52	917.65	13.82	NS
FI_{28-35}	994.01	1033.88	1021.76	8.49	NS
FI_{35-42}	996.42	1052.38	985.15	16.07	NS
FI_{1-42}	3896.77	4036.06	3975.38	42.65	NS
Food conversion ratio (FCR, g)					
FCR_{1-7}	1.35	1.19	1.24	0.04	NS
FCR_{7-14}	1.39	1.37	1.41	0.02	NS
FCR_{14-21}	1.68	1.55	1.62	0.04	NS
FCR_{21-28}	1.87^{a}	1.67^{b}	1.84^{a}	0.04	< 0.05
FCR_{28-35}	1.96	1.94	1.98	0.05	NS
FCR_{35-42}	2.04	2.01	2.02	0.02	NS
FCR_{1-42}	1.82	1.73	1.80	0.02	NS

BWG: body weight gain; BWG_{i-i+1}: body weight gain calculated weekly; BWG_{1-42}: body weight gain determined for the whole experimental period (from day 1 to day 42). FI: Food intake; FI_{i-i+1}: Food intake measured weekly; FI_{1-42}: Food intake determined for the whole experimental period (from day 1 to day 42); FCR: Food conversion ratio; FCR_{i-i+1}: Food conversion ratio measured weekly; $cFCR_{1-42}$: Food conversion ratio determined for the whole experiment period (from day 1 to day 42); NS: not significant.
Different superscripts ^{a,b} in the same row indicate significant differences between groups.

TABLE II: Growth performances, food intakes and food conversion ratios in broiler chickens according to the dietary treatments (control: not supplemented; the others supplemented with 5% glycerol and 10% glycerol distributed for 42 days (n = 90 in each group allotted in 5 pens of 18 birds)). Results are expressed as mean ± standard error of the mean (SEM).

and C20:2 unsaturated acids, differences between dietary regimens were not statistically significant.

Discussion

In this work, the growth promoting effects of glycerol (like as by-product of biodiesel industry) were evaluated in broiler chickens. It was determined that addition of glycerol into broiler diets at level of 5% showed remarkable effects on body weights and body weight gains ($P < 0.05$), particularly in the growing period in the present study. Rising dietary glycerol level up to 10% also showed some numerical differences about body weight and body weight gain parameters compared to the control group but differences didn't show statistically importance (Table II). In the present study, growth performance was similar during the first 21 days of trail in broiler chickens, after than it showed remarkable increased for broilers which fed diets with 5% of glycerol supplementation. However, the food conversion ratio (FCR) has not significantly differed between groups for the whole experimental period because the glycerol addition has, in parallel, slightly stimulated, but not significantly, food consumption in the supplemented groups because the glycerol addition has probably increased the palatability of the diet. Nevertheless, this parameter tended to be weekly improved in 5% glycerol supplemented

	Dietary treatments			SEM	*P*
	0%	5%	10%		
Carcass yield (%)	74.75	76.27	75.45	0.26	NS
Intestinal pH	6.40	6.23	6.35	0.05	NS
Heart (%)	0.52[ab]	0.48b	0.56[a]	0.01	< 0.01
Liver (%)	1.92[a]	1.78[a]	2.26[b]	0.06	0.001
Spleen (%)	0.12	0.11	0.11	0.00	NS
Gizzard (%)	1.34[a]	1.25[ab]	1.21[b]	0.02	< 0.05
Glandular stomach (%)	0.39	0.35	0.35	0.01	NS
Cloacal fat (%)	0.97	1.09	1.14	0.08	NS

Organ yield was calculated by the following formula: 100 x organ weight / carcass weight; NS: not significant.
Different superscripts [a,b] in the same row indicate significant differences (P < 0.05 or more) between treatment groups.

TABLE III: Carcass traits and organ indices in broiler chickens according to the dietary treatments (control: not supplemented; group 1: supplemented with 5% glycerol; group 2: supplemented with 10% glycerol distributed for 42 days (n = 90 in each group allotted in 5 pens of 18 birds)). Results are expressed as mean ± standard error of the mean (SEM).

Fatty acids	**Dietary treatments**			***P***
	0%	**5%**	**10%**	
Saturated	25.90 ± 0.58%	25.46 ± 0.46%	26.10 ± 0.63%	NS
Unsaturated	74.10 ± 0.58%	74.54 ± 0.46%	73.90 ± 0.63%	NS
PUFA	39.14 ± 1.41%	39.34 ± 1.25%	38.05 ± 1.37%	NS
MUFA	34.96 ± 1.10%	35.20 ± 0.93%	35.84 ± 0.96%	NS
PUFA / MUFA	1.33 ± 0.15	1.33 ± 0.15	1.22 ± 0.11	NS
Omega 3	3.01 ± 0.14%	3.18 ± 0.18%	3.11 ± 0.17%	NS
Omega 6	36.07 ± 1.31%	36.09 ± 1.13%	34.88 ± 1.24%	NS
Omega 6/3	14.31 ± 1.86	13.62 ± 1.59	12.86 ± 1.13	NS
Saturated / PUFA	0.79 ± 0.10	0.77 ± 0.08	0.78 ± 0.05	NS

PUFA: polyunsaturated fatty acids; MUFA: monounsaturated fatty acids; NS: not significant.

TABLE IV: Fat acids distribution from cloacal fat in broiler chickens according to the dietary treatments (control: not supplemented; group 1: supplemented with 5% glycerol; group 2: supplemented with 10% glycerol distributed for 42 days (n = 90 in each group allotted in 5 pens of 18 birds)). Results are expressed as mean ± standard error (SE).

chickens and was even significantly affected during the 4th week (during the growing period) in this group compared to the control and the 10% glycerol supplemented groups (*P < 0.05).* These results were in disagreement with previous studies [4, 13] which have reported negative effects of the glycerol supplementation on growth parameters in broiler chickens. These discrepancies may be related to different origins of glycerol or to different levels of glycerol addition to broiler diets. On the other hand, these findings are similar to those of SIMON *et al.* [19] who have also observed improvement of growth (body weights and weight gains) in broiler chickens supplemented with 5% and 10% glycerol. LIN *et al*. [13] tried to determine the effects of 20.5 and 42.2% of dietary energy substituted with glycerol on performance in broiler chicks. At the end of the 3 weeks trail, they found out that addition of 42.1% glycerol showed significant negative effect on food intake (*P < 0.05*) while no differences between groups were observed with 20.1% glycerol addition. SIMON *et al.* [20] investigated the effects of dietary glycerol addition (from 5 to 25%) on growth performance in broilers, and at the end of the experiment, they have noticed that glycerol addition has induced no negative effects on FI and FCR in any inclusion level. As lighting these findings and some previous studies, it could be suggested that addition of glycerol into broiler diets until 10% has usually no adverse affects on growth, food intake and food efficiency in broiler chickens but this hypothesis should be confirmed by further studies exploring the effects of different dietary levels of glycerol in different growing periods.

Although the dietary glycerol addition tended to decreased the intestinal pH in the present study, the present results also demonstrated that the inclusion of glycerol in broiler diets has not significantly affected carcass characteristics measured here (carcass dressing percentage, spleen, glandular stomach and cloacal fat percentages), in agreement with another study [4]. However, the relative heart (*P < 0.01*), liver (*P < 0.001*) and gizzard weights (*P < 0.05*) were significantly depressed in glycerol supplemented birds, especially at a level of 5% glycerol, compared to the control birds. In the same way, the mean gizzard relative weight was significantly lowered in the 10% glycerol added group compared to the control. These results

Fatty acids	Dietary treatments			*P*
	0%	5%	10%	
Saturated				
C8:0	0.013	0.018	0.006	NS
C9:0	0.012	0.010	0.009	NS
C10:0	0.011	0.022	0.014	NS
C11:0	0.030	0.012	0.017	NS
C12:0	0.026	0.017	0.010	NS
C13:0	0.025	0.017	0.009	NS
C14:0	0.509	0.517	0.521	NS
C15:0	0.046	0.073	0.077	NS
C16:0	19.282	18.778	19.192	NS
C17:0	0.170	0.204	0.221	NS
C18:0	5.399	5.216	5.586	NS
C19:0	0.000	0.000	0.000	NS
C20:0	0.266	0.120	0.185	NS
C21:0	0.319	0.255	0.284	NS
C22:0	0.071	0.065	0.097	NS
C24:0	0.198	0.370	0.265	NS
Unsaturated				
Mono unsaturated				
C13:1	0.000	0.000	0.000	NS
C14:1	0.246	0.212	0.214	NS
C15:1	0.000	0.033	0.007	NS
C16:1	4.117	3.785	4.000	NS
C16:1-t	0.150	0.000	0.000	NS
C17:1	0.019	0.016	0.011	NS
C18:1	31.250	30.973	31.646	NS
C20:1	0.042	0.029	0.029	NS
C22:1	0.036a	0.629b	0.150a	< 0.01
Poly unsaturated				
C15:2	0.000	0.000	0.000	NS
C16:2	0.000	0.031	0.000	NS
C18:2	35.492	35.493	33.838	NS
C18:2-t	0.000	0.000	0.000	NS
C18:3	2.932	3.077	2.947	NS
C20:2	0.073a	0.117b	0.106a	< 0.05
C20:3	0.063	0.074	0.075	NS
C20:4	0.494	0.305	0.558	NS
C20:5	0.052	0.039	0.123	NS
C22:2	0.000	0.025	0.009	NS
C22:3	0.030	0.072	0.059	NS
C22:4	0.307	0.407	0.365	NS
C22:5	0.032	0.035	0.024	NS
C22:6	0.030	0.043	0.027	NS

NS: not significant. Different superscripts ^{a,b} in the same row indicate significant differences (P < 0.05 or more) between treatment groups.

TABLE V: Analytical determination of fatty acids found in the cloacal fat from control broilers and broilers supplemented with 5 or 10% glycerol into diet for 42 days.

were partially in accordance with previous studies in which MENGE *et al*. [14] have also observed significant increasing of some organ (liver) weights in channel catfish supplemented with glycerol. At the end of trail they found that percentages of liver weight relative to whole fish weight were showed higher results by the rising quantity of glycerol in diets. On the contrary, the rest of organ weight and yields didn't show any important differences between all treatment groups in their trail (*P > 0.05*).

In the present study, the relative cloacal fat weight tended to increase in broilers fed with glycerol supplemented diets proportionally to the glycerol level. This increase in cloacal fat may result from overestimation of metabolizable energy assigned to glycerol [15]. Similarly, LESSARD *et al*. [12]

have also found out that inclusion of 5% glycerol had increased the cloacal fat pad weight. However, neither the distribution of major saturated and unsaturated fatty acids nor the respective proportions of saturated, monounsaturated and polyunsaturated acids have been significantly altered by the glycerol dietary inclusion for 42 days.

As a conclusion, the results of the current study indicate that different level (5% and 10%) glycerol addition to diets, especially 5% glycerol, had significant positive effects on growth performance (increases in body weights and weight gains but no significant effect on food consumption and food efficiency) in broilers chickens. On the other hand, it was also notable that liver, heart and gizzard weights have gradually risen according to the glycerol addition in broilers. However, cloacal fat composition in fatty acids was not significantly affected. This experiment indicates that glycerol from biodiesel production could be effectively used in broiler diets at levels of 5 or 10%, but the interest of the glycerol addition to diets in poultry have to be confirmed by further studies in broilers fed with diets with various glycerol sources and dosages during different growing periods.

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