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Evaluation of Glycerine from Biodiesel Production as a Feed Ingredient for Broilers[1]

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Abstract: Glycerine from biodiesel production was used as a pure energy source in broiler diets formulated to meet typical commercial standards. In the first experiment, glycerine was added at 0, 5, and 10% of the diet while in the second experiment glycerine was added at 0, 2.5, and 5%. Glycerine was assigned a metabolizable energy value of 3527 ME kcal/kg in formulating the diets. In each experiment the various treatments were assigned to eight replicate pens of 60 male broilers each. In the first experiment, birds fed diets with 5% glycerine did not differ significantly in performance from birds fed the control diet with no glycerine. Birds fed diets with 10% glycerine consumed significantly less feed than did those fed diets with 0 or 5% glycerine and consequently had significantly reduced body weight. It is felt that this was due in large part to reduced flow rate in the feeders used in this study as previous researchers have shown acceptance of higher levels of glycerine. In the second study, birds fed diets with 2.5 or 5% glycerine had growth rate and feed conversion that did not differ significantly from that of birds fed the diet with no glycerine. Breast yield as a percent of the dressed carcass was significantly greater for birds fed diets with 2.5 or 5% glycerine as compared to those fed the diet with no glycerine. These data indicate that glycerine from biodiesel can be a useful energy source for use in broiler diets. Concerns remain regarding acceptable levels of residual methanol resulting from separation of the fatty acids in biodiesel production.

Key words: Glycerine, broilers, biodiesel, carcass

Introduction

An increasing amount of fats and oils are being processed for use as biodiesel fuel. A byproduct of biodiesel production is glycerine[3], the carbohydrate fraction that makes up about 10-11% by weight of typical triglycerides. The U.S. biodiesel industry is expected to produce an estimated 1.4 billion pounds of glycerine between 2006 and 2015 (Niles, 2006). Glycerine is considered “Generally Recognized as Safe” when used in accordance with good manufacturing or feeding practices (CFR, 2004).

Several studies have evaluated glycerine in diets for poultry and swine (Bernal *et al.*, 1978; Barteczko and Kaminski, 1999; Kijora *et al*., 1995, 1997; Simon, 1996; Kuhn, 1996; Kijora, 1996; Francois, 1994; Wagner, 1994; Simon *et al.*, 1996, 1997). The objective of this study was to evaluate the use of glycerol from biodiesel fuel production as an energy source in diets for growing broilers.

Upon ingestion, glycerol can be converted to glycerol-3-phosphate (G3P) which can then form dihydroxyacetone phosphate catalyzed by glycerol kinase and G3P dehydrogenase respectively (Lin *et al*., 1976). Dietary glycerol can induce anatomical, physiological and biochemical adaptations especially in the liver and kidney (Cryer and Bartley, 1973). In birds the addition of glycerol has the ability to form primarily glucose (Emmanuel *et al.,* 1983), pyruvate, or Krebs cycle products such as malate and oxaloacetate (Rosebrough *et al.,* 1980). Thus, many experiments have used glycerol with a high absorption, 95% (Lin *et al*., 1976; Brambilla and Hill, 1966) or the same energy level as corn starch (Lessard *et al.*, 1993). However, the digestibility demonstrated in broilers or rats is around 75% (Simon *et al*., 1996; Hober and Hober, 1939).

The objective of the present study was to examine the use of glycerol in the feed of broilers grown to 42 days of age in litter floor pens and to evaluate its effect on carcass composition and characteristics.

Materials and Methods

Diets were formulated for starter (0-14 d), grower (14-35 d) and finisher (35-42 d) periods based on typical nutrient levels for broilers in a popular agricultural survey (Agri-Stats, Fort Wayne, IN). Glycerine from biodiesel production was included at the rate of 0, 5 or 10% for experiment 1 and 0, 2.5 or 5% for experiment 2. An energy value of 3,527 ME kcal/kg was assigned to the glycerine, based on a Gross Energy value of 3,596 kcal/kg determined by bomb calorimetry and assuming a high digestibility of the glycerine. Composition of diets is shown in Tables 1 and 2 for experiments 1 and 2 respectively. As the level of glycerine increased in the diets, the amount of corn decreased and the amount of soybean meal and poultry oil increased to maintain the diets isocaloric and isonitrogenous. Diets were fortified with complete vitamin and trace mineral mixes and contained 5% of a blended animal protein product, typical of industry use levels for animal protein.

In each experiment each diet was fed to eight pens of 60 male birds each. In experiment 1 all starter diets were fed as crumbles; in experiment 2 four of the replicate pens were fed the diets as crumbles during the starter period while four of the pens were fed the diet pelleted with 1/8 inch die. For the remainder of the feeding period all diets were pelleted using a 3/16 inch die.

Male chicks of a commercial broiler strain (Cobb 500) were obtained from a local hatchery where they had been vaccinated *in ovo* for Marek's disease and had received vaccinations for Newcastle Disease and Infectious Bronchitis post hatch via a coarse spray. Sixty birds were randomly assigned to each of 24 pens (5.2 M^2) located in a broiler house of commercial design. Each pen was equipped with two tube feeders and one automatic water font. Supplemental feeders and waterers were used during the first seven days. Temperature and airflow were controlled by thermostatically controlled gas brooders, ventilation fans, and sidewall curtains. Incandescent lamps supplemented natural daylight to provide 23 hr light daily. Care and management of the birds followed recommended guidelines (FASS, 1999).

Body weight by pen was determined at 1, 14, 35, and 42 d of age. Feed consumption was measured during each feeding period. Birds were checked twice daily for mortality with the weight of dead birds used to adjust feed conversion. At the conclusion of the study, ten representative birds per pen were processed at the University of Arkansas pilot processing plant as described by Fritts and Waldroup (2006) to determine dressing percentage and parts yield. In experiment 2, water uptake by carcasses during a three hour chill in a non-agitated ice bath was determined.

Pen means were served as an experimental unit for statistical analysis. Data were subjected to analysis of variance using the General Linear Models (GLM) procedure of SAS (SAS Institute, 1991). Significant differences among or between means were separated by repeated t-tests using the LSMEANS option of SAS. Mortality data were transformed to $\sqrt{n+1}$ prior to analysis; data are presented as natural numbers.

Results

Experiment 1

Live performance: The effects of the dietary treatments on live performance are shown in Table 3. The inclusion of 5% glycerine had no significant effects on body weight, feed intake, feed conversion, or mortality at any age compared to birds fed the control diet with no glycerine.

The addition of 10% glycerine to the diet resulted in body weight similar to that of birds fed diets with 0 or 5% glycerol at 14 d of age, but at 35 and 42 d of age the body weight of birds fed diets with 10% glycerine was significantly less than that of birds fed the control diet or the diet with 5% glycerine. This reduction in body weight is thought to be related to dietary effects on feed intake. During the first 7 days feed was available in both the tube feeders and in open supplemental feeders and over the first 14 d birds fed diets with 10% glycerine had a significantly higher feed consumption than did birds fed the control diet or the diet with 5% glycerine. However, feed consumption was numerically reduced at 35 d and significantly reduced at 42 d compared to those fed the control diet, but not those fed the diet with 5% glycerine. The diet with 10% glycerine had visibly lower pellet quality and it appeared that the texture of the diet with 10% glycerol had an adverse affect on flow rate of feed in the tube feeders used in the study. Feed conversion at 35 and 42 d was also significantly higher for birds fed the diet with 10% glycerine, reflecting the reduction in body weight gain associated with this diet. No adverse effects on mortality were noted from the addition of 10% glycerine.

During the course of the study it was observed that litter in pens where birds were fed diets with 10% glycerol was much wetter than that of litter in pens where birds were fed the control diet or diet with 5% glycerol. Analysis of the diet for potassium indicated that diets with 10% glycerol contained approximately 0.15% more potassium than did the control diets. A portion of this increased potassium may be associated with the slightly higher levels of soybean meal but is more likely associated with residual potassium levels in the glycerine from the use of potassium hydroxide as a catalyst in the separation of the triglyceride molecule during the production of biodiesel fuel. Further, the presence of glycerol in the litter can give the appearance of wet litter, since 25% of glycerol excretion had been shown on a diet containing 10% glycerol (Simon *et al.,* 1997).

Carcass characteristics: Significant differences in carcass characteristics were observed among birds fed the experimental diets (Table 3). Feeding diets with 10% glycerine had an adverse effect on several carcass characteristics. Birds fed diets with 5% glycerine did not differ significantly from birds fed the control diet for any carcass measurement. Feeding diets with 10% glycerine resulted in a significant reduction in dressing percentage and in weight of breast meat, wings, and leg quarters as compared to those fed the control diet. When expressed as percent of the carcass, however, there were no significant difference in breast or leg quarter yield among birds fed the various experimental diets, although breast yield was numerically reduced (P= 0.11) when the diet contained 10% glycerine. When expressed as a percentage of the carcass, wing yield of birds fed diets with 10% glycerine were significantly greater than that of birds fed the control diet or 5% glycerine.

Table 1: Composition (g/kg) and calculated nutrient content of diets containing glycerol from biodiesel production (Experiment 1)

Ingredient	0-14 d			14-35 d			35-42 d		
	A	B	C	A	B	C	A	B	C
Glycerol	0.00	50.00	100.00	0.00	50.00	100.00	0.00	50.00	100.00
Yellow corn	614.90	553.08	491.25	668.53	606.70	544.87	718.42	656.59	594.76
Soybean meal	279.61	290.41	301.21	221.18	231.98	242.78	174.25	185.06	195.87
Pro-Pak[1]	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Poultry oil	15.19	16.32	17.44	23.74	24.86	26.00	23.77	24.90	26.02
MHA-84[2]	2.41	2.49	2.58	2.44	2.53	2.62	2.05	2.13	2.22
Limestone	10.49	10.34	10.20	8.42	8.28	8.13	8.29	8.15	8.00
Dicalcium phosphate	9.53	9.71	9.89	8.18	8.36	8.54	7.26	7.44	7.62
L-Lysine Hcl	2.22	2.00	1.79	2.12	1.90	1.68	1.42	1.20	0.99
L-Threonine	0.90	0.90	0.89	0.64	0.64	0.63	0.54	0.53	0.52
Constant ingredients[3]	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
Coban-60[4]	0.75	0.75	0.75	0.75	0.75	0.75	0.00	0.00	0.00
Total	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
ME kcal/kg	3085.61	3085.60	3085.60	3195.80	3195.80	3195.80	3250.90	3250.90	3250.90
Crude protein %	22.50	22.50	22.50	20.00	20.00	20.00	18.00	18.00	18.00
Calcium %	0.98	0.99	0.99	0.87	0.87	0.87	0.84	0.84	0.84
Nonphytate P %	0.45	0.45	0.45	0.42	0.42	0.42	0.39	0.39	0.39
Met %	0.58	0.59	0.59	0.55	0.56	0.56	0.50	0.50	0.50
Lys %	1.38	1.38	1.38	1.21	1.21	1.21	1.02	1.02	1.02
Thr %	0.94	0.94	0.94	0.82	0.82	0.82	0.74	0.74	0.74
TSAA %	0.99	0.99	0.99	0.92	0.92	0.92	0.85	0.85	0.85
Sodium %	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25

[1] H. J. Baker & Bro., 595 Summer Street, Stamford, CT 06901-1407. [2]Novus International, Inc., St. Louis MO 63141. [3]Includes 5 g/kg vitamin premix (provides per kg of diet: vitamin A 7715 IU; cholecalciferol 5511 IU; vitamin E 16.53 IU; vitamin B_{12} 0.013 mg; riboflavin 6.6 mg; niacin 39 mg; pantothenic acid 10 mg; menadione 1.5 mg; folic acid 0.9 mg; choline 1000 mg; thiamin 1.54 mg; pyridoxine 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg; 0.15 mg selenium), 5 g/kg sodium chloride, 1 g/kg trace mineral mix (provides per kg of diet: 100 mg manganese; 100 mg zinc; 50 mg iron; 10 mg copper; 1 mg iodine), 0.5 g/kg BMD-50 (Alpharma, Inc, Fort Lee, NJ 07024), 2.5 g/kg Pel-Stik (Uniscope Inc., Johnstown CO 80534). [4]Elanco Animal Health division of Eli Lilly & Co., Indianapolis, IN 46825.

Experiment 2

Live performance: The effects of the dietary treatments on live performance are shown in Table 4. At 14 d birds fed diets with 5% glycerine had significantly greater body weight and greater feed intake than birds fed the negative control or diets with 2.5% glycerine. At 35 and 42 d, birds fed diets with 2.5 or 5% glycerol had numerically greater body weight and greater feed intake than did birds fed the control diet. The inclusion of 2.5 or 5% glycerol had no significant adverse effects on feed conversion at any age compared to those fed the control diet, suggesting that the energy value of 3,526 ME kcal/kg assigned to the glycerine was valid.

Carcass characteristics: Significant differences in carcass characteristics were observed among birds fed the experimental diets (Table 4). No significant differences were observed among birds fed the dietary treatments for dressing percentage or water uptake during chill. Birds fed diets with 2.5 or 5% glycerine had significantly higher breast yield and lower wing yield than did birds fed the control diet with no significant difference in leg quarter yield. Absolute weight of breast and leg quarters was significantly greater for birds fed diets with 2.5 and 5% glycerine as compared to those fed the control diet.

Discussion

Broilers fed 20% glycerol diet had the same weight, feed intake, or feed conversion as control diet during experiments conducted up to 21 d (Lin *et al*., 1976), 28 d (Campbell and Hill, 1962) or 31d of age (Simon *et al.,* 1996). A 5% inclusion rate of glycerol in the diet of broilers grown to 42 days of age improved the feeding value of palm fatty acid distillate (Sanchez *et al.*, 2004) and supported performance similar to those fed the control diet (Lessard *et al.*, 1993).

The effects of glycerol on carcass dressing percentage or parts yield have not been previously been reported. However, broilers fed diets with glycerol were evaluated for nitrogen retention, chemical composition, or abdominal fat of carcass (Simon *et al*., 1996, 1997; Lessard *et al*., 1993). Many studies have shown the beneficial effects of glycerol on amino acid or nitrogen retention in rats (Chan *et al*., 1981) and humans (Brennan *et al*., 1975). This is because glycerol may spare the gluconeogenic amino acids via the inhibition of phosphoenolpyruvate carboxykinase (Cryer and Bartley, 1973; Young *et al*., 1964) or glutamate dehydrogenase activity (Steele *et al.,* 1971). In chickens Simon *et al*. (1997) showed a positive correlation between glycerol up to 20% and nitrogen retention. However, in a subsequent study, Simon *et al*. (1997)

Table 2: Composition (g/kg) and calculated nutrient content of diets containing glycerol from biodiesel production (Experiment 2)

Ingredient	0-14 d			14-35 d			35-42 d		
	A	B	C	A	B	C	A	B	C
Glycerol	0.00	25.00	50.00	0.00	25.00	50.00	0.00	25.00	50.00
Yellow corn	609.19	578.86	548.63	661.66	631.36	601.06	710.25	679.93	649.60
Soybean meal	286.71	291.70	296.48	229.00	233.98	238.96	182.78	187.75	192.75
Pro-Pak[1]	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Poultry oil	15.19	15.56	15.96	24.20	24.56	24.93	24.73	25.10	25.47
MHA-84	2.28	2.33	2.38	2.32	2.37	2.41	1.92	1.97	2.02
Limestone	9.76	9.68	9.59	7.68	7.60	7.51	7.67	7.59	7.50
Dicalcium phosphate	9.46	9.55	9.64	8.11	8.20	8.29	7.19	7.29	7.38
L-Lysine Hcl	1.90	1.81	1.81	1.79	1.69	1.60	1.08	0.98	0.89
L-Threonine	0.76	0.76	0.76	0.49	0.49	0.49	0.38	0.39	0.39
Constant ingredients [2]	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
Coban-60[3]	0.75	0.75	0.75	0.75	0.75	0.75	0.00	0.00	0.00
Total	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
ME kcal/kg	3085.64	3085.60	3085.61	3195.80	3195.80	3195.82	3250.90	3250.87	3250.85
Crude protein %	22.50	22.50	22.50	20.00	20.00	20.00	18.00	18.00	18.00
Calcium %	0.98	0.99	0.99	0.87	0.87	0.87	0.84	0.84	0.84
Nonphytate P %	0.45	0.45	0.45	0.42	0.42	0.42	0.39	0.39	0.39
Met %	0.58	0.58	0.58	0.55	0.55	0.55	0.49	0.50	0.50
Lys %	1.38	1.38	1.39	1.21	1.21	1.21	1.02	1.02	1.02
Thr %	0.94	0.94	0.94	0.82	0.82	0.82	0.74	0.74	0.74
TSAA %	0.99	0.99	0.99	0.92	0.92	0.92	0.85	0.85	0.85
Sodium %	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25

[1] H. J. Baker & Bro., 595 Summer Street, Stamford, CT 06901-1407. [2]Includes 5 g/kg vitamin premix (provides per kg of diet: vitamin A 7715 IU; cholecalciferol 5511 IU; vitamin E 16.53 IU; vitamin B_{12} 0.013 mg; riboflavin 6.6 mg; niacin 39 mg; pantothenic acid 10 mg; menadione 1.5 mg; folic acid 0.9 mg; choline 1000 mg; thiamin 1.54 mg; pyridoxine 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg; 0.15 mg selenium), 5 g/kg sodium chloride, 1 g/kg trace mineral mix (provides per kg of diet: 100 mg manganese; 100 mg zinc; 50 mg iron; 10 mg copper; 1 mg iodine), 0.5 g/kg BMD-50 (Alpharma, Inc, Fort Lee, NJ 07024), 2.5 g/kg Pel-Stik (Uniscope Inc., Johnstown CO 80534). [3]Elanco Animal Health division of Eli Lilly & Co., Indianapolis, IN 46825.

observed no positive effect of glycerol on nitrogen retention in a diet low in protein (18%) or high in carbohydrates. On the other hand, Lessard *et al*. (1993) reported that a 5% glycerol diet had no adverse effect on broiler carcass fat, except abdominal fat pad weight. Moreover, Lin *et al*. (1976) demonstrated that glycerol decreases the rate of fatty acid synthesis and lipogenic enzyme activities in the chicken liver. The dietary glycerol may have a beneficial effect on water intake of broiler carcass due to the easy accumulation of glycerol in chicken muscle (Simon *et al*., 1996) or the high osmotic pressure (Riedesel *et al*., 1987).

The digestibility of glycerine in broilers or rats has been reported to be around 75% (Simon *et al*., 1996; Hober and Hober, 1939). Bernal *et al*. (1978) showed that when diets containing 0 and 8.5% of glycerol were formulated without considering equal ME levels, the addition of 8.5% glycerol resulted in worse feed conversion than did the positive control.

The fact that diets containing 2.5% or 5% glycerol increased the breast yield suggests that glycerol may improve protein deposition. Breast meat contributes about 30% of total carcass meat and as much as 50% of total edible carcass protein (Summers *et al.,* 1988). Glycerol may increase the protein deposition due to the reduction of gluconeogenic amino acids via the inhibition of phosphoenolpyruvate carboxykinase (Cryer and Bartly, 1973; Young *et al*., 1964) or glutamate dehydrogenase activity (Steele *et al*., 1971). Even though glycerol has been proven to improve protein deposition in broilers (Simon *et al*., 1996), rats (Chan *et al.*, 1981) and humans (Brennan *et al.,* 1975), glycerol added to a broiler diet low in crude protein did not affect on the nitrogen retention (Simon *et al*., 1997). On the other hand, a study by Lessard *et al.* (1993) showed that the inclusion of 5% glycerol had the same crude protein and ether extract of the carcass as compared to control diet, but increased the abdominal fat pad weight. This increase in abdominal fat may be result of the overestimation of metabolizable energy assigned to glycerol or the high plasma lipids or lipoproteins as a consequence of the stimulation of mucosal triglyceride esterification by the glycerol (Narayan *et al*., 1977). However, in broilers dietary glycerol decreases the rate of fatty acid synthesis and lipogenic enzyme activities in the liver (Lin *et al*., 1976). Moreover, in rats when glycerol and fat are fed together, they can reduce plasma cholesterol and liver lipids (Narayan and McMullen, 1979) and the esterification of fatty acids in rat fat tissue (Narayan and Ross, 1987).

The fact that diets with 2.5 or 5% glycerol resulted in an increase in breast meat yield in experiment 2 but not in experiment 1 may be due to the lower feed intake in experiment 2 as compared to experiment 1. In situations

Table 3: Effects of dietary glycerol levels on performance of male broilers (Experiment 1)

Parameter	Glycerol, %			Prob > F	CV
	0	5	10		
Body weight, kg					
Day 14	0.499	0.493	0.498	0.82	3.80
Day 35	2.190^{a}	2.171^{a}	2.080^{b}	0.008	3.13
Day 42	2.871^{a}	2.879^{a}	2.706^{b}	0.001	2.94
Feed intake, kg/bird					
Days 0-14	0.528^{b}	0.530^{b}	0.547^{a}	0.038	2.82
Days 0-35	3.447	3.403	3.373	0.18	2.28
Days 0-42	4.886^{a}	4.856^{ab}	4.735^{b}	0.05	2.38
Feed Conversion (kg feed/kg gain)					
Days 0-14	1.175	1.205	1.218	0.20	3.86
Days 0-35	1.610^{a}	1.604^{a}	1.662^{b}	0.016	2.45
Days 0-42	1.732^{a}	1.709^{a}	1.768^{b}	0.006	1.73
Mortality, %					
Days 0-14	1.875	1.876	2.085	0.97	1.02*
Days 0-35	4.999	3.543	3.960	0.73	1.77*
Days 0-42	6.458	4.584	5.416	0.71	2.10*
Carcass characteristics					
Dressing percentage, %	72.85^{a}	72.82^{a}	72.17^{b}	0.018	2.24
Breast, % of carcass	26.45	26.73	25.98	0.11	8.21
Wing, % of carcass	11.12^{a}	11.18^{a}	11.40^{b}	0.019	5.56
Leg quarters % of carcass	31.05	31.11	31.24	0.84	6.72
Breast weight, kg	0.567^{a}	0.563^{a}	0.528^{b}	0.0003	11.32
Wing weight, kg	0.238^{a}	0.235^{ab}	0.231^{b}	0.05	7.17
Leg quarters weight, kg	0.664^{a}	0.655^{a}	0.634^{b}	0.01	9.32

^{ab}Means in row with common superscript do not differ significantly (P $\leq$ 0.05). *CV of transformed means.

Table 4: Effects of dietary glycerol levels on performance of male broilers (Experiment 2)

Parameter	Glycerol, %			Prob > F	CV
	0	2.5	5.0		
Body weight, kg					
Day 14	0.384^{b}	0.391^{b}	0.406^{a}	0.01	3.50
Day 35	2.059	2.115	2.094	0.33	3.54
Day 42	2.618	2.712	2.709	0.09	3.43
Feed intake, kg/bird					
Days 0-14	0.487^{b}	0.489^{b}	0.509^{a}	0.006	2.61
Days 0-35	3.099	3.138	3.157	0.39	2.72
Days 0-42	4.226	4.332	4.337	0.18	3.03
Feed Conversion (kg feed/kg gain)					
Days 0-14	1.437	1.416	1.408	0.45	3.27
Days 0-35	1.539	1.516	1.542	0.21	1.97
Days 0-421.643	1.625	1.629	0.27	1.42	
Mortality, %					
Days 0-14	3.33	3.54	3.95	0.91	1.45*
Days 0-35	6.042	6.458	6.042	0.95	1.45*
Days 0-42	6.25	7.50	6.45	0.67	1.40
*Carcass characteristics					
Dressing percentage, %	72.05	72.34	72.08	0.31	1.83
Water uptake in chill %	2.04	2.10	2.08	0.79	27.71
Breast, % of carcass	25.16^{b}	25.80^{a}	25.96^{a}	0.02	7.27
Wing, % of carcass	11.55^{a}	11.31^{b}	11.31^{b}	0.05	6.23
Leg quarters % of carcass	30.11	30.08	29.70	0.13	4.75
Breast weight, kg	0.471^{b}	0.504^{a}	0.504^{a}	0.0001	10.61
Wing weight, kg	0.215	0.220	0.219	0.10	7.18
Leg quarters weight, kg	0.561^{b}	0.586^{a}	0.576^{a}	0.001	7.25

^{ab}Means in row with common superscript do not differ significantly (P $\leq$ 0.05). *CV of transformed means.

of suboptimal feed intake or carbohydrate intake glycerol may form glucose-sparing gluconeogenic amino acids and consequently increasing the protein deposition. Hence, the fact that glycerol had increased the nitrogen retention in low carbohydrates diets (Simon *et al*., 1996) but not in high carbohydrates diets (Simon *et al.* 1997) may be the partial explanation of this positive effect of glycerol on breast yield in experiment 2. Further Terblanche *et al*. (1981) showed that exercise and fasting rats fed glycerol diets depleted the muscle and liver glycogen stores less rapidly than those fed control diet.

The water uptake of the carcass was not significantly affected by the inclusion of 2.5 or 5% glycerol in the present studies. Even though the glycerol did not increase the water intake during 3 hour of chilling, it can increase the water holding capacity as demonstrated in swine (Mourot *et al*. 1994) and humans (Riedsel *et al.,* 1987). Chilling in the present experiments was conducted in non-agitated chill tanks and water uptake may be different in agitated chill tanks typically used in the poultry industry.

In conclusion, the results of these two experiments indicate that glycerine from biodiesel production can be effectively used in broiler diets at levels of 2.5 or 5%. The use of 10% glycerine resulted in reduced performance that was felt to be highly related to problems with feed flow. In a different type of feeding system it may be possible to use levels higher than 5%. The influence of glycerine levels on pellet quality needs to be evaluated in future studies. The quality of the glycerine is a concern as residual levels of potassium may result in problems with wet litter or imbalances in dietary electrolyte balance. Acceptable levels of residual methanol are yet to be determined.

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[3]When referring to its function in living organisms, the term glycerol is preferred while the crude product obtained from hydrolysis of fats and oils is generally referred to as glycerine.