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Impact of utilizing refined glycerol as an energy source on broiler performance and meat quality

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ABSTRACT

This study aimed to evaluate the effect of using refined glycerol as an energy source in a broiler diet on productive performance and meat quality. The 2,000, one-day-old Ross 308 chicks were randomly allotted into four dietary treatments for 35 days. The chicks were fed the basal diet of 0%, 2.5%, 5%, and 7.5% refined glycerol. Each treatment was composed of 10 replicates with 50 birds per replicate (25 males and 25 females). The results revealed that using 5% refined glycerol in the broiler diet did not affect growth performance, but the addition of 7.5% refined glycerol negatively affected feed intake, weight gain, and performance index. However, using up to 7.5% refined glycerol in the diet did not affect the carcass traits and meat quality. Therefore, refined glycerol is suitable for use as an energy source and can be used up to 5% in the diet without adverse effects on growth performance and up to 7.5% with no effect on carcass traits and meat quality of broiler chickens.

Keywords: glycerol; broiler; pellet quality; growth performance; meat quality

1. INTRODUCTION

In Thailand, alternative energy sources, such as biodiesel, have been promoted in response to the dramatic increase in oil prices since 2008. Typically, the glycerol produced during biodiesel production is crude glycerol, and it is commonly around 10% by weight. Crude glycerol produced as a byproduct of biodiesel production can be refined to obtain a higher purity glycerol product depending on the quality of the raw materials used for biodiesel production and the refining process. The refined glycerol yield can typically range from 30 to 45%. Refined glycerol has numerous applications across various industries, including pharmaceuticals, cosmetics, and animal feed. According to Cerrate et al. (2006) using refined glycerol at 0, 2.5, and 5% in a broiler diet did not affect productive performance. Silva et al. (2012) investigated the use of crude glycerol varying from 0% to 10% in broiler diets on productive performance. The results indicated that using glycerol in broiler diets up to 5% did not affect feed intake (FI), weight gain, or feed conversion ratio (FCR). However, when 10% glycerol was included in the diet, the body weight of the broiler was reduced. Sehu et al. (2013) studied using crude glycerol up to 10% in broiler diets and found no significant effect on carcass traits and relative organ weights. Legawa et al. (2018)

used two types of crude glycerol produced from vegetable oil and palm oil waste in a broiler diet and found that neither product influenced the pH, meat color, drip loss, or cooking loss. Refined glycerol is considered "Generally Recognized as Safe" for use in animal feed (Code of Federal Regulations, 2004) because of the available data on using refined glycerol in a monogastric diet, especially the effect of using refined glycerol in a diet on productive performance and meat quality. This study was performed to determine the effects of using refined glycerol from biodiesel production as an energy feedstuff as a replacement for corn and soybean oil in broiler diets on the productive performance, carcass traits, and meat quality.

2. MATERIALS AND METHODS

This study was performed at the Animal Science Learning Center, Kasetsart University, Kamphaeng Saen Campus, Nakhon Pathom, Thailand. All experimental procedures in this study were reviewed and approved by the Animal Care and Use Committee for Scientific Research of Kasetsart University (ACKU60-AGK-053). Two thousand, one-day-old Ross 308 chicks were allocated into four experimental groups. Each group comprised 10 replications, with 50 chicks per replicate, evenly split between males and females. All chicks were housed in a facility featuring an evaporative cooling system, with curtain-siding and rice husk as litter material. Feed and water are provided ad libitum. The temperature was maintained at approximately 27–30°C and relative humidity at around 75%–80% throughout the experiment. Each replicate was kept in a pen with an area of 4 m^2. The four experimental groups included a corn-soy basal diet with varying proportions of refined glycerol (0, 2.5, 5, and 7.5%). The glycerol used for this experiment had the following specifications: glycerin content 99.58% w/w, methanol <0.015% w/w, MONG 0.35% w/w, gross energy 3842.69 kcal/kg, and apparent metabolizable energy (ME) for broilers at 3,712 kcal/kg. Each diet was formulated to be isocaloric and isoproteic, with the starter diet (1–21 days) containing 3,100 kcal/kg ME and 22% crude protein (CP) and the grower diet (22–35 days) containing 3,150 kcal/kg ME and 20% CP (Table 1).

Table 1. Composition and calculated nutrient content of diets

Feed ingredients (kg)	**Feed stage**							
	Starter (1–21 days)				**Grower (22–35 days)**			
Glycerol	0	2.5	5.0	7.5	0	2.5	5.0	7.5
Corn	47.87	44.99	42.10	39.23	51.92	49.03	46.14	43.28
Rice bran	3.00	3.00	3.00	3.00	5.00	5.00	5.00	5.00
Soybean oil	2.79	2.70	2.61	2.51	3.17	3.08	2.99	2.89
Soybean meal (46% CP)	24.02	24.49	24.97	25.43	21.00	21.47	21.94	22.39
Full fat soybean	18.00	18.00	18.00	18.00	15.00	15.00	15.00	15.00
L-lysine	0.09	0.09	0.09	0.09	0.06	0.06	0.06	0.06
DL-methionine	0.24	0.24	0.24	0.24	0.22	0.22	0.22	0.22
Choline chloride (60%)	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
MCP (P21)	1.82	1.82	1.82	1.82	1.59	1.60	1.60	1.60
$CaCO_3$	1.51	1.51	1.51	1.51	1.38	1.38	1.38	1.38
Salt	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Premixed	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Calculated analyses								
ME (kcal/kg)	3,100	3,100	3,100	3,100	3,150	3,150	3,150	3,150
CP (%)	22.00	22.00	22.00	22.00	20.00	20.00	20.00	20.00

2.1 Data collection

2.1.1 Growth performance

Feed consumption and body weight were recorded by pen on days 0, 21, and 35 for body weight gain (BWG), average FI, and FCR calculation. The number of dead chicks and the causes of death were recorded daily for the calculation of the mortality rate.

2.1.2 Carcass traits

At the end of the experiment (day 35), four chicks (two males and two females) from each pen were randomly sampled for carcass evaluation. The chicks were euthanized by CO_2 inhalation, plucked, and eviscerated after being immersed in boiling water. The heart, gizzard, and liver were removed and weighed following the evisceration process. The weight of each dressed chick was measured individually. After evisceration, the chicks were chilled at 7°C for 1 h before their chilled weight was measured individually. Each chick was then deboned, and the weight of each organ (including the head and neck, wings, breast and skin, drum, abdominal fat, and skeleton) was recorded. The organ weights were computed and presented as a percentage relative to the carcass weight (g per 100 g of carcass weight) (Moharrery & Mohammadpour, 2005).

2.2 Meat quality

2.2.1 Drip loss analysis

Drip loss assessment followed the protocol previously described by Rémignon et al. (1996). One hundred and sixty samples of the left pectoralis major muscle were used for analysis. Each muscle was sliced to a thickness of 1 cm, weighed, and subsequently placed in a polyethylene bag, and stored at 4°C. After a storage period, the muscles were removed from the bag 24 h post-slaughter, wiped, and reweighed. The drip loss was then computed and presented as a percentage of the initial muscle weight.

2.2.2 Cooking loss analysis

Cooking loss was assessed 5 h post-slaughter, using a preheated oven set to 170°C. A total of 160 breast muscle samples were used for cooking loss analysis. Each muscle was cut into equally small pieces (2.0 × 1.0 × 0.5 cm^3) and weighed. The samples were placed into a sealed plastic bag and arranged on trays fitted with aluminum grills, which had been dried beforehand in an incubator. These trays were placed in a preheated oven until the core temperature reached 75°C. Thereafter, the samples were allowed to cool to room temperature (27°C) and reweighed, and the cooking loss was determined by subtracting the final sample weight from the initial weight (Legawa et al., 2018).

2.2.3 Shearing force analysis

The same samples that were used for cooking loss assessment were employed for shearing force evaluation, following the methodology previously described by Papinaho and Fletcher (1996). Samples of the breast muscle (2.0 × 2.0 × 1.13 cm^3) were prepared and inserted into a tensile tester, model 101 (Instron, USA). These samples were positioned to ensure that the muscle fibers ran perpendicular to the blade and the shearing force was calculated based on the average of the samples.

2.2.4 Meat color

The color parameters in the CIELAB Color System 1976, including L* (lightness), a* (redness), and b* (yellowness), were measured using a tristimulus analyzer (Minolta Chroma Meter CR-300) 5 h post-slaughter.

2.3 Statistical analysis

The data were analyzed using the analysis of variance method. The treatment effects were considered significant at a p-value <0.05. Variables exhibiting significance in the F-test were further assessed using Duncan's new multiple-range test function within the rStudio program.

3. RESULTS AND DISCUSSION

3.1 Growth performance

The evaluation of glycerol supplementation on the productive performance of broiler chickens (Table 2) found that supplementing the diet with 2.5% and 5% refined glycerol had no adverse effects on productive performance. However, supplementation at 7.5% resulted in decreased FI, BWG, and FCR at 0–21 days (p<0.05) compared to those at 0%. The productive performance of the broilers at 22–35 days showed a quadratic response in both the FI and BWG. At the supplementation levels of 7.5% glycerol, there was a significant decrease in FI and BWG compared to those at 0%, without affecting FCR. This reduction can be attributed to the observed decrease in FI and growth rate. For the productive performance of the broiler throughout the 0–35 day rearing period, it was observed that both FI and BWG exhibited a quadratic response at the 2.5% supplementation level. Upon examining the FCR and overall broiler production efficiency (production index), a linear response was noted, with a decrease corresponding to the increasing levels of glycerol supplementation. In addition, supplementation at 7.5% resulted in decreased FI, BWG, FCR, and overall broiler production index (p<0.05) compared to the control group. This may be due to a decrease in the hardness of the feed pellets, which is in agreement with the finding by González et al. (2020), where it was reported that higher glycerol usage decreases the tensile strength of the feed pellets. This resulted in increased feed crumbliness, thereby reducing the FI of the chickens, because when the feed pellets crumble easily, the chickens eat by pecking, thus making it more difficult for the chickens, resulting in reduced FI. In line with Parsons et al. (2006), who reported that broilers fed with hard pellets exhibited significantly higher live weight gain and feed efficiency compared to those fed soft pellets. Furthermore, this aligns with the study of Silva et al. (2012) which found that the inclusion of 5% glycerol had no adverse effect on weight gain, FI, and FCR of broilers. However, supplementation at 7.5% tended to decrease the FI and FCR, while supplementation at 10% resulted in a 4.2% reduction in weight gain compared to the control group. This suggests that glycerol serves as a viable energy source in feed formulations up to 5% without affecting the productive performance of broiler chickens. This is consistent with the experiment conducted by McLea (2014) who reported that using glycerol in feed improves the productive performance and FCR up to a certain level. Using high levels of glycerol in feed does not affect productive performance because of the limited functionality of the enzyme glycerol kinase that converts glycerol into glyceraldehyde-3-phosphate before entering glycolysis and the Krebs cycle. Therefore, the addition of substrates or glycerol may not always result in an increase of glyceraldehyde-3-phosphate consistently over time. From this study, it was found that high inclusion levels of refined glycerol for energy sources in the diet negatively affected growth performance because animals cannot fully utilize the energy in their diet.

3.2 Carcass traits

Table 3 shows the impact of the dietary treatments on carcass characteristics. The addition of refined glycerol up to 7.5% did not show any significant differences in the percentage of the carcass weight, head and neck, wing, breast and skin, thigh, drumstick, abdominal fat, shank, and skeleton compared to chicken fed a control diet with no added refined glycerol. The effects of using refined glycerol in broiler diets on carcass traits in this experiment were similar to those of Sehu et al. (2013) who reported that adding up to 10% glycerol in broiler diets did not adversely affect carcass yield. Never (2015) stated that factors influencing carcass composition include genetics, nutrition, age at slaughter, sex of the animal, and weight of the animal. In this experiment, animals with the same genetics were used, the age at slaughter was the same, the weight of the chickens was not significantly different, and each experimental group received the same nutrition. Therefore, the carcass composition did not differ.

Table 2. Effects of feeding glycerol on growth performance of broiler

	Glycerol (%)				*P -value*		
	0	**2.5**	**5**	**7.5**	***Linear***	***Quadratic***	***Cubic***
1–21 days of age							
Initial weight (g)	40.80	40.86	40.71	40.57	0.4839		
FI/bird (g)	1122.68^{a}	1127.50^{a}	1113.27^{a}	1095.77^{b}	0.9742	0.0010	0.0015
Weight gain (g)	796.75^{ab}	803.79^{a}	783.08^{b}	701.50^{c}	<0.001	<0.001	0.1544
FCR	1.41^{b}	1.40^{b}	1.42^{b}	1.56^{a}	<0.001	<0.001	0.0731
Mortality (%)	0.20	0.41	0.20	0.00	0.7206		
22–35 days of age							
FI/bird (g)	2129.28^{a}	2234.79^{a}	2139.52^{a}	1963.68^{b}	<0.001	0.0005	0.1006
Weight gain (g)	1293.03^{a}	1304.90^{a}	1282.21^{a}	1173.67^{b}	0.0029	0.0303	0.6701
FCR	1.65	1.65	1.67	1.67	0.9234		
Mortality (%)	0.20	0.20	0.20	0.20	1.0000		
1–35 days of age							
Final Weight (g)	2130.60	2149.54	2106.00	1915.74	0.4822		
FI/bird (g)	3251.96^{a}	3262.30^{a}	3252.79^{a}	3059.45^{b}	<0.001	0.0003	0.1526
Weight gain (g)	2089.78^{a}	2108.96^{a}	2065.29^{a}	1875.16^{b}	<0.001	0.0007	0.5.64
FCR	1.56^{a}	1.55^{a}	1.58^{a}	1.63^{b}	0.0079	0.1280	0.9215
Mortality (%)	0.41	0.40	0.4	0.60	0.9767		
PI	388.34^{a}	397.30^{a}	379.97^{a}	334.15^{b}	0.0006	0.0152	0.9638

Note: ^{a,b} means within a row with no common superscript differ significantly (p>0.05)

Table 3. Effects of feeding glycerol on carcass traits of broiler

% Live body weight	**Glycerol level (%)**				*P -value*	*Pool±SE*
	0	**2.5**	**5**	**7.5**		
Carcass	93.89	93.93	93.47	93.57	0.6789	0.5192
Head and neck	8.29	8.19	8.18	8.37	0.6759	0.0611
Wing	9.16	9.07	9.04	9.22	0.2616	0.0351
Breast and skin	25.54	26.12	22.64	22.55	0.1993	0.7376
Thigh	15.53	15.78	15.75	15.97	0.2195	0.0721
Drumstick	11.57	11.76	11.71	11.82	0.5403	0.0616
Abdominal fat	1.91	1.93	2.17	2.19	0.0961	0.0499
Shank	4.39	4.38	4.28	4.41	0.6016	0.0355
Skeleton	21.49	21.03	21.03	21.09	0.4137	0.1118

3.3 Meat quality

Table 4 shows the influence of dietary treatments on meat quality. The addition of up to 7.5% refined glycerol did not reveal a significant difference in the percentage of cooking loss, drip loss, shear force, and meat color compared to the control group fed a diet with no added refined glycerol. This is consistent with the findings of McLea (2014) who reported that broiler breast meat from birds fed diets containing up to 8% glycerol had similar moisture loss and tenderness to those fed a control diet.

Table 4. Effects of feeding glycerol levels on meat quality

Items	**Glycerol (%)**				*P -value*	*Pool±SE*
	0	**2.5**	**5**	**7.5**		
Cooking loss (%)	17.47	17.30	17.99	19.77	0.1346	0.4028
Drip loss (%)	4.20	4.44	4.27	4.70	0.3083	0.0999
Shear force (%)	3.47	3.89	3.36	3.83	0.0938	0.0861
Color L*	71.27	70.89	71.42	71.51	0.9491	0.3988
a*	6.60	5.66	6.51	6.41	0.1866	0.1656
b*	17.18	16.29	17.00	18.11	0.0601	0.2276

4. CONCLUSION

Glycerol, as a byproduct of biodiesel production, has the potential to be utilized as an alternative feedstuff in broiler diets. Refined glycerol has a harmless level of methanol and high ME for broiler chickens. The results of this experiment indicate that up to 5% refined glycerol from biodiesel production can be used as an energy source in a broiler diet without negatively affecting growth performance, carcass characteristics, and meat quality. However, feeding broilers with up to 7.5% refined glycerol lowered FI and overall growth performance but did not influence carcass characteristics and meat quality.

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