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Effects of exogenous emulsifier supplementation on growth performance, energy digestibility, and meat quality in broilers

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Abstract

This experiment was conducted to investigate the effects of exogenous emulsifier supplementation on growth performance, energy digestibility, and meat quality in broilers. A total of 60 Ross 308 broilers were treated for two weeks. The three dietary treatments were: (CON) basal diet; (T1) basal diet + 0.1% exogenous emulsifier, and (T2) basal diet + 0.2% exogenous emulsifier. In Period 1 (0–7 days), broilers in the T2 group showed significantly higher body weight gain (BWG) ($p < 0.05$) and broilers in the T1 and T2 treatment groups had significantly lower feed conversion ratios (FCR) ($p < 0.05$). In Period 2 (8–14 days), broilers in the T2 treatment group had significantly higher feed intake (FI) ($p < 0.05$). Therefore, in this experiment (from days 0 to 19), BWG and FCR were affected ($p < 0.05$) by the T1 and T2 treatments. Additionally, the T1 and T2 treatments with added exogenous emulsifier in the broiler feed showed significantly higher energy digestibility ($p < 0.05$) than the CON treatment. Broilers fed the T2 diet had higher water-holding capacity (WHC) ($p < 0.05$) and cooking loss than the broilers fed the CON and T1 diets. Moreover, the shearing force in the meat was decreased ($p < 0.05$) in broilers fed the T2 diet. In conclusion, supplementation with exogenous emulsifier to broiler diets improved growth performance, energy digestibility, and meat quality. The optimal amount of exogenous emulsifier supplementation requires further investigation.

Keywords: Broiler, Energy digestibility, Exogenous emulsifier, Growth performance, Meat quality

INTRODUCTION

An emulsifier can disperse liquids by reducing the surface tension between two substances that are difficult to mix and increase the penetration depth [1,2]. Because of these characteristics, emulsifiers are commonly used as additives to foods, such as bread and ice cream [3].

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Competing interests
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Availability of data and material
Upon reasonable request, the datasets of this study can be available from the corresponding author.

Authors' contributions
Conceptualization: An JS, Cho JH.
Data curation: An JS.
Formal analysis: An JS, Kim KH, Lee SD.
Investigation: Yun W, Lee JH, Oh HJ, Kim TH, Cho EA, Kim GM.
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Writing - review & editing: Cho JH.

Ethics approval and consent to participate
The experimental protocol was approved and conducted under the guidelines of the Animal Care and Use Committee of Chungbuk National University.

Emulsifiers play a diverse role in the livestock industry. As a feed additive, it aids the digestion and absorption of added fat in feed to increase the productivity of broilers and weaning pigs [4]. The supplementation of emulsifiers in feed with vegetable fat was reported to increase growth performance significantly and improve fatty acid digestibility in broilers [5,6]. The digestibility of major nutrients, such as protein and energy, as well as fat, is also increased to improve growth performance [7]. The addition of emulsifiers to feed reduces the viscosity of the digesta, increasing the amount of transfer to the digestive tract [8]. Supplementation with emulsifiers has been shown to effectively reduce the size of the fat globules in feed, thereby increasing the total available surface area for the digestive enzymes [9–14].

The addition of emulsifiers to the feed production process improves the quality of the pellets by controlling the moisture content of the pellets to increase humidity and reduce energy consumption [15]. For this reason, studies of emulsifying agents in livestock have focused on using lecithin to improve the growth performance and digestibility in monogastric animals [11,16]. Therefore, this study was conducted to investigate the effects of supplementation with exogenous emulsifier on the growth performance, energy digestibility, and the meat quality of broilers.

MATERIALS AND METHODS

The experimental protocol was approved and conducted under the guidelines of the Animal Care and Use Committee of Chungbuk National University.

Experimental design and animals

A total of sixty 10-day-olds (184.4 ± 2.3 g) ROSS 308 broilers were used in 19 days. All birds randomly allocated into 3 groups, with 10 replicates per group and 2 chickens per cage that was made with stainless steel of identical size (50 × 35 × 35 cm). The experiment period was of 19 days. The dietary treatments were as follows: (1) control, basal diet (CON), (2) basal diet + 0.1% exogenous emulsifier (T1), (3) basal diet + 0.2% exogenous emulsifier (T2). Exogenous emulsifier (Lipidol®, Easybio Co., Korea) used in this experiment contains lysolecithin. The basal diets were formulated to meet or exceed the NRC [17] requirements (Table 1). All broilers were allowed to consume feed and water *ad libitum*.

Sampling and measurements

The broilers were weighed individually, and body weight was recorded initially and end of the experimental period (19-days) to calculate body weight gain (BWG), feed intake (FI), and feed conversion ratio (FCR). Chromium oxide at 0.2% was supplemented to the diets on the 7 days before the end of the experimental period, as a marker for the apparent digestibility of gross energy. Fresh fecal and feed samples were gathered from each cage at the end of the experiment. Fecal samples were dried at 70℃ for 72 hours in a forced air oven and ground and screened with a 1-mm screen. The gross energy of diets and feces was analyzed using an adiabatic oxygen bomb calorimeter (Parr Instruments, Moline, IL, USA).

The 10 broilers were randomly selected from each treatment. The selected broilers were sacrificed by cervical dislocation and exsanguinated. And the breast meat was removed and weighed. The breast muscle was analyzed immediately. Its Hunter lightness (L*), redness (a*) and yellowness (b*) values were determined by Spectro color meter (Color Techno System Co Ltd, Tokyo, Japan). The pH values values of each sample were measured using a pH-meter (WTW, Weilheim, Germany). The water-holding capacity (WHC) was measured with the methods described by Laakkonenen et al. [18]. The shearing force was determined using a Shearing, Cutting Test by Rheo meter (Sun Sci-

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Table 1. Compositions of the basal diets (as-fed basis)

Items	Content
Ingredients (%)	
Corn	50.28
Soybean meal (44% CP)	16.50
Wheat	20.00
Wheat bran	4.00
Fish meal	1.00
Animal fat	3.00
Rapeseed meal	2.00
Salt	0.23
Choline-HCl (50%)	0.01
DL-Methionine-99%	0.12
Lysine-HCl (78%)	0.66
Calcium carbonate	0.20
Tricalcium phosphate	1.60
Vitamin premix[1)]	0.20
Mineral premix[2)]	0.20
Analyzed composition (%)	
Crude protein	22
Ca	1
Lysine	1.2
Met + Cys	0.87

[1)]Contained per kg of diet: vitamin A, 10,000 IU; vitamin D_3, 2,000 IU; vitamin E, 421 IU; vitamin K, 5 mg; riboflavin, 2,400 mg; vitamin B_2, 9.6 mg; vitamin B_6, 2.45 mg; vitamin B_{12}, 40 ug; niacin, 49 mg; pantothenic acid, 27 mg, biotin, 0.05 mg.
[2)]Contained the mg per kg of diet: Cu 140 mg, Fe 145 mg, Zn 179 mg, Mn 12.5 mg, I 0.5 mg, Co 0.25 mg, Se 0.4 mg.

entific Co Ltd, Tokyo, Japan). Breast samples were heated in a water bath at 70℃ and then chilled to room temperature for 30 minutes. The samples [1.0 cm (width) × 2.0 cm (thickness) × 1.0 cm (length)] were measured max weight. The shearing force test condition was as follows: table speed of 110 mm/min, Graph interval of 20 msec and Load cell (max) of 10 kg using the RDS (Rheology Data System, Tokyo, Japan) Ver 2.01. For cooking loss determination, each breast was weighed and sealed in a polypropylene bag and cooked by immersion in a 70℃ water bath for 40 minutes. After cooking, the samples were chilled by immersion of the bags in an ice water bath for 30 minutes. Each piece of the breast was then weighed and calculated. For drip loss determination, breast samples were kept suspended in a sealed polypropylene bag at 4℃ for 24 h, and loss was calculated as the percentage of weight loss during storage. The TBARS was measured with the extraction method of Witte et al. [19] and was marked as mg malonaldehyde per 1,000 g of samples.

Statistical analysis

Data were statistically analyzed by ANOVA using the GLM procedure SAS ver 9.4 (SAS Institute Inc., Cary, USA), with each cage being used as the experimental unit. Differences among all treatment means were determined using the Duncan's multiple range tests with a $p < 0.05$ indicating a significance.

RESULTS AND DISCUSSION

Growth performance

Table 2 presents the effect of exogenous emulsifier supplementation of broiler feed on growth performance. At the end of the experiment, the final body weight of the broilers was significantly higher ($p < 0.05$) in broilers fed the T2 diet than in the other treatment groups. In Period 1 , broilers in the T2 treatment group showed significantly higher body weight gain (BWG) ($p < 0.05$) compared to the other treatments and broilers in the T1 and T2 treatment groups had significantly lower feed conversion ratios (FCR) ($p < 0.05$) than broilers in the CON treatment group. In Period 2, broilers in the T1 treatment group had significantly higher BWG ($p < 0.05$) than broilers in other treatment groups and broilers in the T2 treatment group had significantly higher feed intake (FI) ($p < 0.05$). The FCR was decreased ($p < 0.05$) in the T1 treatment group. From day 15 to 19 (Period 3), there was no significant difference ($p > 0.05$) on growth performance among the dietary treatment groups. During the overall period, broilers in the T1 and T2 treatment groups showed increased BWG ($p < 0.05$). The FCR was significantly lower ($p < 0.05$) in the T1 treatment group than in the other treatment groups.

In a study conducted on broilers, the results of supplementation lysolecithin in feed showed no significant effect on the growth performance of the broilers for one to 21 days [20]. In a similar study, Dabbou et al. [21] reported that supplementation with natural emulsifiers for one to 10 days significantly decreased the FCR in broilers, but there were no significant differences in BWG or FI. In contrast, a study by Bontempo et al. [15] showed a significant improvement in average daily gain with the supplementation of synthetic emulsifier to the feed for one to 12 days and a significant decline in the FCR for 22 to 44 days. The results of this study also showed a significant difference

Table 2. Effect of supplemental exogenous emulsifier on growth performance in broilers

Item	CON	T1	T2	SE	*p*-value
Initial BW (10 d Broiler)	181.7	185.0	186.7	2.7	0.412
Final BW (29 d Broiler)	1,337.9^{c}	1,382.7^{b}	1,406.0^{a}	5.0	0.005
Period 1 (d 0 to 7)					
Weight gain (g)	348.3^{b}	341.7^{b}	374.2^{a}	3.4	0.013
Feed intake (g)	496.7	460.8	500.0	12.9	0.203
Feed conversion ratio (g/g)	1.426^{b}	1.349^{a}	1.336^{a}	0.032	0.025
Period 2 (d 8 to 14)					
Weight gain (g)	460.8^{b}	490.0^{a}	471.7^{b}	17.6	0.047
Feed intake (g)	718.3^{b}	715.8^{b}	755.0^{a}	14.1	0.042
Feed conversion ratio (g/g)	1.559^{b}	1.461^{a}	1.601^{b}	0.063	0.038
Period 3 (d 15 to 19)					
Weight gain (g)	347.0	366.0	373.5	32.4	0.845
Feed intake (g)	523.3	534.7	551.3	21.2	0.926
Feed conversion ratio (g/g)	1.508	1.461	1.476	0.014	0.178
Overall period (d 0 to 19)					
Weight gain (g)	1,156.2^{b}	1,197.7^{a}	1,219.3^{a}	6.7	0.016
Feed intake (g)	1,738.3	1,711.3	1,806.3	24.0	0.136
Feed conversion ratio (g/g)	1.503^{a}	1.429^{b}	1.481^{ab}	0.014	0.064

Each value is the mean value of 10 replicates (2 broilers/cage).

$^{a-c}$Means in the same row with different superscripts differ ($p < 0.05$).

CON, basal diet; T1, basal diet + 0.1% exogenous emulsifier; T2, basal diet + 0.2% exogenous emulsifier; SE, standard error.

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in the FCR and BWG in the group treated with added exogenous emulsifier in Period 1 and there were significant effects on BWG, FI, and FCR in Period 2 in the group treated with feed containing exogenous emulsifier. Improvement in the growth performance of the broilers may be the result of increased fatty acid and nutrient digestibility [6]. However, the feed intake of broilers may vary depending on the size of the feed, which requires a more precise study of growth performance.

Energy digestibility

The effect of supplementation with exogenous emulsifier in feed on energy digestibility is shown in Table 3. Broilers fed T1 and T2 diets had significantly higher energy digestibility ($p < 0.05$) compared to broilers fed CON diet.

A study by Zhao and Kim [22] showed that the supplementation of emulsifiers to broiler feed significantly improved energy digestibility. Experiments with globin in broiler feed resulted in improved energy digestibility and increased energy efficiency [21]. Also, supplementation with glyceryl polyethylene glycol ricinoleate in the broiler feed increased the ATTD of GE to improve growth performance [23]. The supplementation of emulsifiers to low-energy feeds, as well as general feeds, has been shown to improve energy digestibility [21]. Similar to the previous study, the results of this experiment also showed that the energy digestibility of broilers was improved when exogenous emulsifier was added to the feed.

Energy digestibility with the addition of emulsifiers may vary depending on the composition and proportion of the fat source in the feed [6,24,25]. Jansen et al. [26] reported that the supplementation of emulsifiers to a fat source with low digestibility significantly affected nutrient digestibility. This study suggested that the addition of exogenous emulsifier was effective in improving energy digestibility depending on the fat source in the normal diet.

Meat quality characteristics

The effect of supplemental exogenous emulsifier on meat quality characteristics of chicken breast is presented Table 4. At the end of the experiment, there was no significant difference in the water content and the drip loss among broilers in the treatment groups ($p > 0.05$). The WHC was significantly higher in the T2 treatment group compared to the CON group ($p < 0.05$). Shearing force was significantly reduced ($p < 0.05$) in the T2 treatment group compared to the CON group, resulting in soft meat. In contrast, the cooking loss was significantly higher ($p < 0.05$) in the T1 and T2 treatment group than in the CON group.

The WHC of meat refers to the property of retaining moisture in the meat when an external physical force, such as cutting and heat treatment, is applied [27]. The WHC affects a variety of properties, such as texture and meat color, and increases with changes in the protein structure and ionic level [28]. The experimental results of low-energy feed in broiler showed that the WHC was significantly decreased when emulsifiers were added [29]. The study by Upadhaya et al. [30] also found that the supplementation of emulsifiers reduced the WHC of broiler meat. However, the present study showed the opposite result, which may have been due to the difference in energy levels in the feed and the type of emulsifiers.

Table 3. Effect of supplemental exogenous emulsifier on energy digestibility in broilers

Item	CON	T1	T2	SE	*p*-value
Gross energy	72.74^{b}	77.15^{a}	76.53^{a}	1.50	0.021

Each value is the mean value of 10 replicates (2 broilers/cage).

^{a,b}Means in the same row with different superscripts differ ($p < 0.05$).

CON, basal diet; T1, basal diet + 0.1% exogenous emulsifier; T2, basal diet + 0.2% exogenous emulsifier; SE, standard error.

Drip loss is exudate caused by the formation of gaps in muscle fibers over time after slaughter and tends to decrease as the pH decreases [31–33]. Kim et al. [34] and Akit et al. [35] did not find a significant difference in the drip loss of broiler meat when lecithin was added to the broiler feed. In addition, an experiment with glyceryl-type emulsifiers in broiler feed showed no significant difference in drip loss [29]. Similarly, the results of the current study also showed no significant difference in drip loss, which suggests that the emulsifier does not affect the drip loss of meat.

Regardless of the heating method, when meat is heated, the WHC of the meat is reduced due to the contraction and shortening of the muscle fibers, resulting in a water loss [36]. Also, the shearing force of meat decreases as the storage period increases. This is because the protein is decomposed by the enzymes of microorganisms, as well as intramuscular enzymes, softening tissues and increasing non-protein nitrogen compounds [37]. Shearing force is more explicitly related to muscle fibers than to the collagen content of cooked meat [38]. The addition of lecithin, to pig feed reduced pork elasticity and hardness, but did not significantly change the shearing force values and reduce the cooking loss [35,39]. This is because lecithin affects collagen more than muscle fibers. The addition of exogenous emulsifier in this study affected muscle fibers, regardless of collagen, resulting in decreased shearing force and increased cooking loss.

Meat storage characteristics

Table 5 presents the effect of exogenous emulsifier in broiler feed on meat storage characteristics. The pH was not meaningfully different between the treatments ($p > 0.05$). In the TBARS assay, which measures the rancidity of fat, the results were lower in the T1 and T2 treatment groups than in the CON treatment and were significantly lowest in the T2 group ($p < 0.05$).

The pH value is closely related to meat quality characteristics, such as the WHC and shearing force [40]. When lecithin was added to pig feed, the pH of pork was not significantly changed [35]. Also, the pH of broiler meat did not show a significant difference in experiments with the addition of emulsifiers to low-density feed [41]. The results of the previous studies were similar to this experiment. In general, after slaughter, the pH of the muscle drops from pH 7.0 to pH 5.4–6.0 within 24

Table 4. Effect of supplemental exogenous emulsifier on meat quality characteristics of chicken breast from broilers

Item	CON	T1	T2	SE	*p*-value
Water content (%)	73.83	73.18	73.65	0.22	0.492
Water holding capacity (%)	55.01^{b}	56.37^{ab}	58.27^{a}	0.95	0.044
Drip loss (%)	3.79	3.62	3.82	0.08	0.357
Cooking loss (%)	15.92^{c}	19.36^{b}	20.42^{a}	0.21	0.001
Shearing force (g)	$2,383.5^{a}$	$2,267.9^{ab}$	$2,101.2^{b}$	53.4	0.024

Each value is the mean value of 10 replicates (2 broilers/cage).

$^{a–c}$Means in the same row with different superscripts differ ($p < 0.05$).

CON, basal diet; T1, basal diet + 0.1% exogenous emulsifier; T2, basal diet + 0.2% exogenous emulsifier; SE, standard error.

Table 5. Effect of supplemental exogenous emulsifier on storage characteristics of chicken breast from broilers

Item	CON	T1	T2	SE	*p*-value
pH	5.83	5.96	5.90	0.02	0.136
TBARS (mg MA/kg)	0.20^{a}	0.19^{a}	0.17^{b}	0.01	<.0001

Each value is the mean value of 10 replicates (2 broilers/cage).

^{a,b}Means in the same row with different superscripts differ ($p < 0.05$).

CON, basal diet; T1, basal diet + 0.1% exogenous emulsifier; T2, basal diet + 0.2% exogenous emulsifier; SE, standard error.

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hours [42]. In this experiment, all pH values were within the normal range. Therefore, the addition of exogenous emulsifier to broiler feed is considered to have no significant effect on pH.

The rancidity of meat fat is an indicator of the degree of lipid oxidation and the quality of meat decreases as lipids are degraded by lipolytic enzymes and microbial metabolism [43,44]. In a study by Kim et al. [34], there was no significant difference in the TBARS value as a result of adding lecithin to pig feed. However, the study with soy lecithin in broiler feed showed that the TBARS value declined with the addition of lecithin [45]. Likewise, this experiment showed a positive effect by the addition of exogenous emulsifier, similar to the experiment by Nagargoje [45]. It is assessed that the TBARS value is fresh in the range of 0.2 mg malondialdehyde (MA)/kg or less, and that 4.0 mg MA/kg or more is rancid (Brewer et al., 1992). However, the results of this test are all within the normal range because the values are less than 0.2. The supplementation of exogenous emulsifier was considered to have no significant effect, although there was a significant difference in TBARS.

CONCLUSION

In this experiment, the addition of 0.1% exogenous emulsifier to broiler feed lowered the FCR and improved the growth performance. Also, the addition of 0.2% exogenous emulsifier improved meat quality by increasing the WHC and decreasing the shearing force of broiler breast meat. However, research on the optimal amount of exogenous emulsifier to add in broiler feed is insufficient. Therefore, future research must identify the optimal level of exogenous emulsifier supplementation.

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