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Effect of Detoxified Nano Sulfur Supplementation on the Growth, Nutrient Digestibility, Meat Quality, Excreta Microbes, Gas Emissions, and Blood Profiles of Broilers

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A 35-day experiment was conducted to evaluate the effects of the supplementation of mineral detoxified sulfur dispersion ((DSD); Patent No.: 10-1997773) on the growth performance, meat quality, excreta microbiota, gas emissions, nutrient digestibility, and blood profiles of broilers. In total, 720 one-day-old ROSS 308 broilers, with an initial body weight of 41.9±0.8 g, were divided into two (2) treatment groups with 20 replicate pens/groups composed of 18 birds per pen. Treatments consisted of 1) CON (the control), normal drinking water and 2) TRT (the treatment group), CON+0.001% DSD (1000:1 dilution ratio). Average daily feed intake (ADFI) and feed conversion ratio (FCR) increased in the TRT group ($P<0.05$) between days 1 to 7 and days 7 to 21 of the experimental period. Similarly, body weight gain (BWG) showed a significant increase ($P<0.05$) in the DSD-supplemented group throughout in the length of the experiment. With regard to meat quality, redness (a*) was higher, while drip loss was lower, on the 7th day in the DSD group. Furthermore, DSD supplementation increased ($P<0.05$) *Lactobacillus* excreta but decreased *E. coli* concentrations in the TRT group compared to the CON group. Notably, nutrient digestibility, excreta gas emission, and blood profiles did not show any significant differences ($P>0.05$). DSD supplementation, administered through drinking water, has a positive impact on the growth performance, meat quality, and excreta microbiota of broiler chickens.

Key words: broiler, DSD, excreta microbiota, growth performance, meat quality

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Introduction

Sulfur is a macromineral and an essential component for normal physiological functions in animals. Sulfur is associated with micronutrients, amino acids, proteins, and enzymes. It can be found as volcanic sulfur and in the phytogenic extracts of different plants. Additionally, small amounts of organic sulfur can be found in grains, meat, eggs, fish, unpasteurized milk, medicinal plants, spices, and vegetables (Aarti and Khusro, 2020). Humans and animals fulfill their sulfur requirements by eating these items; however, if their nutrient needs are lacking, inorganic sulfur additives may also be added to their diet.

Amino acids such as cysteine, methionine, taurine, and glutathione N-acetylcystine all contain sulfur. Inorganic sulfur is used in the form of a compound molecule, such as sodium sulfate or potassium sulfate. Meanwhile, the major organic sulfur feed additives are MSM and garlic (*Allium sativum*) extracts. In particular, garlic extract or oil contains 33 sulfur-containing compounds (Aarti and Khusro, 2020). Among the major components of garlic oil, diallylsulfide (57%), allylmethyl (37%), and dimethyl sulfides (6%) are very common. Different sulfur compounds have been tested for their antioxidant, antimicrobial, anti-carcinogenic, and antitoxic properties (Puvaca *et al*., 2015). The antioxidant, antimicrobial, and antitoxic properties of sulfur also protect against different diseases. Sulfur likely has growth-promoting abilities as significant improvements in body weight gain in broilers have been reported from using

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inorganic sulfur and garlic oil (Machlin and Pearson, 1956; Stanacev *et al*., 2011).

Nano materials are the product of nano biotechnology, a field in which particle sizes are reduced. Nano minerals are known to contribute to improved growth performance and immunomodulation, and have more bactericidal effects than more commonly used products (Swain *et al*., 2015). In addition, they are required at lower concentrations. Therefore, sulfur nanoparticles are being tested in animals for their growth-promoting, antioxidant, and antimicrobial properties, with the aim of replacing antibiotic growth promoters.

Mineral detoxified sulfur dispersion (DSD; Patent Reg. No.: 1019977730000) is a detoxified nano sulfur compound (Park, 2019). It is created using a new method of processing nano sulfur for supplementation in animals. DSD is sulfur converted to nanoparticles and detoxified by plant extract fumigation (Park, 2019). Therefore, because of its novelty, there is a scarcity of literature comparing the effects of DSD in broilers. Although no research has been conducted on the use of nano sulfur dispersion as animal feed additives, other forms of sulfur supplementation have shown a positive impact on animal production and microbial prevention (Chowdhury *et al*., 2012; Puvaca *et al*., 2015; El-Gogary *et al*., 2019). We hypothesized that like other sulfur compounds (whether organic or inorganic), DSD has a positive influence on growth performance, and antioxidant and antimicrobial mechanisms in broilers. Therefore, the aim of this study was to determine how DSD supplementation, administered through drinking water, affects the growth performance, meat quality, excreta microbiota, gas emissions, nutrient digestibility, and blood profiles of broilers.

Table 1. **Ingredient composition of experimental diets on an as-fed basis**

Ingredient, %	Starter	Grower	Finisher
Corn	54.19	55.38	56.77
Soybean meal	33.80	26.1	18.23
Canola meal	5.00	10.0	15.0
Soybean oil	2.10	3.62	5.07
MDCP[1]	—	1.28	1.12
DCP[2]	1.70	—	—
Limestone	1.15	1.34	1.22
L-lysine	0.50	0.65	0.81
DL-Methionine	0.46	0.47	0.52
L-Threonine	0.20	0.25	0.32
L-Tryptophan	—	0.01	0.04
$NaHCO_3$	0.10	0.10	0.10
Salt	0.30	0.30	0.30
Vitamin premix[3]	0.20	0.20	0.20
Mineral premix[4]	0.20	0.20	0.20
Choline	0.10	0.10	0.10
ME, kcal/kg	3,000	3,100	3,200
CP, %	23.0	21.5	20.0
Lys, %	1.50	1.40	1.30
Met + Cys, %	1.08	0.99	0.94
AP, %	0.48	0.44	0.41
Ca, %	0.96	0.87	0.81

[1] Monodicalcium phosphate
[2] Dicalcium phosphate
[3] Provided per kg of complete diet: 11,025 IU vitamin A; 1,103 IU vitamin D_3; 44 IU vitamin E; 4.4 mg vitamin K; 8.3 mg riboflavin; 50 mg niacin; 4 mg thiamine; 29 mg d-pantothenic; 166 mg choline; 33 μg vitamin B_{12}
[4] Provided per kg of complete diet: 12 mg Cu (as $CuSO_4 \cdot 5H_2O$); 85 mg Zn (as $ZnSO_4$); 8 mg Mn (as MnO_2); 0.28 mg I (as KI); 0.15 mg Se (as $Na_2SeO_3 \cdot 5$)

Materials and Methods

The experimental procedure was approved (DK-1-1926) by the Animal Protocol Review Committee of Dankook University in the Republic of Korea.

Source of DSD

The mineral detoxified sulfur dispersion (DSD) was supplied by Five N Signature Co., (Incheon, Republic of Korea). The formulation process and product characteristics supplied by the company are as follows: First, mineral sulfur was detoxified by resin vapor that was produced by boiling pine in water. Thereafter, plant juices, such as radish juice, were mixed and stirred with the prepared sulfur, and left to ferment. The purified sulfur water was then mixed with purified nano sulfur juice. Subsequently, the mixture was heated to dissolve the vegetable sugar and chloride to obtain detoxified nano sulfur (Park, 2019). The final product was a water-stock solution of nano sulfur. For this experiment, the sulfur content of the water stock was fixed at 2%. The final product contained only water and nano sulfur molecules. The nano sulfur particles were spherical with an average size of 35 nm (nanometers).

Experimental Design and Animal Management

A total of 720 one-day-old ROSS 308 broiler chicks, with an initial body weight of 41.9±0.8 g, were randomly placed into two (2) treatment groups. Each treatment group contained 20 replication pens which comprised 18 birds each. The same commercial starter, grower, and finisher diets (Table 1) were administered to both groups. The test additive, DSD, was administered via the drinking water of the treatment group at a 1000:1 ratio (0.001%). Treatments were: 1) CON (the control), normal drinking water and 2) TRT (the treatment group) water + 0.001% DSD. Each pen was a 1.75×1.55 m^2 stainless steel cage fitted with nipple drinkers and feeders. Light was provided at 20 lx 24 h/day for the entire duration of the research. At the start, the room temperature was set at 32℃ and was reduced by 2℃ each day until the 5th day; after which, room temperature was kept constant at 24℃. Starter diets were given up to the 14th day, grower diets were fed up to the 24th day, and finisher diets were given until the 35th day. Unimpeded availability of drinking water and feed was ensured.

Growth and Digestibility

Body weight and feed intake were recorded for each broiler pen on the 7th, 21st, and 35th day of the experiment. Body weight gain (BWG), average daily feed intake (ADFI), and the feed conversion ratio (FCR) were calculated from the values obtained for body weight and feed intake. From the 28th day, chromic oxide (0.2%) was mixed with feed as an

indigestible marker to determine apparent total tract digestibility (ATTD). Additionally, from each treatment, 8 fresh mixed fecal samples were randomly collected, yielding a total of 16 samples. The fecal elements were then heated in an oven at 70℃ for 72 h. Thereafter, the dried fecal elements were finely-ground, filtered through a 1 mm strainer and stored at −20℃ until further processing. Chromium intensity was computed using a UV spectrophotometer (UV-1201, Shimadzu, Kyoto, Japan) following William's procedure (Williams *et al*., 1962). Each diet sample and fecal specimen was tested following the AOAC's (2007) methods for determining DM, nitrogen (N), and energy. Nitrogen was determined using a Kjeltec 2300 Nitrogen Analyzer (Foss Tecator AB, Hoeganaes, Sweden) and energy was measured using an oxygen bomb calorimeter (Parr 6100 Instrument Co., Moline, IL, USA). Nutrient digestibility was measured using the following formula:

$$\text{Digestibility (\%)} = \{1 - [(Nf \times Cd)/(Nd \times Cf)]\} \times 100$$

where Nf is the nutrient density in fecal matter (%DM), Cd is the Cr density in diet (%DM), Nd is the nutrient density in diet (%DM), and Cf is the Cr density in fecal matter (%DM).

Meat Quality

On the 35th day, 20 broilers per treatment were randomly selected and a total of 40 chickens were weighed and butchered. A total of 40 samples of each of the following: breast meat, gizzards, bursa of Fabricius, liver, spleen, and abdominal fat were collected from the slaughtered broilers. These were removed by experienced personnel. Each organ was weighed and expressed as a proportion of body weight. Meanwhile, only breast meat was stored at −20℃ for further analysis. Using a Minolta CR410 (Minolta Co., Tokyo, Japan) Chroma Meter, breast muscle color parameters of lightness (L*), redness (a*), and yellowness (b*) were observed. Simultaneously, the pH values were recorded, using a pH meter (Testo 205, Testo, Germany). The pH measurement was done twice per specimen. Approximately 2 g of meat from the stored sample was used to measure drip loss using a plastic bag (Honikel, 1998). Furthermore, Kauffman's procedures were implemented in the determination of the water-holding capacity (WHC) (Kauffman *et al*., 1986). Briefly, a 0.3 g sample was pressed with 3,000 g of weight for 3 min at 26℃ on a piece of filter paper (125 mm in diameter). Two different areas were found before and after pressing the sample, and they were marked. Subsequently, the two areas on each sample were measured using an area-line sensor (MT-10S; M.T. Precision Co. Ltd., Tokyo, Japan). The WHC value was calculated from the ratio of water:meat area (a smaller ratio indicates increased WHC). In addition to this, meat samples were cooked at 80℃ in a water bath until the core temperature of the filet was 72℃. After cooking, the samples were weighed and the cooking loss percentage was calculated (Albercht *et al*., 2019).

Excreta Microbiota

On the 35th day, 20 excreta samples (1 sample/pen) were collected and transported to the laboratory using an ice pack to maintain the temperature. From each sample, one gram was diluted with 9 mL of 1% peptone broth (Becton, Dickinson and Co., Franklin Lakes, NJ, USA) and homogenized after 10-fold dilution. These samples were then cultured on MacConkey agar plates (Difco Laboratories, Detroit, MI, USA), *Lactobacillus* medium III agar plates (Medium 638, DSMZ, Braunschweig, Germany), and *Salmonella Shigella* (SS) agar plates (Becton, Dichinson and Company) to isolate *E. coli*, *Lactobacillus*, and *Salmonella*, respectively. The incubation period for *Lactobacillus* was 48 h at 39℃ under anaerobic conditions. Meanwhile, the MacConkey agar plates and *Salmonella Shigella* (SS) agar plates were incubated at 37℃ for 24 h. The *E. coli*, *Lactobacillus*, and *Salmonella* colonies were counted immediately after removal from the incubator. For each sample, three (3) culture plates were counted. Bacteria were calculated by a visual count of colonies that had 30−300 colonies per plate. The bacterial count was expressed as $\log_{10}$ CFU for each gram of sample (Hong *et al*., 2016).

Excreta Gas Emission

At the end of the experiment, twenty 300 g samples of fresh excreta per treatment were placed in different sealed plastic containers 2600 mL in volume. The samples were then fermented in an incubator (28℃) for the gas emission study (Lee *et al*., 2020). NH_3, H_2S, and methyl mercaptan were measured using a multi-gas meter (MultiRAE Lite model PGM-6208, RAE, San Jose, CA, USA) on days 1, 3, and 5 of fermentation.

Blood Lipid Profiles and Antioxidants

Finally, on the 35th day, a total of 20 blood samples were collected in vacuum tubes from the wing vein of one bird per pen (Becton Dickinson), and stored at 4℃. For serum analysis, approximately 3 mL of the blood samples were centrifuged for 15 min at 4,000×*g* and 4℃ to separate the serum. In addition, superoxide dismutase (SOD) activity in the blood serum was analyzed using a commercial kit (ab65354, Abcam, Cambridge, UK). Lipid profiles in the blood were analyzed using commercially available kits (Sigma Diagnostics, Taufkirchen, Germany) following the manufacturer's instructions.

Statistical Analysis

All data were statistically analyzed by the Student's t-test using the SAS program (SAS Inst. Inc., Cary, NC). Each pen was considered as a replicate for each treatment. Results were considered significant at $P<0.05$, and $P<0.10$ was considered to be a trend.

Results

Growth Performance

The supplementation of DSD in drinking water showed a significant increase in ADFI and FCR in the TRT group on days 1 to 7 and days 7 to 21 ($P<0.05$). Furthermore, BWG underwent the only increase seen ($P<0.05$) throughout the study period (Table 2). In the TRT group, BWG showed a tendency to increase ($P=0.057$) between days 7 and 21, whereas ADFI had an increasing trend ($P=0.052$) throughout the experiment.

Nutrient Digestibility

We did not find any difference ($P>0.05$) in N, DM, and

energy digestibility (Table 3). Furthermore, both groups had similar nutrient digestibility values.

Meat Quality

The effects of DSD supplementation on broiler meat quality are presented in Table 4. Redness (a*) was higher ($P<0.05$) in the DSD group than in the control group, while drip loss was reduced ($P<0.05$) in the TRT group on day 7. However, organ weight, cooking loss, water holding capacity (WHC), and pH did not vary in this experiment ($P>0.05$).

Excreta Microbiota

The results of DSD supplementation on excreta microbiota in broilers are shown in Table 5. DSD supplementation resulted in an increase ($P<0.05$) in *Lactobacillus* concentrations and a reduction ($P<0.05$) in *E. coli* bacterial concentrations when compared to the CON group. Moreover, *Salmonella* bacterial counts were not significantly different ($P>0.05$) between the two experimental groups.

Gas Emission

Table 6 shows the influence of DSD supplementation on noxious gas emissions in broilers. The concentrations of NH_3, H_2S, and methyl mercaptans showed no difference ($P>0.05$) between the two groups.

Blood Profile

As shown in Table 7, blood profiles comprising superoxide dismutase (SOD) and blood lipid profiles did not show

Table 2. **The effect of detoxified nano sulfur dispersion supplementation on growth performance in broilers[1,2]**

Items[3]	CON	TRT	SEM	*P*-value
d 1 to 7				
BWG, g	125	132	5	0.210
ADFI, g	153	169	6	0.015
FCR	1.224	1.289	0.029	0.035
d 7 to 21				
BWG, g	650	655	10	0.057
ADFI, g	968	998	11	0.015
FCR	1.493	1.525	0.023	0.018
d 21 to 35				
BWG, g	956	986	18	0.107
ADFI, g	1808	1811	18	0.878
FCR	1.898	1.840	0.032	0.081
Overall				
BWG, g	1730	1772	20	0.038
ADFI, g	2929	2977	24	0.052
FCR	1.694	1.680	0.014	0.336

[1] CON, Basal diet; TRT, CON + 0.001% detoxified nano sulfur dispersion
[2] Each mean represents 20 replicates with 18 chicks per replicate
[3] BWG, body weight gain; FCR, feed conversion ratio Statistical significance was considered at 5%

Table 3. **The effect of detoxified nano sulfur dispersion supplementation on nutrient digestibility in broilers**

Items, %	CON	TRT	SEM	*P*-value
Dry matter	71.37	72.85	1.06	0.179
Nitrogen	69.60	70.88	1.16	0.288
Energy	71.00	72.47	1.31	0.283

[1] CON, Basal diet; TRT, CON + 0.001% detoxified nano sulfur dispersion
[2] Each mean represents 20 replicates with 18 chicks per replicate

Table 4. **The effect of detoxified nano sulfur dispersion supplementation on organ weight and meat quality in broilers**

Items	CON	TRT	SEM	*P*-value
P^H value	7.77	7.82	0.045	0.280
Breast muscle color				
Lightness (L*)	59.18	59.31	0.64	0.917
Redness (a*)	11.44	12.67	0.35	0.002
Yellowness (b*)	11.89	12.01	0.79	0.829
WHC, %	44.89	44.01	4.69	0.853
Cooking loss	18.57	18.27	2	0.886
Drip loss, %				
d 1	4.61	4.57	0.12	0.707
d 3	7.73	7.52	0.22	0.382
d 5	10.24	10.26	0.19	0.910
d 7	15.06	14.59	0.20	0.033
Relative organ weight, %				
Breast muscle	19.23	18.92	0.89	0.733
Liver	2.89	2.64	0.22	0.257
Bursa of Fabricius	0.14	0.13	0.01	0.954
Abdominal fat	2.95	2.83	0.43	0.716
Spleen	0.14	0.13	0.53	0.830
Gizzard	1.78	1.79	0.16	0.938

[1] CON, Basal diet; TRT, CON + 0.001% detoxified nano sulfur dispersion
[2] Each mean represents 20 replicates with 18 chicks per replicate Statistical significance was considered at 5%

Table 5. **The effect of detoxified nano sulfur dispersion supplementation on microbial in broilers**

Items, log_{10} cfu/g	CON	TRT	SEM	*P*-value
Lactobacillus	7.22	7.55	0.13	0.021
E. coli	5.51	5.29	0.09	0.032
Salmonella	2.98	2.79	0.30	0.543

[1] CON, Basal diet; TRT, CON + 0.001% detoxified nano sulfur dispersion
[2] Each mean represents 20 replicates with 18 chicks per replicate Statistical significance was considered at 5%

Table 6. **The effect of detoxified nano sulfur dispersion supplementation on gas emission in broilers**

Items[3], ppm	CON	TRT	SEM	*P*-value
NH_3	11.9	12.0	1.26	0.951
H_2S	2.6	2.8	0.59	0.796
Methyl mercaptans	2.2	1.2	0.55	0.108

[1] CON, Basal diet; TRT, CON + 0.001% detoxified nano sulfur dispersion
[2] Each mean represents 20 replicates with 18 chicks per replicate
[3] NH_3, ammonia; H_2S, hydrogen sulfide

Table 7. **The effect of detoxified nano sulfur dispersion supplementation on blood profile in broilers**

Items[3]	CON	TRT	SEM	*P*-value
SOD, %	75.1	71.4	3.68	0.323
Total cholesterol, mg/dL	108.4	119.0	7.60	0.181
HDL/C, mg/dL	73.1	75.7	5	0.606
LDL/C, mg/dL	20.6	25.7	3.87	0.201
Triglyceride, mg/dL	38.4	38.3	6.73	0.983

[1] CON, Basal diet; TRT, CON + 0.001% detoxified nano sulfur dispersion
[2] Each mean represents 20 replicates with 1 chicken per replicate
[3] SOD, superoxide dismutase; HDL, high density lipoprotein; LDL, low density lipoprotein

any significant differences ($P > 0.05$) between experimental groups.

Discussion

Our study found significant changes in the growth parameters of the broilers. Studies have shown that inorganic sulfur supplementation can increase the growth performance of broilers (Machlin and Pearson, 1956; Almquist, 1964; Ross *et al*., 1972). In contrast, other researchers (Onibi *et al*., 2009; Elagib *et al*., 2013; El-Gogary *et al*., 2019) have reported that organic sulfur compound supplementation yielded no effect on BW, BWG, and FCR. Interestingly, one study (Elagib *et al*., 2013) reported increased FI in broilers with garlic powder supplementation, while others (Jacobson *et al*., 1967; Kennedy and Siebert, 1972) found that inorganic sulfur supplementation increased feed intake in cattle and sheep. In our study, the increment in ADFI is similar to what was observed in the studies mentioned above and is the reason for the improvement in BWG. Nevertheless, the increase in ADFI might have had a negative effect on FCR in the earlier stages. Although FCR was negatively influenced in the earlier stage, it was neutralized during the later growth stage and in the overall calculations. Furthermore, nutrient digestibility of DM, N, and energy did not differ. This is similar to the findings of a study on dairy cows (Richter *et al*., 2012). Therefore, we can conclude that DSD supplementation had no effect on nutrient digestibility.

DSD supplementation resulted in changes in broiler meat color. The redness (a*) value was higher in the TRT group than the CON group, which we considered to be bad quality. This consideration was made as literature (Allen *et al*., 1997) has reported that darker broiler meat had a shorter shelf-life. It has been suggested that the redness of the meat may be due to the iron content in broiler meat, as sulfur supplementation may influence heme-Fe binding in the myoglobulin in meat (Mortimer *et al*., 2014). Because meat color is mainly affected by myoglobin pigmentation (Coggins, 2007), the increased redness (a*) may be due to the antioxidative property of DSD, which delays metmyoglobin formation. In the current experiment, we found reduced drip loss in meat in the

measurement obtained on day 7. From this result, we considered that DSD may increase the meat's water retention capacity in the later stages of storage. Organ weights and other parameters, such as pH, WHC, and cooking loss, were not significantly influenced by DSD supplementation.

Reduction of the bacterial count of excreta *E. coli* proved the antimicrobial property of sulfur. In a study, on nano sulfur components versus antibiotic-resistant bacteria, there was a positive result that was evidence to the antimicrobial property of nano sulfur (Chowdhury *et al*., 2012). A positive effect of nano sulfur against dandruff-causing microorganisms (Baskar *et al*., 2015) and the effect of processed sulfur against human skin pathogens (Ha *et al*., 2009) have also been reported in the literature. It is important to note that the absence of competing bacteria can increase the population of other bacteria in the digestive system, such as *Lactobacillus* (Wang *et al*., 2017). However, this factor did not affect the *Salmonella* count in this experiment.

Silva *et al*. (2014) mentioned that sulfur is an important component of sulfur-containing amino acids used by microbes in microbial digestion. We found that sulfur had a positive effect on the *Lactobacillus* population, which may have partly increased microbial digestion and, consequently, increase feed intake. However, it has been reported that this increase in microbial digestion mainly utilizes cellulose, and the broiler diet does not contain a large amount of cellulose like that of ruminants. Therefore, our digestibility parameters were not affected by bacterial growth or microbial digestion. Again, Ghavi *et al*. (2020) reported that sulfur-containing amino acids can improve FI by balancing amino acid requirements. Although supplemented DSD does not have a direct effect like amino acid supplementation, it may take part in synthesizing a small amount of sulfur-containing amino acids in the broiler. In short, DSD supplementation increased BWG by increasing FI and not by nutrient digestion.

Very little evidence is available concerning the influence of DSD on excreta gas emission. Therefore, we do not know the actual reason for the lack of a significant difference in excreta gas emissions in our experiment. We are aware that higher nutrient digestibility will cause less noxious gas emissions (Yan *et al*., 2011). However, as our experiment has no variation in nutrient digestibility, stating that there is no difference in noxious gas emissions is probably a reasonable conclusion. Sharma *et al*. (2017) reported that increased breakdown of protein and sulfur-containing amino acids increases NH_3, H_2S, and mercaptan emissions in excreta. However, our supplied DSD is just inorganic sulfur and while it may increase the synthesis of sulfur-containing amino acids, this is not the same as the direct supplementation of sulfur-containing amino acids. Therefore, we did not observe any changes in digestibility or gas emission. Further studies with higher concentrations of DSD may be conducted for greater insight on excreta gas emissions.

It has been reported that bioactive sulfur components have anti-inflammatory and antioxidant effects (Puvaca *et al*., 2015). Sulfur components have the ability to reduce reactive oxygen species, bind to metal, perform antitumor activity, and reduce oxidation (Amirshahrokhi and Khalili, 2016; Faten *et al*., 2018). In a recent study, 2-mercaptoethane sulfate reduced alcohol-induced oxidation and inflammation in gastric tissues (Amirshahrokhi and Khalili, 2016). However, our study showed that DSD supplementation did not affect serum superoxide dismutase (SOD) levels. Because our experiment was conducted in an environmentally controlled facility where no scavenging facility was provided, the birds did not have any variation in levels of stress or oxidative damage. As a result, SOD did not vary. Similar data are not available to discuss the reasons for this result. Nevertheless, for SOD, we can say that DSD might not provide efficient antioxidant or free radical-removing activity in broilers. Garlic extract contains a high amount of sulfur compounds and reduces cholesterol, triglycerides, and LDL, while increasing HDL in broilers (Hosoda *et al*., 2006). However, our study showed no changes in blood lipid profile. It is noteworthy to mention that blood profile concentrations, such as total cholesterol, triglyceride, HDL, and LDL can be used to assess glucose and lipid N metabolism (Hosoda *et al*., 2006). As our study showed no effect on nutrient digestibility and possibly had unaffected lipid digestibility, the cholesterol, triglyceride, LDL, and HDL in blood did not change between treatment groups. We can also conclude that DSD may not have antioxidant and LDL-reducing capabilities like that of other chemical and phytogenic sulfur components.

Although detoxified sulfur dispersion (DSD) supplementation showed a negative effect on the feed conversion ratio (FCR), due to increased feed intake (FI), overall body weight gain (BWG) was positively influenced. Moreover, the microbial population in the digestive system was distinctly influenced in a positive way. Drip loss properties were also positively influenced by the DSD. Therefore, DSD as a feed additive in broiler production may be partially beneficial.

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Conflicts of Interest

The authors declare no conflict of interest.

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