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Original Article

Effect of Dietary Almond Hull on Growth Performance, Nutrient Digestibility, Organ Weight, Caecum Microbial Counts, and Noxious Gas Emission in Broilers.

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ABSTRACT

This study was conducted to investigate the impact of a diet supplemented with almond hulls on growth performance, nutrient utilization, cecum microbiota, noxious gas emissions, and the organ weight of broilers. A total of 540, one-day-old Ross-308 broilers were used in this 35-day-long feeding trial. All birds were divided into 3 treatment groups of 10 replicates, each with 18 chicks (18 birds/replication), according to a completely randomized design. The Tukey's test was used to compare the differences among the 3 treatments. The dietary treatments were a basal diet supplemented with 0%, 1%, and 2% almond hull, respectively. The body weight gain (BWG) of broilers supplemented with almond hull improved ($p<0.05$) during days 1–7 and in the overall period, whereas it tended to increase ($p<0.10$) during days 22–35. Additionally, feed intake (FI) tended to increase ($p<0.10$) during days 1–7 and in the overall experiment period. However, the feed conversion ratio (FCR) remained unchanged ($p>0.05$) through the supplementation of almond hull up to 2%. The nutrient digestibility of nitrogen and energy tended to increase ($p<0.10$), whereas the digestibility of dry matter was unchanged ($p>0.05$). Inclusion of almond hull in broiler diets showed a tendency to decrease ($p<0.10$) caecal *Salmonella* count. Moreover, broilers fed a diet supplemented with almond hull decreased ($p<0.05$) their excreted NH_3 emissions. Similar ($p>0.05$) organ weights were found in broilers with a 2% almond hull-supplemented diet as compared to the control diet. In summary, incorporating up to 2% of almond hulls into broiler diets can enhance growth performance, increase nutrient digestibility, and reduce both microbial count and noxious gas emissions, thereby establishing almond hulls as a promising ingredient for broiler feed.

INTRODUCTION

Almond hulls, a byproduct of almond processing, offer a unique composition that includes fibers, nutrients, and bioactive compounds (Salgado-Ramos *et al.*, 2022). In recent years, both researchers and producers have been exploring alternative feed resources to enhance the economic and nutritional aspects of broiler diets. Among these alternatives, the supplementation of almond hulls has gained attention for its potential to contribute to broiler nutrition while addressing sustainability concerns. In response to this growing demand, it is urgent for the poultry industry increase feed production to adjust the growth of poultry farming. This need leads to increased exploration of alternative feed ingredients that can be produced locally, aiming to replace more expensive feed components in poultry farming. Some examples of unconventional feed components considered for the broiler industry are corn gluten meal, distillers' dried grains with solubles, wheat middlings, brewers' spent grain, almond hulls, and soybean hulls. While almond hulls themselves are not among the most expensive ingredients, their inclusion in the diet can partially replace more expensive components, such as some portions of corn or soybean meal. This substitution helps manage costs while maintaining dietary balance. It's important for nutritionists to carefully formulate diets to optimize cost-effectiveness without compromising the nutritional needs of the broilers. The amount of available surplus of this ingredient is due to the rapid increase in almond production for humans. It is recognized as a fibrous resource, and possesses moderate nutritive value for ruminants and swine (Williams *et al.*, 2018; Yalchi & Kargar, 2010). Despite dietary fibers being traditionally regarded as nutrient diluters on nutrient digestion and absorption, their importance in boosting immunity and sustaining gut health in broilers has recently gained attention (Jha & Leterme, 2012). Conversely, some previous researches has shown that insoluble fibers in minimal quantities improve growth performance, digestion, absorption, and gut flora in broilers (Gemen *et al.*, 2011; Jiménez-Moreno *et al.*, 2013ab; Sadeghi *et al.*, 2015). Broilers fed diets with insoluble fiber from oat hulls perform better in terms of growth when their inclusion level is between 2 and 3% (Mateos *et al.*, 2012). Beyond dietary fibers, almond hulls reportedly contain a total sugar content ranging from 25 to 46%, a potential energy source in broiler diets (Holtman *et al.*, 2015). Moreover, almond hulls are abundant in antioxidants like polyphenols, triterpenoids, betulinic acid, oleanolic acid, and ursolic acid, all known for their robust antioxidative activities (Esfahlan *et al.*, 2010; Prgomet *et al.*, 2017). The dietary fibers, fermentable sugars, and antioxidants in almond hulls could present valuable nutrients for broilers (Takeoka & Dao, 2003; Jha & Leterme, 2012). As broilers cannot digest higher amounts of fiber due to the absence of microbial digestion like ruminants (Mateos *et al.*, 2012), we planned to work with a smaller amount of almond hull in this experiment. We hypothesized that the incorporation of the lower level (2%) of almond hulls in a broiler diet would result in improved growth performance, nutrient digestibility, microbial count, and lowered noxious gas emissions. The objective of this study was to assess the impact of dietary supplementation of almond hulls on the growth performance, nutritional digestibility, organ weight, caecum microbial counts, and noxious gas emissions of broilers.

MATERIALS AND METHODS

The Institutional Animal Care and Use Committee of Dankook University, South Korea, investigated and approved the experimental protocols (DK-1-2220) on the management and care of animals.

Processing of almond hull

Almond hulls are the outer protective layer of the almond seed and are obtained after the almond kernels are removed.

The process typically involves the following steps:

1. Harvesting Almonds: Almond trees produce almonds, which consist of an outer hull containing an edible kernel inside.
2. Hulling: The almonds are mechanically hulled to remove the outer hull, leaving the edible almond kernel.
3. Separation: The hulled almonds are then separated from the hulls.
4. Processing Almond Hulls: The separated almond hulls can be processed to create a feed ingredient suitable for poultry diets. This processing may involve grinding, drying, and possibly pelleting.

Experimental design, animals, and diets

In a 35-day study, 540 broilers (one-day-old male ROSS 308) with average body weights of 47.91± 0.28 g were analyzed to assess growth performance, nutritional digestibility, caecum microbiota, noxious gas emission, and organ weight. Broilers were allotted to three treatments, each with ten replications and 18 birds per pen, according to a completely randomized design. The following diet treatment groups were set up: 1) CON, Basal diet, 2) TRT1, CON + 1% almond hull, and 3) TRT2, CON + 2% almond hull.

The experiment was carried out at the Dankook University research farm in Sejong, South Korea. The guidelines of NRC (1994) were used to formulate the composition of the basic diet (Table 1). The broiler house room temperature was 33 ± 1°C for the first week, and then it was consistently reduced to 24 ± 1°C, with more than 60% retaining moisture (Munezero *et al.*, 2022). A nipple drinker and a plastic feeder were attached to each pen, through which birds had free access to feed and water during the experiment. The measurement of each pen was 1m× 1.6m (three-layer battery cages), and the density of birds was 12 birds/ square meter. Light and dark periods were respectively maintained at 18 h and 6 h every day. The poultry house was duly maintained under proper biosecurity and hygienic conditions.

Chemical analysis, sampling, and measurements

Growth performance

Body weight was calculated per treatment on days 0, 7, 21, and the last day (35 days). Feed intake was measured according to this formula:

Feed intake = feed amount during BWG – remaining feed amount

Feed conversion ratio (FCR) was calculated following this calculation:

$$\text{Feed conversion ratio (FCR)} = \frac{\text{Feed intake}}{\text{BWG}}$$

Nutrient Digestibility

Chromium oxide (Cr_2O_3, 0.20%), an indigestible marker mixed diet, was given to broilers 7 days before the end of the experiment. On day 35, excreta were collected to evaluate nutrient digestibility. The feed and excreta sample, dried in an oven at 60 °C for 72 hours, was pulverized to a fine consistency, enough for passing through a 1 mm screen. After that, the dried samples were analyzed using AOAC standard methods (2022) for GE, DM, and N. UV absorption spectrophotometry (UV-1201, Shimadzu, Japan) was used to determine the levels of chromium. We followed the following formula to calculate digestibility: Digestibility=1-[(Nf×Cd)/(Nd×Cf)] ×100, where Nf = concentration of nutrient in excreta (% DM), Nd = concentration of nutrient in the diet, Cd = concentration of chromium in the diet, and Cf = concentration of chromium in the excreta (Munezero *et al.*, 2022).

Organ weight

At the end of the experiment (35 days), samples including breast meat, liver, bursa of fabricius, abdominal fat, spleen, and gizzard were weighed using an electronic balance (Sartorius BCE323I-1S Entris II Essential Balance Int. Cal., 320g, 1mg). A total of 60 broilers were slaughtered, with 20 birds randomly selected per treatment (2 birds per replication). The weight of all organs was indicated as a percentage of body weight.

Caecum microbial counts

Excreta samples were sourced from 10 pens per treatment and pooled before being transported to the study site and submitted to a microbiological examination while being kept chilled. One gram of excreta was diluted in sterile peptone water, and the mixture was vortexed for one minute. *Escherichia coli, Lactobacillus*, and *Salmonella* were isolated by adding live bacteria via a series of 10-fold dilutions. Three kinds of agar were used for these bacteria: MRS agar (Difco, USA) for *Lactobacillus*, MacConkey agar (Difco, USA) for *E.coli*, and SS agar (Difco, USA) for *Salmonella*. Before colony counting, *Lactobacillus*, *E. coli*, and *Salmonella* were incubated at 39 °C for 48 hours, 37 °C for 24 hours, and 37 °C for 24 hours, respectively. After adding up the colonies, the results were displayed as log10 converted data (Shanmugam *et al.*, 2022).

Noxious gas emission

300g of excreta samples were taken from each pen and combined uniformly. The samples were collected using a stainless-steel collection tray and stored in pairs in 2.6-L plastic boxes. A small hole was first drilled in the center of the side wall of the plastic boxes to be prepared, and then the hole was sealed with adhesive plastic items. Fermentation of the samples required storage at room temperature for seven days. After the fermentation period, the MultiRAE (MultiRAE Lite model PGM-6208, RAE, USA) was used for gas detection for ammonia (NH_3), hydrogen Sulfide (H_2S), methyl mercaptans, carbon dioxide (CO_2) and acetic acid. In these measurements, a hole was made in the adhesive plaster, and 100 mL of overhead air was sampled approximately two centimeters above the fecal surface. Each box was again wrapped with adhesive plaster after air sampling. After 48 hours, head space measurements were once more carried out. Two readings from the same box were averaged to determine the gas contents.

Statistical Analyses

The GLM technique was applied to analyze the data using the SAS software (Version 9.4; SAS Inst. Inc., Cary, NC, US). Data on growth performance, nutrient digestibility, organ weight, caecum microbial counts, and noxious gas emission were observed on a pen basis, whereas data on organ weight was calculated for individual broilers. The Tukey's test was used to compare the differences among the three treatments. Linear, quadratic polynomial contrasts were applied to examine the effect of the dietary treatments. The standard error of the mean (SEM) was used to account for the variability of the data, the level of significance was determined at $p<0.05$, and tendencies were identified at $p<0.10$.

Table 1 – Broiler feed composition (as fed-basis).

Items	Starter			Grower			Finisher		
	CON	TRT1	TRT2	CON	TRT1	TRT2	CON	TRT1	TRT2
Ingredients (%)									
Corn	43.63	42.16	40.72	47.87	46.44	44.99	54.75	53.29	51.85
Soybean meal (48%)	35.08	35.21	35.32	31.22	31.34	31.46	28.02	28.14	28.26
Corn gluten meal	13.00	13.00	13.00	13.00	13.00	13.00	10.00	10.00	10.00
Wheat bran	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Soybean oil	1.76	2.10	2.43	1.61	1.93	2.27	1.19	1.53	1.86
Tri calcium phosphate	1.81	1.81	1.81	1.72	1.72	1.72	1.60	1.60	1.60
Limestone	0.94	0.94	0.94	0.80	0.79	0.78	0.66	0.66	0.65
Common salt	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
DL-Methionine (99%)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
L-Lysine	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Mineral mix[1]	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Vitamin mix[2]	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Almond hull	-	1.00	2.00	-	1.00	2.00	-	1.00	2.00
Total	100	100	100	100	100	100	100	100	100
Calculated value									
Crude protein, %	23.00	23.00	23.00	21.50	21.50	21.50	20.00	20.00	20.00
Calcium, %	1.10	1.10	1.10	1.00	1.00	1.00	0.90	0.90	0.90
Phosphorus, %	0.83	0.83	0.83	0.80	0.80	0.80	0.75	0.75	0.75
Available Phosphorus, %	0.54	0.54	0.54	0.51	0.51	0.51	0.48	0.48	0.48
Lysine, %	1.26	1.26	1.26	1.15	1.15	1.15	1.05	1.05	1.05
Methionine, %	0.54	0.54	0.54	0.52	0.52	0.52	0.50	0.50	0.50
ME, kcal/kg	3200	3200	3200	3200	3200	3200	3200	3200	3200
Fat, %	4.45	4.77	5.08	4.39	4.69	5.01	4.04	4.35	4.66
Fiber, %	3.55	3.67	3.80	3.49	3.62	3.74	3.31	3.44	3.56
Ash, %	6.76	6.82	6.88	6.34	6.39	6.44	5.82	5.88	5.93

[1]Provided per kg of complete diet: 37.5 mg Zn (as $ZnSO_4$); 37.5 mg Mn (as MnO_2); 37.5 mg Fe (as $FeSO_4{\cdot}7H_2O$); 3.75 mg Cu (as $CuSO_4{\cdot}5H_2O$); 0.83 mg I (as KI); and 0.23 mg Se (as $Na_2SeO_3{\cdot}5H_2O$).

[2]Provided per kg of complete diet: 15,000 IU of vitamin A, 3,750 IU of vitamin D_3, 37.5 IU of vitamin E, 2.55 mg of vitamin K_3, 3 mg of Thiamin, 7.5 mg of Rivoflavin, 4.5 mg of vitamin B_6, 24 ug of vitamin B_{12}, 51 mg of Niacin, 1.5 mg of Folic acid, 0.2 mg of Biotin and 13.5 mg of Ca-Pantothenate

RESULTS AND DISCUSSION

Almond hulls as fiber sources showed the same physical and chemical traits as the hulls of other cereals, such as oats, rice, and soybeans. The effect of the dietary supplementation with almond hulls at up to 2% in broiler diets is shown in Table 2. Body weight gain ($p<0.05$) and feed intake ($p<0.10$) were increased through the supplementation of the almond hull during the first week of the experiment. During days 22-35, body weight gain tended to increase ($p<0.10$) through the supplementation of almond hulls. and in the overall experimental period, there was an improved body weight gain ($p<0.05$) and feed intake ($p<0.10$) through the supplementation of the almond hulls. Similarly, according to Jiménez-Moreno *et al.* (2013a), 50 g of oat hulls in diets had a linear influence on the total relative weight of the intestinal tract and a quadratic effect on the body weight gain of broilers. Additionally, Adewole *et al.* (2020) reported that incorporating 3% of oat hulls in the diet resulted in enhanced broiler growth performances and reduced FCR. Although the major fibers found in almond hulls (such as cellulose, hemicellulose, and lignin) are insoluble in water and not easily fermentable (Holtman *et al.*, 2015), almond hulls still contain energy in the form of fermentable sugars, including glucose, fructose, and sucrose. Although the fermentation process may not be as significant as in ruminants, the positive impact on the gut environment can indirectly influence broilers' body weight and performance. When comparing the starch present in cereals to sugars, it can be observed that sugars have a lower molecular weight and are absorbed more easily (Aller *et al.*, 2011). Thus, insoluble fibers could improve body weight and nutrient utilization in broilers (Adedokun *et al.*, 2012). Jiménez-Moreno *et al.* (2013ab) also reported that a moderate level of 3% dietary fiber was deemed appropriate for broilers, while including dietary fiber up to 3.6% in their diets could promote the growth and development of the gastrointestinal tract organs in young broilers. However, including a high amount of dietary fibers

Table 2 – The effect of dietary almond hull supplementation on growth performance of broilers[1]

Items	CON	TRT1	TRT2	SEM[2]	*p*-value[3]	
					Linear	Quadratic
Day 0 to 7						
BWG, g	153	159	163	2	0.0014	0.6371
FI, g	176	180	183	3	0.0709	0.9390
FCR	1.150	1.131	1.127	0.016	0.3448	0.6992
Day 8 to 21						
BWG, g	640	650	658	8	0.1165	0.9405
FI, g	856	867	876	11	0.1943	0.9364
FCR	1.342	1.339	1.336	0.019	0.8210	0.9894
Day 22 to 35						
BWG, g	955	967	987	12	0.0617	0.7760
FI, g	1869	1884	1917	21	0.1142	0.7130
FCR	1.963	1.953	1.948	0.032	0.7430	0.9546
Overall period						
BWG, g	1748	1776	1808	15	0.0095	0.9066
FI, g	2901	2931	2977	26	0.0522	0.7983
FCR	1.662	1.653	1.648	0.020	0.6348	0.9297

[1]Abbreviation: BWG, body weight gain; FCR, feed conversion ratio; FI, feed intake; CON, basal diet; TRT1, basal diet + 1% almond hull; TRT2, basal diet + 2% almond hull

[2]Standard error of means.

[3a,b] Means in the same row with different superscripts differ significantly (p<0.05).

could have a negative impact on the growth of broilers (Mateos *et al.*, 2012). Furthermore, a diet containing 9% of almond hulls had more significant adverse effects on broilers' body weight gain (BWG), feed intake (FI), and feed conversion ratio (FCR) during the 0–19-day period (Wang *et al.*, 2021a). According to the previous study, it was indicated that broilers fed 10% of almond hulls had reduced body weight and lower fat percentage (Wang *et al.*, 2021b). The slight reduction in body weight gain (BWG) resulting from the inclusion of a high level of almond hulls can be attributed to the high-fiber nature of the diet, which is known to promote weight loss, particularly in terms of body fat (Walugembe *et al.*, 2014). The study suggests that utilized 1% and 2% almond hulls, despite being water insoluble, may still be digested and absorbed by the body. This digestion and absorption of fiber likely contributed to the observed improvement in body weight gain (BWG).

The nutrient digestibility of broilers in different treatment groups is shown in Table 3. The current study showed that the inclusion of almond hulls at 0-2% tended to increase the digestibility of nitrogen and energy. However, 0-2% inclusion rates had no significant influence on the digestibility of DM. Similarly, almond hull at inclusion levels of 7.5–15% improved the gross energy and N digestibility of poultry but had no impact on apparent dry matter digestibility (Wang *et al.*, 2021a). Additionally, Scholey *et al.* (2020) stated that the digestibility of broilers is

Table 3 – The effect of dietary almond hull supplementation on nutrient digestibility of broilers[1]

Items, %	CON	TRT1	TRT2	SEM[2]	*p*-value[3]	
					Linear	Quadratic
Finish						
Dry matter	72.72	73.74	74.17	0.83	0.2350	0.7763
Nitrogen	71.00	72.49	72.95	0.73	0.0802	0.5754
Energy	71.94	73.44	73.91	0.79	0.0958	0.5987

[1]Abbreviation: CON, basal diet; TRT1, basal diet + 1% almond hull; TRT2, basal diet + 2% almond hull

[2]Standard error of means.

[3a,b]Means in the same row with different superscripts differ significantly (p<0.05).

increased without any adverse impacts on gut fill and intake when the diet contains a lower level of oat hull (3% of the total diet). However, the performance of broilers and nutrient digestibility were unaffected by the addition of 2% lignocellulose, according to Kheravii *et al.* (2017). On the other hand, according to Wang *et al.* (2021b), the ileal digestibility of DM and energy was reduced when 3% and 9% almond hulls were used, but the inclusion of the 6% almond hull had no significant effect on DM, ME, or ileal protein digestibility. The present research revealed that nitrogen digestibility and energy digestibility tend to increase, suggesting that the almond hull's entire fiber content (lower amount of hulls, at 2%) has likely been properly ingested. Consequently, almond hulls in the diet exhibit functional properties similar to those of proper insoluble fibers, contributing to their beneficial effects. Jiménez-Moreno *et al.* (2010) found that the inclusion of insoluble fiber in broiler diets significantly stimulates the proventriculus to produce a substantial amount of hydrochloric acid (HCl). The substantial production of HCl in the proventriculus has the potential to enhance pepsin activity, promote protein synthesis, and improve nutrient utilization in broilers (Macelline *et al.*, 2021).

The main site of microbial fermentation in poultry is the cecum. The microbiota of the caeca can change in response to changes in dietary fiber levels, which may indicate that fiber components have been transported to the caeca (Svihus *et al.*, 2013). Previous research has indicated that the greater fiber contents in oat hull may boost bacterial population (Kheravii *et al.*, 2018). The fiber sources from almond hulls, which are primarily lignin and cellulose, may contribute to microbial diversity (Wang *et al.*, 2021bc). The effect of dietary almond hull supplementation on the caecum microbial count is shown in Table 4. Caecal *Salmonella* counts tended to reduce (p<0.05), whereas the caecal *Lactobacillus* and *E. coli* counts remained unchanged through the dietary supplementation of almond hull. According to Xu *et al.* (2003), when a fructo-oligosaccharide was introduced to broiler chicken diets, the overall number of anaerobes, including *Bifidobacteria* and *Lactobacilli*, increased in the caeca, while the amount of *E. Coli* declined. The addition of 0.2% xylo-oligomers did not significantly alter the number of caecal enterobacteria or *Lactobacilli*, but the inclusion of these oligosaccharides in the diet significantly increased the number of *Bifidobacteria*, from 103 to 108, in just one week (Courtin *et al.*, 2008). Rougière and Carré (2010) discovered just a modest trend for the caecal microbial count to increase when broiler chicks were fed diets containing 15% sunflower hulls. At a dose of 0.5% lignocellulose (insoluble fibre source), it was demonstrated that *Lactobacillus spp.* and *Bifidobacterium spp*. populations increased, while *E. coli* populations decreased (Boguslawska-Tryk *et al.*, 2015). Receiving fermentable lignocellulose in the cecum is necessary for the diversity of the bacterial population in the cecum of broilers (Zeitz *et al.*, 2019). However, no significant differences in the diversity of the caecal microbiota were found between treatments at 3%, 6%, and 9% inclusion levels of the almond prime hull (Wang *et al.*, 2021a). Indeed, the variation in results regarding the effects of almond hull inclusion on caecum microbial population in broilers could be influenced by factors such as the level of almond hull inclusion, the source of fiber used, and the specific strain of birds used in our study. Furthermore, we know that protein utilization may occur while birds may also have lower pH in the upper digestive tract (Macelline *et al.*, 2021), which was not detected in our study. The later digestive tract pathogenic bacteria may be affected by this lower pH, which encourages the growth of helpful bacteria (Engberg *et al.*, 2004). In the current study, *Salmonella* counts decreased, which may be due to lower digestive tract pH and the phenolic compound contents of almond hulls.

Table 4 – The effect of dietary almond hull supplementation on the caecum microbial counts of broilers[1]

Items	CON	TRT1	TRT2	SEM[2]	p-value[3]	
					Linear	Quadratic
Finish						
Lactobacillus	8.84	8.85	8.94	0.06	0.2716	0.5993
E. coli	7.47	7.45	7.41	0.03	0.2333	0.7975
Salmonella	5.24	5.12	5.03	0.07	0.0712	0.8759

[1]Abbreviation: CON, basal diet; TRT1, basal diet + 1% almond hull; TRT2, basal diet + 2% almond hull

[2]Standard error of means.

[3a,b]Means in the same row with different superscripts differ significantly (p<0.05).

The effect of dietary supplementation of almond hull in broiler diets on the excretal noxious gas emission is shown in Table 5. In this current study, NH_3 reduced significantly, but there was no effect on other noxious gases such as H_2S, Methyl mercaptans, CO_2, and Acetic acid. Excreta noxious gas levels in broilers are influenced by the nutrient digestibility of the feed and gut microbiota (Park & Kim, 2020). According to (Xu *et al.*, 2003), higher digestibility means less substrate is accessible for microbial fermentation in the large intestine, which promotes proper digestion and lessens noxious gas emissions. A decrease in harmful bacteria results in a reduction in the levels of ammonia gases (Li *et al.*, 2012). We assume that decreased salmonella populations and improved nitrogen digestibility in broiler chickens may be responsible for the decrease in excreta ammonia gas contents.

Table 5 – The effect of dietary almond hull supplementation on noxious gas emission of broilers[1]

Items, ppm	CON	TRT1	TRT2	SEM[2]	p-value[3]	
					Linear	Quadratic
Finish						
NH_3	11.75	10.38	9.38	1.3	0.0265	0.9063
H_2S	1.73	1.58	1.33	0.4	0.5404	0.9284
Methyl mercaptans	5.63	4.50	3.75	0.8	0.1413	0.8514
CO_2	1200	1125	1100	126	0.5937	0.8762
Acetic acid	2.38	2.00	1.75	0.7	0.5233	0.9402

[1]Abbreviation: CON, basal diet; TRT1, basal diet + 1% almond hull; TRT2, basal diet + 2% almond hull

[2]Standard error of means.

[3]a,bMeans in the same row with different superscripts differ significantly (p<0.05).

The organ weight of broilers in different treatment groups is shown in Table 6. The current study shows that there was no significant disparity in the breast muscle, liver, spleen, abdominal fat, bursa of Fabricius, and gizzard weights of broilers after the study period. Similarly, González-Alvarado *et al.* (2007) found that the gross organ weight of broilers had no significant difference at the inclusion level of 3% soy hulls in the diet, compared to the control group. Additionally, inclusion level of 4%-8% of soybean hulls had no significant impact on internal organs, except for the liver (Tejeda & Kim, 2020). Moreover, Moradi *et al.* (2021) indicated that sweet almond hull doses of 7%, 14%, 21%, and 28% had no tangible effects on the bursa of Fabricius and spleen of broilers. Arjomandi *et al.* (2015) showed that the inclusion of sweet almond hulls in the diet had no impact on the relative weight of the various internal organs of quails. However, Rezaei *et al.* (2018) showed that a greater amount of dietary fiber promotes the size of internal organs (i.e., gizzard and intestines) to make up for the increased volume of feed going through intestines as a result of bulky diets. Moreover, insoluble fibers have indeed been demonstrated to impact the weights of various organs, as well as the gastrointestinal tract's propensity to digest feed and the conversion of feed in chickens (Hetland *et al.*, 2004, 2005; Mateos *et al.*, 2012). Yokhana *et al.* (2016) stated that the liver and gizzard's weights increased noticeably after being fed insoluble fiber diets for an additional five weeks, until 18 weeks of age (but not for the proventriculus). No significant effects of almond hulls on broiler organ weight could be attributed to factors such as low inclusion levels, length of study duration, nutrient composition, and strain of broiler population. There are few studies on the impact of the almond hull on the carcass characteristics of broilers, and further research is necessary to determine the real causes.

Table 6 – The effect of dietary almond hull supplementation on the organ weight of broilers[1]

Items, %	CON	TRT1	TRT2	SEM[2]	*p*-value[3]	
					Linear	Quadratic
Relative organ weight (%)						
Breast muscle	17.76	18.00	18.28	0.27	0.2198	0.9450
Liver	3.35	3.38	3.47	0.20	0.6945	0.3111
Spleen	0.14	0.15	0.16	0.01	0.2363	0.8842
Abdominal fat	2.26	2.28	2.30	0.04	0.4796	0.8458
Bursa of Fabricius	0.15	0.16	0.17	0.02	0.4372	0.8182
Gizzard	1.21	1.28	1.38	0.12	0.3599	0.9101

[1]Abbreviation: CON, basal diet; TRT1, basal diet + 1% almond hull; TRT2, basal diet + 2% almond hull

[2]Standard error of means.

[3a,b]Means in the same row with different superscripts differ significantly ($p<0.05$).

CONCLUSION

Supplementation of broiler diets with almond hulls enhanced the growth performance and nutrient digestibility, decreasing salmonella counts in the broilers' excreta microflora and reducing ammonia gases at 35 days. Therefore, a supplementation at the inclusion level of 2% of almond hulls in diets could be recommended for the overall performance of broilers.

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