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Impact of Dietary Corn Fiber on Growth Performance, Digestive Organs, Intestinal Morphology, and Nutrient Digestibility in Broiler Chickens

Mohammad Reza Sharifi[1] & Abbas Masoudi[2]

[1] Research & Development Department, Salizfood Co, Shiraz, Iran
[2] Department of Animal Science, Faculty of Agriculture, University of Lorestan, Khorramaabad, Iran

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Corresponding author
Mohammad Reza Sharifi
Sharifi.Mohammadr@gmail.com

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Abstract
Adding moderate levels of insoluble dietary fiber is a promising and economical method for enhancing broiler chickens' health status and performance. The current research aimed to determine the effect of corn bran (CB) as an insoluble fiber on performance parameters, digestive organs, intestinal morphology, and nutrient digestibility in broiler chickens. A total of 240 one-day-old Ross broilers were randomly divided into four treatments: a control (without CB inclusion) and three treatments with CB at 25, 50, and 75 g/kg. Dietary inclusion of 50 and 75 g/kg of CB significantly decreased daily feed intake and weight gain during the entire rearing period. However, the feed conversion ratio was not affected by the experimental treatments. Carcass yields significantly increased in birds fed control and 25 g/kg CB diets compared to those fed on 50 and 75 g/kg of CB. On the other hand, feeding 50 and 75 g/kg of CB caused a significant increase in the gastrointestinal tract and gizzard relative weights compared to the control. The groups fed 50 and 75 g/kg CB-containing diets had the heaviest ileal and cecal weights relative to the control group. The shortest compartments of the small intestine were observed in the group fed the control diet compared to the CB inclusion treatments ($P < 0.05$). No significant differences were observed in intestinal morphology and nutrient digestibility among treatments. In conclusion, supplementing CB as an insoluble fiber at 25 g/kg improved the health status of broiler chickens without impairing growth performance.

Introduction
The poultry industry has always faced variable challenges in improving and maintaining gut health, especially since the restriction and ban of antibiotics from poultry diets due to their adverse effects on human health (Tejeda & Kim, 2021b). Therefore, gastrointestinal health is one of the most critical topics of interest to poultry researchers and nutritionists (Tejeda & Kim, 2021b; Singh & Kim, 2021). Many chemical additives and natural ingredients such as herbal components and fibers have been studied on broiler chickens to improve health status and increase the growth rate (Demir *et al*., 2003; Abd El-Hack *et al*., 2022). Dietary fiber encompasses highly diverse polymers with large differences in physicochemical properties generally derived from certain cereals and usually categorized as water-soluble or insoluble (Masoudi & Azarfar, 2017).

The inclusion of insoluble fibers improves the weight of digestive organs (Gonzalez-Alvarado *et al*., 2007; Svihus, 2011), stimulates digestive enzymes and bile acid production and activity (Tejeda & Kim, 2021b), increases fermentation capability (Jiménez-Moreno *et al*., 2009), increase digestive viscosity (Saadatmand *et al*., 2019), and had bulking effect on the GIT (Abd El-Hack *et al*., 2022) in broiler chickens, which reflects in improving the health status and increasing performance. The accurate use of dietary insoluble fiber sources has been introduced as a management and nutritional strategy for normal digestive organ functioning, maintaining the poultry GIT health, and improving performance in broiler chickens.

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Corn bran represents a valuable byproduct derived from the cereal milling industry, widely recognized as an insoluble dietary ingredient for poultry (Moradi *et al.*, 2021). The findings, in line with previous research (Rose *et al.*, 2010), indicated that CB primarily comprises hemicellulose, cellulose, and lignin. Hemicellulose was the most abundant fiber component, constituting approximately 700 g/kg of the CB's total fiber content. Cellulose content ranged from 200 to 280 g/kg, while lignin content was measured at 10 g/kg.

These results highlight the significant presence of complex carbohydrates and structural components in CB. The substantial content of hemicellulose and cellulose in CB suggests its potential as a valuable source of dietary fiber for poultry. These fiber types are known to positively impact gut health, aiding in digestion and nutrient absorption. Integrating CB into poultry diets may promote digestive health and enhance feed utilization efficiency and overall poultry performance. While numerous studies have investigated the effects of diverse insoluble fiber sources on broiler nutrition and gut health, limited attention has been given to using CB as a natural and cost-effective component in broiler chicken diets. Therefore, the objective of this study is to assess the influence of CB as an insoluble fiber on broiler chickens' growth performance and gut function.

Materials and Methods

Birds and experimental facility

In this experiment, 240 mixed-sex Ross 308 broiler chickens in a completely random design were divided into four treatments with four replicates per treatment and 15 one-day-old chickens per replicate. The birds were fed a starter diet (containing 2,900 kcal of ME/kg and 21.5% CP) from days 1 to 21 and a grower diet (containing 3,050 kcal of ME/kg and 19.5% CP) from days 22 to 42, based on the NRC (1994) recommendations. Throughout the study, birds had free access to water and feed, and the rearing temperature adhered to standard Ross broiler conditions.

Treatments

Four formulated dietary treatments including a commercial diet (maize-soybean meal, with no supplemental CB) were prepared as a control group. Three additional diets were prepared by adding 25 g/kg (T1), 50 g/kg (T2), and 75 g/kg (T3) of CB to the control diet. All diets had the same metabolizable energy and crude protein concentration and were offered in mash form. The ingredients and nutrient contents of the diets are shown in Table 1. Prior to the commencement of the experiment, CB was ground with a 2 mm diameter hammer mill. The chemical composition of CB was analyzed using the nutrient analysis method recommended by AOAC (2000). The neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined based on Van Soest *et al.* (1991).

Table 1. Ingredient composition and chemical analysis (% as feed basis) of experimental diets during the two feeding phases

Ingredients	Starter (1-21)				Grower (22-42)			
	Control	T1	T2	T3	Control	T1	T2	T3
Corn	54.86	50.70	46.54	42.39	59.32	55.98	52.66	49.32
Soybean Meal-44%	38.64	39.29	39.96	40.60	33.75	33.86	33.96	34.07
Corn bran[1]	0	2.5	5	7.5	0	2.5	5	7.5
Oil	1.70	2.76	3.84	4.89	3.12	3.91	4.71	5.50
Calcium carbonate	1.17	1.15	1.13	1.12	1.00	0.96	0.92	0.89
Dicalcium Phosphate	1.90	1.9	1.88	1.87	1.47	1.46	1.45	1.43
Sodium bicarbonate	0.09	0.09	0.08	0.08	0.18	0.17	0.17	0.17
Vitamin Premix[2]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Mineral Premix[3]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Common salt	0.32	0.32	0.32	0.31	0.27	0.27	0.26	0.26
DL-Methionine	0.33	0.33	0.33	0.33	0.21	0.22	0.22	0.22
L-Lysine	0.32	0.30	0.28	0.28	0.13	0.12	0.11	0.10
Threonine	0.17	0.16	0.14	0.13	0.05	0.05	0.04	0.04
Calculated composition								
ME (Kcal/kg)	2900	2900	2900	2900	3050	3050	3050	3050
Protein (%)	21.50	21.50	21.50	21.50	19.50	19.50	19.50	19.50
Calcium (%)	0.96	0.96	0.96	0.96	0.79	0.79	0.79	0.79
Phosphorous (%)	0.48	0.48	0.48	0.48	0.63	0.64	0.64	0.65
Lysine (%)	1.28	1.28	1.28	1.28	1.03	1.00	1.03	1.03
Methionine+Cystine (%)	0.95	0.95	0.95	0.95	0.80	0.80	0.80	0.80

[1]Corn bran had 95.63% dry matter, 10.43% crude protein, 1.02% ether extract, 39.81% acid detergent fiber, and 67.32% neutral detergent fiber.
[2]Vitamin premix provided the following per kilogram of diet: vitamin A (retinol), 9000 IU; vitamin D3 (cholecalciferol), 2000 IU; vitamin E (tocopheryl acetate), 18 mg; vitamin K3, 2 mg; thiamine 1.8 mg; riboflavin, 6.6 mg; niacin, 35 mg; folic acid, 1 mg; pyridoxine, 4 mg; pantothenic acid, 10 mg; cyanocobalamin, 0.015 mg; biotin, 0.1 mg; choline chloride, 250 mg.
[3]Mineral provided the following per kilogram of diet: Fe ($FeSO_4$), 50 mg; Mn ($MnSO_4$), 100 mg; Zn (ZnO,), 100 mg; Cu ($CuSO_4$), 10 mg; I (KI); Se ($NaSeO_3$), 0.2 mg.

Measurements

Growth performance, carcass traits, and digestive organs

The body weight gain (BWG) and feed intake (FI) of chickens in each treatment were recorded at different phases of the experiment. Feed conversion ratio (FCR) data was calculated and corrected for mortality body weights in the trial.

On day 42, eight birds were selected from each pen with body weights close to the mean weight and euthanized by cervical dislocation. The whole carcass, liver, and spleen weights were measured and reported as a percentage of live body weight. The ratio of the gizzard, proventriculus, duodenum, jejunum, ileum, cecum, and entire gastrointestinal tract (GIT) to the live body weight was calculated and reported. Additionally, the length of the intestinal segments, specifically the duodenum, jejunum, ileum, and cecum, were measured individually.

Morphology of the small intestine

At the end of the rearing phase, two birds from each treatment were euthanized to evaluate morphological parameters of the small intestine, including villus height, crypt depth, and the villus height to crypt depth ratio (VH:CD). Approximately 2 cm from the middle parts of the jejunum and ileum were taken and washed with phosphate-buffered saline solution (PBS, pH = 7) to remove contamination and then placed in Clark's fixative solution for 45 minutes. The samples were subsequently transferred to ethyl alcohol until morphological examination. To measure the morphological parameters, taken samples were stained with acid-Schiff reagent, and the villi were separated and placed on glass slides for examination under a light microscope. Villus height was measured from the top of the villus to the top of the lamina propria, while crypt depth was calculated by measuring from the base of the villus to the submucosa. Finally, the VH: CD ratio was calculated. (Hassanpour *et al*., 2013).

Determination of nutrient digestibility

Dry matter, organic matter, protein, and fat apparent ileal digestibility were determined in collected ileal samples. The experimental group was supplemented with titanium oxide (TiO2) as an indigestible marker. To facilitate the determination of nutrient digestibility, 5 g of TiO2 was supplemented in the diet three days before the collection of ileal digesta (day 39), and at 42 days of age, three birds were randomly selected and euthanized from each replicate. Samples of their ileal contents from Meckel's diverticulum to the ileocecal junction were collected and placed in numbered nylon bags, stored at −20 °C until further analysis. Organic matters were calculated based on the differences between dry matter and ash weight. Crude protein digestibility was calculated using the Kjeldahl method, and crude fiber was calculated using the Soxhlet method. The apparent ileal digestibility of parameters was estimated using TiO2 ratios in the diet and ileal content by the following formula proposed by Khodambashi-Emami *et al*. (2013):

Apparent ileal digestibility = 100- [(TiO2 in feed/TiO2 in ileal content) × (nutrient in ileal content/nutrient in feed) × 100]

Statistical analysis

Results were analyzed by the GLM procedure of SAS (2007) software in a completely randomized design. Significant differences for all data were presented at the probability level of $P < 0.05$. Means were separated by Duncan’s multiple range test.

Results

The growth performance of chickens is shown in Table 2. Including dietary CB at 50 and 75 g/kg levels significantly decreased BWG and FI during the entire rearing period ($P < 0.05$). However, BWG and FI did not significantly change ($P > 0.05$) with the inclusion of 25 g/kg CB. The inclusion of CB in the diets did not alter FCR as compared to the control.

Table 2. Effects of dietary corn fiber on the performance of broiler chickens at different rearing periods

Items	Corn bran				*SEM**	*P*-value
	Control	T1	T2	T3		
Starter (1-21d)						
BWG[1] (g/d)	36.66[a]	34.95[ab]	34.04[b]	32.54[b]	1.56	0.007
FI[2] (g/d)	49.4[a]	48.3[ab]	46.2[b]	45.6[b]	1.09	0.011
FCR[3] (g/g)	1.371	1.395	1.387	1.405	0.017	0.242
Grower (22-42d)						
BWG (g/d)	71.93[a]	68.1[ab]	65.51[b]	63.87[b]	2.07	0.026
FI (g/d)	158.5[a]	154.2[b]	145.3[b]	146.2[b]	2.67	0.004
FCR (g/g)	2.19	2.18	2.22	2.28	0.039	0.342
Whole period (1-42d)						
BWG (g/d)	54.3[a]	51.5[ab]	49.8[b]	48.2[b]	1.02	0.007
FI (g/d)	103.3[a]	101.1[ab]	95.3[b]	94.7[b]	3.05	0.003
FCR (g/g)	1.92	1.93	1.93	1.96	0.021	0.281

T1: Supplemented with 25 g/kg CB; T2: Supplemented with 50 g/kg CB; T3: Supplemented with 75 g/kg CB;
1BWG: body weight gain
[2]FI: feed intake
[3]FCR: Feed conversion ratio
[ab] In a row means assigned different lowercase letters are significantly different, $P < 0.05$
[*] *SEM*: Standard error of means

The effects of CB inclusion on carcass yield and digestive organs are shown in Table 3. Carcass yield significantly decreased in chickens fed 75 g/kg of CB compared to the control and 25 g/kg CB groups. The groups fed the diets containing 50 and 75 g/kg of CB had the heaviest GIT and gizzard weights ($P < 0.05$), and this effect was also seen in the relative weights of ileum and cecum. The groups containing 50 and 75 g/kg of CB showed the longest ileum and cecum compared to the control group ($P < 0.05$). No statistical differences among the dietary treatments were observed in the spleen, liver, duodenum, and jejunum weights relative to body weight ($P > 0.05$).

Table 3. Effects of dietary corn fiber on carcass yield, digestive organs, and intestine parameters of broiler chickens

Items	Corn bran				*SEM*	*P*-value
	Control	T1	T2	T3		
Carcass yield (% BW)	70.5[a]	70.3[a]	69.3[ab]	68.4[b]	0.512	0.034
Gastrointestinal tract (% BW)	13.53[b]	13.85[ab]	14.37[a]	14.45[a]	0.194	0.027
Gizzard (% BW)	3.18[b]	3.29[b]	3.53[a]	3.56[a]	0.038	0.008
Proventriculus (% BW)	0.41	0.43	0.45	0.42	0.441	0.056
Liver (% BW)	2.37	2.42	2.34	2.33	0.162	0.233
Spleen (% BW)	0.131	0.128	0.126	0.128	0.017	0.632
Duodenum weight (%BW)	0.95	0.97	1.02	1.01	0.058	0.211
Jejunum weight (%BW)	2.28	2.27	2.34	2.37	0.152	0.148
Ileum weight (%BW)	2.11[b]	2.12[b]	2.37[a]	2.35[a]	0.037	0.064
Cecum weight (%BW)	0.567[b]	0.598[ab]	0.615[a]	0.626[a]	0.013	0.013
Duodenum length (Cm)	27.43	27.19	28.09	29.56	1.44	0.646
Jejunum length (Cm)	78.44	79.43	81.37	80.31	2.93	0.006
Ileum length (Cm)	70.78[b]	73.93[ab]	75.81[a]	78.06[a]	1.64	0.031
Cecum length (Cm)	34.22[b]	36.77[ab]	39.23[a]	41.20[a]	1.53	0.014

T1: Supplemented with 25 g/kg CB; T2: Supplemented with 50 g/kg CB; T3: Supplemented with 75 g/kg CB; [ab] In a row means assigned different lowercase letters are significantly different, *P < 0.05*

* *SEM*: Standard error of means

The results for intestinal morphology are shown in Table 4. Broilers received 25 and 50 g/kg of CB had greater jejunum and ileum villus height than the control, but the results were not significant among the treatments ($P > 0.05$). The tested diets did not significantly affect the crypt depth and VH: CD ratio. The results for nutrient digestibility (Table 5) show no statistical differences in the digestibility of DM, OM, CP, and EE ($P > 0.05$) among the treatments.

Table 4. Effects of dietary corn fiber on the intestinal morphology of broiler chickens

Items	Corn bran				*SEM*	*P*-value
	Control	T1	T2	T3		
Jejunum						
Villi height (µm)	1164	1174	1204	1177	21.24	0.119
Crypt depth (µm)	125	125	123	131	4.46	0.577
VH/CD	9.16	9.2	9.38	9.06	0.26	0.271
Ileum						
Villi height (µm)	686	716	729	701	15.83	0.455
Crypt depth (µm)	103	101	102	100	2.49	0.501
VH/CD	6.89	7.18	7.12	7.09	0.17	0.281

T1: Supplemented with 25 g/kg CB; T2: Supplemented with 50 g/kg CB; T3: Supplemented with 75 g/kg CB;
VH/CD: Villus height/crypt depth.
ab In a column means assigned different lowercase letters are significantly different, P < 0.05
* *SEM*: Standard error of means

Table 4. Effects of dietary corn fiber on the intestinal morphology of broiler chickens

Items	Corn bran				*SEM*	*P*-value
	Control	T1	T2	T3		
DM	71.86	72.62	70.19	71.46	1.754	0.622
OM	71.27	73.79	72.48	69.56	3.81	0.406
CP	64.82	65.35	64.34	63.73	4.43	0.628
EE	81.32	85.02	84.76	83.27	4.45	0.323

T1: Supplemented with 25 g/kg CB; T2: Supplemented with 50 g/kg CB; T3: Supplemented with 75 g/kg CB;
VH/CD: Villus height/crypt depth.
ab In a column means assigned different lowercase letters are significantly different, P < 0.05
* *SEM*: Standard error of means

Discussion

In the 25 g/kg CB treatment, BWG and FI did not differ significantly from the control group, which is similar to previous reports indicating that the inclusion of a small amount of insoluble dietary fiber did not negatively impact broiler growth (Amerah *et al*., 2009; Sacranie *et al*., 2012; Tejeda & Kim, 2021a). However, the CB-containing treatments with 50 and 75 g/kg had lower FI and BWG than the control treatment throughout the rearing period. These results are in accordance with those reported in broilers fed diets containing rice hulls (Gonzalez-Alvarado *et al*., 2007; Sadeghi *et al*., 2015) and soy hulls (Tejeda & Kim; 2021a), leading to a lower FI than birds that were not fed with insoluble fibers. However, Scholey *et al*. (2020) reported that slight oat hull inclusion had no impact on broilers' performance, but higher inclusion levels (30% oat with 17% hull) did deleteriously affect FI because of increased gut fill from the fiber. Insoluble dietary fiber is known to be a nutrient diluent in poultry because of the absence of enzymes that can break down the β 1-4, β 1-3, and β 1-6 linkages in non-starch polysaccharides. This reduces the digestibility and absorption of these fibers, which can slow down and dilute nutrient intake. If high amounts of insoluble and indigestible fibers are included in the diet of broiler chickens, it can adversely affect their growth rate (Tejeda & Kim, 2021b).

Adedokun and Adeola (2020) reported that ileal endogenous losses of His, Glu, Pro, Ile, Met, nitrogen, and total amino acid in birds fed corn fiber-based diets were higher than in birds received pectin-based diets because the higher levels of amino acids and crude fiber in corn fiber. Kluth and Rodehutscord (2009) showed that including cellulose in chicken diets could increase ileal amino acid losses. According to these results, nitrogen and amino acid losses in birds-fed insoluble fibers are other factors that could be considered in decreasing birds' performance in this experiment.

The insoluble fibers on intestinal motility and passage rate (Tejeda & Kim, 2021a), differences in nutritional content in experimental diets (no isonitrogenous or isocaloric diets) (Tejeda & Kim, 2021b), differences in components and sizes of insoluble fibers (Abd El-Hack *et al*., 2022), and nutrients of different insoluble fibers maybe some other reasons for the difference in performance observed in other studies investigating insoluble fibers for broilers. In the current experiment, FCR was not affected by the experimental treatments. However, Jimenez-Moreno *et al*. (2013) reported that a modest amount of fiber (approximately 25 g/kg) improved the FCR of 1- to 18-day-old chickens.

Broilers received 50 and 75 g/kg of CB had heavier whole GIT and gizzard weights than those fed 25 g/kg of CB and control. Compared to the other treatments, the heaviest and longest jejunum, ileum, and cecum were also observed in the groups containing 50 and 75 g/kg of CB. These results are in accordance with Tejeda & Kim (2021a), who similarly reported heavier gizzards and longer small intestines in broilers fed soy hulls as insoluble fiber. The researchers observed that soy hulls, as an insoluble fiber, increased polymerization levels and muscular activity in the gizzard. This, in turn, may have stimulated the weight of the sphincter muscles.

Insoluble fibers with a high lignin content have a longer retention time in the gizzard due to their greater resistance to grinding. This stimulates the grinding activity of the gizzard and promotes the development and function of the muscular layers of the gizzard, as reported by Jiménez-Moreno *et al*. (2009) and Mateos *et al*. (2012). In addition, insoluble fiber particles tend to accumulate in the upper part of the GIT, mechanically stimulating the development of the muscular layers of the gizzard (Gonzalez-Alvarado *et al*., 2007; Jimenez-Moreno *et al*., 2019).

Jimenez-Moreno*et al*. (2019) reported that the addition of oat hulls, rice hulls, and sunflower hulls with 2 levels of inclusion (2.5% and 5.0%) increased the absolute and relative weights of the empty gizzard, especially with 5.0% versus 2.5% fiber inclusion, and with oat hulls compared with the other two fiber sources. In another study, the average weight of gizzard and small intestine was found to be higher in birds that were fed oat hulls, rice hulls, and sunflower hulls as compared to the control group. Furthermore, there was a significant increase in the length of the small intestine (Moradi *et al*., 2021).

Tejeda & Kim (2021a) observed the heaviest small intestine weight (including duodenum, jejunum, and ileum) in the groups containing 8% soy hull compared to the control and the rest of the treatments received low levels of soy hull on day 21. These researchers suggested that soy hull-containing diets increased intestinal viscosity and reduced the passage rate of digesta because the carbohydrate portion of soy hulls is composed of 30% pectins. These factors could increase feed weight by its accumulation in the small intestine. Some researchers reported increased weights of the different digestive tract and ileum compartments by adding oat hulls to chicken diets (Jiménez-Moreno *et al*., 2019; Moradi *et al*., 2021).

CB did not affect proventriculus capacity, spleen, and liver weight at all levels in this study. No effect of CB on the liver indicated that the addition of CB did not affect the metabolic processes in chickens, possibly due to the diets being isonitrogenous and isocaloric. In agreement with these results, Jimenez-Moreno *et al*. (2019) showed that proventriculus capacity and liver weight did not change by including oat hulls, rice hulls, and sunflower hulls at different levels. In the current study, birds fed 50 and 75 g/kg of CB gained heavier relative weights of GIT than the other groups, which may be one of the reasons for the decreased carcass yield in these groups compared to the control group.

Scholey *et al*. (2020) reported that the weights and lengths of the duodenum, jejunum, and ileum in broilers were not affected by the inclusion of oat hulls, although overall small intestine length was improved in birds fed oat hulls compared with those fed de-hulled oat diets. Taylor and Jones (2004) expressed that an increase in gizzard size and more effective feed grinding could reduce small intestine size.

Cecal relative weight and length significantly improved in the group fed 50 and 75 g/kg of CB compared to the control, but these differences were not seen at 25 g/kg of CB. Jiménez-Moreno *et al*. (2019) showed that adding 3% oat hulls and sugar beet pulp increased cecal relative weight relative to control groups. However, some researchers did not observe significant differences in the cecal weights of broilers fed soy hulls compared to non-inclusion groups (Tejeda & Kim, 2021a; Gonzalez-Alvarado *et al*., 2007).

In this study, the dietary treatments did not significantly affect small intestinal morphology. However, contrasting findings were reported by Tejeda & Kim (2021a), where the inclusion of soy hulls at 4% in the broiler diet resulted in improved intestinal morphology.

In the current research, the inclusion of CB did not alter nutrient digestibility, including dry matter, organic matter, crude protein, and ether extract. In agreement with these results, Abdollahi *et al*. (2018) found that adding Ligno-Cellulose at 1-2% had no effect on protein and gross energy digestibility in broilers fed a diet based on the corn-soybean meal. Also, Adibmoradi *et al*. (2016) reported that adding rice and barely hull to broiler chicken diets did not positively affect fat digestibility. In fact, developing gizzard and proventriculus increases pancreas enzymatic activity, increases the retention of bolus in the upper GIT, slows down the passage rate, and increase the exposure of feed components to HCl are the main reason that insoluble fibers in moderate levels (3–5%) can improve nutrient digestibility (Moradi *et al*., 2021; Tejeda & Kim, 2021).

According to Tejeda & Kim (2020), a slight inclusion of insoluble fibers could increase the retention time, allowing for more dry matter breakdown. These researchers reported that dry matter digestibility was lower for the 8% soy hull group than the 4% treatment and negatively affected by the presence of soluble fibers in the soy hull.

Conclusions

The functional properties of fibrous feed components greatly depend on dietary fiber inclusion. In the present study, adding 25 g/kg of CB to the diet resulted in performance similar to that of the control group while improving the weight and length of digestive organs. Moderate levels of CB (25 and 50 g/kg) improved intestinal morphology, indicating its positive effect on the GIT. However, high levels of CB increased the relative weights of the gizzard and small intestine but negatively affected the broilers' performance. These results indicate that CB can be added up to 25 g/kg to improve GIT functionality without any adverse effect on growth performance in broilers.

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