Gastrointestinal Tract in Broiler Chickens

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Recently, moderate amounts of insoluble dietary fiber have been shown to be beneficial to nutrient utilization by improving the physiology of the gastrointestinal tract in poultry. Wheat bran, a byproduct of the milling process, is rich in insoluble fiber, consisting mainly arabinoxylans and, to a lesser extent, cellulose and β-glucans. This study used wheat bran as a source of insoluble fiber to investigate wheat bran on digestive function in broiler chickens. The findings indicate that supplementation of 30 g/kg wheat bran enhanced nutrient digestibility by improving antioxidant status, gizzard development, intestinal digestive enzyme activities and morphology in broilers. Therefore, wheat bran could be used for improving feed efficiency in broilers.

Keywords: antioxidant status ; broilers ; digestive enzyme activities ; gastrointestinal development ; morphology ; nutrient digestibility ; wheat bran

1. Introduction

At present, developing new feeding strategies for healthier digestive system development and more efficient nutrient utilization of broilers has received increasing attention [1][2]. Traditionally, dietary fiber (DF) has been considered a diluent of the diet or even an anti-nutritional factor [3]. However, DF has attracted increasing attention due to various beneficial effects on gut health [4]. However, further studies demonstrated that there is a lack of consistency with regard to the effects of DF, suggesting that the effects of DF depend on their physicochemical characteristics [5][6]. Soluble dietary fiber (SDF) generally has a viscous structure, thus increasing digesta viscosity and reduces passage rate, and eventually reduces nutrient utilization [3]. In contrast, insoluble dietary fiber (IDF) has a nonviscous structural component, and recent studies in poultry have demonstrated that moderate amounts (20–30 g/kg) of IDF to be beneficial to nutrient utilization by improving gastrointestinal development and enzyme secretion [6][7]. Therefore, supplementing insoluble dietary fiber to broiler diets may be a feasible method to improve feed efficiency.

Wheat bran (WB), a byproduct of the milling process, is rich in insoluble fiber, consisting mainly arabinoxylans and, to a lesser extent, cellulose and β-glucans [8]. Previous studies have mostly focused on how to eliminate the anti-nutritional effects of a high level of WB [9]. However, with the development of research and exploration, the WB has been shown to be involved in the regulation of gastrointestinal physiology such as gastric emptying time and intestinal transit rate, which may consequently influence digestive function [10]. Besides, some studies demonstrated that WB plays an important role in metabolic regulation (particularly in lipid metabolism) in rats and humans, which is associated with the digestion and absorption of nutrients [11][12]. In addition, arabinoxylan or arabinoxylooligosaccharides derived from WB has been shown to improve gut health such as gut microbiota, which may in turn improve digestive traits [13][14]. Furthermore, in vitro experiments have proved that WB has antioxidant properties due to the presence of phenolic acids, which is favorable to the maintenance of gut homeostasis [15].

2. Nutrient Digestibility

The effects of WB supplementation on nutrient digestibility in broilers on Day 42 are presented in Table 1. Dietary inclusion of WB increased ($p < 0.05$) DM, OM, GE and CP digestibility compared with CON. Dietary treatments did not influence NDF and ADF digestibility.

Table 1. Effects of wheat bran on nutrient digestibility in broilers on Day 42.

Item	CON	WB	SEM	*p*-Value
Dry matter	0.73	0.75	0.002	0.02

Organic matter	0.77	0.79	0.002	0.02
Crude protein	0.63	0.67	0.009	0.03
Gross energy	0.76	0.78	0.003	0.01
Neutral detergent fiber	0.45	0.46	0.021	0.84
Acid detergent fiber	0.20	0.18	0.008	0.26

CON, control diet; WB, 30 g/kg wheat bran diet; SEM, standard error of mean.

3. Serum Biochemical Parameters

The effects of WB supplementation on serum biochemical parameters in broilers on Day 21 and 42 are presented in Table 2. On Day 21, there were no differences in serum concentrations of UN, HDL-C, LDL-C, TG, TP, ALB and GLU between treatments. However, birds fed WB had ($p < 0.05$) lower serum TC concentration than those fed CON. On Day 42, serum concentrations of HDL-C, TP, ALB and GLU still did not differ among treatments. However, compared with CON, dietary inclusion of WB decreased ($p < 0.05$) serum concentrations of LDL-C, TC and TG, and tended ($p = 0.06$) to decrease serum concentration of UN.

Table 2. Effects of wheat bran on serum biochemical parameters in broilers on Day 21 and 42.

Item	**CON**	**WB**	**SEM**	***p*-Value**
Day 21				
Urea nitrogen, mmol/L	1.40	1.38	0.05	0.74
High-density lipoprotein mmol/L	2.36	2.07	0.10	0.14
Low-density lipoprotein, mmol/L	0.39	0.33	0.02	0.11
Total cholesterol, mmol/L	3.25	2.78	0.12	0.03
Triglyceride, mmol/L	0.56	0.43	0.08	0.37
Total protein, g/L	23.21	24.14	1.12	0.58
Albumin, g/L	11.53	11.60	0.44	0.91
Glucose, mmol/L	12.27	12.27	0.64	0.99
Day 42				
Urea nitrogen, mmol/L	1.22	1.16	0.02	0.06
High-density lipoprotein cholesterol, mmol/L	1.06	0.93	0.04	0.11
Low-density lipoprotein cholesterol, mmol/L	0.30	0.14	0.02	< 0.01

Total cholesterol, mmol/L	1.67	1.03	0.10	< 0.01
Triglyceride, mmol/L	0.35	0.28	0.02	0.03
Total protein, g/L	11.57	10.33	0.97	0.53
Albumin, g/L	6.22	4.92	0.38	0.17
Glucose, mmol/L	8.82	8.12	0.30	0.20

CON, control diet; WB, 30 g/kg wheat bran diet; SEM, standard error of mean.

4. Serum Antioxidant Status

The effects of WB supplementation on serum biochemical parameters in broilers on Day 21 and 42 are presented in Table 3. On Day 21, serum SOD activity and T-AOC were not affected by dietary treatments. However, birds fed WB had greater ($p < 0.05$) serum GSH-Px activity and tended ($p = 0.07$) to have lower serum MDA concentration when compared with CON. On Day 42, none of the dietary treatments led to remarkable changes in serum GSH-Px activity and T-AOC. However, serum SOD activity was greater ($p < 0.05$) in WB than in CON. In addition, the lower serum MDA concentration was observed in birds fed WB compared with those fed CON ($p < 0.05$).

Table 3. Effects of wheat bran on serum antioxidant status in broilers on Day 21 and 42.

Item	**CON**	**WB**	**SEM**	***p*-value**
Day 21				
Total antioxidant capacity, U/mL	1.14	1.59	0.24	0.26
Superoxide dismutase, U/mL	32.10	32.51	1.07	0.81
Glutathione peroxidase, µmol/L	31.55	36.33	0.67	0.01
Malondialdehyde, nmol/L	7.45	6.65	0.20	0.06
Day 42				
Total antioxidant capacity, U/mL	2.99	3.24	0.58	0.79
Superoxide dismutase, U/mL	38.62	47.69	1.59	< 0.01
Glutathione peroxidase, µmol/L	31.92	37.90	2.22	0.21
Malondialdehyde, nmol/L	7.08	4.87	0.52	0.02

CON, control diet; WB, 30 g/kg wheat bran; SEM, standard error of mean.

5. Gastrointestinal Development

The effects of WB supplementation on gastrointestinal development in broilers on Day 21 and 42 are presented in Table 4. The relative weight of proventriculus and small intestine, as well as the relative length of small intestine did not significantly vary with any of the dietary treatments on Day 21 or 42. However, birds fed WB had a greater ($p < 0.05$) relative weight of gizzard than those fed CON on both Day 21 and 42.

Table 4. Effects of wheat bran on gastrointestinal development in broilers on Day 21 and 42.

Item	CON	WB	SEM	*p*-Value
Day 21				
Relative weight of proventriculus, g/kg BW	6.53	7.04	0.25	0.18
Relative weight of gizzard, g/kg BW	19.76	24.78	0.70	< 0.01
Relative weight of small intestine, g/kg BW	34.95	39.17	1.46	0.06
Relative length of small intestine, cm/kg BW	189.39	202.37	9.41	0.38
Day 42				
Relative weight of proventriculus, g/kg BW	3.20	3.63	0.20	0.17
Relative weight of gizzard, g/kg BW	11.33	12.70	0.25	0.01
Relative weight of small intestine, g/kg BW	26.61	27.63	1.30	0.62
Relative length of small intestine, cm/kg BW	61.02	63.98	1.81	0.39

CON, control diet; WB, 30 g/kg wheat bran diet; SEM, standard error of mean; BW, body weight.

6. Digestive Enzyme Activities

The effects of WB supplementation on digestive enzyme activities in pancreas and jejunal mucosa of broilers on Day 21 and 42 are shown in Table 5. On Day 21, supplementation of WB increased ($p < 0.05$) activities of amylase and trypsin in pancreas and jejunal mucosa when compared with CON. No differences were found in lipase activity in pancreas and jejunal mucosa among treatments. On Day 42, birds fed WB also had greater ($p < 0.05$) amylase activity in pancreas and jejunal mucosa than those fed CON. Moreover, birds fed WB tended ($p = 0.09$) to have greater trypsin activity in pancreas than those fed CON. Dietary treatments did not affect the activities of lipase and trypsin in jejunal mucosa.

Table 5. Effects of wheat bran on digestive enzyme activities in pancreas and jejunum of broilers on Day 21 and 42.

Item	CON	WB	SEM	*p*-Value
Day 21				
Pancreas				
Amylase, U/g	185.09	227.03	10.94	0.02

Lipase, U/mg	43.30	47.94	2.29	0.21
Trypsin, U/mg	20.73	26.52	1.35	0.04
Jejunum				
Amylase, U/g	166.22	209.91	7.51	< 0.01
Lipase, U/mg	13.40	15.43	1.24	0.28
Trypsin, U/mg	4.40	5.63	0.30	0.02
Day 42				
Pancreas				
Amylase, U/g	234.37	275.29	8.91	0.01
Lipase, U/mg	56.38	65.16	3.79	0.16
Trypsin, U/mg	24.63	33.02	3.06	0.09
Jejunum				
Amylase, U/g	190.63	233.16	11.30	0.02
Lipase, U/mg	15.60	16.96	0.54	0.11
Trypsin, U/mg	6.32	7.41	0.50	0.16

CON, control diet; WB, 30 g/kg wheat bran diet; SEM, standard error of mean.

7. Intestinal Morphology

The effects of WB supplementation on intestinal morphology in broilers on Day 42 are shown in Table 6. In duodenum, there was no difference in the villus height, crypt depth, and villus height to crypt depth ratio among treatments. However, in jejunum, compared with CON, the WB increased ($p < 0.05$) villus height and villus height to crypt depth ratio. A similar pattern was also observed in ileum. The supplementation of WB increased ($p < 0.05$) villus height and villus height to crypt depth ratio when compared with CON.

Table 6. Effects of wheat bran on intestinal morphology in broilers on Day 42.

Item	**CON**	**WB**	**SEM**	***p*-Value**
Duodenum				
Villus height, µm	2080	2242	65.88	0.12
Crypt depth, µm	263	263	17.34	0.97

Villus height to crypt depth ratio	8.17	8.65	0.61	0.60
Jejunum				
Villus height, µm	1333	1610	50.17	0.01
Crypt depth, µm	248	236	16.47	0.60
Villus height to crypt depth ratio	5.50	6.95	0.41	0.03
Ileum				
Villus height, µm	1121	1388	62.32	0.01
Crypt depth, µm	165	164	12.41	0.92
Villus height to crypt depth ratio	6.86	8.64	0.40	0.01

CON, control diet; WB, 30 g/kg wheat bran diet; SEM, standard error of mean.

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