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Effects of dietary fiber on growth performance, fecal ammonia nitrogen, and gastrointestinal tract pH in broilers from 1 to 21 days of age

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Abstract

The present study was conducted with starter chickens (1 to 21 days of age) to investigate the effects of dietary fiber on growth performance, fecal ammonia nitrogen, and gastrointestinal tract pH. A total of 420 one-day-old Ross 308 chicks were divided into five groups with seven replicates of twelve chicks each. The experimental diets, which contained different sources and levels of fiber, were as follows: none (control); 2.5% rice hulls (2.5% RH); 2.5% soybean hulls (2.5% SH); 5.0% rice hulls (5.0% RH), and 5.0% soybean hulls (5.0% SH). All diets were formulated to be isocaloric and isonitrogenous. Chickens were placed in cage under continuous lighting, and had *ad libitum* access to diet and water from 1 to 21 days. The body weight gain of broilers in the control, 2.5% RH, 5.0% RH, and 5.0% SH groups were significantly higher than those of the 2.5% SH group ($p < 0.05$). Fecal ammonia nitrogen of broilers decreased in the 2.5% RH and 5.0% SH groups ($p < 0.01$). Fiber inclusion reduced gizzard pH ($p < 0.05$) but did not alter duodenum, jejunum, and ileum ($p > 0.05$). These findings suggest that the inclusion of different fiber sources in the diet of young broilers improves gizzard pH, resulting in decreased levels of fecal ammonia nitrogen.

Keywords: Rice hull, soybean hull, young broilers

Introduction

At present, increasing levels of livestock production are causing many environmental problems. Animal manure from livestock production can be a cause of ammonia (NH_3) emission, which impacts both animal and human health. Nitrogen (N) content in feces containing undigested dietary N, endogenous N, and microbial N (Jha & Berrocoso, 2016) can lead to NH_3 emission to the atmosphere and later converted to nitrate during storage (Ferket et al. 2002). NH_3 emissions contribute to acid rain and nitrogen deposition that damage natural ecosystems. Many researchers have used the diet composition improving method to decrease manure pollutants. Interestingly, dietary fiber has been shown to lower NH_3 emission from pigs (Canh et al. 1997; Shriver et al. 2003) and laying hens (Roberts et al. 2007).

Fiber is naturally present in plant-based feed ingredients, and constitutes an important component in poultry diets. Historically, dietary fiber has been considered a dietary diluent, with a negative impact on voluntary feed intake, growth performance, and carcass quality (Janssen & Carré, 1985; Mateos et al. 2002; Rougière & Carré, 2010). Some studies, however, have shown that fibrous material in moderate levels enhances growth performance of broiler chicks (Jiménez-Moreno et al. 2009; González-Alvarado et al. 2010). Other research has reported on the favorable effects of a moderate dosage of insoluble fiber in the diet. Findings have shown that the inclusion of dietary fiber may improve HCl (Jiménez-Moreno et al. 2010), bile acids, enzyme secretion (Hetland et al. 2003), and better gizzard function (Hetland et al. 2005), all of which contribute to improved nutrient digestibility and performance traits of broilers (Jiménez-Moreno et al. 2009).

The effects of dietary fiber on gastrointestinal tract (GIT) physiology, microbiota growth, and poultry behaviour differ according to the source of fiber and the nutritive characteristics of the diet (Shakouri et al. 2006; Saki et al. 2011). For example, insoluble, highly lignified fiber might have different effects on the GIT than does soluble, low-lignin fiber. In this respect, insoluble fiber sources, such as rice hulls (RH), increase retention time in the upper part of the GIT, thus stimulating gizzard development and endogenous enzyme production. The result is improved digestibility of starch, lipids, and other dietary components (Mateos et al. 2002; Hetland et al. 2003; Hetland et al. 2005). The physical structure of the feed might also affect the response of birds to the inclusion of fiber in their diet. The digestive system of newly hatched chicks is not completely adapted to the feed digestion and absorption. As such, during this period, the development of the gastrointestinal tract is stimulated by feed consumption (Longo et al. 2007). In similarly report, feed intake and intestinal development were controlled in the young chicks to meet the nutrient requirements (Uni et al. 1999). The nutritional and physiological effects must be considered, however, these effects caused by the amount of cell wall and their chemical composition, as well as structure.

Therefore the aim of this experiment was to investigate the effects of dietary fiber on growth performance, fecal ammonia nitrogen, and gastrointestinal tract pH in broilers from 1 to 21 days of age.

Materials and methods

Animals and diets

A total of 420 one-day-old broiler chicks (ROSS 308) were obtained from a commercial hatchery. Chicks were individually weighed and randomly divided into five groups of chicks with similar mean body weight, each with seven replicates of twelve chicks. They were placed in cages under continuous lighting and had *ad libitum* access to water from 1 to 21 days.

Starter (1-21 day) diets were used as the basal diets in this experiment. The RH and SH were ground through a hammer mill with a 2-mm screen. The experimental diets containing different levels of fiber sources were as follows: none (control); 2.5% rice hulls (2.5% RH); 2.5% soybean hulls (2.5% SH); 5.0% rice hulls (5.0% RH), and 5.0% soybean hulls (5.0% SH). Experimental diets were formulated according to the nutritional recommendations of the NRC (National Research Council, 1994) for broilers (**Table 1**). Body weight and feed consumption of chicks were recorded on a group basis, and feed intake (FI), body weight gain (BWG), and feed conversion ratio (FCR) were calculated from these data at the end of experimental period.

The experiment was conducted in accordance with the guidelines and rules for animal experiments of the Faculty of Animal Science and Agricultural Technology, Silpakorn University, Thailand.

Table 1 Feed compositions and calculated nutrient value of experimental diets (0 - 21 days of age).

Item	Control	2.5% RH	2.5% SH	5.0% RH	5.0% SH
Ingredient (%)					
Corn	43.10	38.72	39.32	34.35	35.55
Soybean meal	40.10	40.68	40.38	41.26	40.67
Soybean oil	7.12	8.41	8.10	9.71	9.09
Rice bran	5.00	5.00	5.00	5.00	5.00
Rice hull	-	2.50	-	5.00	-
Soybean hull	-	-	2.50	-	5.00
Monocalcium phosphate	2.09	2.10	2.10	2.11	2.11
Limestone	1.22	1.21	1.22	1.21	1.21
Premix*	0.60	0.60	0.60	0.60	0.60
Salt	0.42	0.42	0.42	0.42	0.42
D,L-methionine	0.17	0.17	0.17	0.18	0.18
Choline Chloride	0.07	0.07	0.07	0.07	0.07
L-lysine	0.05	0.04	0.04	0.03	0.03
L-threonine	0.02	0.02	0.02	0.02	0.02
Calculated analysis (%)					
Crude protein	23	23	23	23	23
Metabolizable energy (kcal/kg)	3,200	3,200	3,200	3,200	3,200
Crude fiber	3.20	4.06	3.96	4.92	4.71
Crude fat	9.70	11.06	10.83	12.32	11.87
Ash	5.90	5.93	6.02	5.91	6.09
Calcium	0.90	0.90	0.90	0.90	0.90
Available phosphorus	0.50	0.50	0.50	0.50	0.50
Available lysine	1.15	1.15	1.15	1.15	1.15
Available methionine	0.47	0.47	0.47	0.47	0.47

RH = rice hulls; SH = soybean hulls
*Premix included the following (per kg of diet): retinol, 8,250 IU; cholecalciferol, 2,750 IU; tocopherol, 17.9 IU; menadione, 1.1 mg; thiamine, 1.4 mg; riboflavin, 5.5 mg; pyridoxine, 1.1 mg; cyanocobalamin, 12 μg; niacin, 41.3 mg; pantothenic acid, 11 mg; biotin, 41 μg; folic acid, 1.4 mg; manganese, 125 mg; iron, 282 mg; copper, 27.5 mg; zinc, 275 mg; iodine, 844 μg; selenium, 250 μg.

Sample collection for ammonia nitrogen

The ammonia nitrogen was measured during the last week of period. The birds were randomly allotted into the five dietary treatment groups (four birds/group) of similar mean body weight and then moved to the individual cages. The feces were subsequently collected over three consecutive 24-h periods on plastic trays within each cage. The feces from each of the 24-h periods were polled within group and stored at -20°C until analysis. Fecal ammonia nitrogen was analyzed by the method of AOAC (Association of Official Analytical Chemists, 2000).

Measurement for pH of gastrointestinal tract (GIT)

At the end of experimental period, seven birds from each group were weighed individually and killed by decapitation. The digestive organs were carefully removed, and the contents of gizzard, duodenum, jejunum, and ileum were collected individually. Samples of digesta of each bird were then diluted 1:3 (w/w) with deionized distilled water and stirrer-mixed. The pH was measured using a digital pH meter (AD12, Adwa Instruments, Hungary).

Statistical analysis

All data were statistically analyzed using one-way analysis of variance (ANOVA) in the SPSS statistical software package (version 19.0; IBM Corp. Armonk, NY, US). Significant differences among the treatments were determined with Duncan's multiple range test. Statistical significance was set at $p < 0.05$.

Results

The broiler performance results are presented in **Table 2**. No significant differences were found in feed intake and feed conversion ratio among the dietary treatment groups. Body weight gain of broilers in the control, 2.5% RH, 5.0% RH, and 5.0% SH groups, however, was significantly higher than of those of the 2.5% SH group ($p < 0.05$).

Table 2 Effects of type of dietary fiber on growth performance (mean ± SE; n = 7) in 21 days old broiler chickens.

Items	Treatment					SEM	P-value
	Control	2.5% RH	2.5% SH	5.0% RH	5.0% SH		
Feed intake (g)	1190.00	1161.42	1100.83	1170.85	1144.28	20.50	0.75
Body weight gain (g)	852.62^{a}	827.37^{a}	747.00^{b}	831.27^{a}	805.11^{a}	14.62	0.01
Feed conversion ratio	1.39	1.40	1.48	1.40	1.42	0.02	0.89

^{ab}Values with different superscripts in the same row are significantly different ($p < 0.05$).

Table 3 shows the results of the fecal ammonia nitrogen and pH of gastrointestinal tract of the chicks fed the experimental diets. The fecal ammonia nitrogen of broilers decreased in the 2.5% RH and 5.0% SH groups ($p < 0.05$). The gizzard pH was lower in broilers fed the 2.5% SH diet than in those fed the control diet ($p < 0.05$). The treatments, however, had no effect on the pH of duodenum and jejunum ($p > 0.05$). Moreover, a trend of improved ileum pH ($p = 0.072$) was found following inclusion of fiber.

Table 3 Effects of type of dietary fiber on fecal ammonia nitrogen (mean ± SE; n = 4) and pH of the gastrointestinal tracts (GIT) in in 21 days old broiler chickens (mean ± SE; n = 7).

Items	Dietary fiber (%)					SEM	P-value
	Control	2.5% RH	2.5% SH	5.0% RH	5.0% SH		
Fecal ammonia nitrogen (mg/g)	0.93^{a}	0.13^{b}	0.58^{ab}	0.72^{a}	0.11^{b}	0.08	0.001
pH of GIT							
Gizzard	3.90^{a}	3.45^{ab}	2.96^{b}	3.37^{ab}	3.44^{ab}	0.09	0.018
Duodenum	5.97	6.10	6.17	6.17	6.13	0.05	0.742
Jejunum	5.87	5.95	6.04	6.19	5.83	0.05	0.240
Ileum	5.89	6.41	6.33	6.65	6.09	0.09	0.072

^{ab}Values with different superscripts in the same row are significantly different ($p < 0.05$).

Discussion

Numerous studies have reported on the strong detrimental effect of increases in dietary fiber on broiler growth performance (Janssen & Carré, 1985; Sklan et al. 2003). Additionally, inclusion of soybean hull and rice hull in laying hen diets was reported to decrease yolk pigmentation and egg specific gravity (Praes et al. 2014). In this present study, no differences were observed in the feed intake and feed conversion ratio of experimental chickens. Body weight gain, however, was lower for broilers fed the 2.5% SH diet than for those fed the control, 2.5% RH, 5% RH, and 5% SH diets ($p < 0.05$). In a study of young turkeys (1 to 4 wk of age), it has been reported that turkeys fed 3% soybean hull had lower body weight than those fed 6 or 9% soybean hull (Sklan et al. 2003). Contrary to these findings, the inclusion of oat hull, soy hull, and sugar beet pulp improved productive performance of broilers (González-Alvarado et al. 2010; Jiménez-Moreno et al. 2010). The latter finding could be partly explained by the dietary insoluble fiber increased rate of feed passage, resulting in increased feed intake and, hence, greater growth performance (Montagne et al. 2003; Hetland & Svihus, 2001), a situation that was not observed in the present study. The abovementioned discrepancies might be due to the differences in the physicochemical characteristics of the fiber sources and supplementing levels, as well as the age of the bird. Dietary treatments had no effect on the feed intake and feed conversion ratio of broilers in this experiment.

The present study demonstrated that the dietary RH and SH reduced the gizzard pH in broiler chickens. As previously noted, the lower gizzard pH might be induced by including fiber in the diet, resulting in the longer retention time of the fiber particles in the gizzard (Jiménez-Moreno et al. 2009). The decline may have been caused by the insoluble fiber contents of RH and SH in the experimental diets, which might have stimulated hydrochloric acid secretion. The results of other studies indicate that the pH of the gastrointestinal tract correlates with dietary fiber (González-Alvarado et al. 2008). This observation is supported by the findings of (Duke, 1986), who found that the ingested feed in the gizzard induces the secretion of hydrochloric acid in the proventriculus, causing a reduction in pH in this organ. Therefore, the reduced gizzard pH of chickens observed in the present study can be considered beneficial.

Generally, nitrogen excretion in feces consists of undigested dietary nitrogen and endogenous nitrogen, mainly as amino acids and bacterial protein. In poultry feces, the volatilization of ammonia has been attributed to microbial decomposition of nitrogenous compounds, mainly uric acid (Li et al. 2006). Therefore, nitrogen content was determined from broiler feces. Of the fiber inclusion, 2.5% RH and 5.0% SH affected the fecal ammonia nitrogen. This finding was anticipated because dietary fiber extends the fermentation of microbes in the large intestine, and, therefore, confirms the suitability of that fiber diets to lower NH_3 emission from the manure (Roberts et al. 2007). Similar results were reported in a study by Kirchgessner et al. (1994), the inclusion of fiber in pig diets affected growth of bacterial populations in the large intestine, resulting in decreased NH_3 emission. The fecal ammonia nitrogen decreased, a finding that is consistent with data reported by González-Alvarado et al. (2007), who found that the gizzard pH has an important role in nutrient utilization. As a result, decreased gizzard pH leading to improved nutrient utilization might result in decreased fecal ammonia nitrogen. Further studies are needed, however, to improve our knowledge of the effect of dietary fiber on grower broilers (22 to 42 days of age).

Conclusions

Results of the present study indicate that the inclusion of different fiber sources in the diet improves gizzard pH with no effect on the pH of duodenum, jejunum and ileum. The fecal ammonia nitrogen can be reduced by dietary fiber in the diets. The beneficial effects of fiber inclusion on fecal ammonia nitrogen might be related to the gizzard pH. These findings suggest that the inclusion of different fiber sources in the diet enhances gizzard pH, thus improving fecal ammonia nitrogen in young broilers.

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