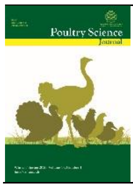

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At what Age Can Broiler Chickens Achieve the Best Performance Using Soluble and Insoluble Fiber?

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Abstract

The type of fiber utilized in broiler diets at different ages has not been extensively studied, and the data supporting this theory are scare. A total of 160 hatched Ross 308 male broiler chicks were randomly distributed among four dietary groups, each with four replicates and ten chicks per replicate. The treatment groups were as follows: basal diet without any additives until the finisher period (Control); diet containing 3% rice hull (RH) in the grower period and 3% sugar beet pulp (SBP) in the finisher period (RG-SF); diet containing 3% SBP in the grower period and 3% RH in the finisher period (SG-RF); and diet containing 1.5% RH and 1.5% SBP in the grower and finisher periods (RS-GF). The findings indicated a significant improvement in the feed conversion ratio of broilers in the RG-SF group from days 11 to 24, as well as in body weight gain in the RG-SF and RS-GF groups from days 11 to 42 ($P< 0.05$). The proventriculus and gizzard percentage in the SG-RF group increased at 24 and 42 days of age, respectively ($P< 0.05$). At 42 days of age, the greatest percentage of thigh and intestinal weights was observed in the RG-SF group ($P< 0.05$). The small intestinal relative length decreased at 24 and 42 days of age in the RS-GF group compared to the control group ($P< 0.05$). In conclusion, our results showed that the 3% RH and 3% SBP in broiler diets at grower and finisher periods, respectively (RG-SF group), and supplementation with 1.5% RH and 1.5% SBP in both grower and finisher periods (RS-GF group) could improve broiler performance.

Introduction

Impact of dietary fiber on broiler performance is related to many factors such as fiber levels, fiber source (hydration capacity, particle size, and solubility), age and species of the bird (Mateos *et al*., 2012; Berrocoso *et al*., 2020). Diets with moderate inclusion (3.0%) may alter the composition of bacterial populations in broiler chickens, which could lead to improved growth performance compared to control diets (Shang *et al*., 2020). Dietary fiber typically enhances gizzard activity, resulting in more effective feed digestion (Svihus, 2014).

Dietary fiber supplementation may aid in protecting the health of both the large and small intestines via improving mucosal structure, as well as enhancing the variety and abundance of beneficial bacteria in the intestine (Jha and Mishra, 2021). Sadeghi *et al*. (2015) reported that the intestinal length of the ileum increased by supplementation of 3% sugar beet pulp (SBP) at 42 days of age. A prebiotic fiber source like mannan-oligosaccharides, fructo-oligosaccharides, inulin, and xylo-oligosaccharides was shown to enhance beneficial intestinal microbiota, reduce the pathogenic bacteria and enhance *Lactobacillus* spp in the cecum (Teng and Kim, 2018; Xia *et al*., 2019). Sources of insoluble fiber are typically not easily fermented and have a limited capacity to alter the gut microbial environment (Tejeda and Kim, 2021). In contrast, small amounts of soluble fiber that are highly fermentable can beneficially modulate the microbial composition of the gastrointestinal tract (Tejeda and

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Kim, 2021; Rybicka *et al*., 2024). Gonzalez-Alvarado *et al*. (2007) revealed that increasing the fiber (insoluble) composition of the diet significantly improved body weight gain in broiler chicks from 14 to 21 days of age but had no significant effect from 4 to 14 days of age. In 15-day-old broiler chicks, total non-starch polysaccharides and oligosaccharides digestibility is lower than that of adult cockerels, which is related to their intestinal absorption efficiency (Carré *et al*., 1995). The age of the bird can also affect the digestion of fibers.

Therefore, poultry's response to fiber in the diet can be different depending on the type of fiber used at different ages (Jha and Mishra, 2021). This study was whether the inclusion of insoluble (rice hulls) and soluble (sugar beet pulp) fibers at different ages can affect the performance of the broiler. Therefore, the present research aimed to determine the effects of two different types of fiber (rice hulls and sugar beet pulp) on broiler growth performance and carcass characteristics at different ages.

Materials and Methods

This study was performed at the Department of Animal Science, Sari University of Agricultural Sciences and Natural Resources (Sari, Iran). All experimental procedures involving animals were conducted in accordance with the ethical standards approved by the Ethics Committee of Sari University of Agricultural Sciences and Natural Resources, Sari, Iran.

Table 1: Ingredients and chemical composition (% as-fed basis) of the experimental diets at different ages (dry matter basis, %)

Item	Starter (1 to 10 d)	Grower (11 to 24 d)				Finisher (25 to 42 d)			
		CON[1]	RH[2]	BP[3]	RH/BP[4]	CON	RH	BP	RH/BP
Ingredients (%)									
Corn grain	51.02	54.42	52.16	52.71	52.43	59.21	56.94	57.50	57.22
Soybean meal	40.71	35.35	36.08	35.54	35.81	30.24	30.97	30.44	30.71
Sand	-	3.00	-	-	-	3.00	-	-	-
Rice hull[5]	-	-	3.00	-	1.50	-	3.00	-	1.50
Sugar beet pulp[6]	-	-	-	3.00	1.50	-	-	3.00	1.50
Soybean oil	3.61	2.95	4.56	4.46	4.51	3.58	5.18	5.08	5.13
DCP	1.76	1.57	1.58	1.59	1.58	1.41	1.42	1.43	1.42
$CaCO_3$	1.20	1.11	1.03	1.10	1.07	1.02	0.95	1.01	0.98
Salt	0.34	0.34	0.34	0.34	0.34	0.34	0.35	0.35	0.35
Mineral premix[7]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin premix[8]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
L-Lysine HCL	0.34	0.31	0.29	0.30	0.30	0.30	0.29	0.29	0.29
L-Threonine	0.14	0.12	0.12	0.12	0.12	0.10	0.09	0.09	0.09
DL-Methionine	0.38	0.33	0.34	0.34	0.34	0.30	0.31	0.31	0.31
Chemical composition									
Metabolizable energy (Kcal/kg)	2910	2945	2945	2945	2945	3040	3040	3040	3040
Crude protein (%)	22.3	20.4	20.4	20.4	20.4	18.5	18.5	18.5	18.5
Crude fiber (%)	3.97	3.73	4.99	4.25	4.62	3.48	4.74	4.00	4.37
Calcium (%)	0.96	0.87	0.87	0.87	0.87	0.79	0.79	0.79	0.79
Available phosphorous(%)	0.48	0.43	0.43	0.43	0.43	0.39	0.39	0.39	0.39
Sodium (%)	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
DCAB (meq/kg)[9]	247	224	224	221	223	201	201	199	200
Methionine (%)	0.68	0.62	0.62	0.62	0.62	0.56	0.56	0.56	0.56
Lysine (%)	1.44	1.29	1.29	1.29	1.29	1.16	1.16	1.16	1.16
Methionine + Cystine (%)	1.08	0.99	0.99	0.99	0.99	0.91	0.91	0.91	0.91
Threonine (%)	0.97	0.88	0.88	0.88	0.88	0.78	0.78	0.78	0.78

[1] Control, basal diet.
[2] RH, basal diet supplemented with rice hulls;
[3] BP, basal diet supplemented with sugar beet pulp;
[4] RH/BP, basal diet supplemented with a combination of rice hulls and sugar beet pulp.
[5] Rice hull chemical composition, %: dry matter, 91.80; crude protein, 3.70; ether extract, 3.60; neutral detergent fiber, 67.80; acid detergent fiber, 51.70.
[6] Sugar beet pulp chemical composition, %: dry matter, 85.40; crude protein, 10.70; ether extract, 4.59; neutral detergent fiber, 49.10; acid detergent fiber, 20.10.
[7] Mineral premix per kg of diet: Mn ($MnSO_4.H_2O$, 32.49% Mn), 75 mg; I (KI, 58% I), 1 mg; Cu ($CuSO_4.5H_2O$), 8 mg; Fe ($FeSO_4.7H_2O$, 20.09% Fe), 50 mg; Se ($NaSeO_3$, 45.56% Se), 0.2 mg.
[8] Vitamin premix per kg of diet: vitamin A (retinol), 8,000 IU; vitamin D3 (cholecalciferol), 2,000 IU; vitamin E (tocopheryl acetate), 12.5 IU; vitamin K3, 2 mg; vitamin B1; 1.8 mg; vitamin B2, 6 mg; B5, 10 mg; B6, 2.8 mg; niacin, 40 mg; biotin, 0.1 mg; folic acid, 1 mg.
[9] Dietary cation-anion balance (Na + K − Cl).

Birds, housing and treatments

This study was conducted on 160 one-day-old male Ross 308 broilers with an average weight of 39 ± 3.12 g. From day 1 to 10, chicks were reared on the floor, under standard temperature and lighting programs recommended for Ross 308 broilers. The chicks were randomly assigned to four treatments, each with four replicates of 10 birds. Experimental treatments included: a diet without rice hull (RH) and SBP addition for the entire experimental period (control); diet containing 3% rice hull in grower period and 3% sugar beet pulp in finisher period (RG-SF); diet containing 3% sugar beet pulp in grower period and 3% rice hull in finisher period (SG-RF); diet containing 1.5% rice hull and 1.5% sugar beet pulp in grower period and finisher period (RS-GF). The diets were adjusted based on three periods of starter (1 to 10 days of age), grower (11 to 24 days of age), and finisher (25 to 42 days of age). Ingredients and chemical composition of experimental diets are shown in Table 1. Chicks had *ad libitum* access to feed and water, and the diets were prepared in mash form throughout the experiment. During the first 3 days, the room temperature was set at 32 °C, which gradually decreased afterwards until it was fixed at 22 to 24 °C in 42 d.

Growth performance

Daily weight gain (DWG), feed intake (FI), and feed conversion ratio (FCR) were recorded in three experimental periods of grower (11 to 24 d of age), finisher (25 to 42 d of age), and whole period (11 to 42 d). The FCR in each phase was calculated by dividing the FI by BWG (body weight gain).

Carcass characteristics

At the end of each period (24 and 42 days of age), following a period of six hours of fasting (Li *et al*., 2023), two chickens per pen, with a body weight close to the average pen weight, had been selected and slaughtered to assess the carcass yield and organs weight (thigh, gizzard, heart, liver, bursa of Fabricius, spleen, pancreas, proventriculus, and intestine). The results were presented as percent of live body weight.

Relative intestinal length

The length of the small intestine in slaughtered birds was measured and calculated as relative intestinal length (cm/kg) by dividing the small intestinal length (cm) by live body weight (kg).

Statistical analysis

The experimental data were analyzed using the General Linear Model (GLM) procedure in SAS software (SAS, 2002), based on a completely randomized design. Differences between means were assessed through Duncan's multiple range test at a significance level of α = 0.05.

Results

Table 2: Effect of experimental treatments on the growth performance of broilers at different ages

Items[3]	Treatments[1]				SEM[2]	P-value
	Control	RG-SF	SG-RF	RS-GF		
11-24 d						
FI (g/bird)	1157[c]	1300[b]	1329[ab]	1359[a]	17.646	<0.0001
BWG (g/bird)	674[c]	822[a]	776[ab]	733[bc]	24.034	0.0058
FCR (g/g)	1.71[b]	1.58[c]	1.71[b]	1.85[a]	0.036	0.0024
25-42 d						
FI (g/bird)	2881[a]	2799[a]	2508[b]	2877[a]	33.276	<0.0001
BWG (g/bird)	1353[b]	1424[b]	1324[b]	1592[a]	38.744	0.0017
FCR (g/g)	2.13[a]	1.97[ab]	1.90[b]	1.80[b]	0.065	0.0280
11-42 d						
FI (g/bird)	4039[b]	4100[b]	3849[c]	4236[a]	41.687	0.0002
BWG (g/bird)	2028[b]	2247[a]	2100[b]	2325[a]	37.323	0.0004
FCR (g/g)	1.99[a]	1.82[b]	1.83[b]	1.82[b]	0.036	0.0176

[1]Dietary treatments: Control: basal diet; RG-SF: Diet containing 3% rice hull in grower period (11-24 d) and 3% sugar beet pulp in finisher period (25-42 d); SG-RF: Diet containing 3% sugar beet pulp in grower period (11-24 d) and 3% rice hull in finisher period (25-42 d); RS-GF: Diet containing 1.5% rice hull and 1.5% sugar beet pulp in grower period (11-24 d) and finisher period (25-42 d).

Different letters in each row have a significant difference ($P< 0.05$).

[2] SEM, standard error of the means.

[3] Items: FI, feed intake; BWG, body weight gain; FCR, feed conversion ratio.

Growth performance

The impact of experimental treatments on broiler growth performance is presented in Table 2. At 11–24 days of age, the control group had the lowest FI when compared to the other groups ($P< 0.05$). In comparison to the other groups, the birds in the SG-RF group exhibited the lowest ($P< 0.05$) FI for two periods (25-42 and 11-42 days of age). When comparing the control group to the

RG-SF and SG-RF groups, the BWG of the control group was the lowest from 11 to 24 days (*P*< *0.05*). At 25 to 42 days of age, the broiler in the RS-GF group had a significantly higher BWG than the other groups (*P*< *0.05*). In RG-SF and RS-GF groups, BWG was greater (*P*< *0.05*) when compared to the control and SG-RF groups at 11-42 days of age. When compared to other groups, broilers fed RG-SF diets had an improved feed conversion ratio (FCR) from 11 to 24 days (*P*< *0.05*). Comparing the control group to the SG-RF and RS-GF groups, the control group had the highest FCR from 25 to 42 days (*P*< *0.05*). At 11–42 days of age, broilers in the control group showed a considerably greater FCR (*P*< *0.05*) than the other groups.

Carcass characteristics

Tables 3 and 4 display carcass characteristics at different ages. At 24 days of age, the SG-RF group had a significantly higher proventriculus percentage than the other groups (*P*< *0.05*). The lowest thigh percentage at the age of 42 days was observed (*P*< *0.05*) in broilers fed with the control diet. The gizzard percentage decreased in the control and RG-SF groups in comparison to the SG-RF and RS-GF groups at 42 days of age (*P*< *0.05*). At 42 days of age, the percentage of pancreas and intestinal weight significantly decreased in the control group in comparison to the RG-SF and SG-RF groups. Comparing the control group to the RG-SF and SG-RF groups, the control group had the highest percentage of liver weight from 42 days of age (*P*<*0.05*).

Table 3: The effect of experimental treatments on the weight of different parts of the carcass at 24 days of age (% of live body weight)

Items (%)	Treatments[1]				SEM[2]	P-value
	Control	RG-SF	SG-RF	RS-GF		
Carcass	57.23	58.36	57.67	55.91	0.701	0.2164
Gizzard	4.296	4.997	5.098	4.361	0.214	0.0795
Bursa of Fabricius	0.220	0.237	0.303	0.201	0.030	0.2672
Spleen	0.110	0.085	0.094	0.113	0.008	0.1691
Heart	0.880	0.819	0.726	0.713	0.059	0.2141
Proventriculus	0.667^{b}	0.621^{b}	0.894^{a}	0.692^{b}	0.032	0.0029
Liver	3.496	3.172	3.070	3.308	0.118	0.1655
Small intestine	9.662	10.32	11.10	11.10	0.685	0.4732

[1]Dietary treatments: Control: basal diet; RG-SF: Diet containing 3% rice hull in grower period (11-24 d) and 3% sugar beet pulp in finisher period (25-42 d); SG-RF: Diet containing 3% sugar beet pulp in grower period (11-24 d) and 3% rice hull in finisher period (25-42 d); RS-GF: Diet containing 1.5% rice hull and 1.5% sugar beet pulp in grower period (11-24 d) and finisher period (25-42 d).
Different letters in each row have a significant difference (*P*< 0.05).
[2] SEM, standard error of the means.

Table 4: The effect of experimental treatments on the weight of different parts of the carcass at 42 days of age (% of live body weight)

Items (%)	Treatments[1]				SEM[2]	p-value
	Control	RG-SF	SG-RF	RS-GF		
Carcass	73.07	73.68	74.88	74.74	0.502	0.0811
Breast	26.15	26.29	27.66	26.46	0.508	0.2755
Thigh	17.80^{c}	19.50^{a}	18.47^{b}	18.68^{b}	0.140	0.0020
Gizzard	2.500^{b}	2.630^{b}	3.080^{a}	3.020^{a}	0.075	0.0037
Heart	0.682	0.625	0.584	0.582	0.045	0.4260
Liver	3.011^{a}	2.633^{bc}	2.367^{c}	2.895^{ab}	0.088	0.0011
Bursa of Fabricius	0.156	0.193	0.171	0.186	0.023	0.7377
Spleen	0.114	0.115	0.099	0.088	0.006	0.0639
Pancreas	0.192^{b}	0.237^{a}	0.226^{a}	0.208^{ab}	0.007	0.0431
Proventriculus	0.384	0.379	0.341	0.379	0.018	0.4801
Small intestine	5.591^{c}	7.688^{a}	7.010^{ab}	6.446^{bc}	0.229	0.0031

[1]Dietary treatments: Control: basal diet; RG-SF: Diet containing 3% rice hull in grower period (11-24 d) and 3% sugar beet pulp in finisher period (25-42 d); SG-RF: Diet containing 3% sugar beet pulp in grower period (11-24 d) and 3% rice hull in finisher period (25-42 d); RS-GF: Diet containing 1.5% rice hull and 1.5% sugar beet pulp in grower period (11-24 d) and finisher period (25-42 d).
Different letters in each row have a significant difference (*P*< 0.05).
[2] SEM, standard error of the means.

Relative intestinal length

As shown in Figure 1, the broiler in the RS-GF group had a lower relative intestinal length than the control and SG-RF groups at 24 days of age (*P< 0.05*). However, at 42 days of age, the relative intestinal length was significantly decreased in the RS-GF group in comparison to the control and RG-SF groups.

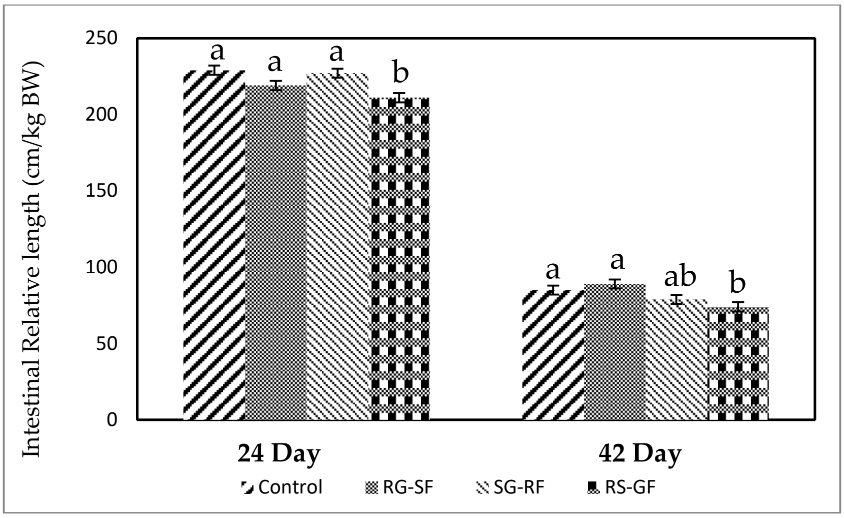

Figure 1. Effect of experimental treatments on the small intestinal relative length of broiler at different ages. Values are means ± SEM, with four replicates. Different letters denote a significant difference (*P*< 0.05). Abbreviations: Control: basal diet; RG-SF: Diet containing 3% rice hull in grower period (11-24 d) and 3% sugar beet pulp in finisher period (25-42 d); SG-RF: Diet containing 3% sugar beet pulp in grower period (11-24 d) and 3% rice hull in finisher period (25-42 d); RS-GF: Diet containing 1.5% rice hull and 1.5% sugar beet pulp in grower period (11-24 d) and finisher period (25-42 d).

Discussion

Growth performance

The effect of dietary fiber on broiler performance depends on various factors such as fiber sources, age of birds during rearing and composition of the diet (González-Alvarado *et al*., 2010; Jha and Mishra, 2021). While SBP was included in the diet of the RG-SF group from 25 to 42 days of age and had no significant effect on FCR and BWG, RH was included in the same treatment during 11 to 24 days of age and significantly improved FCR and BWG of broilers. It has been established that using insoluble fiber such as wood shavings, soy hulls, and oat hulls in the diets of broilers enhances body weight gain by 2 to 5% and feed efficiency by 3 to 5% (Amerah *et al*., 2009).

The present study discovered that RS-GF (1.5%:1.5% ratio of RH to SBP) enhanced FI in broilers from 11 to 24 days of age compared to the control and RG-SF groups. It seems that chicks fed the RS-GF group diet have lower digesta viscosity than chicks fed the control or RG-SF diets (data not shown); thereby, reducing the viscosity and increasing the passage rate and FI. By increasing their feed consumption, birds are able to compensate for lower nutrient levels in the diet when fiber is supplemented (Jha and Mishra, 2021). According to our findings, Saki *et al*. (2011a) reported that feeding insoluble and soluble fiber (1.5% cellulose and 1.5% modified pectin) increased daily FI from 1 to 21 days of age. Sadeghi *et al*. (2015) found that adding 1.5% SBP and 1.5% RH in the broiler diet lowered daily FI, BWG, and impaired FCR from 14 to 28 days of age. In the current study, broiler FCR improved in the RG-SF, SG-RF, and RS-GF groups from 11 to 42 days of age as compared to the control group.

The inclusion of RH and SBP in the diets likely improved FCR through multiple mechanisms. RH, despite its high fiber content, may enhance gut motility and stimulate digestive secretions, indirectly supporting nutrient absorption (Jiménez-Moreno *et al*., 2016). SBP is some fermentable fiber source rich in pectin's, which supports the proliferation of beneficial gut microbiota and increases the production of short-chain fatty acids (SCFAs), such as butyrate. These SCFAs serve as an energy source for enterocytes, improving intestinal health and function (Jha and Berrocoso, 2016). In contrast to our findings, adding 3% SBP to the diet reduced feed efficiency from 1 to 42 days of age (Sadeghi *et al*., 2015). According to Saadatmand *et al*. (2019), adding 3% RH or SBP to the broiler diet increased the FCR from 1–14 days but had no significant effect for the 1–42 days of age.

Carcass characteristics

How fiber acts in the gastrointestinal tract is dependent on its chemical structure, level, and different ages of rearing (Gonzalez-Alvarado *et al*., 2007; Holscher, 2017). Adding dietary fiber components may dilute the diet and enhance intestinal peristalsis (Zhang *et al*., 2023). The present study discovered that SG-RF and RS-GF enhanced the percentage of gizzard weight in broilers at 42 days of age compared to the control and RG-SF groups, which may be related to the consumption of rice hulls in treatments (SG-RF) and (RS-GF). These results indicate that gizzard development was stimulated by RH at older ages because, at older ages of treatment (SG-RF) and (RS-GF), both contain RH. Gonzalez-Alvarado *et al*. (2010) found that insoluble fiber was more effective in enlarging the organ's weight than soluble fiber, which was related to the hardness degree of lignification. Well-developed gizzard would be able to ground feed particles and enhance nutritional digestion and utilization fully (Adewole *et al*., 2020).

The present study indicated that SG-RF enhanced the percentage of proventriculus weight in broilers aged 24 days compared to the other groups. The enlargement of the proventriculus and gizzard is a logical consequence of the reduced passage rate of intact feed particles, requiring muscular grinding in the gizzard for digestion (Tejeda and Kim, 2021). A high-fiber diet may cause increased dilatation of the proventriculus (Jha and Misha, 2021). The present trial showed that RG-SF and SG-RF groups in the diet of broilers reduced the percentage of liver weight from 42 days of age. Sadeghi *et al*. (2015) showed a reduction in the percentage of liver weights of chicks given SBP compared to the control group. All high-fiber meals lower liver and heart weight without decreasing the food intake and weight gain in rats (Shinnick *et al*., 1988). In humans, a diet rich in fiber can help patients lose fat, improve indicators of metabolism like liver enzymes, and decrease the amount of fat that is deposited in the liver (Henney *et al*., 2023).

According to reports, adding 1% of insoluble fiber to layer diets can improve pancreatic proteolytic activity and enhance the percentage of liver weights (Yokhana *et al*., 2016). In a similar trend, in chickens fed 3% wheat bran, the trypsin and pancreatic amylase activity significantly increased, which was linked to improved nutrient digestibility (Shang *et al*., 2020). Saadatmand *et al*. (2019) reported that at 42 days of age, the percentage of pancreas weight increased with feeding both soluble and insoluble fiber sources. In addition, greater pancreas weight in birds given SBP is associated with enhanced digesta viscosity in their digestive tracts (Banfield *et al*., 2002). However, increased pancreas weight associated with feeding insoluble dietary fiber like RH could influence gastro-duodenal reflux and increase pancreatic enzyme secretion (Svihus *et al*., 2004). These findings are consistent with the results of Saki *et al*. (2011b), who demonstrated that varying dietary insoluble to soluble fibers ratios resulted in lower percentages of heart and pancreas weights.

Relative intestinal length

The present study discovered that treatment (RS-GF) decreased intestinal relative length in broilers from 24 to 42 days compared to the control group. This may be due to the decrease in digesta viscosity in treatment (RS-GF) (data not shown), thereby increasing the rate of passage and decreasing the intestinal relative length in broilers from 24 to 42 days.

Chicks fed with SBP, which contains soluble fiber, had longer intestines than those fed with rice hulls, which contain insoluble fiber (Jimenez-Moreno *et al*., 2013). However, the higher relative length of the small intestine in broilers fed with different fiber sources could be attributed to the organ's adaptation to increase feed consumption (Mourão *et al*., 2008). As a result, our study demonstrated that an equal amount of SBP and RH was shown to have a synergistic impact on intestine relative length. In contrast to our findings, quails fed 1.5% micronized wheat fiber showed an enhancement in the relative length of gut sections (Rezaei *et al*., 2018).

Conclusion

The results of the present study revealed that in chicks fed with RG-SF (3% RH in the grower period and 3% SBP in the finisher period) and RS-GF (1.5% RH and 1.5% SBP in the grower and finisher periods) groups from 11 to 42 days of age, BWG improved. The percentage of thigh and intestinal weights in the RG-SF group, which received SBP at the finisher period, significantly increased compared to the control group at 42 days of age. The percentage of gizzard weights in the SG-RF and RS-GF groups, which received RH at the finisher period, increased at 42 days of age. Furthermore, the equal use of RH and SBP in the grower and finisher period (RS-GF group) significantly reduced the small intestinal length compared to the control group. Thus, the addition of 3% RH and 3% SBP in the grower and finisher periods, respectively, or 1.5% RH and 1.5% SBP in both the grower and finisher periods in broiler diets can be beneficial.

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