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Insoluble Fibers Affected the Performance, Carcass Characteristics and Serum Lipid of Broiler Chickens Fed Wheat-Based Diet

Research Article

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ABSTRACT

The current study was conducted to survey the influences of addition of alfalfa meal (AM), rice bran (RB) and wood shaving (WS) in wheat-based diets [contain soluble non starch polysaccharides (NSP)] on performance carcass characteristic and serum lipids of broilers from 11 to 42 d of age. Seven hundreds 10-d-old male Ross 308 chicks were placed into 35 pens and allocated to seven wheat-soybean meal-based dietary treatments which were a control (CT) diet (without any fiber source) and six fiber-included diets consisting of three sources of fiber (AM, RB and WS) and two levels of fiber inclusion (3 and 6%) in a 3 × 2 factorial arrangement. According to the results, the average daily gain (ADG), average daily feed intake (ADFI), feed conversion ratio (FCR), corrected-FCR (C-FCR) and crop, proventriculus, gizzard (relative full weights) and heart, abdominal fat, liver, breast and thigh (relative weights) and serum low density lipoprotein (LDL) were affected by different types of fibers ($P<0.05$). The inclusion of insoluble fibers in wheat-based diet improved ADG and FCR in broilers, so that, the highest amount of ADG and the lowest amount of C-FCR was related to 3% WS contained diet ($P<0.05$). The highest amount of gizzard weight was depended to 6% WS contained diet ($P<0.05$) and the lowest breast and thigh weight were also related to RB diets ($P<0.05$), but the aforementioned treatments had no effect on the different intestine sections weight ($P>0.05$). In general, the inclusion of 3 to 6% insoluble fibers, except for 6% WS, in wheat-based diet improved growth performance in broiler chickens.

KEY WORDS broilers, carcass traits, insoluble fiber, wheat.

INTRODUCTION

Wheat based diet is mainly used in some parts of the world such as Europe and Canada (Mahammadi Ghasem Abadi *et al.* 2014). Variations in nutritive values and nature of NSP of wheat result in inefficiencies in diet formulations, particularly in terms of energy and amino acid (Mahammadi Ghasem Abadi *et al.* 2014). NSPs as components of several poultry feed ingredients have been the interest of researches in recent years. These polysaccharides include a large variety of molecules that divided to main groups of soluble NSP (S-NSP) and insoluble NSP (I-NSP) (Shakouri *et al.* 2006). Some previous studies (Jiménez-Moreno *et al.* 2013; Taheri *et al.* 2016) showed that anti-nutritive effects of S-NSP on intestinal microflora, gut histomorphology, excreta moisture and performance. In fact, S-NSPs produce high digesta viscosity in intestine and inhibit digestion and absorption of nutrients such as lipids, protein and starch and decreased the performance (Hetland *et al.* 2004; Kalmendal *et al.* 2011). In contrast, most research conducted on poultry feeding, I-NSP has been considered a diluent of the diet (Rezaei *et al.* 2011). It has been demonstrated, based on research conducted in recent years, that the inclusion of moderate amounts of different fiber sources in the diet improves digestive organ development (Mateos *et al.* 2012) and increases HCl, bile acids and enzyme secretion (Molist *et al.* 2009; Svihus *et al.* 2004). These changes might result in improvements in nutrient digestibility (Rogel *et al.* 1987), growth performance (González-Alvarado *et al.* 2007; Taheri *et al.* 2016), increase in gizzard weight and gizzard contents and increase in apparent metabolizable energy corrected for nitrogen (AMEn) (Amerah *et al.* 2009; Jiménez-Moreno *et al.* 2009), gastrointestinal tract (GIT) health and eventually, animal welfare (Mateos *et al.* 2012). Consequently, the effects of dietary fiber (DF) on aforementioned factors will differ depending on the source and inclusion level of the fiber (Molist *et al.* 2009) as well as on the nature of the basal diet (Jiménez-Moreno *et al.* 2013). The alfalfa, wood shaving and rice bran are as good source of insoluble fiber, which can be used in poultry nutrition.

Alfalfa is widely used in animal feeding. It is moderately rich in protein, vitamins K, A and minerals but has low levels of energy (Mansoub and Pooryousef Myandoab, 2012). Dehydrated alfalfa meal generally is used at very low levels in poultry feeding, due primarily to its high fiber and low energy content (Jiang *et al.* 2012). The use of alfalfa in diets for monogastric animals is limited (Tkacova *et al.* 2011) by its high fiber content (above 7%). Alfalfa is well balanced in amino acids and rich in vitamins, carotenoids and saponins (Jiang *et al.* 2012). Carotenoids are polyenoicterpenoids having conjugated trans double bonds. They include carotenes (β-carotene and lycopene), which are polyene hydrocarbons, and xanthophylls (lutein, zeaxanthin, capsanthin, canthaxanthin, astaxanthin, and violaxanthin) having oxygen in different form (Tkacova *et al.* 2011). Mansoub and Pooryousef Myandoab (2012) reported that inclusion of alfalfa meal to the layer diets at the levels of 50, 100, 150 and 200 g/kg had no effect on feed intake (FI), but an addition of more than 5% decreased egg production (EP). Guclu *et al.* (2004) indicated that addition of 90 g/kg alfalfa meal into the laying quail diets had no adverse effect on performance and increased some of egg quality parameters.

Wood is essentially composed of cellulose, hemicelluloses, lignin, and some extractives compounds. The close to significant effect of wood shavings on total bile salt content of gizzard chyme in all layers, as well as the positive effect of wood shavings on jejuna amylase activity (U/g feed) observed in birds fed on whole wheat diets, indicate that stimulation of digestive processes may occur also in older birds (Hetland *et al.* 2003).

The rice bran is a powdery fine and fluffy material that consists seeds or kernels, in addition to particles of pericarp, seed coat, aleurone, germ and fine starchy endosperm. Rice bran is rich in B-vitamins and tocopherols and its nutrient density and profiles of amino acids and fatty acids, including 74% of unsaturated fatty acids, are superior to cereal grains (Adrizal and Ohtani, 2002). Both rice bran protein and fat are of relatively high biological value (Ersin Samli *et al.* 2006). The results of a study carried out with poultry using rice bran at 0, 5, 10, 15, 20 and 25% levels indicated that use of 25% of mixed rice bran in layer diets had no adverse effect on the productive performance (Ersin Samli *et al.* 2006). With regard to effects of dietary inclusion of insoluble fibers on growth performance and digestive traits of birds, the aim of this research was to study the influence of AM, RB and WS in the wheat-based diet on growth performance, carcass traits and serum lipids of broilers in the grower phase.

MATERIALS AND METHODS

Experimental design and handling

The present study was conducted from June to July of 2015, when the climate condition was relative hot and humid. A total of 700 commercial broiler chicks (10-d-old male, Ross 308 strain) were divided into 35 groups, which consisted of 5 replications of 20 birds each and fed to seven wheat-based diets treatments which were a control diet (without any fiber source) and six fiber-included diets consisting of three sources (AM, RB and WS) and two levels of fiber inclusion (3 and 6%) in a 3 × 2 factorial arrangement. They were arranged using a completely randomized design (CRD). The photoperiod was 23 h light: 1 h dark, throughout the experiment. The rearing room (1.5×1.5 m) was provided with fans and coolers to adjust the environmental temperature to 24 ± 1 ˚C and this temperature were almost stable for total of experiment. Prophylactic measures against the most common infectious diseases were conducted.

The experimental starter diets contained 3098 to 3102 kcal ME and 2147 to 2152 % CP (not showed) and the grower diets (Table 1) were formulated to meet the requirements of broiler chickens according to recommendations of Aviagen for Ross 308 broilers (Aviagen, 2014).

Chemical evaluation of diets

The diets were analyzed for nutrient concentrations according to the standard procedures of AOAC (2000). Fiber sources and diets were analyzed for S-NSP and I-NSP according to the procedure of Englyst *et al.* (1994).

Growth performance

After an adaptation period, the ADG, ADFI and FCR were determined by pen from 25 to 42 d of age. Data were corrected by subtracting the amount of added WS from the total feed consumption (Hetland *et al.* 2003) to obtain C-FCR.

Table 1 Ingredient composition, nutrient content and particle size distribution of the experimental diets (% as-fed basis, unless otherwise indicated) from 25 to 42 d of age

Ingredient	Control	Alfalfa meal		Rice bran		Wood shaving	
		3%	6%	3%	6%	3%	6%
Wheat grain	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Corn grain	20.57	17.40	14.60	18.00	15.10	11.45	8.25
Soybean meal	28.79	28.06	27.10	28.27	27.99	29.90	31.13
Alfalfa meal	-	3.0	6.0	-	-	-	-
Rice bran	-	-	-	3.0	6.0	-	-
Wood shaving	-	-	-	-	-	3.0	6.0
Soybean oil	6.60	7.60	8.44	6.70	6.90	8.60	10.60
Dicalcium phosphate	1.41	1.40	1.39	1.39	1.37	1.42	1.43
Calcium carbonate	0.96	0.88	0.79	0.99	1.00	0.97	0.96
Common Salt	0.16	0.18	0.16	0.20	0.20	0.20	0.20
Sodium bicarbonate	0.29	0.27	0.28	0.25	0.24	0.27	0.27
L-threonine	0.10	0.10	0.10	0.10	0.10	0.10	0.09
DL-methionine	0.33	0.34	0.35	0.33	0.33	0.34	0.34
L-lysine HCl	0.27	0.27	0.29	0.27	0.27	0.25	0.23
Mineral premix[1]	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin premix[2]	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Calculated analysis[3]							
AME_n (kcal/kg)	3198	3200	3200	3200	3200	3200	3200
CP	19.49	19.51	19.47	19.46	19.51	19.47	19.48
Methionine + cystine	0.91	0.91	0.91	0.91	0.91	0.91	0.91
Lysine	1.16	1.16	1.16	1.16	1.16	1.16	1.16
Determined analysis							
Dry matter (DM)	91.4	90.3	90.1	91.5	90.8	90.7	90.0
Gross energy (kcal/kg)	4026	4057	4086	4012	4007	4102	4191
Crude protein (CP) (N×6.25)	19.04	19.08	19.13	19.10	19.22	19.06	19.10
Ether extract	8.14	9.10	9.92	8.52	8.99	9.82	11.53
Calcium	0.80	0.81	0.81	0.80	0.80	0.80	0.80
Total phosphorus	0.66	0.65	0.64	0.63	0.63	0.65	0.64
Crude fiber	2.87	3.42	3.91	3.12	3.36	4.91	7.80
Neutral detergent fiber	11.93	13.37	14.05	12.76	13.60	14.08	16.26
Acid detergent fiber	4.80	5.44	5.97	5.23	5.68	6.90	8.99
S-NSP	2.24	2.28	2.35	2.21	2.20	2.20	2.18
I-NSP	13.99	14.94	15.65	14.82	15.56	16.63	19.07

[1] Provided the following per kilogram of diets: Manganese ($MnSO_4H_2O$): 75 mg; Zinc (ZnO): 85 mg; Iron ($FeSO_47H_2O$): 50 mg; Copper ($CuSO_45H_2O$): 10 mg; Selenium (Na_2SeO_3): 0.2 mg; Iodine (Iodized NaCl): 0.8 mg and Choline: 250 mg.
[2] Provided the following per kilogram of diets: vitamin A: 9000 IU; Cholecalciferol: 2000 IU; vitamin E: 36 IU; vitamin B_{12}: 0.015 mg; Menadione: 2 mg; Riboflavin: 6.6 mg; Thiamine: 1.8 mg; Pantothenic acid: 7.3 mg; Niacin: 30 mg; Folic acid: 1 mg; Biotin: 0.1 mg and Pyridoxine: 3 mg.
[3] According to NRC (1994).
S-NSP: soluble non-starch polysaccharide and I-NSP: insoluble non-starch polysaccharide.

Before weighing, the chicks were fasted for six h to ensure a consistent gut fill among all birds (Shirzadegan *et al.* 2014).

Carcass characteristics

Subsequent to the weighing of broiler chickens at the end of the experiment (42 days), three birds were selected from each of the replicate groups per treatments. These birds were slaughtered by severing the bronchial vein to determine some measurements of carcass yield involve internal organs (crop, heart, proventriculus, liver, abdominal fat, gizzard, small intestine, caecum and colon) as full digestive tract and external organs (carcass, breast and thigh). The weights of these organs were expressed as percentages of live body weight (Shirzadegan *et al.* 2014).

Serum metabolites

At the 42nd days of the experiment, blood samples (three bird each replicate) from the brachial veins of all chickens were collected for analysis. After coagulation, the blood samples were centrifuged at 3000 rpm for 10 min and the obtained serum was stored in a freezer at -20 ˚C for further analysis. In the blood serum, the following parameters were determined: total cholesterol (TC), triglyceride (TG) and low-density lipoproteins (LDL) by spectrophotometric method using commercially available kits (Parsazmun, Iran) (Shirzadegan *et al.* 2014).

Statistical analysis

Data were analyzed as a completely randomized design with seven treatments (diets) using the GLM procedure of

SAS (SAS, 2003). Differences among treatments were considered significant at (P<0.05). Significant differences between means (diets) were separated by Fisher's Least Significant Difference test (protected t-test). In addition, the effects of fiber source (AM, RB and WS), inclusion level (3 and 6%) of fiber and the interaction between source and level of fiber were studied as a 2 × 3 factorial arrangement analysis.

RESULTS AND DISCUSSION

Growth performance

The effect of fiber source and level of fiber on ADFI, ADG, FCR and C-FCR are shown in Table 2. Birds fed the RB or the WS diets showed the higher ADFI (P<0.001) than those fed the CT diet, however, the 3% AM diet decreased the ADFI compared to the CT diet and the ADFI was higher for birds fed the WS diet than for birds fed the RB diet. Birds fed the fiber-included diets showed the higher ADG (P<0.001) compared to the CT diet. The ADG was higher (P<0.01) for birds fed the WS or the RB diets than for birds fed the AM diet.

Feeding the fiber-included diets, except the 6% WS, improved (P<0.001) the FCR compared to the CT diet. The birds fed the AM diet showed the lowest FCR (P<0.001) compared to other fiber sources, and FCR was higher for birds fed the WS diet than for birds fed the RB diet. Birds fed the fiber-included diets showed the lower C-FCR (P<0.001) than those fed the CT diet. The C-FCR was higher (P<0.001) for birds fed the WS or the RB diets than for birds fed the AM diet.

Totally, an increase in the inclusion level of fiber in the diet increased the FCR and the C-FCR, but the effects were more pronounced for the WS diets than for the AM or the RB diets. Likewise, the interaction effect (P<0.001) was observed on growth performance traits (ADFI, ADG, FCR and C-FCR) between the fiber source and the inclusion level of fiber.

Organs weight

Influences of dietary fibers on full digestive tract weight (Table 3) and other carcass characteristic (Table 4) of broiler chicks are presented in below. Results indicated that the effects of treatments on carcass traits were statistically significant at 42 days old (P<0.05).

However, the crop, proventriculus, gizzard (full relative weights) and heart, abdominal fat, liver, breast and thigh (relative weights) were affected by different sources of fibers, so that, the highest amount of gizzard weight was depended to 6% WS contained diet (P<0.05) and the lowest abdominal fat weight was related to 6% AM group (P<0.05).

The lowest breast and thigh weight were also related to RB diets (P<0.05), but the treatments had no significant effect on the carcass yield, small intestine, ceca and colon weights of birds (P>0.05).

Serum lipids

Results of effects of dietary fibers on serum metabolites of broilers are presented in Table 5. These findings indicate that different inclusion of dietary fibers did not significantly (P>0.05) effect on the blood TG and TC concentrations, but plasma LDL percentages were affected (P<0.05) by treatments. According to results, the highest serum LDL at 40 days old was observed in the chicks fed on ration 3% WS compared to control. Moreover, the LDL level of birds fed 6% WS was lower than 6% RB (P<0.05), whereas, the other fiber-included diets not had different to control group (P>0.05).

According to the results, the decreased feed intake of the birds on the diets containing wheat compared to the fiber included diets probably is because of increasing the intestinal digesta viscosity that causes increase of feed retention time in the gastrointestinal tract (Rogel *et al.* 1987; Mateos *et al.* 2012). Since, there is a relationship between rate of feed passage through the gut and feed consumption in young chickens (Taheri *et al.* 2016), inclusion of this S-NSP in the diet leads to less feed intake. In the present study, it was found that the inclusion of wood shavings increased ADFI and decreased the FCR and C-FCR in chickens compared to other fiber sources. Similarly, Shakouri *et al.* (2006) found that diluting the diet with cellulose increased feed intake, whereas, Hetland *et al.* (2003) found that diluting a wheat-based diet with oat hulls had no influence on the weight gain and feed intake, but, in turkeys, diluting a maize-based diet with wood shavings was reported to improve the gain/feed during the critical first 7 d posthatch period (Jiang *et al.* 2012).

Taheri *et al.* (2016) also showed the broiler chickens receiving 4 and 8 % wheat bran in a barley-based diet had lower FCR than those fed the barley-based diet. It has been suggested that the birds are able to maintain normal weight gain when fed diets diluted with insoluble fibre by the increased capacity of the digestive system and/or faster passage through the digestive tract (Hetland *et al.* 2004). Consequently, the higher feed intake in birds fed on diets diluted with fibers in the present study can probably be explained by the larger gizzard sizes observed and faster gut emptying (Kalmendal *et al.* 2011). A large, well-developed gizzard improves gut motility and may increase cholecystokinin release (Svihus *et al.* 2004), which in turn stimulates the secretion of pancreatic enzymes and gastroduodenal refluxes, as a result, the growth performance could be better in birds.

Table 2 Effect of fiber source and level of fiber on growth performance of broilers from 25 to 42 d

Factors	ADFI (g)	ADG (g)	FCR	C-FCR*
Diets				
Control	161.5^{d}	77.1^{d}	2.08^{b}	2.08^{a}
Alfalfa meal-3%	152.5^{e}	80.0^{cd}	1.91^{e}	1.91^{d}
Alfalfa meal-6%	158.4^{d}	81.4^{c}	1.95^{d}	1.95^{c}
Rice bran-3%	171.3^{bc}	85.0^{b}	2.01^{c}	2.01^{b}
Rice bran-6%	167.5^{c}	82.3^{bc}	2.03^{c}	2.03^{b}
Wood shaving-3%	173.4^{b}	90.0^{a}	1.92^{de}	1.87^{e}
Wood shaving-6%	179.9^{a}	81.5^{c}	2.20^{a}	2.08^{a}
SEM (n=5)	1.96	1.10	0.012	0.012
Fiber source (FS)				
Alfalfa meal	155.5	80.7	1.93	1.93
Rice bran	169.4	83.7	2.02	2.02
Wood shaving	176.7	85.8	2.06	1.97
SEM (n=10)	1.38	0.78	0.008	0.008
Inclusion level of FS (g/kg)				
30	165.8	85.0	1.95	1.93
60	168.6	81.7	2.06	2.02
SEM (n=15)	1.16	0.65	0.007	0.007
Probability				
Diets	0.01	< 0.0001	< 0.0001	< 0.0001
Fiber source	< 0.0001	0.0005	< 0.0001	< 0.0001
Inclusion level of FS	0.09	0.001	< 0.0001	< 0.0001
Fiber source × inclusion level of FS	0.03	0.0006	< 0.0001	< 0.0001

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
ADFI: average daily feed intake; ADG: average daily gain; FCR: feed conversion ratio.
* C-FCR: corrected-FCR, data were corrected by subtracting the amount of added wood shavings from the total feed consumption (Hetland *et al.* 2003).
SEM: standard error of the mean.

Table 3 Effect of fiber source and level of fiber on the relative weight (% live BW) of full digestive tract of broilers at 42 d of age

Factors	Crop	Proventriculus	Gizzard	Duodenum	Jejunum	Ileum	Total intestine	Ceca	Colon
Diets									
Control	0.83^{cd}	0.62^{c}	3.11^{d}	1.13	2.57	1.67	7.26	1.25	0.64
Alfalfa meal-3%	0.82^{d}	0.61^{c}	3.74^{b}	1.08	2.43	1.48	6.78	1.15	0.63
Alfalfa meal-6%	0.90^{a}	0.69^{ab}	3.77^{b}	1.11	2.53	1.53	7.01	1.21	0.63
Rice bran-3%	0.86^{abcd}	0.66^{abc}	3.17^{cd}	1.10	2.54	1.60	7.04	1.17	0.62
Rice bran-6%	0.88^{abc}	0.66^{abc}	3.48^{bc}	1.12	2.47	1.63	7.13	1.27	0.64
Wood shaving-3%	0.84^{bcd}	0.64^{c}	3.64^{b}	1.15	2.58	1.48	7.06	1.22	0.64
Wood shaving-6%	0.90^{a}	0.70^{a}	4.17^{a}	1.14	2.39	1.65	7.13	1.30	0.66
SEM (n=5)	0.019	0.018	0.125	0.017	0.099	0.061	0.153	0.059	0.018
Fiber source (FS)									
Alfalfa meal	0.86	0.65	3.75	1.10	2.48	1.51	6.9	1.18	0.63
Rice bran	0.87	0.66	3.32	1.11	2.51	1.62	7.1	1.22	0.63
Wood shaving	0.87	0.67	3.91	1.14	2.48	1.56	7.1	1.26	0.65
SEM (n=10)	0.014	0.013	0.090	0.012	0.068	0.042	0.116	0.042	0.013
Inclusion level of FS									
3%	0.84	0.64	3.52	1.11	2.52	1.52	7.0	1.18	0.63
6%	0.90	0.68	3.81	1.12	2.47	1.60	7.1	1.26	0.64
SEM (n=15)	0.011	0.010	0.073	0.010	0.055	0.034	0.095	0.034	0.011
Probability									
Diets	0.02	0.009	< 0.0001	0.12	0.79	0.16	0.50	0.57	0.91
Fiber source	0.75	0.50	0.0004	0.03	0.96	0.21	0.42	0.43	0.64
Inclusion level of FS	0.001	0.005	0.01	0.42	0.52	0.10	0.35	0.12	0.58
Fiber source × inclusion level of FS	0.27	0.11	0.18	0.39	0.35	0.46	0.87	0.96	0.74

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the mean.

The lower weight gain and higher FCR of the broilers fed control diet are also predictable due to less feed intake and less nutrients utilization because of high viscosity of the chime in birds (Shakouri *et al.* 2006), but chickens fed the coarse insoluble fiber (such as WS or RB diets) showed the higher ADFI than those fed the control diet, which it may be due an increase in the flow rate of feed in GIT.

The results of this study was in agreement with results of Gonzalez-Alvarado *et al.* (2007) and Jiménez-Moreno *et al.* (2009) when oat hulls, rice hulls or sunflower hulls were included in low fiber diets for broilers and suggests that the beneficial effects of dietary fiber on feed/gain ratio and growth performance of broilers were due primarily to an increase in diet digestibility and well-developed gizzard which resulted in more nutrients available for growth. Furthermore, in conjunction to better FCR in birds fed RB and AM diets, Guclu *et al.* (2004) indicated that adding alfalfa meal into the laying quail diets (90 g/kg) had no adverse effect on performance and increased some of egg quality parameters. Tkacova *et al.* (2011) also reported that broilers fed diets with high doses of alfalfa (60 g/kg diet) had lower feed conversion. However, it was reported that inclusion of alfalfa in diets of laying hens reduced performance expressed in terms of body weight and egg mass (EM) (Jiang *et al.* 2012).

However, results of Ersin Samli *et al.* (2006) experiment showed that rice bran could be included up to 10% without any adverse effect on laying performance, egg quality and digestive organs. The higher ADG and better FCR showed in experimental birds in present study may be due to mainly vitamins and essential nutrients found in rice bran.

Results of this experiment also indicated that addition of I-NSP to diet affected some characteristics of gastrointestinal tract of broilers.

In this way, there was a significant effect of NSP solubility on cecum weight, with pigs fed the S-NSP diet having heavier cecum than those on the I-NSP diets on both days 6 and 14 (Wellock *et al.* 2008). As well as, asserted the treatments containing an equal or higher ratio of cellulose resulted in increased intestine weight of broilers at 21 days of age.

This finding is conflicting with other researchers who have shown that cellulose usage decreases intestine weight in younger broilers (Sklan, 2003). Notably, broilers adapt to high levels of insoluble fibers by enlarging the GIT (Gonzalez-Alvarado *et al.* 2010). As a result, their weights increase. The relative empty weights of jejunum, ileum and small intestine of broilers were also affected by dietary insoluble fiber (Amerah *et al.* 2009). This adaptation is a rapid attempt to increase the absorptive surface area of the GIT in response to the lower diffusion rates, and it occurs by increasing the digesta viscosity levels (Jiménez-Moreno *et al.* 2009; Mateos *et al.* 2012). However, the breast, thigh and intestinal sections in our study were not improved by administration of fiber in diet.

Moreover, reported, abdominal fat decreased at 20% rice bran inclusion in the diet. Oladunjoye and Ojebiyi (2010) also noted that body fat content of chicken reduced when 40% oat hull was included in their diet. Gizzard weight and the length of small intestine, large intestine, duodenum and ileum were however increased significantly at 20% rice bran inclusion level.

This can be attributed to high fiber in this diet. Similarly reported, access to coarse hulls (such as wood shaving) stimulated gizzard development (Mateos *et al.* 2012), which this is in agreement with previous studies to fiber source such as wood shaving (Amerah *et al.* 2009) and alfalfa (Jiang *et al.* 2012).

Table 4 Effect of fiber source and level of fiber on the relative weight (% live BW) of carcass, breast, thigh + drumstick, abdominal fat, heart and liver in broiler at 42 d of age

Factors	Carcass	Breast	Thigh + drumstick	Abdominal fat	Heart	Liver
Diets						
Control	72.7	27.6^{ab}	25.2^{a}	1.95^{abc}	0.45^{a}	2.58^{a}
Alfalfa meal-3%	73.3	27.7^{a}	25.1^{a}	1.92^{bc}	0.41^{c}	2.43^{ab}
Alfalfa meal-6%	73.5	27.2^{ab}	24.6^{ab}	1.86^{c}	0.40^{c}	2.38^{b}
Rice bran-3%	72.5	26.7^{bc}	23.9^{b}	1.99^{ab}	0.42^{bc}	2.31^{b}
Rice bran-6%	72.7	27.1^{ab}	24.6^{ab}	2.00^{ab}	0.42^{bc}	2.40^{b}
Wood shaving 3-%	73.4	27.3^{ab}	25.1^{a}	2.02^{ab}	0.44^{ab}	2.31^{b}
Wood shaving-6%	72.3	26.1^{c}	24.9^{a}	2.03^{a}	0.41^{c}	2.30^{b}
SEM (n=5)	0.39	0.31	0.29	0.036	0.008	0.056
Fiber source (FS)						
Alfalfa meal	73.4	27.4	24.9	1.89	0.40	2.40
Rice bran	72.6	26.9	24.2	2.00	0.42	2.36
Wood shaving	72.8	26.7	25.0	2.03	0.42	2.31
SEM (n=10)	0.26	0.21	0.21	0.025	0.006	0.040
Inclusion level of FS						
3%	73.1	27.3	24.7	1.98	0.42	2.35
6%	72.8	26.8	24.7	1.97	0.41	2.36
SEM (n=15)	0.21	0.17	0.17	0.020	0.005	0.032
Probability						
Diets	0.14	0.02	0.048	0.02	0.002	0.02
Fiber source	0.045	0.046	0.047	0.002	0.049	0.23
Inclusion level of FS	0.39	0.049	0.99	0.70	0.04	0.88
Fiber source × inclusion level of FS	0.12	0.04	0.15	0.50	0.18	0.50

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the mean.

Table 5 Effect of fiber source and level of fiber on serum lipid parameters (mg/dL) in broiler at 40 days old

Diets	TG	TC	LDL
Control	103.8	135.8	45.2[bc]
Alfalfa meal-3%	124.6	156.8	58.6[ab]
Alfalfa meal-6%	112.0	149.2	54.4[abc]
Rice bran-3%	134.6	146.0	52.0[bc]
Rice bran-6%	115.4	151.0	57.6[ab]
Wood shaving-3%	116.0	140.0	67.8[a]
Wood shaving-6%	112.6	138.0	42.6[c]
SEM (n=5)	7.71	6.22	4.87
Fiber source			
Alfalfa meal	118.3	153.0	56.5
Rice bran	125.0	148.5	54.8
Wood shaving	114.3	139.0	55.2
SEM (n=10)	5.66	4.55	3.54
Inclusion level			
3%	125.1	147.6	59.5
6%	113.3	146.1	51.5
SEM (n=15)	4.63	3.71	2.89
Probability			
Diets	NS	NS	0.02
Fiber source	NS	NS	NS
Inclusion level	0.046	NS	0.044
Fiber source × level	NS	NS	0.02

TG: triglyceride; TC: total cholesterol and LDL: low density lipoprotein.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the mean.

The coarse hull particles are retained in the gizzard until they are ground to certain critical size that allows them to pass through the pyloric sphincter (Hetland *et al.* 2003). This leads to an increase in the volume of the organ's contents and a muscular adaptation to meet the greater demand for grinding. Showed that the increase in grinding activity of the gizzard, increase in digestive secretions, HCL, bile acid and endogenous enzymes together with a better mixing of digestive juices with the digesta (González-Alvarado *et al.* 2007) affect the functioning of the GIT and may modify microbial growth at specific digestive organ sites, might explain the positive effects of I-NSP on the digestibility of dietary components (Rezaei *et al.* 2011; Mateos *et al.* 2012). This study, the highest proventriculus and gizzard weights and the better growth performance were observed in fiber included diets that it could be refer to aforementioned subject.

The result of this study showed that inclusion of different I-NSP in diet significantly altered the blood metabolites of broilers in grower phase. In depending to this result, Sarikhan *et al.* (2009) reported that at starter period, blood lipids levels were significantly affected by levels of insoluble fibers in grower phase. In their research, serum TG levels were significantly lower in broilers fed diets containing 0.75% insoluble fibers and higher levels of high density lipoprotein (HDL) and lower concentrations of very low density lipoprotein (VLDL) observed in the serum of 0.50 and 0.75% insoluble fibers dietary groups.

Taheri *et al.* (2016) was also showed the broilers receiving 12% wheat bran in a barley-based diet had lower TC than those fed the corn-based diet. In contrast to our study, it showed that the blood TC and TG concentration were significantly reduced in bird fed diets supplemented to alfalfa powder (Oladunjoye and Ojebiyi, 2010).

The main reason of cholesterol and triglyceride reduction in serum of chicks may be due to substances like carvacrol and thymol (Mansoub and Pooryousef Myandoab, 2012) and high levels (2 to 3% dry matter) of saponins present in alfalfa, which have showed hypocholesterolemic, anticarcinogenic, anti-inflammatory, hypocholesterolemic and antioxidant activity (Jiang *et al.* 2012). Furthermore, indicated that rice bran insoluble fiber function as lower agent of TC and coronary artery disease. These effects are due to tocols (0.2%) of crude rice bran, which about 70 % are tocotrienols.

Tocol possess potent antioxidant activity and decreases serum cholesterol and hepatic cholesterol synthesis by the suppression of hydroxyl methyl glytaryl coenzyme A reductase (Ju and Vali, 2005). However, addition of fiber to diets in our study increased plasma LDL (3% WS diet) and abdominal fat, which it may be because of increase in nutrient passage rate and little degradation of bile salts by gut microorganisms and higher cholesterol absorption in broilers intestine.

CONCLUSION

Generally, based on the results of growth performance, the inclusion of 3 or 6% insoluble fiber, except for 6% WS, in wheat-based diet improved the ADG, FCR and gizzard function in broilers simultaneously from 25 to 42 d of age. The beneficial effect of insoluble fiber inclusion in the diet may be related to some extent to the longer feed passage in the upper part of the gastrointestinal tract, faster feed passage rate in the distal part of the gastrointestinal tract and the increase of nutrient retention. However, more research is needed to determine all the roles of I-NSPs on broilers performance.

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