Effect of Dietary Supplemental Wheat Starch By-Product on Growth Performance, Carcass Traits and Immune Responses of Broiler Chickens

S.S. Ale Saheb Fosoul, M. Shahryari*, A. Emadinia, A. Davoodi, M. M. Najari, G. Jalili, P. Arzani Shehni

Research and Development Centre, Ariya Tejarat Mehr Espadana, Isfahan, Iran
*Corresponding author: E-mail:mshahryari87@gmail.com ; Ph: +98 31 32306400

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Abstract

This experiment was conducted to investigate effects of a wheat starch by-product (WSB) on growth performance, carcass traits and immune responses of broiler chickens. A total of 300 one-day old broiler chicks (Ross 308) were assigned to 5 dietary treatments and 5 replicates in a completely randomized design during 9 to 16, 17 to 25, 26 to 39, and 40 to 50 days of experiment. Dietary treatments included a basal diet without WSB supplementation (CTL) or graded levels of low (LSS; 100, 150, 200, and 250 g/kg), medium (MSS; 200, 250, 300, 350 g/kg), high (HSS; 300, 350, 400, 450 g/kg) and extra (ESS; 400, 450 500, and 550 g/kg) inclusion rates of wheat starch during the starter, growing, finisher 1, and finisher 2 periods, respectively. Dietary supplementation of WSB did not have adverse effect on growth and feed conversion ratio of broiler chickens across 9 to 25 days of age but compromised growth performance during finisher and the entire rearing periods ($P < 0.05$). Feeding diets containing WSB decreased carcass yield in broiler chickens ($P < 0.05$). Antibody titer against Newcastle disease virus decreased following dietary HSS and ESS supplementation ($P < 0.05$). Moreover, supplementation of LSS and ESS to the feed decreased relative weight of spleen ($P < 0.05$). In conclusion, dietary supplementation of WSB is recommended up to 450 g/kg across 9 to 25 days of age without any adverse effect on growth performance of broiler chickens. However, supplementation of WSB may impair immune responses of broiler chickens.

Keywords: Broiler chickens; Wheat starch by-product; Growth performance; Humoral immunity

Introduction

Energy is a component of poultry diets, representing about half of the expenses that producers have to pay for broilers' feed (Cooke, 1987). There is a wide range of feedstuffs accounted as dietary energy sources available in the feed industry. Therefore, decision to use a specific feedstuff is often price dependent and nutritionists are looking for alternative energy sources to use in diet of broiler chickens. Corn is the main source of energy in broiler diet, but its price have increased during the last decade due to climate change and the increased demand of biofuel industry(FAO, 2017). Thus, using alternative feed ingredients seems necessary and plausible. Wheat is another important feed component, providing up to 70% of the metabolizable energy and 40% protein requirement of broiler chickens (Jahanian et al., 2007). Several wheat by-products encompass of wheat screening, bakery by-products and wheat mill run have been used in diet of broiler chickens (Boros et al., 2004; Saki & Alipana, 2005; Torki & Kimiaee, 2011). In this respect, supplementation of wheat screening up to 600 g/kg to the feed was reported to have not any adverse effect on growth performance of broiler chickens during 25 to 42 days of age (Mazhari et al., 2015). Also, it has been demonstrated that dietary corn could be totally replaced with bakery by-products without any adverse effect on performance and egg quality of laying hens.

Starch is the main abundant nutrient in diet of broiler chickens, contributing about 40% of diet and more than half of the metabolic energy intake (Svihus, 2011). The digestibility of starch is generally very high, but the rate of degradation in the intestine varies (Weurding et al., 2003). Wheat Starch by-product (WSB) is derived from the separation and purification of starch from wheat flour. In wheat starch separation process, 2 types of by-products are separated with one of them is free of protein content withfood gradeusage. The other type is containing about 7 to10 % protein with potential to be used in animal nutrition.To the authors' knowledge, there is lack of information regarding the effect of WSB on growth performance and immune responses of broiler chickens. As such, the purpose of the present experiment was to investigate the effect of WSB in graded levels on growth performance, carcass traits and immune responses of broiler chickens.

Materials and methods

All experimental procedures were evaluated and approved by the Institutional Animal Care and Ethics Committee of the Islamic Azad University, Isfahan (Khorasgan) Branch. This experiment was conducted in research farm of Davoodi commercial group, Isfahan, Iran with longitude of 32.64464 and latitude of 51.97744.

Wheat starchby-product and diet analysis

The WSB was purchased from a commercial supplier and analyzed for chemical composition (Table 1). Furthermore, chemical composition of dietary samples was determined (Table 2). In WSB samples, crude protein was determined using method 990.03 (AOAC 2000). The ash content was determined based on methods reported by Debon and Tester (2001). The neutral detergent fiber and acid detergent fiber of fibrous materials were determined sequentially as described by Van Soest et al. (1991) and expressed on ash free basis.Diet samples were analyzed for crude protein (990.03; AOAC 2000), Ca, and P contents (Method 2011.14; AOAC 1990).

Birds, diets and management

A total of 300 one-day old mix sex broiler chicks (Ross 308) were purchased from a commercial hatchery, wing banded, weighed, and randomly distributed in 25 pens (length 150 cm × width 130 cm × height 60 cm) in a power-ventilated house. Before the trial commence, broiler chicks were fed on a pre-starter diet for the first 9 days post-hatch with an average weight of 200 ± 1 g and then entered the experiment. Five replicate pens of 12 chicks each were randomly allotted to 5 treatments in a completely randomized design. Experimental treatments consisted of a basal diet without WSB supplementation (CTL) or basal diet supplemented with low (LSS), medium (MSS), high (HSS), and extra (ESS) levels of WSB at different periods of experiment. In this respect, supplemental levels of WSB included LSS: 100, 150, 200, and 250 g/kg, MSS; 200, 250, 300, 350 g/kg, HSS:300, 350, 400, 450 g/kg, and ESS: 400, 450 500, and 550 g/kgwhich appliedduring the starter (9 to 16 days), growing (17 to 25 days), finisher 1 (26 to 39 days), and finisher 2 (40 to 50 days) periods, respectively in replacement of corn and soybean meal. Diets were formulated to meet or exceed the nutrient requirements of broiler chickens provided by Ross 308 manual (Aviagen 2014). Dietary treatments were fed in pelleted form and offered *ad libitum* throughout the study. All birds had free access to water during the experiment. There was no record of mortality during the experiment. All pens were provided with wood shavings and nipple drinkers. Broilers were kept at 32°C from day 1 to 7, 29°C for d 8–14, 26°C for d 15–21 and 22°C for d 22 to the end of trial. The lighting program consisted of 23-hour light and 1-hour darkness.

Table 1: Chemical composition of wheat starch by-product (g/kg)

Item	
Crude protein	106
Acid detergent fiber (ADF)	38.8
Neutral detergent fiber (aNDF)	126
Ash	16.1
Sodium	1.9
Calcium	1.1

Table 2. Dietary composition and nutrients of broiler chickens during different periods of experiment

Items	Starter (9-16)	Growing (17-25)	Finisher 1 (26-39)	Finisher 2 (40-50)
Ingredients (g/kg)				
Corn (77 g/kg crude protein)	490.55	507.85	547.15	560.85
Wheat (123 g/kg crude protein)	100	100	100	100
Starch (100 g/kg crude protein)	0	0	0	0
SBM (480 g/kg crude protein)	225	203	144	109
CGM (580 g/kg crude protein)	20	20	10	20
Canola meal (380 g/kg crude protein)	60	60	70	90
Wheat DDGS (320 g/kg crude protein)	30	40	60	70
Sesame meal (430 g/kg crude protein)	20	20	20	0
Soybean oil	10	10	13	15
Monocalcium phosphate	10	8.1	6.7	5
Calcium carbonate	17.3	16.0	14.4	14.7
DL-Methionine	2.7	1.9	1.8	1.4
L-lysine HCL	4.2	3.9	3.9	4.1
L-Threonine	1.5	1.1	0.9	0.9
Vitamin and mineral premix[1]	2.8	2.4	2	2
Sodium chloride	2	1.8	2	2.2
$NaHCo_3$	1.3	1.3	1.5	2.2
Phytase[2]	0.1	0.1	0.1	0.1
Multi-enzyme[3]	0.05	0.05	0.05	0.05
Toxin binder[4]	2	2.0	2	2
Choline chloride	0.5	0.5	0.5	0.5
Calculated nutrient level (as-fed basis)				
ME (Kcal/kg)	2911	2940	3000	3072
Crude protein (g/kg)	210.5	203.1	183.0	17.11
Digestible lysine (g/kg)	11.5	10.8	9.5	0.91
Digestible Met + Cys (g/kg)	9	8.2	7.5	0.71
Digestible Threonine (g/kg)	7.8	7.3	6.3	0.6
Calcium (g/kg)	9.6	8.7	7.8	0.74
Available phosphorous (g/kg)	4.8	4.35	3.9	0.37
Sodium (g/kg)	1.7	1.7	1.7	0.16
Chloride (g/kg)	2.1	2.6	2.7	0.25
Analyzed values (as-fed basis)				
Crude protein (g/kg)	210.6	203.6	183.4	172.0
Calcium (g/kg)	9.7	8.8	7.9	7.4
Total phosphorous (g/kg)	5.3	4.9	4.7	4.4

SBM, Soybean meal; CGM, Corn gluten meal

[1]Vitamin premix provided per kg of diet: vitamin A (retinol), 2.7 mg; vitamin D3 (Cholecalciferol), 0.05 mg; vitamin E (tocopheryl acetate), 18 mg; vitamin k3, 2 mg; thiamine 1.8 mg; riboflavin, 6.6 mg; panthothenic acid, 10 mg; pyridoxine, 3 mg; cyanocobalamin, 0.015 mg; niacin, 30 mg; biotin, 0.1 mg; folic acid, 1 mg; choline chloride, 250 mg; antioxidant 100 mg; Mineral premix provided per kg of diet: Fe ($FeSO_4.7H_2O$, 20.09% Fe), 50 mg; Mn ($MnSO_4.H_2O$,32.49% Mn), 100 mg; Zn (ZnO, 80.35% Zn), 100 mg; Cu ($CuSO_4.5H_2O$), 10 mg; I (KI, 58% I), 1 mg; Se ($NaSeO_3$, 45.56% Se), 0.2 mg.[2]hostazyme 5000[3]Rovabio Excel[4] Zarin binder

Growth performance, carcass traits, and digestive organs

Daily feed intake (DFI) and daily weight gain (DWG) of broiler chickens in each pen were recorded during 9 to 16, 17 to 25, 26 to 39 and 40 to 50 days period and feed conversion ratio (FCR; feed intake/weight gain) was calculated, accordingly. At the end of the experiment, two broiler chickens close to the mean body weight of pen were slaughtered after 4 hours feed deprivation to evaluate carcass traits. Carcass, proventriculus, gizzard, duodenum, jejunum, ileum, cecum, pancreas, heart, liver, abdominal fat, spleen and bursa of Fabricius were collected, weighed and expressed as a percentage of live body weight.

Immune responses

On day 7 of age, Newcastle and influenza antigenswere injected subcutaneously with 0.2 mL per chickwith a dual vaccine of Newcastle-influenza (H9N2 subtype). On day 33 of experiment, the same wing-banded birds were bled todetermine antibody titers against influenza diseasevirus (IDV), and Newcastle disease virus (NDV). Antibody titers against IDV and NDV were separatelymeasured by the hemagglutination inhibition method(HI). The HI antibodies were then converted to $\log_2$. Lymphoid organs including the spleen andbursa of Fabricius were evaluated after slaughter at the end of experiment.

Statistical analysis

Data for recorded traits were subjected to analysis of variance procedures appropriate for a completely randomized design using the General Linear Model procedure of SAS 9.2 (SAS Institute Inc., Cary, NC). All birds in a pen were considered as an experimental unit for different parameters. For all statistical analyses, significance was declared at $P \leq 0.05$, unless otherwise stated. The Fisher's protected least significant difference test was used for multiple treatment comparisons.

Results

Growth performance, carcass traits, and digestive organs

Supplementation of WSB did not affect DFI, DWG and FCR of broiler chickens compared to those fed on CTL diets during the starter period while broilers fed on HSS had greater DFI than birds received LSS and ESS dietary treatments ($P < 0.05$; Table 3). Supplementation of ESS caused reduction in DFI of broiler chickens compared to birds received the other dietary treatments across the growing phase whereas DWG only decreased in response to ESS supplementation compared to the birds received MSS and LSS ($P < 0.05$; Table 3). Feed consumption of broiler chickens decreased in response to feeding LSS than those fed CTL, HSS, and ESS diets during 26 to 39 days of age ($P < 0.05$; Table 3). Otherwise, supplementation of ESS increased DWG compared to broilers in CTL and the other dietary treatments ($P < 0.05$; Table 3). During the finisher 1 period, the lowest FCR observed in broilers fed diets containing extra supplemented level of WSB ($P < 0.05$; Table 3) while the other inclusion rates of WSB impaired FCR compared to broilers received CTL diet ($P < 0.05$; Table 3). The DWG decreased while FCR increased across the finisher 2 period when diet of broiler chickens supplemented with WSB. Although DFI of broiler chickens was not affected by dietary treatments across the entire grow-out period, DWG compromised following dietary supplementation of WSB to the feed ($P < 0.05$; Figure 1). With exception of supplemental ESS, broiler chickens had impaired FCR after dietary LSS, MSS and HSS supplementation ($P < 0.05$; Figure 1).

As indicated in Table 4, carcass yield decreased after supplementation of WSB to the feed ($P < 0.05$). Relative weight of the heart was not affected by inclusion of WSB to the feed ($P < 0.05$) but broilers received ESS added feed had greater heart weight than those fed on diets containing HSS. Also, dietary supplemental HSS and ESS increased liver weight compared to those fed on CTL and LSS added diet ($P < 0.05$). Supplementation of MSS and LSS increased abdominal fat compared to broilers fed on CTL diet ($P < 0.05$).

Pancreas weight increased after dietary WSB supplementation compared to broilers fed on CTL diet ($P < 0.05$; Table 5). Supplementation of WSB to the feed increased jejunum weight ($P < 0.05$; Table 5). In comparison to the birds fed on CTL diet, supplementation of LSS and MSS increased ileum weight of broiler chickens ($P < 0.05$; Table 5).

Immune responses

Data on the effect of dietary supplemental WSB on immune responses in broiler chickens are summarized in Table 6. Antibody titer against IDV decreased in broilers fed on HSS and ESS supplemented diets ($P < 0.05$) but NDV was not affected by dietary treatments. Also, relative weight of spleen decreased following dietary LSS, and ESS supplementation compared to CTL treatment ($P < 0.05$).

Table 3. Effects of dietary treatments on growth performance of broiler chickens at different ages

	Dietary treatments					SEM	*P*-value
Parameters	CTL[1]	LSS[2]	MSS[3]	HSS[4]	ESS[5]		
DWG (g/d)							
9-16 d	48.9	47.9	47.9	48.8	47.3	0.299	0.420
17-25 d	56.3^{ab}	58.0^{a}	57.8^{a}	55.5^{ab}	52.7^{b}	0.663	0.063
26-39 d	74.8^{b}	61.7^{d}	63.3^{d}	70.3^{c}	77.9^{a}	1.339	<.001
40-50 d	90.1^{a}	84.1^{b}	80.2^{bc}	72.2^{d}	75.9^{cd}	1.411	<.001
DFI (g/d)							
9-16 d	52.0^{ab}	50.8^{b}	51.3^{ab}	53.0^{a}	50.3^{b}	0.312	0.050
17-25 d	115.8^{a}	116.8^{a}	116.8^{a}	114.2^{a}	106.0^{b}	1.261	0.018
26-39 d	142.9^{ab}	136.3^{c}	139.6^{bc}	145.1^{a}	142.4^{ab}	0.924	0.013
40-50 d	171.2	170.9	167.2	165.8	167.7	0.919	0.254
FCR							
9-16 d	1.06	1.06	1.07	1.07	1.06	0.004	0.929
17-25 d	2.06	2.01	2.02	2.05	2.01	0.018	0.885
26-39 d	1.91^{c}	2.20^{a}	2.20^{a}	2.06^{b}	1.83^{d}	0.033	<.001
40-50 d	1.90^{d}	2.03^{c}	2.09^{c}	2.29^{a}	2.21^{b}	0.029	<.001

DWG= daily weight gain; DFI= daily feed intake; FCR= feed conversion ratio

[1] Control diet (basal diet)

[2] Supplementation of100, 150, 200, and 250 g/kg wheat starch during starter, grower, finisher 1and 2, respectively

[3] Supplementation of200, 250, 300, and 350 g/kg wheat starch during starter, grower, finisher 1and 2, respectively

[4] Supplementation of300, 350, 400, and 450 g/kg wheat starch during starter, grower, finisher 1and 2, respectively

[5] Supplementation of400, 450, 500, and 550 g/kg g/kg wheat starch during starter, grower, finisher 1and 2, respectively

[a,b,c,d] Means in the same row with different superscript differ significantly (P<0.05) (n=5)

Table 4. Effects of dietary treatments on carcass traits of broiler chickens on day 42 of age

	Dietary treatments					SEM	*P*-value
Parameters	CTL[1]	LSS[2]	MSS[3]	HSS[4]	ESS[5]		
Carcass yield (%)	66.61^{a}	64.52^{b}	64.89^{b}	64.67^{b}	64.86^{b}	0.203	0.001
Abdominal fat (%)	1.98^{c}	2.33^{b}	2.80^{a}	1.76^{c}	1.79^{c}	0.090	<.001
Heart (%)	0.50^{ab}	0.53^{ab}	0.53^{ab}	0.47^{b}	0.56^{a}	0.010	0.067
Liver (%)	1.77^{b}	1.80^{b}	1.95^{ab}	2.14^{a}	2.11^{a}	0.043	0.012

[1] Control diet (basal diet)

[2] Supplementation of100, 150, 200, and 250 g/kg wheat starch during starter, grower, finisher 1and 2, respectively

[3] Supplementation of200, 250, 300, and 350 g/kg wheat starch during starter, grower, finisher 1and 2, respectively

[4] Supplementation of300, 350, 400, and 450 g/kg wheat starch during starter, grower, finisher 1and 2, respectively

[5] Supplementation of400, 450, 500, and 550 g/kg g/kg wheat starch during starter, grower, finisher 1and 2, respectively

[a,b,c,d] Means in the same row with different superscript differ significantly (P<0.05) (n=5)

Table 5. Effects of dietary treatments on digestive organs of broiler chickens

	Dietary treatments					SEM	*P*-value
Parameters	CTL[1]	LSS[2]	MSS[3]	HSS[4]	ESS[5]		
Gizzard (%)	1.20	1.18	1.15	1.19	1.16	0.026	0.035
Pancreas (%)	0.13^{d}	0.18^{b}	0.17^{bc}	0.17^{bc}	0.21^{a}	0.006	<.001
Proventriculus (%)	0.36	0.34	0.33	0.37	0.33	0.009	0.526
Duodenum (%)	0.53	0.56	0.58	0.60	0.60	0.018	0.773
Jejunum (%)	0.86^{b}	1.14^{a}	1.20^{a}	1.31^{a}	1.14^{a}	0.040	0.001
Ileum (%)	0.72^{b}	1.04^{a}	1.03^{a}	0.72^{b}	0.74^{b}	0.040	0.001
Caecum (%)	1.02	1.05	1.07	1.04	1.06	0.034	<.001

[1] Control diet (basal diet)

[2] Supplementation of100, 150, 200, and 250 g/kg wheat starch during starter, grower, finisher 1and 2, respectively

[3] Supplementation of200, 250, 300, and 350 g/kg wheat starch during starter, grower, finisher 1and 2, respectively

[4] Supplementation of300, 350, 400, and 450 g/kg wheat starch during starter, grower, finisher 1and 2, respectively

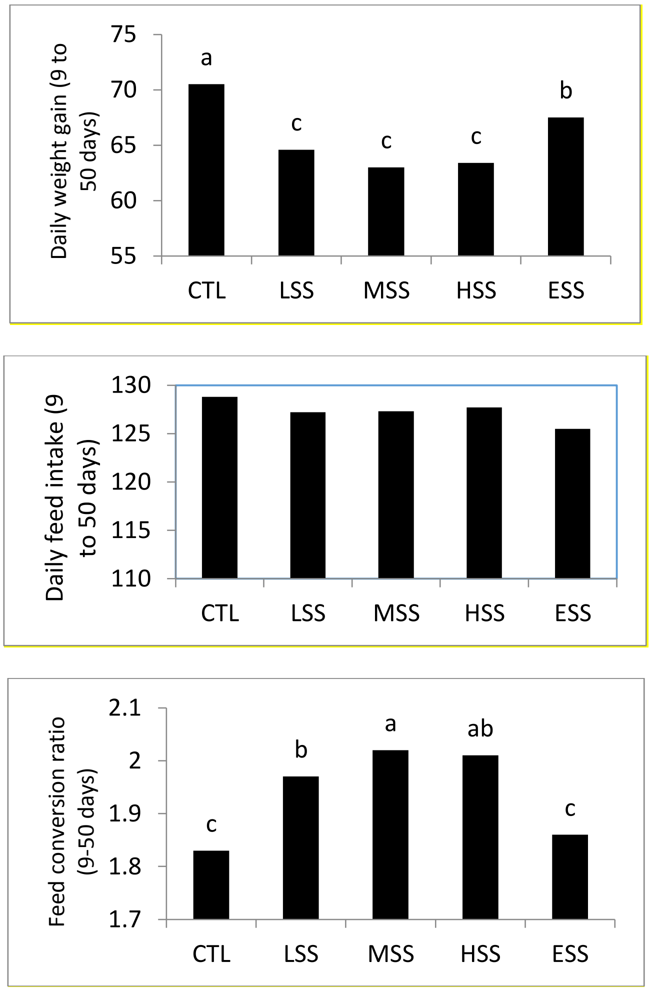
[5] Supplementation of400, 450, 500, and 550 g/kg g/kg wheat starch during starter, grower, finisher 1and 2, respectively

[a,b,c,d] Means in the same row with different superscript differ significantly (P<0.05) (n=5)

Table 6. Effects of dietary treatments on immune responses of broiler chickens

	Dietary treatments					SEM	*P*-value
Parameters	CTL[1]	LSS[2]	MSS[3]	HSS[4]	ESS[5]		
IDV (log_2)	5.7^{a}	5.3^{ab}	6.0^{a}	4.6^{b}	4.6^{b}	0.168	0.024
NDV (log_2)	3.8	4.1	4.1	4.0	3.8	0.108	0.801
Spleen (%)	0.12^{ab}	0.07^{c}	0.13^{a}	0.11^{b}	0.09^{c}	0.005	<.001
Bursa of Fabricius(%)	0.07	0.05	0.06	0.06	0.06	0.004	0.531

IDV= Influenza disease virus; NDV= Newcastle disease virus; [1] Control diet (basal diet)
[2] Supplementation of100, 150, 200, and 250 g/kg wheat starch during starter, grower, finisher 1and 2, respectively
[3] Supplementation of200, 250, 300, and 350 g/kg wheat starch during starter, grower, finisher 1and 2, respectively
[4] Supplementation of300, 350, 400, and 450 g/kg wheat starch during starter, grower, finisher 1and 2, respectively
[5] Supplementation of400, 450, 500, and 550 g/kg g/kg wheat starch during starter, grower, finisher 1and 2, respectively
[a,b,c,d] Means in the same row with different superscript differ significantly ($P < 0.05$) (n=5)



CTL= Control diet (basal diet); LSS=Supplementation of100, 150, 200, and 250 g/kg wheat starch during starter, grower, finisher 1and 2, respectively; MSS=Supplementation of200, 250, 300, and 350 g/kg wheat starch during starter, grower, finisher 1and 2, respectively; HSS=Supplementation of300, 350, 400, and 450 g/kg wheat starch during starter, grower, finisher 1and 2, respectively; ESS=Supplementation of400, 450, 500, and 550 g/kg g/kg wheat starch during starter, grower, finisher 1and 2, respectively; [a,b,c,d] Means in the same row with different superscript differ significantly ($P < 0.05$) (n=5)

Figure 1: Effect of dietary treatments on growth performance of broiler chickens during the entire rearing period

Discussion

Different feed additives and economic feed have been tried for increase in growth performance (Omerovic et al 2016, Aderami et al 2017) and immunity (Emadinia et al 2017) of broiler chicken with varied results. In the present study effect of dietary supplemental WSB on growth performance, carcass traits and immune responses of broiler chickens was studied.

Although supplementation of ESS decreased DFI of broiler chickens during 17 to 25 days of age but WSB did not have any adverse effect on DWG and FCR across the starter and growing periods. It may show that dietary WSB supplementation up to 450 g/kg had not any detrimental impact on growth performance of broiler chickens until 25 days of age. With exception of dietary ESS supplementation during 26 to 39 days of age, dietary inclusion of WSB decreased growth performance of broiler chickens as broilers aged across finisher 1, finisher 2, and the entire grow-out period. At the same period, DFI of broilers was not affected by experimental treatments, suggesting that impaired DWG and FCR was not related to DFI and might have impaired owing to lower digestibility of WSB. Dietary inclusion of wheat screenings, bakery by-products and wheat mill run in concert with supplementation of an effective enzyme improved growth performance of broiler chickens (Boros et al., 2004). Moreover, Saki and Alipana (2005) suggested that 20% dietary inclusion of wheat screening could decrease the price of diet in broiler chickens. Furthermore, Torki and Kimiaee (2011) have shown that dietary corn can be totally replaced with bakery by-products with no adverse effect on production performance and egg quality of laying hens. It has been shown that digestibility of starch is affected by several factors including amylose to amylopectin ratio, granule size and content, as well as properties of proteins, lipids and phosphates on the surface of starch granules (Svihus, 2011). Moreover, feed intake and structure of diet are the other factors with effect on wheat starch digestibility (Svihus, 2011). In this respect, low starch digestibility values were characterized by dietary high wheat inclusion level.(Svihus, 2011). Generally, products derived from wheat may contains non-starch polysaccharide (NSP), forming viscous gel in the intestinal lumen (Annison 1991). In such situation, contact between digestive enzymes and food particles is decreased and result in poor utilization of nutrients during digestion and absorption (Choct and Annison 1992; Van der Klis et al., 1993). As such, lower growth performance of broiler chickens received WSB may attribute to noted reasons. The compromising impact of age in broilers received wheat starch on growth of broilers indicate that gastrointestinal tract is immature at hatch and it takes time to efficiently digest dietary components (Sklan, 2001). Therefore, difference observed between the effects of WSB on growth performance of broilers was more tangible across finisher period. There is dearth of reports on the effect of WSB on growth performance of broiler chickens and further research is warranted.

Reduction in carcass yield of broiler chickens fed with WSB might be due to lower DWG and consequently lower muscle growth of them across the entire rearing period. On the contrary, Sadeghi et al. (2017) did not observe any effect of 0 to 50% inclusion levels of wheat screening as a wheat by-product on carcass yield of broiler chickens. Feeding diets supplemented with HSS and ESS increased the liver weight of broiler chickens, in contrast to Sadeghi et al. (2017) who reported the lack of the wheat screening effect on liver weight in broiler chickens. The increased relative weight of abdominal fat in birds fed on LSS and MSS containing diets could show the reduction in digestion and absorption of diet, cased disruption in balance of energy and protein utilization and altered metabolism of proteins. Therefore, extra energy in the body precipitated in form of the fat. Otherwise, the reason behind that greater levels of WSB did not affect the fat stored in abdomen area needs further research.

Relative weight of the pancreas increased in response to dietary WSB supplementation. Likewise, Yaghobfar and Kalantar (2017) reported the increased pancreas weight due to NSP contents of diets supplemented with wheat, leading to elevated secretions of lipase and amylase which subsequently resulted in hypertrophy of pancreas. Also, jejunum weight increased in broilers fed on diets containing WSB probably because of increased intestinal viscosity resulted from greater NSP contents of WSB added diet which led to increased gut motility and digestive excretions and therefore increased size of this tract. Similar to our findings, Mazhari et al. (2015) reported elevation of small intestinal weight in broiler chickens received dietary graded levels of wheat screening.

It has been reported that supplementation of wheat in diet of broiler chicken decreases gram positive bacteria such as l*actobacillus* and *bifidobacteria* with probiotic effects, modulating initial immunity of host animal (Christensen et al., 2002) and assist development of lymphoid organs (Rhee et al., 2005). Furthermore, Yaghobfar and Kalantar (2017) reported that using wheat in diet of broiler chickens increased population of gramnegative bacteria such as *E.coli* and *clostridium* in the ileum with detrimental impacts on the intestinal function as harmful secondary metabolites. Hence, noted reasons may have decreased antibody titer against IDV and proportional weight of the spleen. In line with our results, El-Katcha et al. (2014) reported that dietary inclusion of wheat decreased phagocytic activity of broiler chickens. Moreover, they showed that 25 and 50 % replacement of wheat with corn significantly decreased antibody titer against NDV on day 28 and 42 of age.

Conclusion

Dietary supplementation of WSB is recommended up to 450 g/kg feed across 9 to 25 days of age with no adverse effects on growth performance but may impair immune responses of broiler chickens.

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Conflict of interest

No potential conflict of interest was reported by the authors.

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