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Original article

BROILER CHICKEN PERFORMANCE IN RESPONSE TO VARIOUS LEVELS OF RAW AND AUTOCLAVED RICE BRAN

E. EIZADI, F. SHARIATMADARI, M. A. KARIMI TORSHIZI & H. R. HEMATI MATIN

Department of Animal Science, Faculty of Agriculture, Tarbiat Modares University, Tehran, Iran

Summary

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The inclusion of raw or autoclaved rice bran (RB) into broiler chicken diets was evaluated. A total of 420 broiler chickens (Ross 308) were assigned to a basal diet (without RB) or diets containing 6, 12, and 18% raw or autoclaved RB with 3 replicates of 20 chickens. By polynomial orthogonal contrasts, a significant reduction in body weight gain and feed intake (L: P =0.048), the weight of abdominal fat (L: P=0.048), ether extract digestibility (L: P=0.025), villus height (L: P=0.046), and crypt depth (L and Q: P=0.043) was achieved by increasing the inclusion levels of raw or autoclaved RB in the diets. On day 42, significant decreases were found in the weights and the ash contents of tibia (L: P=0.003) with increasing the level of raw RB in the diets. Decreased serum cholesterol was obtained following the inclusion of increasing levels of raw RB (Q: P=0.015) or autoclaved RB (L and Q: P=0.015) in the diets. The inclusion of RB in the diets resulted in poorer nutrient digestibility and performance, although it had some modulation effects on blood lipid biochemistry. It is suggested that the inclusion of raw RB in the diets should be limited to 6%, however, autoclaving allowed inclusion of RB up to 12% in the broiler diets.

Key words: abdominal organs, blood biochemistry, broiler performance, digestibility, rice bran, tibia

INTRODUCTION

The rice bran (RB) has become popular as a part of poultry diets. It has great potential as a byproduct dietary ingredient because it is a good source of protein, energy, vitamins, and minerals (Saunders, 1990). It is used in broiler diets at a level up to 12% without substantial effects (Gallinger *et al*., 2004). The use of RB might be restricted by its anti-nutritional substances i.e. non-starch polysaccharides, python (Lue *et al*., 1991), trypsin inhibitor (Barber & Benedito, 1978), and low availability of amino acids (Farrell, 1994). There are several potential methods of accomplishing stabilisation, which mostly are associated with some type of heating (Mujahid *et al*., 2005). The heat treatment could improve RB quality (Lue *et al*., 1991) which is especially effective in the presence of moisture (Ramezanzadeh, 1999), and its inclusion in diets resulted in a significant improvement in performance of broiler chickens (Kratzer & Payne, 1977; Saunders, 1990). The autoclaving is a combination of heat and moisture for RB treatment (Kratzer & Payne, 1977), but the information on the inclusion of autoclaved RB in broiler diets is scarce and contradictory. Therefore, the present study was carried out to determine the effect of different levels of raw RB or autoclaved RB on bone mineralisation, intestinal morphology, nutrient digestibility, and broiler chicken performance.

MATERIALS AND METHODS

The Animal Ethics Committee of the Tarbiat Modares University, Tehran, Iran has approved the experiment.

Birds and husbandry

A total of 420 unsexed broiler chickens (Ross 308) were allocated to seven diets with 3 replicates of 20 chickens in each at a completely randomised design. Broiler chickens were placed as 20 birds/2 m^2. All

Table 1. Composition of the diets for broiler chickens from 15 to 28 and from 29 to 42 days of age (% as fed basis or as stated)

	15 to 28 days of age				29 to 42 days of age			
	control	6% RB	12% RB	18% RB	control	6% RB	12% RB	18% RB
Ingredients								
Corn grain	59.00	53.99	48.55	43.06	63.46	58.30	52.90	47.60
Soybean meal (440 g CP/kg)	31.00	29.60	28.80	28.05	26.00	24.90	24.00	23.00
Fish meal	3.19	3.70	3.75	3.78	3.52	3.79	3.93	4.11
Soybean oil	3.32	3.40	3.61	3.85	3.75	3.87	4.07	4.24
Rice bran	0.00	6.00	12.00	18.00	0.00	6.00	12.00	18.00
Dicalcium phosphate	1.27	1.13	1.06	1.02	1.14	1.04	0.99	0.92
Oyster shells	0.76	0.86	0.89	0.91	0.83	0.83	0.84	0.86
Common salt	0.32	0.30	0.32	0.31	0.31	0.30	0.030	0.30
Premix[1]	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
DL-methionine (980 g/kg)	0.25	0.24	0.24	0.24	0.21	0.21	0.21	0.21
L-lysine HCl	0.10	0.08	0.08	0.08	0.07	0.06	0.06	0.06
Vitamin E	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Total	100	100	100	100	100	100	100	100
Calculated								
Metabolisable energy (kcal/kg DM)	3,050	3,051	3,050	3,050	3,150	3,150	3,150	3,150
Crude protein	20.34	20.34	20.34	20.34	18.71	18.70	18.71	18.70
Calcium	0.87	0.87	0.87	0.87	0.84	0.83	0.83	0.83
Available phosphorus	0.44	0.43	0.43	0.43	0.41	0.41	0.41	0.41
Methionine	0.60	0.60	0.60	0.60	0.59	0.54	0.54	0.59
Lysine	1.21	1.20	1.20	1.20	1.07	1.07	1.08	1.08

[1]Mineral premix Mn, 64 g; Zn, 44 g; Fe, 100 g; Cu, 16 g; I, 0.64 g; Vitamin premix; B_1, 3.3 g; B_2, 0.72 g; K_3, 1.6 g; Vitamin E; 14.4 g; Vitamin D, 7 g; Vitamin A, 7.7 g; Pantothenic acid, 12 g; Pyridoxine, 6.2, mg, B_{12}, 14.4 g; Choline chloride, 440 mg per kg of the diet.

broiler chickens were fed similar starter diet from 1 to 14 days of age (metabolisable energy 2,950 kcal/kg and crude protein 21.45%). Diets consisted of basal diet (without RB addition), basal diet plus raw RB or autoclaved RB at the levels of 6, 12, or 18% for grower (15 to 28 days) and finisher (29 to 42 days) periods. The diets were formulated based on NRC (1994) recommendations as isocaloric and isonitrogenous (Table 1) and were offered *ad libitum*. The light regimen was set as 23 h light and 1 h darkness and temperature was gradually reduced by 3°C from the initial 32 °C in each week. Feed intake (FI), body weight gain (BWG), and feed conversion ratio (FCR) were measured weekly. To autoclaving, the RB samples were placed in shallow trays and were heated in the autoclave at 15 p.s.i. pressure and 121°C (Kartzer & Payne, 1977).

Blood sampling and analyses

Six birds (2/replicate) were randomly selected and blood samples were taken from the wing vein at 42 days of age. Serum samples were taken and blood cholesterol and triglycerides were measured by specific kits (Pars Azmoon, Tehran) and a spectrophotometer (UV) at 546 nm wavelength.

Carcass traits

At 42 days of age, six birds (2/replicate) were randomly selected, weighed, slaughtered and, immediately after dressing, the complete gastrointestinal tract (GIT) was removed. Liver, abdominal fat, gizzard, pancreas and the right tibias were removed. These organs were cleaned, weighed and expressed relative to live body weights. The tibias were boiled for 2 min, the surrounding meat and cartilaginous caps were removed. The weight of tibias was recorded and the lengths, large and small diameter of tibias were measured using a digital caliper (0.01 mm, Mitutoyo, Japan). The bones were dried in a forced-air oven for 24 h at 105 °C and their weights were recorded (Gallinger *et al*., 2004).

Intestinal morphology

Histological indices were measured according to Iji *et al*. (2001) method. Formalin-fixed tissue samples were dehydrated, cleared, and impregnated with paraffin. The processed tissues were then embedded in paraffin wax. Sections were cut (5–6 µm) from the waxed tissue on the microtome. The slides were stained by haematoxylin and eosin. Histological indices were determined using a computer-aided light microscopic image analyzer (Dino Capture 2.0). The villi height (VH) and crypt depth (CD) were measured, and the calculation was made for VH to CD ratio (villi index, VI). Five adjacent, vertically oriented villous-crypt units per section were used for analysis.

Nutrient digestibility analysis

A balance trial (39 to 42 d) was made with titanium oxide (TiO_2, 2 g/kg diets) as an indigestible marker for determination of nutrient digestibility. Six birds (2/replicate) were sacrificed after a three-day adaptation period at 42 days of age. The ileal digesta between the yolk sac and the terminal ileum (2 cm above the ileocaecal junction) were gently removed and digesta samples were stored at –20 °C until further processing. Titanium in feed and digesta was determined based on the method described by Short *et al*. (1996). Samples of oven-dried diets and digesta were ground to a fine texture. Diets and digesta were analysed for chemical composition. Dry matter, organic matter, crude protein, and ether extract of diets and digesta were determined by methods according to the

Association of Official Analytical Chemists (AOAC, 1990). Gross energy was determined by an adiabatic bomb calorimeter standardised using benzoic acid (Parr Instruments, Moline, IL). Finally, nutrients digestibility were calculated using standard equations of digestibility.

Statistical analysis

The pen was used as the experimental unit and data were analysed as a completely randomised design by the GLM procedure of SAS (2004). Polynomial orthogonal contrasts were individually carried out for raw RB and autoclaved RB levels to investigate the linear and quadratic trends. In addition, independent comparisons were done for the groups fed RB vs. the control group. P values of ≤0.05 were considered as significant.

RESULTS

Metabolisable energy, dry matter, crude protein, ether extract, crude fibre, Ca, total phosphorus, and ash contents of tested RB was 2950 kcal/kg, 91.06, 12.98, 13.20, 12.40, 0.07, 1.50, and 12.10 %, respectively. Increasing the inclusion levels of raw or autoclaved RB in the diets caused a significant reduction in BWG, FI, and a significant increase in FCR (L: P =0.048) at both periods (Table 2). On day 42, the tibia weight and tibia ash contents decreased (L: P=0.003) by increasing the levels of raw RB in the diets (Table 3). No significant trends were observed in other parameters.

The effect of diets on the organs and abdominal fat weights of broiler chickens at day 42 is displayed in Table 4. Increased dietary levels of raw or autoclaved RB increased the weights of gizzard (L and Q: P=0.034) and pancreas (L: P=0.045) as well as decreased abdominal fat weights (L: P=0.048). On the 42nd day, significant decrease was obtained in serum cholesterol after inclusion of increasing levels of raw RB (Q: P=0.015) and autoclaved RB (L and Q: P=0.015) in the diets (Table 5). No significant trend was observed in serum triglycerides.

Table 2. Effects of increasing levels of raw and autoclaved rice bran (RB) in broiler chicken diets on body weight gain (BWG/g), feed intake (FI/g), and feed conversion ratio (FCR) in grower and finisher phases (means ± SEM)

	Grower (days 15 to 28)			Finisher (days 29 to 42)		
Item	BWG	FI	FCR	BWG	FI	FCR
Control diet	987±3.2	1675±3.8	1.69±0.001	1285±9.0	2724±5.3	1.93±0.001
6% raw RB	975±3.2	1668±3.2	1.70±0.008	1254±3.0	2704±5.5	1.96±0.003
12% raw RB	906±3.6	1616±1.7	1.78±0.007	1195±3.0	2660±4.9	2.03±0.004
18% raw RB	814±2.7	1552±2.1	1.90±0.007	1073±4.2	2600±1.7	2.20±0.007
P value for trend						
Linear	0.037	0.021	0.021	0.017	<0.001	<0.001
Quadratic	0.225	0.110	0.019	0.148	0.051	0.001
6% autoclaved RB	977±3.9	1665±4.0	1.70±0.003	1257±5.7	2706±2.3	1.95±0.009
12% autoclaved RB	906±1.5	1619±3.2	1.78±0.003	1200±3.8	2664±3.8	2.03±0.009
18% autoclaved RB	815±5.9	1556±2.1	1.9±0.011	1079±3.4	2596±7.5	2.19±0.012
P value for trend						
Linear	0.048	0.017	0.016	0.026	0.001	0.111
Quadratic	0.129	0.319	0.078	0.689	0.223	0.122

Table 3. Effects of increasing dietary levels of raw and autoclaved rice bran (RB) on tibia characteristics at 42 days of age (means ± SEM)

Item	Weight (g)	Ash (%)[1]	Length (cm)	External diameter (cm)		Internal diameter (cm)	
				Small	Large	Small	Large
Control diet	8.50±0.06	43.25±0.02	9.98±0.08	0.83±0.01	0.98±0.05	0.54±0.11	0.58±0.03
6% raw RB	8.01±0.03	42.02±0.08	9.6±0.18	0.81±0.04	1.01±0.03	0.57±0.09	0.62±0.04
12% raw RB	8.11±0.11	39.85±1.02	9.94±0.11	0.80±0.11	0.97±0.01	0.50±0.12	0.61±0.05
18% raw RB	7.45±0.21	39.02±0.28	9.87±0.12	0.77±0.10	0.94±0.07	0.56±0.01	0.63±0.11
P value for trend							
Linear	0.131	0.211	0.155	0.217	0.255	0.087	0.065
Quadratic	0.346	0.054	0.518	0.211	0.118	0.111	0.058
6% autoclaved RB	8.03±0.11	42.51±0.18	9.64±0.32	0.73±0.17	0.94±0.03	0.57±0.02	0.56±0.04
12% autoclaved RB	8.06±	41.52±1.39	9.69±0.47	0.77±0.04	0.98±0.04	0.53±0.09	0.57±0.11
18% autoclaved RB	8.01±	41.62±1.08	9.87±0.39	0.80±0.02	0.97±0.01	0.62±0.06	0.69±0.12
P value for trend							
Linear	0.003	0.001	0.529	0.065	0.329	0.085	0.091
Quadratic	0.131	0.001	0.155	0.057	0.055	0.067	0.555

[1] As percentage of dry bone weight.

Table 4. Effects of increasing levels of raw and autoclaved rice bran (RB) in broiler chicken diets on the gizzard, pancreas, liver, and abdominal fat weights (% of live body weight) at 42 days of age (means ± SEM)

Item	Gizzard	Pancreas	Liver	Abdominal fat
Control diet	1.25±0.015	0.23±0.004	2.03±0.221	2.16±0.286
6% raw RB	1.53±0.025	0.24±0.047	2.1±0.303	1.96±0.0168
12% raw RB	1.56±0.68	0.25±0.006	1.9±0.187	1.74±0.0150
18% raw RB	1.57±0.025	0.27±0.004	2.13±0.048	1.62±0.019
P value for trend				
Linear	0.011	0.045	0.321	0.037
Quadratic	0.034	0.418	0.110	0.225
6% autoclaved RB	1.53±0.066	0.22±0.006	2.22±0.064	1.94±0.218
12% autoclaved RB	1.53±0.017	0.23±0.005	2.11±0.165	1.82±0.127
18% autoclaved RB	1.64±0.856	0.25±0.004	2.27±0.026	1.73±089
P value for trend				
Linear	0.031	0.029	0.211	0.048
Quadratic	0.021	0.165	0.312	0.129

Table 5. Effects of increasing levels of raw and autoclaved rice bran (RB) in broiler chicken diets on serum cholesterol and triglycerides at 42 days of age (means ± SEM)

Item	Total cholesterol, mmol/L	Triglycerides, mmol/L
Control diet	3.03±0.081	0.79±0.019
6% raw RB	2.99±0.034	0.79±0.045
12% raw RB	2.88±0.014	0.78±0.036
18% raw RB	2.79±0.033	0.89±0.006
P value for trend		
Linear	0.618	0.321
Quadratic	0.015	0.110
6% autoclaved RB	3.03±0.031	0.80±0.059
12% autoclaved RB	2.87± 0.091	0.79±0.021
18% autoclaved RB	2.81±0.047	0.78±0.037
P value for trend		
Linear	0.009	0.211
Quadratic	0.015	0.312

Table 6 shows the effect of the diets on ileal digestibility of nutrients in broiler chickens at day 42. Significant decreases was found in the digestibility of dry matter, metabolisable energy (L and Q: P=0.046), crude protein and ether extract (L: P=0.025) after increasing the levels of raw or autoclaved RB in the diets. Table 7 illustrates the effect of RB inclusion in the diets on intestinal morphology of broiler chickens. Increased levels of raw or autoclaved RB reduced significantly the VH (L: P=0.046) and the CD (L and Q: P=0.043). In addition, the broiler chickens fed the diets with increasing levels of autoclaved RB had lower VI (L and Q: P=0.024).

On day 42, the length of jejunum, ileum, caecum, and the relative length of caecum increased paralelly to dietary levels of raw or autoclaved RB (Table 8, L and Q: P=0.043). A significant increase

Table 6. Effects of increasing levels of raw and autoclaved rice bran (RB) in broiler chicken diets on the apparent ileal digestibility of nutrients (means ± SEM)

Item	Dry matter	Organic matter	Metabolisable energy	Crude protein	Ether extract
Control diet	86.56±0.70	74.88±0.57	76.00±0.63	75.89±0.48	66.22±0.99
6% raw RB	84.73±0.55	74.67±0.47	75.20±1.22	74.99±0.64	65.74±0.79
12% raw RB	82.86±1.26	74.60±0.75	74.61±0.23	73.16±0.19	63.61±0.99
18% raw RB	76.70±1.57	73.31±0.91	73.79±1.04	71.00±0.80	61.78±0.62
P value for trend					
Linear	0.003	0.113	0.009	0.011	0.001
Quadratic	0.089	0.618	0.139	<0.001	0.001
6% autoclaved RB	86.13±0.86	74.75±0.50	75.84±0.49	75.28±0.84	65.46±2.09
12% autoclaved RB	83.70±1.40	74.74±0.67	75.83±1.26	73.42±0.87	63.79±1.26
18% autoclaved RB	77.13±1.12	73.78±.48	75.83±1.29	71.79±0.82	61.45±1.65
P value for trend					
Linear	0.046	0.678	0.041	0.025	0.024
Quadratic	0.099	0.512	0.370	0.772	0.273

Table 7. Effects of increasing levels of raw and autoclaved rice bran (RB) in broiler chicken diets on jejunal villi height, crypt depth, and villi index at 42 days of age (means ± SEM)

Item	Villi height (mm)	Crypt depth (mm)	Villi height/crypt depth
Control diet	0.286±0.003	0.263±0.006	0.208±0.061
6% raw RB	0.288±0.025	0.267±0.001	0.214±0.039
12% raw RB	0.291±0.028	0.253±0.015	0.210±0.310
18% raw RB	0.286±0.029	0.270±.006	0.214±0.009
P value for trend			
Linear	0.046	0.043	0.221
Quadratic	0.219	0.019	0.422
6% autoclaved RB	0.295±0.056	0.274±0.028	0.209±0.338
12% autoclaved RB	0.288±0.055	0.256±0.012	0.211±0.128
18% autoclaved RB	0.287±0.009	0.269±0.007	0.216±0.067
P value for trend			
Linear	0.025	0.038	0.001
Quadratic	0.553	0.019	0.024

was observed in the weight of duodenum (Q: P=0.016) and caecum (L and Q: P=0.028) (Table 9). Moreover, the relative weights of ileum (L: P=0.045) and caecum (L and Q: P=0.042) were higher with the increasing levels of raw or autoclaved RB in diets, without significant trends in other parameters.

DISCUSSION

The results for the performance in the present study were in agreement with the findings of Mujahid *et al.* (2005), who reported that increasing the levels of RB in broiler chicken diets caused significant decreases in BWG and FI. There is a relationship between the rate of feed passage

Table 8. Effects of increasing levels of raw and autoclaved rice bran (RB) in broiler chicken diets on intestine length at 42 days (means ± SEM)

	Length (cm)				Relative length (cm/100 g of BW)			
Item	Duodenum	Jejunum	Ileum	Caecum	Duodenum	Jejunum	Ileum	Caecum
Control diet	32.88±0.67	81.40±0.55	82.03±0.48	24.03±0.65	0.64±0.03	2.79±0.16	2.82±0.16	0.82±0.39
6% raw RB	33.68±1.16	81.70±0.42	82.55±0.22	24.37±0.86	0.66±0.02	2.90±0.11	2.93±0.09	0.86±0.30
12% raw RB	34.16±0.27	82.16±0.31	82.92±0.55	25.37±0.65	0.72±0.09	3.16±0.41	3.19±0.38	0.97±0.94
18% raw RB	34.84±0.73	84.25±1.16	83.11±0.74	29.01±2.54	0.73±0.02	3.19±0.21	3.15±0.18	1.10±0.45
P value for trend								
Linear	0.011	0.009	0.040	0.043	0.068	0.136	0.215	0.011
Quadratic	0.012	0.002	0.019	0.019	0.053	0.233	0.129	<0.001
6% autoclaved RB	33.46±1.06	81.59±0.72	82.88±0.57	25.60±0.65	0.71±0.09	3.17±0.39	3.22±0.38	0.99±0.98
12% autoclaved RB	33.69±0.68	82.60±0.88	82.98±0.52	25.62±1.05	0.73±0.04	3.26±0.19	3.27±0.21	1.01±0.50
18% autoclaved RB	34.59±0.49	84.60±0.97	83.87±0.57	27.40±1.3	0.74±0.07	3.21±0.14	3.19±0.14	1.04±0.34
P value for trend								
Linear	0.031	0.005	0.025	0.018	0.119	0.058	0.239	<0.001
Quadratic	0.034	0.006	0.033	0.019	0.146	0.278	0.441	0.025

Table 9. Effects of increasing levels of raw and autoclaved rice bran (RB) in broiler chicken diets on intestine weight at 42 days (means ± SEM)

Item	Weight (g)				Relative weight (g/100 g of BW)			
	Duodenum	Jejunum	Ileum	Caecum	Duodenum	Jejunum	Ileum	Caecum
Control diet	18.59±0.33	39.70±0.61	25.57±0.49	3.49±1.10	0.64±0.03	1.36±0.09	0.88±0.05	0.12±0.17
6% raw RB	18.57±0.51	40.87±1.49	28.84±1.29	3.82±1.41	0.66±0.02	1.45±0.08	1.03±0.04	0.14±0.03
12% raw RB	18.61±0.19	41.23±1.42	28.04±2.11	3.78±1.41	0.72±0.09	1.59±0.26	1.07±0.09	0.14±0.42
18% raw RB	19.19±0.42	41.98±1.22	28.69±1.57	4.10±0.85	0.73±0.02	1.60±0.12	1.08±0.08	0.15±0.19
P value for trend								
Linear	0.140	0.053	0.078	0.013	0.239	0.311	0.045	0.021
Quadratic	0.016	0.519	0.053	0.618	0.149	0.432	0.418	0.010
6% autoclaved RB	18.17±0.32	40.08±0.39	29.51±1.13	3.67±1.12	0.71±0.09	1.56±0.19	1.15±0.18	0.14±0.47
12% autoclaved RB	18.61±0.11	41.77±0.42	28.71±1.72	3.89±1.92	0.73±0.04	1.59±0.26	1.13±0.67	0.15±0.02
18% autoclaved RB	19.38±0.59	41.67±0.75	28.49±1.35	4.18±1.24	0.74±0.07	1.58±0.09	1.09±0.07	0.16±0.16
P value for trend								
Linear	0.322	0.218	0.319	0.028	0.341	0.625	0.029	0.011
Quadratic	0.003	0.119	0.136	0.012	0.375	0.752	0.165	0.042

through the intestine and FI in young chickens (Almirall & Garcia, 1994). The level of dietary fibre increases with inclusion of RB in diets (Sharma *et al*., 2004), which led to FI decreases (Van der Klis *et al*., 1993; Langhout *et al*., 1999). In addition, the viscosity of small intestinal digesta increases after inclusion of dietary fibre (Van der Klis *et al*., 1993) and thereby decreases utilisation of feed. This phenomenon was supported by the nutrient digestibility reduction measured in the present study. Lower BWG of broiler chickens on these diets was accompanied by lower FI. The use of autoclaved RB rather than raw RB resulted in relatively better BWG and FCR (Kratzer & Pyne, 1977; Masood *et al.,* 1995) which is in agreement with the results of the current study. The initial quality of RB is a determining factor on RB effects after autoclaving and broiler growth parameters in response to consumption of autoclaved RB in the diets.

Similar to the results of the current study, it is reported that tibia weight and ash contents of broilers are reduced by increasing the level of RB in diets which is attributed to the phytic acid and fibre content of RB (Adrizal *et al.,* 1996; Galinger *et al*., 2004). The content of phytic acid and its derivatives is 5 to 7% in polished rice (Nelson *et al*., 1968). Also, about 90% of phosphorus in RB is as phytate (McCall *et al*., 1953). Phytate form some complexes with protein, vitamin, and minerals, which decrease the bioavailability of nutrients in poultry diets (Zyla *et al*., 1989), and lead to reduction in the Fe, Ca, and Zn accumulation of tibia (Khalique *et al.,* 2003). Therefore, the broiler chickens fed the diets containing raw RB might have poorer mineralisation parameters. The autoclaved RB contains by 80% more available phosphorus than raw RB (Tangendjaja *et al.,* 2006). Thus, autoclaving of RB could improve bone formation and mineralisation related parameters.

The weight and size of GIT organs development after consumption of RB was attributed to its arabinoxylan content (Shibuya & Twasaki, 1985). The use of RB in broiler diets increases pancreatic weights because of the trypsin inhibitor in RB (Shibuya *et al*., 1985; Eshwaraiah *et al*., 1988). The trypsin inhibitor is extremely sensitive to heat and is completely destroyed by autoclaving (Kratzer & Payne, 1977). Inclusion of RB (autoclaved for 15 min) in broiler diets improved growth rate with normal pancreatic weight. These results are consistent with the findings of the present study. El-Ghamry *et al*. (2005) reported that pancreatic and gizzard weights increased with RB increasing level in the diets. Increasing percentage of gizzard could be explained by increase in crude fibre content of RB which induced gizzard enlargement and in turn increased gizzard weight. In addition, broilers fed diets with high amounts of dietary fibre had lower abdominal fat (Shahin & Abdelazim, 2005). In the presence of dietary fibre, the secretion of bile acids and hepatic-intestinal circulation was reduced (Mathlouthi *et al*., 2002) which restricted lipids emulsification. These events result in decreased lipids absorption and lead to lower abdominal fat contents (Shahin & Abdelazim, 2005). Oladunjoye & Ojebiyi (2010) reported that the high level of incorporation of RB in the diets led to a reduction in abdominal fat.

The reduction of cholesterol by increasing the levels of RB in the diets could relate to the high content of fatty acids in RB, which increases insoluble complexes and soap compounds and leads to lower cholesterol absorption. In line with the results of the present study, the cholesterol lowering properties of RB were approved by other researchers (El-Ghamry *et al*., 2005).

The higher levels of crude fibre in diets containing RB (levels >6%) may be an important factor for explaining the reductions in nutrient digestibility in the current study. This is in agreement with other studies (Mujahid *et al*., 2005). The processing of RB by autoclaving resulted in some improvement in digestibility parameters. Heating RB in the presence of moisture (similar to autoclaving) was reported to be much more effective in achieving permanent improvements (Kratzer *et al*., 1977; Barber *et al*., 1978; Ramezanzadeh *et al*., 1999). The autoclaving of RB inactivates the lipases, trypsin inhibitors, and denaturates the anti-nutritional factors which improve the nutrients digestibility as reported by others (Saunders, 1990; Ramezanzadeh *et al*., 1999). Therefore, the autoclaving of RB increases digestibility of nutrients when included in diets as compared to raw RB.

The VH reduction in the presence of RB (especially 18% raw RB) could be due to its anti-nutritional effects rather than viscosity (Iji *et al*., 2001) and RB physical presence which leads to villi attrition. The attrition effects of fibre components shown in other studies (Leterme *et al*., 1998; Montagne *et al*., 2003) might lead to a waste of nutrients and endogenous cell losses in the lumen. Autoclaving omits some destructive effects of RB on villi characteristics. Inclusion of 18% raw RB in diets increased jejunum CD. The viscose material in broiler diets results in deeper crypts at day 14 (Iji *et al*., 2001). Actually, the crypt is regarded as the villus factory and a large crypt indicates fast tissue turnover and a high demand for new tissue (Xu *et al*., 2003). Therefore, increased CD suggests a high potential for cell proliferation (Iji *et al*., 2001). As a result, deeper crypt obtained by treatments is due to unusual demand for cell proliferation and new tissue. These events were not observed with autoclaving of RB which could suggest that autoclaving moderates RB properties. The VI is a useful criterion for estimating the digestive capacity of the small intestine (Mateos *et al*., 2012). The raw or autoclaved RB at a level of 18% in diets led to the worst VI. This indicates that RB reduced digestive capacity of small intestine by VI reduction.

Saki (2005) noted that the diets containing fibre products (wheat and barley) increased the length of intestinal segments in broiler chickens, an adaptation to increase the exposure of the nutrients to digestive enzymes. The higher dietary RB levels increase dietary fibre contents. It is likely that increases in the jejunum, ileum, and caecum lengths are related to the contribution of RB to the physical enlargement of the intestine or RB with high water holding capacity or swelling capacity increases the retention time of feed in intestine and induces enlargement of intestinal segments (Ritz *et al*., 1995). Moreover, it is shown that older broilers adapt to diets containing fibre by developing the caeca (Jorgensen *et al*., 1996). Although this hypothesis is not proved, it is shown elsewhere that short-chain fatty acid diffusion stimulates cell proliferation (Johnson & Gee, 1986) and could lead to caecum elongation. Other plausible mechanisms include caecal digesta osmolality and water holding capacity (Johnson & Gee, 1986).

As previously noted, broilers adapt to high levels of fibres in diets by enlarging the GIT (Jorgensen *et al*., 1996), consequently, their weights increase. 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 (Johnson & Gee, 1986; Viveros *et al*., 1994; Smits & Annison, 1996; Iji *et al*., 2001; Banfield *et al*., 2002; Jiménez-Moreno *et al*., 2009). The results of the current study are in agreement with other studies in broiler chickens (Gallinger *et al*., 2004) and layers (Samli *et al*., 2006).

CONCLUSIONS

The diets containing rice bran had significantly poorer growth parameters compared with the control diet. Increasing the levels of rice bran in broiler chicken diets reduced nutrients digestibility and tibial bone ash. Feed intake and body weight gain of broiler chickens decreased by diets containing raw rice bran in excess of 6%. Autoclaving with improving nutritional value of rice bran has positive effects on nutrients digestibility and its inclusion in broiler diets could increase up to 12% levels without having any adverse effects on bone mineralisation and broiler chicken performance.

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Correspondence:

Farid Shariatmadari
Department of Animal Science,
Faculty of Agriculture,
Tarbiat Modares University,
Tehran, 14115-336, Iran,
tel: +982148292372,
e-mail: shariatf@modares.ac.ir