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Effect of Ground or Whole Wheat and Triticale on Productive Performance, Egg Quality, Gastrointestinal Tract Traits and Nutrient Digestibility of Laying Japanese Quails

Research Article

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ABSTRACT

This study was conducted to investigate the effect of ground or whole wheat and triticale on productive performance, egg quality, gastrointestinal tract (GIT) traits and nutrient digestibility in laying Japanese quails. A total of 210 laying Japanese quails at 18 to 26 weeks of age were used. The experiment was designed as a 2 × 2 + 1 factorial arrangement with five treatments: a control diet was based on corn and soybean meal, two grain sources (wheat and triticale) and two physical forms of grain (ground and whole). Each treatment was replicated 6 times and the experimental unit was a cage with 7 birds each. Egg production, egg weight, egg mass, and feed conversion ratio were not affected by grain source, except for the average daily feed intake (ADFI), which was decreased by triticale but not wheat (P=0513). Average daily feed intake and egg production were higher in the group fed with whole grain versus the group fed with ground grain (P<0.05). Yolk color decreased by wheat or triticale compared with the control group (P<0.05). Relative weights of the liver, proventriculus, pancreas, gizzard and cecum were not affected by any of the treatments. The pH of the jejunum (P=0.0014), cecum (P<0.05), and intestinal viscosity increased (P<0.001) by feeding whole than ground grain. Dry matter digestibility (P<0.01), decreased by triticale but not wheat (P<0.05). In conclusion, ground triticale inclusion in the diet had a negative effect on ADFI, egg production and nutrient digestibility but feeding whole grain improved the productive performance and dry matter digestibility in laying quails.

KEY WORDS grain source, laying quail, nutrient digestibility, performance, whole grain.

INTRODUCTION

The important part of feed ingredients as a main source of energy is related to corn in the poultry diet. In Iran, corn production does not provide all feed requirements, so it must be imported. Corn price is increasing because of the limited world yield in covering the demands for both humans and livestock and using part of corn yield in the production of bio-ethanol. Due to limitation corn crop in Iran, approximately 50% of the corn required for poultry nutrition is supplied through the imports. Wheat is also a major feed ingredient in poultry diets and is available in almost all countries of the world. Triticale is more resistant to various diseases and dry weather. Thus, both wheat and triticale have been successfully grown under Iranian conditions (Chizari and Hajiheidary, 2010). The main non-starch polysaccharide (NSP) constituent in the endosperm cell walls of triticale is pentosan with some β-glucan, as in wheat and rye (Engberg *et al.* 2004). These compounds reduce the nutritive value by increasing gut viscosity and thus reducing the availability of nutrients for digestion and absorption. Ebrahimi *et al.* (2017) have reported that substitution corn with triticale in quail grower diets (zero, 50 and 100%) didn't have any adverse effect on the final weight and daily body weight gain as well as improved feed conversion ratio.

Whole grain feeding is also attractive as it meets the consumer demand for natural feeding in animal production systems and improved animal welfare (Gabriel *et al*. 2008). The primary aim of whole grain feeding is to lower feed costs by eliminating the grinding and transport steps. Whole wheat feeding is common in broilers in Europe, Australia, and Canada. In some parts of the world, whole wheat feeding is also used as part of a strategy for broiler breeders and egg layers.

Although whole grain is more suited for feeding of adult birds, studies evaluating whole grain feeding in layers are limited (Singh *et al*. 2014). Whole grain feeding may influence the development and the gastrointestinal tract physiology and consequently nutrient utilization and bird performance.

The most importantly interesting to use whole grain feeding is its effect on gizzard development, which is associated with a range of benefits in terms of digestive function (Svihus, 2011). Abdollahi *et al.* (2016) have shown that pre-pelleting inclusion of whole wheat (250 g/kg) in broilers' diet had greater relative gizzard weights and improved nutrient digestibility. Faruk *et al.* (2010) have noted that feeding whole wheat (350 g/kg) had no negative effect on performance and in laying hens and increased feed efficiency.

Mixed feeding (MF) is also a commonly used method of whole grain feeding. In MF, whole grain is either substituted for a part of the ground grain in a complete diet or added to a complete diet in the same feeder at the same time in pellet or mash form. Mixed feeding allows for simple management without investment in additional feeders and manpower.

In recent years, quail production is common in Iran because of its inexpensive rearing requirement, rapid maturation and adaptability to a wide range of environmental conditions (Ebrahimi *et al.* 2017). There are a lot of traditional quail breeding houses in Iran; hence, producers use whole grain in their diet to eliminate a grinding step. However, available information on the effects of MF on the performance of laying quail is quite limited. Therefore, the aim of this study was to evaluate the effect of ground or whole wheat or triticale inclusion in the diet on productive performance, egg quality, gastrointestinal tract traits and nutrient digestibility of laying Japanese quails from 18 to 26 weeks of age.

MATERIALS AND METHODS

Laboratory analysis

Representative samples of corn, wheat, and triticale were grounded using a 1 mm screen laboratory mill (Cyclotech Mill, Tecator, Sweden) followed by chemical analysis using standard methods (AOAC, 1990); for dry matter (method 967.03), total ash (method 942.05), crude protein (method 976.06), and ether extract (method 920.29). Crude fiber (CF) was measured sequentially using a filter bag system (Ankom Technology, Macedon, NY) (Van Soest *et al*, 1991).

Amino acid profiles were estimated by near-infrared spectroscopy (NIRs; Evonik-Degussa, Hanau, Germany). Gross energy was determined using an adiabatic bomb calorimeter (model 1356, Parr Instrument Company, Moline, IL). The geometric mean diameter (GMD) of the experimental diets was determined in 100 g samples using a Retsch shaker (Retsch, Stuttgart, Germany) provided with eight sieves ranging in mesh from 40 to 5000 μm, as described by the American Society of Agricultural Engineers (1995). All analyses were conducted in triplicate. Table 1 shows the chemical composition of these experimental grains.

Husbandry and experimental diets

In total, 210 Japanese laying quail (18 weeks of age) with 86 percent egg production and 257.20 g body weight were randomly allocated to 30 cages (100×60 cm^2) with nipple drinkers and a trough feeder each. The experiment was conducted as a completely randomized design with 5 treatments, 6 replicates and 7 quails in each. Treatments were as follows: control (basal diet based on ground corn and soybean meal), two grain sources (wheat and triticale) and two physical forms of grain (ground and whole). Wheat or triticale was added as a 20% ground or 10% whole + 10% ground grain.

In the current experiment, whole grains were mixed with other ingredients in mash form by the MF method (Singh *et al*. 2014). The average temperature and relative humidity were maintained in 20-22 ˚C and 50-60%, respectively. The light program consisted of 16 hours of light: 8 hours of dark. Water and feed were offered *ad libitum*. The diets were formulated to meet the nutrient requirements of the quail as recommended by NRC (1994) (Table 2).

Productive performance and egg quality traits

Egg production and egg weight were recorded daily and feed intake was measured weekly. This information was used to calculate ADFI, egg mass and feed conversion ratio (FCR; feed intake/egg mass).

Table 1 Analyzed proximate and total amino acid content of the experimental grain sources (%, as fed basis)

Item	Corn	Wheat	Triticale
Dry matter	90.34	90.90	91.19
Total ash	1.20	2.30	1.73
Crude protein	8.15	10.45	13.89
Ether extract	3.70	1.67	1.67
Crude fiber	1.9	2.8	3.80
Amino acid contents[1]			
Lysine	0.233	0.309	0.457
Methionine	0.159	0.165	0.228
Methionine + cysteine	0.348	0.411	0.526
Cysteine	0.189	0.246	0.297
Threonine	0.285	0.306	0.439
Tryptophan	0.060	0.136	0.145
Arginine	0.400	0.508	0.721
Isoleucine	0.269	0.337	0.486
Leucine	0.985	0.685	0.908
Valine	0.373	0.445	0.628
Histidine	0.234	0.249	0.325
Phenylalanine	0.391	0.459	0.656

[1] Estimated by NIR spectroscopy.

Table 2 Ingredient and chemical composition of the experimental diets (% as fed basis, unless otherwise indicated)

Ingredients	Control[1]	Wheat[2]	Wheat[3]	Triticale[4]	Triticale[5]
Corn	58.54	38.83	38.83	39.88	39.88
Soybean meal (46.82% CP)	28.51	28.32	28.32	28.53	28.53
Corn gluten meal (59.69% CP)	2.96	2.30	2.30	0.87	0.87
Wheat	-	20.00	20.00	-	-
Triticale	-	-	-	20.00	20.00
Soybean oil	2.12	2.72	2.72	2.87	2.87
Dicalcium phosphate	1.31	1.28	1.28	1.30	1.30
Oyster shell	5.60	5.60	5.60	5.59	5.59
Nacl	0.31	0.30	0.30	0.32	0.32
Mineral premix[6]	0.25	0.25	0.25	0.25	0.25
Vitamin premix[7]	0.25	0.25	0.25	0.25	0.25
Methionine	0.12	0.13	0.13	0.14	0.14
Lysine	0.03	0.02	0.02	-	-
Calculated analysis					
AME_n (kcal/kg)	2900	2900	2900	2900	2900
Crude protein	20.0	20.0	20.0	20.0	20.0
Calcium	2.5	2.5	2.5	2.5	2.5
Available phosphorus	0.35	0.35	0.35	0.35	0.35
Methionine	0.45	0.45	0.45	0.45	0.45
Methionine + cysteine	0.79	0.79	0.79	0.79	0.79
Lysine	1.00	1.00	1.00	1.00	1.00
Tryptophan	0.23	0.23	0.23	0.23	0.23
Threonine	0.74	0.74	0.74	0.74	0.74
Arginine	1.26	1.26	1.26	1.26	1.26
Determined analysis					
Dry matter	93.08	92.40	92.63	92.35	92.40
Total ash	10.60	10.00	10.25	10.33	10.40
Crude protein	19.07	19.20	19.33	19.52	19.42
GMD ± GSD[8]	867±1.7	829±1.8	921±1.9	831±1.9	913±1.8

[1] Control: basal diet containing ground corn and soybean meal.
[2] Wheat was added to the basal diet as 20% ground grain wheat.
[3] Wheat was added to the basal diet as 10% whole + 10% ground grain.
[4] Triticale was added to the basal diet as 20% ground grain triticale.
[5] Triticale was added to the basal diet as 10% whole + 10% ground grain.
[6] Mineral premix provided per kilogram of diet: Mn: 70 mg; Fe: 60 mg; Zn: 60 mg; Cu: 8 mg; I: 1.1 mg; Co: 0.15 mg and Se: 0.25 mg.
[7] Vitamin premix provided per kilogram of diet: vitamin A: 10.000 IU; vitamin D_3: 2.500 IU; vitamin E: 20 mg; vitamin K_3: 2.5 mg; vitamin B_1: 2 mg; vitamin B_2: 5 mg; vitamin B_6: 3.5 mg; vitamin B_{12}: 0.015 mg; vitamin C: 50 mg; Niacin: 30 mg; Pantothenic acid (D-Ca pantothenate): 8 mg; Folic acid: 1 mg; D-biotin: 0.025 mg and Choline (choline chloride): 300 mg.
[8] Geometric mean diameter ± geometric standard deviation.

Egg quality traits were measured using 3 eggs from each replicate at 20, 22, 24 and 26 wk of age. The eggs (3 eggs per replicate were taken after feeding the diets) were individually weighed and the egg external (egg weight, shape index, shell weight, and shell thickness) and internal quality (yolk index, yolk color, and Haugh unit) were measured. The shell was separated from the yolk and albumen, dried overnight at 60 ˚C and weighed (Grobas *et al.* 2001). Egg shell thickness was measured using a digital micrometer (Echometer 1061, Robotmation Company, Tokyo, Japan). Egg shell ratio was calculated by dividing shell weight to egg weight. The Haugh unit was calculated by using the egg weight (g) and albumen height (AH/mm) (Haugh, 1937).

Internal organ weights, pH of the GIT and intestinal viscosity

At 26 weeks of age, two birds per replicate were randomly selected, weighed individually, and euthanized using thiopental sodium (15 mg/kg of body weight, Sandoz GmbH, Kundl, Austria). The liver, proventriculus, pancreas, gizzard and cecum were weighed and expressed as the percentage of live body weight. The digesta pH of the gizzard, jejunum, ileum, and cecum was measured using a digital pH meter (Corning Glass Works, Medfield, MA), as described by Pang and Applegate (2007). For viscosity analysis, approximately 3 g (wet weight) of the fresh digesta were immediately placed in a microcentrifuge tube and centrifuged (12000×g) for 5 min. The viscosity of non-diluted supernatants was measured at 25 ˚C using a digital viscosimeter (Brookfield Engineering, Stoughton, MA, USA). Viscosity was expressed as centipoises (cP) (Khoramabadi *et al.* 2014).

Nutrient digestibility

At 26 weeks of age, chromium oxide was added at 5 g/kg to the experimental diets as an indigestible marker. The metabolism trial was composed of a 3 d preliminary adaptation period, followed by 2 d of excreta collection. Representative samples of excreta were dried (60 ˚C for 72 h), homogenized, and grounded (1 mm). Dry matter and crude protein digestibility and AMEn of the diets were determined as indicated by Garcia *et al.* (2008).

Statistical analysis

This experiment was conducted as a completely randomized design with 5 treatments in a 2 × 2 + 1 factorial arrangement and the main effects were analyzed by ANOVA using the GLM procedure of SAS (2004). The model included the control diet, two grain sources (wheat and triticale) and two physical forms of grains (ground and whole) as main effects.

When the main effects were significant, the Duncan test was used to make pairwise comparisons among sample means. All differences were considered significant at $P \leq 0.05$.

RESULTS AND DISCUSSION

Productive performance and egg quality traits

For the entire experimental period, egg production, egg weight, egg mass, and FCR were not affected by grain source, except for the ADFI which was decreased with triticale but not wheat (P=0.0513). Average daily feed intake and egg production were higher in whole grain versus ground grain (P<0.05). The birds that fed with ground triticale had the lowest ADFI (P<0.05) and egg production (P<0.001) compared to other birds (Table 3). Zarghi and Golian (2009) reported that the poorer FCR of the triticale-fed birds might be due to lower nutrient amounts, limited nutrient availability, or higher anti-nutritional factors such as soluble pentosans, trypsin inhibitor, and pectin content. Consistent with these results, Ebrahimi *et al.* (2017) reported that corn substitution by triticale in the quail grower diets reduced feed intake. Triticale-based diets contained higher amounts of soluble arabinoxylans as well as total NSP and crude fiber in comparison with wheat, which was also reflected in higher ileal chyme viscosities (Jozefiak *et al.* 2007). In addition, Ciftci *et al.* (2003) reported that there were no significant effects of grain type (triticale, wheat or corn) on egg weight, egg mass, or feed efficiency of laying hens. Abdel Wahed *et al.* (2010) reported that egg weight, egg mass, and FCR were not affected when corn was replaced with triticale in laying Japanese quail diets. Senkoylu *et al.* (2009) showed that the inclusion of whole grain wheat in the laying hen diets improved productive performance compared to the ground grain wheat. These researchers also observed that feed intake increased with whole grain, which could be due to selective feeding of birds, in agreement with the data reported herein.

Egg quality was not affected by grain type or their physical form (Table 4), which is in agreement with results of Jamroz *et al.* (2001), who did not observe any effect of grain source on egg quality in hens fed diets based on wheat, barley, or triticale.

The yolk color in birds, that consumed control diet was significantly higher than other groups (P<0.05), which might be due to the difference in levels of corn gluten meal used in corn than wheat and triticale diets (2.96 *vs.* 2.30 and 0.87%, respectively). The lower color of yolk can be due to the lack of carotenoids in wheat and triticale diets relative to corn, as reported by Roberts *et al.* (2007). In the current study, feeding quails with ground triticale decreased the Haugh unit.

Table 3 Influence of whole or ground wheat and triticale on productive performance of laying Japanese quails from 18 to 26 weeks of age

Main effects		ADFI (g/d/b)	Egg production (%)	Egg weight (g)	Egg mass (g/d)	FCR
Grain source	Wheat	31.05[a]	89.06	12.74	11.34	2.738
	Triticale	29.93[b]	86.68	12.64	10.96	2.731
Physical form	Ground	29.82[b]	86.28[b]	12.75	11.00	2.711
	Whole	31.17[a]	89.46[a]	12.63	11.30	2.758
SEM		0.400	0.971	0.179	0.248	0.0652
Treatments						
Control		30.11[ab]	92.40[a]	12.15	11.23	2.681
Ground wheat		30.85[a]	88.77[a]	12.72	11.29	2.732
Whole wheat		31.26[a]	89.34[a]	12.76	11.40	2.742
Ground triticale		28.78[b]	83.79[b]	12.78	10.70	2.689
Whole triticale		31.08[a]	89.57[a]	12.50	11.21	2.772
SEM		0.551	1.320	0.229	0.326	0.085
P-value						
Grain source		0.0513	0.0884	0.6904	0.4392	0.9809
Physical form		0.0199	0.0243	0.6382	0.6676	0.6193
Grain source × physical form		0.1007	0.0627	0.5236	0.8339	0.5144
Treatment		0.0134	0.0005	0.2573	0.9126	0.8545

ADFI: Average daily feed intake and FCR: feed conversion ratio.
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 means.

Table 4 Influence of whole or ground wheat and triticale on egg quality from 18 to 26 weeks of age[1]

Main effects		Egg weight (g)	Shape index (%)	Yolk index (%)	Yolk color	Haugh unit	Shell weight (g)	Shell ratio (%)	Shell thickness (mm)
Grain source	Wheat	12.79	77.32	42.53	4.29	55.79	0.90	7.19	0.278
	Triticale	12.64	77.31	42.23	4.17	55.94	0.86	6.86	0.276
Physical form	Ground	12.85	77.60	42.13	4.16	55.57	0.87	6.87	0.283
	Whole	12.58	77.03	42.63	4.29	56.16	0.89	7.18	0.271
SEM		0.242	0.637	0.670	0.092	0.364	0.020	0.160	0.0031
Treatments									
Control		12.60	78.03	42.43	4.58[a]	55.99[ab]	0.91	7.36	0.276
Ground wheat		12.60	77.97	41.48	4.16[b]	56.10[ab]	0.87	7.00	0.287
Whole wheat		12.97	76.67	43.58	4.41[ab]	55.49[ab]	0.94	7.37	0.269
Ground triticale		13.10	77.24	42.78	4.16[b]	55.04[b]	0.86	6.75	0.280
Whole triticale		12.18	77.39	41.68	4.16[b]	56.83[a]	0.85	6.97	0.272
SEM		0.353	0.839	1.016	0.137	0.533	0.028	0.224	0.004
P-value									
Grain source		0.6972	0.9957	0.7608	0.1726	0.7668	0.0738	0.1712	0.7577
Physical form		0.4630	0.5412	0.6153	0.1720	0.2480	0.2348	0.2005	0.0981
Grain source × physical form		0.0673	0.4304	0.1005	0.3472	0.0250	0.1763	0.7466	0.2878
Treatment		0.3559	0.7705	0.7529	0.0149	0.1783	0.1523	0.2529	0.5102

[1] Data represent means based on 5 replicates per treatment, 3 eggs per replicate.
SEM: standard error of the means.

Abdel Wahed *et al.* (2010) have reported similar results that the substitution of corn by triticale decreased Haugh unit in laying Japanese quail. However, insignificant differences were detected in other egg quality characteristics as compared to the control diet. In the current study, the physical form of grain did not affect egg weight, shape index, yolk index, Haugh unit, shell weight, shell ratio and shell thickness. Haugh unit was increased with whole than ground triticale (P<0.05), which could be due to increased albumen height.

Internal organ weights, pH of the GIT and intestinal viscosity

Relative weights of the liver, proventriculus, pancreas, gizzard, and cecum were not affected by grain type, physical form of grain or dietary treatments (Table 5). Ebrahimi *et al.* (2017) reported that triticale inclusion in the quail s' grower diets decreased the relative weight of crop and proventriculus at 21 days of age. This decrease can be associated with reduced feed intake. The relative weight of the small intestine increased with increasing levels of triticale in the diet that might be influenced by an increase in the activity of this organ in response to higher levels of dietary NSP. There is mounting evidence that gizzard responds rapidly to changes in the diet, particularly to changes in insoluble fiber and particle size (Svihus, 2011). The extent to which gizzard weight may increase in different experiments is probably due to different degrees of grain hardness, bird genotypes, and nutritive values of feeds used in the control group. The lack of the effect on gizzard size and gut-segments might probably be related to the age (18 to 26 weeks of age) of quails used in the current study, as they were already mature in terms of their body development. It is clear that gastrointestinal development occurs during the early stages of life (Uni *et al.* 1998). These results are similar to those of Konca and Beyzi (2013) who reported that feeding of quails with triticale or wheat had no effect on the weight of total GIT, liver, small intestine and heart. Ciftci *et al.* (2003) also reported that relative weights of pancreas, crop, proventriculus, gizzard, and cecum were not affected by grain type (triticale, wheat and corn) in laying hens. Senkoylu *et al.* (2009) observed that whole wheat supplemented with or without xylanase had no significant effect on gizzard weight in laying hens. Wu and Ravindran (2004b) and Ravindran *et al.* (2006) did not observe any change in relative weights of gizzard with the inclusion of whole wheat, consistent with the results reported herein.

The pH of different segments of the GIT was not affected by the grain source. However, the pH of the jejunum (P<0.01) and cecum (P<0.05) significantly increased by whole grain than with ground grain (Table 6). In the current experiment, increased intestinal pH might be related to a higher intake of whole grain than ground grain (Svihus, 2014).

Also, the feeding of coarse particle size seemed to stimulate pancreatic secretions. An increased pancreatic bicarbonate secretion may therefore partly explain the higher intestinal pH values observed in this diet (Engberg *et al.* 2002).

In agreement with our study, Mirzaie *et al.* (2012) reported that digesta pH of different organs of the GIT was not affected by wheat inclusion in laying hens.

Frikha *et al.* (2011) did not find any effect of wheat inclusion in substitution of corn on gizzard pH in 120-d-old pullets. The effect of whole wheat feeding on the pH of intestinal contents is also contradictory (Singh *et al.* 2014).

Senkoylu *et al.* (2009) reported that the inclusion of whole wheat into the diets of laying hens decreased gizzard pH from 4.68 (control) to 4.35 (whole wheat), that disagreed with our findings.

Intestinal viscosity was not affected by grain source, but it was increased with whole than ground grain (P<0.01). Also, intestinal viscosity was lower for control than other treatments (P<0.01; Table 6).

Ciftci *et al.* (2003) reported that intestinal viscosity was significantly affected by grain type (triticale, wheat and corn) in laying hens. Soluble NSP content of grains increases digesta viscosity, which reduces intestinal passage time and availability of nutrients.

In agreement with the data reported herein, Wu *et al.* (2004a) showed that whole wheat increased digesta viscosity in the duodenum and jejunum of broilers fed diets containing 20% whole wheat. Whole wheat feeding may also influence the feed passage rate and digesta viscosity but published data on these aspects are limited. Engberg *et al.* (2004) also reported that whole wheat feeding increased digesta viscosity.

Table 5 Influence of whole or ground wheat and triticale on relative weight (% BW) of internal organs of laying Japanese quails at 26 weeks of age

Main effects		**Liver**	**Proventriculus**	**Pancreas**	**Gizzard**	**Cecum**
Grain source	Wheat	2.71	0.38	0.33	1.48	1.06
	Triticale	2.59	0.41	0.34	1.44	1.12
Physical form	Ground	2.75	0.39	0.36	1.51	1.09
	Whole	2.55	0.40	0.31	1.42	1.08
SEM		0.087	0.018	0.032	0.087	0.073
Treatments						
Control		2.96	0.41	0.31	1.72	1.15
Ground wheat		2.78	0.37	0.34	1.43	1.06
Whole wheat		2.64	0.40	0.31	1.53	1.05
Ground triticale		2.71	0.41	0.38	1.56	1.12
Whole triticale		2.46	0.41	0.30	1.31	1.12
SEM		0.131	0.025	0.043	0.120	0.095
P-value						
Grain source		0.3416	0.3190	0.8055	0.7269	0.5875
Physical form		0.1534	0.6733	0.2644	0.5464	0.9626
Grain source × physical form		0.6870	0.5112	0.5536	0.1971	0.9546
Treatment		0.1879	0.7221	0.6804	0.2497	0.9494

SEM: standard error of the means.

Table 6 Influence of whole or ground wheat and triticale on the pH of the organs of the gastrointestinal tract and intestinal viscosity of laying Japanese quails at 26 weeks of age

Main effects		Gizzard	Jejunum	Ileum	Cecum	Intestinal viscosity (cP)
Grain source	Wheat	3.57	7.10	7.28	6.12	10.69
	Triticale	3.52	7.14	7.50	5.99	10.68
Physical form	Ground	3.58	6.71[b]	7.29	5.79[b]	10.42[b]
	Whole	3.51	7.58[a]	7.50	6.33[a]	10.95[a]
SEM		0.225	0.103	0.215	0.116	0.081
Treatments						
Control		3.97	6.84[b]	7.54	5.86[ab]	9.86[c]
Ground wheat		3.64	6.88[b]	7.26	6.09[ab]	10.45[b]
Whole wheat		3.50	7.33[a]	7.31	6.18[a]	10.93[a]
Ground triticale		3.52	6.54[b]	7.31	5.49[b]	10.39[b]
Whole triticale		3.53	7.74[a]	7.69	6.49[a]	10.98[a]
SEM		0.306	0.116	0.253	0.154	0.104
P-value						
Grain source		0.8991	0.8346	0.5629	0.4725	0.9319
Physical form		0.8512	0.0014	0.5690	0.0304	0.0005
Grain source × physical form		0.8118	0.0452	0.6316	0.0530	0.6549
Treatment		0.7902	0.0010	0.8230	0.0242	0.0001

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 means.

Table 7 Influence of whole or ground wheat and triticale on nutrient digestibility and AMEn content of the experimental diets

Main effects		Dry matter (%)	Protein (%)	AMEn (kcal/kg)
Grain source	Wheat	68.15[a]	42.16	2928[a]
	Triticale	67.65[b]	42.51	2912[b]
Physical form	Ground	67.80	42.35	2920
	Whole	68.00	42.34	2919
SEM		0.104	0.140	3.4
Treatments				
Control		68.30[a]	43.00	2947[a]
Ground wheat		68.20[a]	42.20	2931[b]
Whole wheat		68.11[a]	42.13	2925[bc]
Ground triticale		67.40[b]	42.50	2910[c]
Whole triticale		67.90[a]	42.53	2914[c]
SEM		0.152	0.194	4.5
P-value				
Grain source		0.0094	0.1171	0.0119
Physical form		0.0759	0.9354	0.8173
Grain source × physical form		0.2113	0.8082	0.3841
Treatment		0.0137	0.0656	0.0015

AMEn: apparent metabolizable energy corrected by nitrogen.
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 means.

In contrast, Konca and Beyzi (2013) reported that choice feeding with triticale and wheat to quail had no effect on intestinal viscosity. The degree of digesta viscosity is dependent upon the amount of NSP, which varies among grains (Amerah *et al.* 2007).

Nutrient digestibility

Dry matter digestibility (P<0.01) and AMEn of the diet (P<0.05) were higher for birds fed with wheat than for triticale. Nutrient digestibility and AMEn were not affected by the physical form of grain. Dry matter digestibility significantly decreased by ground triticale than with other treatments (P<0.05). Also, AMEn of the diet was higher for control than for other treatments (P<0.01). The use of high viscosity grains such as rye, barley, oat, triticale, and wheat in the diet increases the viscosity of the digestive tract content of birds. These conditions reduce nutrient release, digestibility and absorption capacity and, consequently, loss of yield.

Low nutrient digestibility of triticale may be more related to NSP as it has been reported, the use of triticale in feeding poultry is limited due to the presence of NSP, especially those of xylane and arabinoxylan. These compounds reduce the nutritional value of triticale by increasing the viscosity of the digestive system and consequently reducing the availability of nutrients for digestion and absorption. Several authors have suggested that the improvement in nutrient utilization with diets containing whole wheat was partially due to an increase in starch digestibility. Consistent with the current results about the improvement of DM digestibility by whole than ground grain, Svihus *et al.* (2004) reported that the inclusion of 375 g/kg whole wheat significantly increased starch digestibility. Preston *et al.* (2000) also reported an increase in AME when ground wheat was replaced by whole wheat in broiler diet, whereas Uddin *et al.* (1996) found no differences when two wheat cultivars were fed ground or whole at different levels (100-400 g/kg) to broiler chickens from 19 to 27 days. An improvement of AMEn and amino acid digestibility with whole wheat may be due to a slower passage rate of large feed particles through the gizzard (Nir *et al.* 1994) and increased exposure to hydrolytic digestion in the gizzard. Amerah *et al.* (2012) observed that inclusion of whole wheat (100 and 200 g/kg) increased ileal protein digestibility, but had no effect on apparent ileal digestible energy. Biggs and Parsons (2009) reported that birds fed whole wheat had increased AMEn at 4, 7, 14 and 21 days of age and amino acid digestibility also increased at 21 days. No improvement with whole grain on AMEn might be caused by the low level of whole grain used in the quail s' diet in the current research.

CONCLUSION

The results of this study have indicated that triticale inclusion in the diet had a negative effect on feed intake, egg production, nutrient digestibility and AMEn of the diet compared to wheat which was pronounced for ground form. The feeding of whole grain in mixed feeding, improved feed intake, egg production and dry matter digestibility compared with ground form. The yolk color in birds, that consumed wheat and triticale was lower than the control group. Haugh unit increased by the inclusion of whole triticale in the diet.

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