Effects of mixed or separate feeding with whole barley or triticale on growth performance, gastrointestinal system, nutrient digestibility and blood constituents in turkeys

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SUMMARY

This study was conducted to investigate the effects of feeding with whole barley and triticale (unground) either through a mixed or separate feeding on the growth performance, gastrointestinal system, nutrient digestibility, and blood constituents in turkeys. A total of 150 four-week-old Hybrid female turkey poults randomly allotted in 5 equal groups were fed for 14 weeks with age adapted basal diets (control group), with whole barley or triticale mixed to diets (groups BM and TM, respectively) or given in a separate feeder (groups BS and TS, respectively). Growth parameters (body weights and weight gains) mainly during the last 6 weeks were significantly increased in the TS group and were coupled to a slight improvement of the food efficiency. In parallel, ileal viscosity was significantly depressed in this group and associated with slight increases in digestibility of organic matter and crude fat. Whole barley mixed to the basal diets or given separately has induced no significant effects on growth, intestinal pH and viscosity and nutrient digestibility, but the absolute and relative colon weights were markedly enhanced in birds fed with barley mixed to basal diets. Although plasma concentrations of lipoproteins and cholesterol tended to increase in birds fed with barley or triticale, no significant change was evidenced on blood biochemistry. These results show that barley and particularly triticale may be added separately to the basal ration without negatively impacting growth and digestion performances in turkeys, therefore offering some economical advantages.

Keywords: Whole barley, whole triticale, turkey, mix and separate feeding, growth, gastro-intestinal traits, nutrient digestibility, cholesterol.

RÉSUMÉ

Effets de l'orge ou du triticale en grains distribués séparément ou mélangés à la ration de base sur la croissance, le système gastro-intestinal, la digestibilité des nutriments et les constituants sanguins chez la dinde

Cette étude vise à évaluer les effets chez la dinde d'une alimentation enrichie en grains entiers d'orge ou de triticale distribués mélangés ou séparément de l'aliment de base sur la croissance, le système gastro-intestinal, la digestibilité des nutriments, et certains analytes plasmatiques. Au total, 150 dindes hybrides femelles âgées de 4 semaines, réparties aléatoirement en 5 groupes égaux, ont été nourries pendant 14 semaines avec l'aliment de base adapté à l'âge (groupe contrôle), mélangé à l'orge (groupe BM) ou au triticale (groupe TM) ou séparé des 2 céréales (groupes BS et TS, respectivement). Les paramètres de croissance (poids vifs et gains de poids) ont été significativement augmentés dans le groupe TS, plus particulièrement durant les 6 dernières semaines, et ont été associés à une légère amélioration de l'efficacité alimentaire. Parallèlement la viscosité iléale a été significativement diminuée dans ce groupe et couplée à de faibles augmentations de la digestibilité de la matière organique et des graisses. L'utilisation d'orge n'a en revanche eu d'effet ni sur la croissance, ni sur le pH ou la viscosité intestinale et ni sur la digestibilité des nutriments. Cependant, le poids absolu ou relatif du colon a été nettement augmenté chez les oiseaux nourris avec une ration mélangée à l'orge. Bien que les concentrations plasmatiques des lipoprotéines et du cholestérol aient eu tendance à augmenter chez les oiseaux recevant de l'orge ou du triticale, aucun effet significatif des 2 céréales incorporées à la ration n'a pu être mis en évidence sur la biochimie sanguine. Ces résultats montrent que l'orge et plus encore le triticale peuvent être utilisés dans l'alimentation des dindes séparément de l'aliment de base sans déprécier la croissance et l'efficacité de la digestion, ce qui peut présenter un avantage économique.

Mots clés : Orge entier, triticale entier, dinde, ration mélangée ou séparée, croissance, paramètres gastro-intestinaux, digestibilité des nutriments, cholestérol.

Introduction

Whole grain feeding for poultry has attracted considerable attention for a long time for economic and health reasons [12-14]. It was reported that whole grain feeding might increase feed efficiency and might eliminate the costs of grinding, mixing and many of handling processes associated with mash and pellet preparation [16]. Acceptable growth rate can be achieved when fowls are allowed for free access to both basal diet and whole-grain cereals such as maize, wheat [11] and barley [9]. Whole cereal feeding may stimulate larger gizzard and increased development of the pancreas [10, 14]. A more developed gizzard may enhance the grinding of feeds that will increase the exposure of nutrients to digestive fluids and improve nutrient digestion [14, 17] and bird performance [11, 26]. Also, beneficial effects of choice of a feeding method were also observed on digestive microflora and decrease in pathogen microflora [10].

Most of the whole cereal feeding trials has been performed with wheat [3, 14] and maize [11] but also with barley [4, 5]

and triticale [19] in poultry. Barley is rarely used as a feed ingredient in regions where wheat is grown and it has received limited attention in whole grain feeding programs of turkeys [5], due to the presence of (1-3)(1-4)-β-glucans that may create a viscous environment within the intestinal lumen [31]. Furthermore barley contains relatively large amounts of cellulose and, as compared to wheat, lower proportions of starch and protein [24]. BENNETT *et al*. [4] reported that feeding with 35% whole barley had no effect on body weight gain (BWG) and feed conversion ratio (FCR) in broilers. SVIHUS *et al*. [33] found that broiler chickens fed with whole barley grew at the same rate as birds fed with rolled barley and faster than those fed with ground barley. COWAN and MICHIE [9] reported that turkeys could voluntarily consume about half of their feed intake as whole barley.

Triticale is a hybrid of wheat and rye and a new product compared to other grains. It has an increasing production in the world and receiving greater interest as an ingredient in poultry diets [35]. Protein and amino acid concentrations as well as metabolisable energy are the key contributors of triticale to its feeding value [19]. However, arabinoxylans content of triticale may increase digesta viscosity, reduce digestibility of various nutrients and also provoke over consumption of water by birds, which results in watery excreta [6]. In contrast to wheat or maize, there is not much available information about impacts of different levels and varieties of triticale in poultry nutrition [15].

Researches revealed that free access to whole grain and diet may decrease carcass quality due to high abdominal fat [20]. On the other hand, cereals containing β-glucans may change blood constituents like blood cholesterol types in broilers [36]. There is little research about effects of whole cereal feeding with whole barley and triticale in turkeys. Therefore, the present study was conducted to investigate the effects of mixed and separate feeding with whole barley and triticale on the performance, gastrointestinal system (GIS), intestinal viscosity, nutrient digestibility, and blood constituents of turkeys.

Material and Methods

ANIMALS AND HOUSING, PROTOCOL DESIGN

A total of 150 four-weeks-old Hybrid white female turkey poults were used for feeding treatments. The turkey chickens were obtained from a local hatchery and grown to 4 weeks of age without any treatment. Bird wings were enumerated, individually weighed then ranked for minimal differences and divided into 5 dietary treatment groups. Each treatment had 6 replicates with 5 poults. The birds were housed in floor pens (2 birds/m^2) covered with dry wood shavings bedding. The lighting schedule was light for 16 hours and dark for 8 hours (from 22:30 p.m to 06.30 a.m).

The 5 dietary treatments were the following: birds received basal diet in group 1 (control, mash); basal diet and whole (unground) barley mixture in one feeder (BM) in group 2, basal diet and whole barley in separate two feeders (BS) in group 3; basal diet and whole triticale mixture in one feeder (TM) in group 4 and basal diet and whole triticale in separate two feeders (TS) in group 5. In mixed feeding groups, basal diet and whole barley or triticale were blended homogeneously before fill to feeders. In the separate feeding groups, basal diet and barley or triticale were offered in two separate feeders, 0.5 m apart from each other. Barley and triticale cultivars were obtained from commercial sources. The whole grains were given at fixed rates at every 4 weeks period and progressively increased as 9.1, 13.0 and 16.7 and 16.7 % for 4 to 8, 8 to 12, 12 to 16 and 16 to 18 weeks of age, respectively. Basal diet and whole cereals were weighed and given as 10 kg basal diet and 1.0 kg whole cereal as barley and triticale for 4 to 8 weeks, 10 kg basal diet and 1.5 kg whole cereal for 8 to 12 weeks, and 10 kg basal diet and 2.0 kg whole cereal for 12 to 16 and 16 to 18 weeks. Basal diet nutrient composition was adjusted according to the NRC recommendations [24] based on age intervals (4 to 8; 8 to 12; 12 to 16 and 16 to 18 weeks). Feed and water were provided *ad libitum*. Barley and triticale analyzed composition were given in Table I and feedstuff and nutrient composition of the diets were shown in Table II.

Nutrient composition	Barley	Triticale
Dry matter (g/kg)	892.1	878.7
Crude proteins (g/kg)	120.6	114.6
Crude fibres (g/kg)	42.2	26.6
Crude ash (g/kg)	21.4	20.6
Crude fat (g/kg)	22.4	26.6

TABLE I: Analysis of nutrient composition of barley and triticale.

PERFORMANCE ANALYSIS

Individual body weight (BW) was measured on weeks 4, 8, 12, 16 and 18. Daily feed intake (DFI) was measured on pen bases on the same days. Leftovers of feed were reweighed. Total feed consumption for each period determined and daily feed intake were calculated from this data. In case of mortality, feed intake rates were corrected for number of animals in the pen. Feed conversion ratio was calculated as the ratio DFI: BWG of all birds in each pen.

ANALYSIS OF NUTRIENT DIGESTIBILITY

To determine the metabolisable nutrients, one turkey in each pen was kept and excreta samples were collected for 3 consecutive days when birds were 19 weeks old. A partially modified version of the method developed by SIBBALD [30] was used for excreta collection. A total of 30 fresh excreta samples were collected in plastic trays, weighed and stored in a cup in a freezer until end of the 3rd day, then they were homogenized using a blender and analyzed for dry matter, nitrogen and ether extract. In the experimental diets, contents of dry matter, crude ashes, crude proteins, crude fibres and ether extract of barley, triticale and excreta samples were determined according to AOAC [2]. In order to estimate protein digestibility, faecal and urinary nitrogen were chemically separated according to the method of MARQUARDT [21]. Metabolisable nutrients were determined by accurately measuring feed intake and

Periods (week)	4 to 8					8 to 12					12 to 16					16 to 18				
Groups	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Ingredients (g/kg)																				
Maize			483.85					593.40					600.00					600.00		
Soybean meal			462.83					359.47					277.27					208.23		
Wheat			0.00					0.00					75.10					142.67		
Vegetable oil			15.77					14.21					18.86					25.25		
DL methionine			0.53					0.53					0.45					0.00		
L Lysine			0.04					0.83					0.00					0.00		
Limestone			10.82					9.76					8.68					8.24		
Salt			2.69					2.00					1.63					1.57		
Monensin sodium			1.00					1.00					1.00					0.00		
Dicalcium phosphate			19.97					16.30					14.51					11.54		
VMP			2.50					2.50					2.50					2.50		
Composition (g/kg)																				
Dry matter	866.9	869.2	869.3	868.0	868.0	880.0	881.6	881.9	879.8	879.8	879.0	881.2	881.4	879.0	879.0	889.0	889.5	889.5	887.3	887.2
Crude proteins	258.2	245.7	245.4	245.2	245.2	213.2	201.1	198.8	200.3	196.3	184.4	173.8	172.9	172.8	172.8	166.0	158.4	158.2	157.4	156.8
Crude fibres	31.6	32.6	32.6	31.2	31.2	30.6	32.1	32.4	30.1	29.9	32.0	33.7	33.8	31.1	31.1	27.7	30.1	30.2	27.5	27.5
Crude ash	51.6	48.9	48.8	48.8	48.8	59.8	54.8	53.8	54.7	53.1	45.6	41.6	41.2	41.4	41.4	50.0	45.2	45.1	45.1	44.8
Crude fat	35.8	34.6	34.6	35.0	35.0	43.6	40.8	40.3	41.4	40.7	54.6	49.2	48.8	49.9	49.9	42.0	38.7	38.6	39.4	39.3
L Lysine	15.2	13.8	13.8	13.8	13.8	12.8	11.1	10.8	11.1	10.6	8.5	7.1	7.0	7.1	7.1	6.5	5.4	5.4	5.4	5.4
Methionine	5.0	4.6	4.6	4.6	4.6	4.2	3.7	3.6	3.7	3.5	3.8	3.2	3.2	3.2	3.2	3.2	2.7	2.7	2.7	2.7
Calcium	10.0	9.1	9.1	9.1	9.1	8.5	7.4	7.2	7.4	7.1	7.5	6.3	6.2	6.3	6.3	6.5	5.5	5.4	5.5	5.4
Available phosphorus	6.0	5.5	5.5	5.5	5.5	4.2	3.7	3.6	3.7	3.6	3.8	3.2	3.2	3.2	3.2	3.2	2.7	2.7	2.7	2.7
ME (MJ/kg)	12.13	12.11	12.11	12.14	12.14	12.55	12.47	12.45	12.51	12.50	12.97	12.79	12.78	12.86	12.86	13.39	13.14	13.13	13.21	13.19

Group 1: basal diet; group 2: barley mixed with basal diet; group 3: barley separate from basal diet; group 4: triticale mixed with basal diet; group 5: triticale separate from basal diet; Mixed diets' nutrient composition were calculated according to their fixed ratio, but in the separate feeding groups consumed amount of basal diet with whole barley or triticale were considered

VMP: vitamin and mineral premix supplied per kg of the feed: Vitamin A, 15000 I.U; Vitamin D3, 2000 I.U; Vitamin E, 40.0 mg; Vitamin K, 5.0 mg; Vitamin B1 (thiamin), 3.0 mg; Vitamin B2 (riboflavin) 6.0 mg; Vitamin B6, 5.0 mg; Vitamin B12, 0.03 mg; Niacin, 30.0 mg; Biotin, 0.1 mg; Calcium D-pantothenate, 12 mg; Folic acid, 1.0 mg; Choline chloride, 400 mg; Manganese, 80.0 mg; Iron, 35.0 mg; Zinc, 50.0 mg; Copper, 5.0 mg; Iodine, 2.0 mg; Cobalt, 0.4 mg; Selenium, 0.15 mg; ME: metabolisable energy calculated according to Turkish Standards Institutes formulation; Lysine, methionine, calcium and available phosphorus contents were calculated according to the NRC recommendations [24].

TABLE II: Ingredients and composition of experimental diets.

excreta output. From these measurements, together with chemical analysis for nutrients, the metabolisable nutrients were calculated. The starch and sugar contents of barley and triticale were determined according to the procedures of the AOAC [2]. The metabolisable energy (ME) was estimated using a prediction equation [28]. Mixed and separate diets (after consumption, according to consumed basal diet and barley or triticale) nutrient compositions were calculated and showed in the Table II.

GASTROINTESTINAL SYSTEM ANALYSIS

Twelve turkeys in each group were selected (closest to the average weight, totally 60 turkeys) and slaughtered when they were 18 weeks old. The abdomen was immediately opened and the intestinal tract was removed. Internal organs (parts of the gastro-intestinal parts, pancreas, liver, spleen and heart) were weighted and their relative indices (100 x organ weight/body weight) were determined at this time.

After ligation of the small intestine into two parts, to prevent post-mortem movements of digesta, the total intestinal content was collected from the end of the duodenal loop to Merckel's diverticulum (jejunum samples) and from Merckel's diverticulum to the ileo-caecal junction (ileum samples). The pH values of the jejunal and ileal samples were determined with a pH meter (Hanna Instruments-8413) and measured using a direct probe by thrusting into the jejunal and ileal content. Several microtubes were filled with each sample, labelled and centrifuged (4300 g, for 10 minutes at room temperature).

The centrifuge tubes with fresh digesta were immediately placed on ice in an isolated box until viscosity measurements were performed within 1 hour following slaughter. The supernatant was withdrawn and the viscosity of a 0.5 mL aliquot measured using a Brookfield Digital Viscometer (Model DV-II+PRO, Brookfield Engineering Laboratories, Stoughton, MA) maintained at 40°C. The litter moisture was determined according to AOAC [2] at 14, 16 and 18 weeks of age.

BLOOD ANALYSIS

Twelve blood samples in each pen were obtained by vena puncture of left wing vein from 18 weeks old turkeys (totally 60 turkeys) for blood chemical analysis. Blood samples were kept on ice and transferred to the laboratory and centrifuged

at 1500 g for 10 minutes at room temperature; the serum were carefully harvested and stored at -20°C until analysed. The serum glucose, total protein, albumin, triglyceride, cholesterol total and associated to high density lipoprotein (HDL) or low density lipoprotein (LDL) concentrations and the alkaline phosphatase (ALP) activity were measured in an auto-analyzer (Accute, Toshiba, Japan) using kits provided by the same manufacturer.

STATISTICAL ANALYSIS

Randomized block design with six replications was used for experimental setup. Data were analysed using General Linear Model procedure of the Statistical Analysis System (SPSS [32]). The models included 5 groups as control, mixed barley, separate barley, mixed triticale and separate triticale. Means were compared by Duncan's multiple range tests. The results were expressed as mean values and standard error of the means (SEM) in Tables. Differences were considered as significant when *P* value was below 0.05.

Results

Mortality rates were 3.3% in the control group, 0% in the groups fed with barley (mixed with basal diet or given separately) and 3.3% in the groups fed with triticale.

Growth performances in turkeys are summarized in Table III. At 8, 12 and 16 weeks, body weights did not significantly differ according to the dietary treatments but on week 18, the final body weights in birds receiving cereals separately of basal diets appeared higher compared to the other groups ($P < 0.05$ for triticale, not significant for barley). In parallel, the total weight gain calculated for the whole experimental period increased in the same groups, particularly in the group 5 (triticale given separately from the basal diet; $P < 0.05$). In addition, significant differences with control values were also observed in body weight gains calculated for the 8-12 weeks, 12-16 weeks and 16-18 weeks periods for the group 5 ($P < 0.05$) and in the 12-16 weeks period for the group 3 (birds receiving barley separately of basal diet) ($P < 0.05$).

	Dietary treatments (groups)					SEM
	1 (C)	2 (BM)	3 (BS)	4 (TM)	5 (TS)	
Body weight (kg)						
At 4 weeks	0.72	0.73	0.76	0.75	0.73	0.02
At 8 weeks	2.80	2.94	2.92	2.72	2.87	0.09
At 12 weeks	5.32	5.56	5.46	5.34	5.65	0.19
At 16 weeks	7.78	8.00	8.29	7.93	8.75	0.27
At 18 weeks	10.25^{a}	10.14^{a}	10.78^{ab}	10.37^{a}	11.45^{b}	0.30
Weight gains (g/day/bird)						
From 4 to 8 weeks	74.3	78.9	77.1	70.4	76.4	3.27
From 8 to 12 weeks	90.8^{a}	93.5^{a}	90.7^{a}	93.6^{a}	99.3^{b}	5.16
From 12 to 16 weeks	87.9^{a}	87.1^{a}	101.1^{b}	92.5^{ab}	110.7^{b}	8.10
From 16 to 18 weeks	176.4^{a}	152.9^{a}	177.9^{a}	174.3^{a}	192.9^{b}	10.21
From 4 to 18 weeks	97.2^{a}	96.0^{a}	102.2^{ab}	98.2^{a}	109.4^{b}	3.41
Daily feed intake (g/day/bird)						
From 4 to 8 weeks	117.2	124.3	130.8	115.8	114.7	6.33
From 8 to 12 weeks	225.5	216.4	238.3	204.8	223.2	11.94
From 12 to 16 weeks	285.7	303.4	317.0	350.9	323.5	20.68
From 16 to 18 weeks	418.0	419.7	482.8	421.5	449.4	22.80
From 4 to 18 weeks	239.3	244.0	265.0	252.1	253.2	9.15
Feed conversion ratio (g/g)						
From 4 to 8 weeks	1.58	1.58	1.70	1.64	1.50	0.10
From 8 to 12 weeks	2.48	2.31	2.63	2.19	2.25	0.14
From 12 to 16 weeks	3.25^{a}	3.48^{ab}	3.14^{a}	3.79^{b}	2.92^{a}	0.42
From 16 to 18 weeks	2.37^{a}	2.74^{b}	2.71^{b}	2.42^{a}	2.33^{a}	0.12
From 4 to 18 weeks	2.46^{ab}	2.54^{b}	2.59^{b}	2.57^{b}	2.31^{a}	0.22
Total consumed proteins (g/kg of WG)	442.7	438.0	446.2	436.4	393.5	
Total consumed energy (MJ/kg of WG)	31.60	32.27	32.94	32.78	29.54	

Group 1: basal diet (control); group 2 (BM): barley mixed with basal diet; group 3 (BS): barley separate from basal diet; group 4 (TM): triticale mixed with basal diet; group 5 (TS): triticale separate from basal diet.
Different superscripts in the same row indicate significant difference ($P < 0.05$).

TABLE III: Effects of dietary treatments on body weight (BW), daily body weight gain (BWG), daily feed intake (DFI) and feed conversion ratio (FCR) of turkeys. Results are expressed as means ± standard errors of the mean (SEM).

Daily feed intake tended to increase compared to the controls when barley was incorporated to the basal rations during the first 16 weeks (groups 2 and 3) as well as when triticale was added to the rations during the last 6 weeks (groups 4 and 5) and globally this parameter was slightly but not significantly enhanced in birds receiving barley or triticale. Additionally, it was observed that the specific daily consumption of barley or triticale was weakly increased when cereal was given separately compared to the mixed diets (from 12.2 to 42.3 g/day/bird vs. 11.2 to 37.7 g/day/bird for barley and from 10.4 to 40.8 g/day/bird vs. 10.4 to 38.6 g/day/bird for triticale according to the age periods). Consequently, the food efficiency was significantly altered in birds receiving mixed barley or triticale diets ($P < 0.05$) mainly during the last 6 weeks and for the whole experimental period whereas it was slightly improved when the 2 cereals and specifically triticale were given separately. In addition, the total consumed proteins and the total consumed energy calculated per kg of body weight gain tended to decrease in the group 5 (turkeys receiving triticale in a separate feeder).

As shown in Table IV, no differences in absolute weights and in the corresponding relative indices for proventriculus, gizzard, duodenum, small intestine, caecum, pancreas, liver, spleen and heart were evidenced among groups. On the other hand, colon weight and its relative index were markedly and significantly higher in turkeys fed with barley mixed diets than in the controls and in birds fed with triticale mixed diets ($P < 0.05$). The jejunal and ileal pH, viscosity, litter moisture percentages and digestibility of nutrients were presented in Table V. The

Organs	Dietary treatments (groups)					SEM
	1 (C)	2 (BM)	3 (BS)	4 (TM)	5 (TS)	
Proventriculus						
Weight (g)	17.58	18.23	18.35	18.12	18.92	0.94
Relative indice (%)	0.18	0.18	0.17	0.18	0.17	0.01
Gizzard						
Weight (g)	170.4	194.8	191.2	178.0	187.8	12.12
Relative indice (%)	1.70	1.91	1.76	1.76	1.72	0.11
Duodenum						
Weight (g)	30.00	35.25	33.17	32.13	27.68	2.40
Relative indice (%)	0.30	0.34	0.31	0.32	0.26	0.02
Jejunum and ileum						
Weight (g)	116.1	133.5	128.7	124.1	132.2	5.43
Relative indice (%)	1.16	1.29	1.18	1.23	1.22	0.06
Caecum						
Weight (g)	37.45	41.58	40.90	44.97	42.60	2.34
Relative indice (%)	0.37	0.40	0.38	0.45	0.39	0.02
Colon						
Weight (g)	18.30^{a}	30.33^{b}	22.95^{ab}	16.73^{a}	21.62^{ab}	2.78
Relative indice (%)	0.18^{a}	0.29^{b}	0.21^{ab}	0.17^{a}	0.20^{ab}	0.03
Total gastrointestinal tract						
Weight (g)	402.1	469.8	447.9	425.6	443.1	18.64
Relative indice (%)	3.89	4.40	4.00	4.09	3.96	0.18
Pancreas						
Weight (g)	10.68	12.53	12.62	11.48	12.22	0.64
Relative indice (%)	0.106	0.121	0.116	0.114	0.113	0.01
Liver						
Weight (g)	136.3	143.6	141.0	134.9	133.1	9.61
Relative indice (%)	1.36	1.38	1.29	1.33	1.23	0.10
Spleen						
Weight (g)	7.44	7.88	6.62	6.98	7.90	0.49
Relative indice (%)	0.063	0.075	0.061	0.069	0.073	0.01
Heart						
Weight (g)	40.75	47.67	45.37	43.77	44.14	1.56
Relative indice (%)	0.41	0.46	0.42	0.43	0.41	0.02

Group 1: basal diet (control); group 2 (BM): barley mixed with basal diet; group 3 (BS): barley separate from basal diet; group 4 (TM): triticale mixed with basal diet; group 5 (TS): triticale separate from basal diet.
Different superscripts in the same row indicate significant difference ($P < 0.05$).

TABLE IV: Effects of dietary treatments on gastrointestinal system parts and internal organ weight of turkeys. Results are expressed as means ± standard errors of the mean (SEM).

jejunal and the ileal pHs and the jejunal viscosity were not significantly modified according to the dietary treatments; however, the distribution of separate triticale has induced a significant reduction in ileal viscosity compared to the controls or to birds fed with triticale mixed rations ($P < 0.05$). In addition, the litter moisture percentage was significantly higher in birds receiving barley separately from the basal diets (group 3) or triticale mixed to the rations (group 4) ($P < 0.01$).

No significant changes in blood constituents investigated in the present study (Table VI) were observed according to the dietary treatments. Nevertheless, it was observed that the concentrations of the HDL and LDL and the total cholesterolemia (at a lesser extend) tended to increase in groups receiving barley or triticale, the highest values being recorded in the group 5 (birds receiving triticale separately from the basal diets).

Discussion

In the present study, growth performance (body weights and weight gains) appeared higher in turkeys fed with triticale separately from the basal diets compared to the other groups whereas the use of whole barley in a mixed diet and in a separate feeder had no effect or poor effect on performance traits. In addition, food efficiency was improved in the group 5 (birds fed with triticale given in a separate feeder) slightly compared to the controls but significantly compared to the other groups receiving whole cereals, and mainly whole barley. The results are in agreement with those of BENNETT *et al.* [5] who reported that diet containing 20% whole barley could be given to turkeys with little or no depression of growth. Similarly, SVIHUS *et al.* [33] used whole barley at a rate of 700 g/kg in the diet and observed no effect on performance in broilers. Moreover, NAHAS and LAFRANCOIS [23] noted increases

Parameters	Dietary treatments (groups)					SEM
	1 (C)	2 (BM)	3 (BS)	4 (TM)	5 (TS)	
pH and viscosity						
jejunal pH	5.69	5.79	5.77	6.00	6.10	0.21
ileal pH	6.63	6.69	6.38	6.32	6.37	0.19
jejunal viscosity (cP)	1.46	1.63	1.32	1.69	1.41	0.12
ileal viscosity (cP)	2.07^{a}	1.78^{ab}	1.77^{ab}	1.96^{a}	1.51^{b}	0.11
Litter moisture (%)	56.65^{a}	58.24^{ab}	67.54^{c}	64.12^{bc}	59.31^{ab}	2.12
Metabolisable nutrients (%)						
Organic matter	75.16	72.53	75.86	74.96	77.03	2.18
Crude proteins	56.60	51.01	54.49	53.83	52.74	5.32
Crude fat	82.59	83.09	81.40	81.40	83.85	2.57

Group 1: basal diet (control); group 2 (BM): barley mixed with basal diet; group 3 (BS): barley separate from basal diet; group 4 (TM): triticale mixed with basal diet; group 5 (TS): triticale separate from basal diet.
Different superscripts in the same row indicate significant difference ($P < 0.05$).

TABLE V: Effects of dietary treatments on ileal and jejunal pH and viscosity, litter moisture and metabolisable nutrients in turkeys. Results are expressed as means ± standard errors of the mean (SEM).

Parameters	Dietary treatments (groups)					SEM
	1 (C)	2 (BM)	3 (BS)	4 (TM)	5 (TS)	
Total protein (g/L)	32.8	27.9	31.9	29.8	30.8	1.5
Albumin (g/L)	15.7	12.4	14.1	13.3	16.9	1.5
Globulins (g/L)	17.1	15.7	17.8	16.5	13.9	1.3
Triglycerides (mg/L)	684.0	625.0	683.3	710.0	636.0	104.2
Cholesterol (mmol/L)	3.08	2.90	3.26	3.27	3.44	0.13
HDL-Cholesterol (mg/L)	286.7	351.2	346.3	337.7	369.8	29.3
LDL-Cholesterol (mg/L)	651.7	665.0	685.0	701.7	701.7	37.6
Glucose (mmol/L)	13.98	13.77	13.86	14.30	13.04	0.44
ALP (U/L)	1728	1653	1617	1570	1749	151

Group 1: basal diet (control); group 2 (BM): barley mixed with basal diet; group 3 (BS): barley separate from basal diet; group 4 (TM): triticale mixed with basal diet; group 5 (TS): triticale separate from basal diet; ALP: alkaline phosphatase; HDL: high density lipoproteins; LDL: low density lipoproteins. Different superscripts in the same row indicate significant difference ($P < 0.05$).

TABLE VI: Effects of dietary treatments on some blood parameters in turkeys. Results are expressed as means ± standard errors of the mean (SEM).

in body weights and weight gains, decrease in food conversion ratio and no alteration of food intake when whole barley was incorporated at 10% and 20% in the broiler diets. By contrast, BENNETT *et al*. [4] observed that broiler chickens fed with 50 and 65% whole barley exhibited lower weight gain.

NRC [24] showed that triticale is richer than wheat and maize in terms of lysine and methionine, and has higher methionine content than barley. Therefore, in the present study, the improvement in growth in turkey fed with triticale distributed in a separate feeder could be attributed to adjusting nutrient density with triticale. There is a little research regarding the choice for feeding with triticale in fowl. Most of studies have been carried out to investigate replacing of wheat or maize by triticale in poultry diets [29]. However, some studies on triticale usage in the poultry diets revealed no effect [27, 35] and others reported improvement in body weights [18]. In parallel, the total consumed protein rate and the total consumed energy rate calculated per kg of weight gain in the present study were lower in birds fed with triticale separately from basal diets than in others, although not significantly. In fact, basal diet and triticale intakes were similar in the groups 4 (triticale mixed with the rations) and 5 (triticale given in a separate feeder), but the offering type was different, leading to different intake times. Since it was observed that turkeys preferred to consume barley to basal diet, there was a priority with bigger appetite in barley consumption and barley was consumed first in the feeder. On the other hand, the triticale consumption showed a normal distribution during the entire day, leading to a balance in the mixed diet consumptions. These findings have an important economical advantage because the cost of whole barley and triticale are generally lower than that of specific turkey diets. It is, therefore, possible that whole barley and triticale can replace diets without any negative effect on performance of turkeys and even triticale may offer some advantage on growth performance.

The treatments did not affect gastrointestinal weight and relative indices except for the colon traits in this experiment. In previous studies conducted with separate distribution of whole cereals, increases in gastrointestinal weight and corresponding indices were reported [10, 14, 23]. It was hypothesized that whole grain feeding may initially enhance the grinding activity of the gizzard and secondary may alter gut motility, increase peptic digestion in the gizzard and enzymatic digestion in the intestine. It was also suggested that an active gizzard increased starch availability [17]. In the current study, however, gizzard weight was not significantly affected by the dietary treatments, probably, due to limited offers of barley and triticale in the diets (between 9.1% and 16.7% of diet). Similar observations were obtained by BENNET *et al*. [5]; they noted that 20% whole barley did not affect gizzard weights. On the other hand, the colon weights of turkeys fed with control and triticale mixed diets were significantly lower than that of birds fed with barley mixed diets. The colon weight may increase with increasing barley consumption and consequent high cellulose consumption.

In the present study, jejunal and ileal pH, jejunal viscosity and metabolisable nutrient rates were not affected by the different dietary treatments. It is known that barley and triticale have non-starch polysaccharide (NSP) fractions. Digestion of NSP fractions is highly variable due to lack of digestive enzymes and the NSP presence may create a viscous environment within the intestinal lumen [8] and wet litter [6]. However, NSPs can be hydrolyzed by enzymes which are produced by the caecal microflora [8]. On the other hand, proportion of barley and triticale used in the diets probably was not high enough to cause viscous content of intestine. However, as assumed in the present study, the litter moisture rate was lower in the control group than in birds fed with whole cereals mixed to the diets or given separately. As monogastric animals cannot synthesize β-glucanase, the amount of β-glucanase derived from barley grain and bacteria in the gastrointestinal tract is insufficient to completely hydrolyze β-glucans [7]. Consequently, β-glucans in barley diets can create a viscous environment in the chick digestive tract [8], causing poor absorption of dietary nutrients and reducing growth rate. WANG *et al.* [36] noted that viscosity of small intestinal digesta was great in the chicks fed with barley (69.8% of diet) than in those fed with corn-soybean diet and significant negative correlations occurred between viscosity of the small intestinal contents and average daily weight gain, as well as with digestibility of lipids and proteins. On the other hand, BENNETT *et al.* [5] noted that jejunal viscosity was not affected by feeding between 5 to 50% whole barley in diets in turkeys. Similarly, TAYLOR and JONES [34] reported that inclusion of 200 g/kg of barley did not alter viscosity of digesta beyond the duodenum but it was increased in the duodenum. In contrast, PALANDER *et al*. [25] reported that 50% whole barley in the basal diet increased jejunal viscosity of turkeys. On the other hand, the ileal viscosity was significantly depressed in turkeys fed with triticale in a separate feeder (group 5) compared to the controls. Since lower viscosities extend the intestinal digestion duration and increase absorption rates of nutrients, the growth improvement in this group may be related to the low ileal viscosity. In this way, it was observed here that the digestibility of organic matter and crude fat was slightly increased in the group 5 although differences among groups were not statistically significant. The consumption of basal diets and whole triticale in separate feeders may induce a good viscosity in ileum, promoting food efficiency and growth.

The health benefits of barley β-glucans include reduction of blood cholesterol and glucose concentrations and control of heart disease and type-2 diabetes in humans [1]. Additionally, it is shown that barley diets exhibited hypocholesterolemic effects in male broiler chicks and that β-glucans may also bind to bile acids, interfering with digestion and affecting plasma cholesterol concentrations [36]. It is also noted that plasma total cholesterol and LDL cholesterol concentrations were lower in chickens fed with barley diet (698 g/kg barley of diet) than in those fed with maize-soybean based diet [36] whereas MERT [22] showed that 20% barley in the broiler diets did not significantly affect serum cholesterol and triglyceride concentrations. In the present study, circulating cholesterol and lipoprotein concentrations were not significantly altered compared to the controls in birds fed with whole barley enriched diets (groups 2 and 3) while they tended to increase in turkeys fed with triticale based diets (groups 4 and 5). However, there is no available report on triticale effects on blood biochemistry in poultry to our knowledge.

As a conclusion, the present results revealed that the incorporation of triticale in the rations of turkeys in a separate way

has induced significant improvement in growth parameters, probably due to a lower ileal viscosity, leading to slight increase in nutrient digestibility. On the other hand, whole barley did not affect performance traits. Indeed, because of the low barley and triticale costs, economic advantage may be obtained from separate feeding with cereals. Further research is required to determine the effect of feeding with different barley and triticale grains in separate feeding system on the growth and fattening performance of turkeys.

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