RESEARCH ARTICLE

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Effects of enzyme supplementation on replacing corn with barley in diet of broiler chicks

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ABSTRACT

Two experiments were carried out to evaluate the effects of an enzyme complex (Agrozyme®, a cocktail of cellulolytic, amylolytic, and proteolytic enzymes) on barley energy content and its nutritive value for broiler chicks. In the first experiment, the effect of enzyme on barley energy content was determined using adult Leghorn cockerels. In the second experiment, the effects of the enzyme on performance, carcass characteristics, and nutrient digestibility of broilers fed diets containing 0, 50 and 100% replacement of diet corn with barley was investigated using 360 1-d-old chicks. Enzyme had no effect on barley energy content (first experiment). During 1 to 21 d period, chicks fed diet in which 100% of corn was replaced by barley had lower weight gain than those fed diet in which 50% of corn was replaced by barley. The high barley diet resulted in a significant increase in feed conversion ratio. During 21 to 35 d period, chicks fed the corn diets had lower weight gain than those fed barley containing diets. Enzyme had no effect on weight gain, but feed conversion ratio was improved by enzyme when chicks fed high barley diet. In the overall period, enzyme addition had no effect on performance. Carcass and abdominal fat weight was reduced, whereas the small intestine weight was increased when chicks fed diet in which 100% of corn was replaced by barley. Dietary treatments had no effect on dry matter, crude protein, and crude fat digestibilities.

Key words: broilers, digestibility, *Hordeum vulgare,* metabolizable energy

Introduction

Corn is the major cereal grain that used in broiler diets (Wang et al., 2005). However, because of the world-wide high cost of corn, especially in corn importer countries, using locally grown grains such as barely in broiler diets has become more appealing. Although barley has lower price, its level of inclusion is limited because of its negative effects on bird performance, litter quality, increasing the incidence of sticky droppings and lower metabolizable energy (Hesselman et al., 1981; Gracia et al., 2003; Onderci et al., 2008). These undesirable features have been attributed to the non-starch polysaccharides, especially β-glucan which consists of units of glucose joined by β-1,3 and β-1,4 bonds. Beta-glucans form gels in the bird digestive tract that are not broken down because of the lack of appropriate enzymes and the rapid rate of passage in poultry (Leeson et al., 2000).

The use of feed enzymes, most notably those containing β-glucanase activity, in barley-based diets may raise broiler performance (Fuente et al., 1995; Gracia et al., 2003). Friesen et al. (1992) showed a reduction in feed intake by using 35 and 70% barley in broiler diets, whereas enzyme supplementation improved weight gain and feed conversion ratio in chicks fed diet containing 70% barley. In broilers receiving enzyme supplemented barley-based diet, Onderci et al. (2008) reported 3 and 7.25% improvement in feed conversion ratio and body weight from 1 to 21 d of age, respectively. These improvements are less pronounced in older broilers. Young broilers (less than 3 wk of age) may receive diets containing up to 20% barley when supplemented with appropriate enzymes. From 3 to 6 wk of age, broilers may be fed by diets containing up to 40% barley. This level may be increased to 50% of the diet for broilers over 6 wk of age (Jeroch & Danicke, 1995; Onderci et al., 2008). It has been reported that enzyme inclusion in high barley diets improve nutrient digestibility. Friesen et al. (1992) showed that enzyme supplementation in a diet containing 70% barley improved protein digestibility from 5 to 29% and fat digestibility from 13 to 85%. Also, there are reports on improved starch and crude protein digestion after enzyme inclusion in broiler diets (Annison & Choct, 1991;

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Gracia et al., 2003; Onderci et al., 2008). The improvement in nutrient digestibility could increase metabolizable energy content of barley for broilers.

The objective of this study was to evaluate the effect of recommended inclusion levels of a commercial enzyme complex (Agrozyme®, a cocktail of cellulolytic, amylolytic, and proteolytic enzymes) on the energy content of locally grown barley and response of broiler chicks to replacement of corn by barley.

Materials and Methods

All experimental protocols adhered to the guidelines of, and were approved by, the Animal Ethics Committee of University of Kurdistan (Sanandaj, Iran).

Experiment 1

In this experiment, the effect of enzyme on barley energy content was determined using adult Leghorn cockerels (2348±165 g in weight and 24 months in age). The samples of barley and corn (in 10 replicates) were dried in a forced air oven at 60°C for 48 h and ground in a Wiley mill (1-mm screen), and dry matter, ash, crude fat and nitrogen was determined based on standard procedures of the AOAC (1990). Gross energy was determined using an adiabatic bomb calorimeter (Parr Instrument, Moline, IL, USA) using a benzoic acid standard. Metabolizable energy was determined by the method of Sibbald (1986) with recommendations of McNab & Blair (1988). Fifteen Leghorn adult cockerels were allocated to individual cages. During one month before experiment, they were fed on a corn-soybean meal diet for adaptation. Forty-eight hours before force feeding, feed was withdrawn and 40 and 16 h before tube feeding each bird received 40 mL of a glucose solution (38.5%). Forty grams of ground barley seeds with (1 g/kg according to the manufacture recommendation) or without a commercial enzyme (Agrozyme® a cocktail of cellulolytic, amylolytic and proteolytic enzymes, Merck Sharp and Dohme Research Laboratories) was individually precision fed to five cockerels by tube. Five cockerels considered as control to correct endogenous energy and they were tube fed 40 g of glucose. Thirty-two hours after force feeding, all birds received 40 mL water by tube. Forty-eight hours after feeding, total excreta of birds were collected in a clean aluminum tray, carefully cleaned of feathers and stored at –20 until freeze dried. In order to determine AMEn and TMEn the excreta samples were analyzed for nitrogen contents (AOAC, 1990).

Experiment 2

In this experiment, the effects of the enzyme complex on performance, carcass characteristics, and nutrient digestibility of birds fed diets containing different levels of barley was investigated using broiler chicks. A total of 360 as hatched 1-d-old broiler chicks of a commercial breed (Arian) were placed in 24 pens, 15 per each. The chicks were allocated randomly to six experimental diets. This experiment was a randomized design with a 3×2 factorial arrangements in which barley was substituted for corn at 0, 50 and 100% by weight with or without enzyme (1 g/kg diet according to the manufacture recommendation). The diets (Table 1) were formulated to meet nutrient requirements according to NRC (1994). Each treatment consisted of four replicates.

All feeds were fed in mash form and feed and water were provided ad libitum. Broilers were weighed on a pen basis at 1, 21, 35, 42, and 49 d of age and weight gains were calculated. Feed intake was recorded at the same periods and feed conversion ratio was calculated after adjusting feed intake for mortality. Mortality was recorded daily. Two birds (one male and one female) from each replicate (eight birds per treatment) were slaughtered at d 49 and carcass, abdominal fat, liver, pancreas, and small intestine were removed, weighed, and presented as a percentage of live body weight.

For all treatments 0.3% chromic oxide (Cr_2O_3) was added to diets as an indigestible marker. After 2 d adaptation period, excreta were collected for 3 d. Total excreta collection was followed by a 2 d further adaptation period, 24 h fasting and 4 h free access to feed, after which the birds were killed by mechanical stunning and subsequent neck dislocation and ileal digesta was collected. This procedure was conducted as quickly as possible to minimize changes in digesta composition. The ileum was dissected from Meckel's diverticulum to the ileocaecal junction and digesta were collected from the distal half. Apparent ileal and excreta digestibilities were calculated using Cr_2O_3 as an external marker as follows:

$$\text{Apparent ileal and excreta digestibility} = \frac{\left(\frac{N}{Cr_2O_3}\right)d - \left(\frac{N}{Cr_2O_3}\right)ie}{\left(\frac{N}{Cr_2O_3}\right)d}$$

Where:

$\left(\frac{N}{Cr_2O_3}\right)$ d = the dietary ratio of nutrient to Cr_2O_3;

$\left(\frac{N}{Cr_2O_3}\right)$ ie = the ratio of nutrient to Cr_2O_3 in ileal digesta or excreta.

Dry matter, crude fat, and crude protein were determined based on standard procedures of the AOAC (1990), while Cr_2O_3 was determined following the procedure of Williams et al. (1962).

Data were analyzed by two-way ANOVA with the general linear model procedures of SAS (2003), using a model that included barley level and enzyme inclusion as the main effects and their interaction. Duncan's multiple range tests were used to compare treatment means at *P*<0.05 significant level.

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Table 1. *Ingredients and nutrients composition of the experimental chicken diets.*

Item (%, unless indicated otherwise)	Level of barley substituted for corn in diet								
	1-21 d			22-35 d			36-49 d		
	0	50	100	0	50	100	0	50	100
Ingredients									
Corn	62.60	31.00	–	65.60	32.20	–	68.00	34.00	–
Barley	–	31.00	60.00	–	32.20	63.00	–	34.00	66.50
Soybean meal	26.10	24.30	23.30	24.10	22.00	20.20	23.00	20.60	18.80
Fish meal	6.50	6.50	6.50	5.00	5.00	5.00	3.00	3.00	3.00
Vegetable oil	1.00	4.25	7.25	2.00	5.50	8.70	2.70	5.70	9.10
Dicalcium phosphate	0.94	0.94	0.94	0.90	0.90	0.90	0.60	0.60	0.60
Oyster shell	1.30	1.30	1.30	1.20	1.20	1.20	1.35	13.50	1.35
Salt	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
DL-Methionine	0.06	0.06	0.06	0.60	0.65	0.70	0.15	0.20	0.25
Mineral premix [1]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin premix [2]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Calculated composition									
Metabolizable energy (kcal/kg)	2930	2923	2916	3036	3030	3014	3090	3068	3049
Crude protein	21.10	21.00	20.98	19.10	19.00	18.92	17.70	17.55	17.42
Methionine	0.47	0.46	0.46	0.42	0.42	0.42	0.32	0.32	0.32
Methionine + Cysteine	0.81	0.80	0.80	0.77	0.77	0.77	0.65	0.65	0.65
Lysine	1.30	1.30	1.30	1.15	1.15	1.15	1.00	1.00	1.00
Available phosphorus	0.48	0.47	0.47	0.41	0.41	0.41	0.31	0.31	0.31
Calcium	1.00	1.00	1.00	0.90	0.90	0.90	0.77	0.77	0.77

[1] Supplemented (mg/kg of diet): Mn, 1200; Fe, 60; Zn, 120; Cu, 12; I, 1.2; Se, 0.24.
[2] Supplemented (mg or IU/kg of diet): Vitamin A, 10800 IU; Vitamin D_3, 2400 IU; Vitamin E, 21.6 IU; Vitamin K_3, 2.4 IU; Vitamin B_1, 2.16; Vitamin B_2, 7.9; Vitamin B_3, 12; Vitamin B_5, 3.6; Vitamin B_9, 1.2; Vitamin B_{12}, 0.015; Vitamin Biotin, 0.12; Choline chloride, 600; and adequate antioxidant.

Results

Experiment 1

Crude protein and crude fiber content of barley grain were higher (P<0.05) than those of corn grain (Table 2). However, crude fat, gross energy, and metabolizable energy of barley grain was lower than those of corn grain (P<0.05). Enzyme supplementation increased barley energy content, but this increase was not statistically significant (P>0.05).

Experiment 2

Growth performance of chicks is shown in Table 3. No significant difference was observed in feed intake during the overall experimental period (P>0.05). During 1 to 21 d of age, chicks fed diets in which 100% of corn was replaced by barley had lower weight gain than those fed diets in which 50% of corn was replaced by barley (P<0.05). From 21 to 35 d of age, chicks fed corn diets had lower weight gain than those fed any of the barley containing diets (P<0.05). Body weight gain was not significantly affected by the partial and total replacement of dietary corn with barley from 35 to 49 d of age (P>0.05). In the overall experimental period, chicks fed diets in which 50% of corn was replaced by barley had higher weight gain than those fed corn diet (P<0.05). Enzyme supplementation had no significant effect on body weight gain (P>0.05) and there was no interaction between barley and enzyme on body weight gain (P>0.05). The whole replacement of corn with barley resulted in a significant increase (P<0.05) in feed conversion ratio during 1 to 21 d period of the experiment (P<0.05), and enzyme supplementation could not compensate for this effect (P>0.05). Similar pattern was observed from 21 to 35 d of age, except that feed conversion ratio was improved by enzyme supplementation in chicks fed high barley diet (P<0.05). However, feed conversion ratio of the chicks fed corn diet increased significantly by enzyme supplementation (P<0.05). In the higher ages and in the overall period, replacing corn with barley and enzyme addition had no significant effect on feed conversion ratio (P>0.05).

Table 4 shows the effect of dietary treatments on carcass yield and organ weights in 49-d-old chicks. Carcass yield and abdominal fat weights tended to decrease as the level of barley in the diet was increased, and they were significantly reduced when chicks fed diets in which 100% of corn was replaced by barley (P<0.05). There were no significant differences in pancreas and liver weights among the chicks receiving different barley levels (P>0.05). The weight of small intestine was increased when chicks fed diets in which 100% of corn was replaced by barley (P<0.05).

Dietary treatments had no significant effect (P>0.05) on ileal and excreta digestibilities of dry matter, crude protein, and crude fat (Table 5).

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Table 2. *Chemical composition (%) and energy content (kcal/kg) of corn and barley grain.*

Composition	Corn	Barley	Barley + Enzyme[1]	*Significance*[2]
Dray matter	91.7	91.03	ND[3]	NS
Crude protein (N × 6.25)	8.93[b]	10.20[a]	ND	*
Crude fat	3.41[a]	2.27[b]	ND	*
Crude fiber	2.98[b]	5.97[a]	ND	**
Gross energy	4140[a]	3693[b]	ND	**
AME_n	3033[a]	2641[b]	2665[b]	**
TME_n	3571[a]	3179[b]	3205	**
AME and TME differences (%)	15.06	16.92	16.84	NS

Row means with different superscripts are significantly different, Duncan's least significance multiple-range test was applied to compare means.
[1] 1 g/kg Agrozyme® a cocktail of cellulolytic, amylolytic and proteolytic enzymes, Merck Sharp and Dohme Research Laboratories
[2] ***P*<0.01; **P*<0.05; NS = *P*>0.05.
[3] ND = not determined

Table 3. *Effects of different levels of barley (%) and enzyme supplementation on feed intake, body weight gain and feed conversion ratio of broiler chickens.*

		Feed intake (g/chick)				Body weight gain (g/chick)				Feed conversion ratio (g feed/g gain)			
Barley	**Enzyme**[1]	**d 1-21**	**d 21-35**	**d 35-49**	**d 1-49**	**d 1-21**	**d 21-35**	**d 35-49**	**d 1-49**	**d 1-21**	**d 21-35**	**d 35-49**	**d 1-49**
0	–	997.07	1366.86	2457.77	4821.50	536.55	690.30	780.66	2007.57	1.85	1.98[bc]	3.17	2.40
0	+	1007.20	1370.10	2159.08	4536.50	543.27	664.42	814.56	2022.25	1.85	2.07[a]	2.66	2.24
50	–	1023.82	1413.09	2416.35	4828.25	544.85	724.13	892.84	2176.52	1.87	1.95[c]	2.75	1.73
50	+	1035.12	1417.04	2430.72	4907.75	564.67	734.85	829.83	2129.35	1.84	1.93[c]	2.92	2.30
100	–	1051.25	1416.54	2777.67	5245.50	515.85	686.05	898.12	2100.05	2.04	2.06[a]	3.10	2.50
100	+	1047.72	1423.43	2489.78	4961.00	519.17	734.63	771.70	2025.52	2.01	1.93[c]	3.20	2.44
Main effects													
Barley													
0		1002.14	1368.48	2308.43	4679.00	539.91[ab]	677.36[b]	797.61	2014.91[b]	1.85[b]	2.03[ab]	2.92	2.32
50		1029.47	1415.07	2423.54	4868.00	554.76[a]	729.49[a]	861.34	2152.80[a]	1.86[b]	1.94	2.84	2.02
100		1049.49	1419.99	2633.73	5076.63	517.51[b]	710.34[a]	834.91	2062.79[b]	2.03[a]	2.00	3.15	2.47
Enzyme													
–		1024.05	1398.83	2550.60	4965.08	532.42	700.16	857.21	2094.71	1.92	2.00	3.01	2.21
+		1030.01	1403.52	2359.86	4801.75	542.37	711.30	805.36	2059.04	1.90	1.98	2.93	2.33
Pooled SEM		10.03	14.48	71.65	83.88	5.78	9.44	20.79	24.55	0.022	0.019	0.081	0.094
Significance[2]													
Barley		NS	NS	NS	NS	*	*	NS	*	***	NS	NS	NS
Enzyme		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Barley × Enzyme		NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS

Means within column with different superscripts are significantly different, Duncan's least significance multiple-range test was applied to compare means.
SEM= Standard error of the mean.
[1] 1 g/kg Agrozyme® a cocktail of cellulolytic, amylolytic and proteolytic enzymes, Merck Sharp and Dohme Research Laboratories
[2] ****P*<0.001; **P*<0.05; NS = *P*>0.05.

Discussion

The results of the performance study confirmed that barley can replace corn successfully in broiler diets. Compared to the corn diet, feeding a diet in which 50% of corn was replaced by barley had almost no effect on feed intake and feed conversion ratio but accelerated growth rate at all ages, which could be related to a better availability or balance of the amino acids in the diet. Moreover, in barley containing diets, a high amount of vegetable oils was used to meet chick energy requirements. An increase in diet AME content due to more vegetable oil could thus be another possible explanation, as indicated previously by Allen et al. (1997).

It has been reported that feeding high barley diets could decrease body weight gain, with no change (Mansoori et al., 2011), decrease (Ribeiro et al., 2012) or increase (Onderci et al., 2008; Shirzadi et al., 2009) of feed conversion ratio. In the present study, total replacement of corn with barley increased feed conversion ratio during the starting and growing periods. A similar trend was seen by Bennett et al. (2002), who found that inclusion of barley at any level above 5% in broiler diet resulted in a temporary loss in early growth and feed conversion efficiency. It seems that the presence of a more developed digestive system in mature, compared with immature, birds presumably enables the birds to utilize more efficiently diets rich in viscous polysaccharides (Nahas & Lefrancois, 2001).

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Performance data from the present study also revealed that the addition of an enzyme complex to the barley containing diets did not lead to any improvement in performance of the broilers, except for feed conversion ratio during the growing period. Feed conversion ratio was improved by enzyme supplementation when chicks receiving

Table 4. *Effects of different levels of barley (%) and enzyme supplementation on carcass characteristics (% of body weight) of broilers at 49 d of age.*

Barley	Enzyme[1]	Carcass yield	Abdominal fat	Liver	Pancreas	Small intestine
0	–	70.22	1.97	2.29	0.23	6.32
0	+	76.54	2.15	2.65	0.23	5.55
50	–	69.80	1.85	2.34	0.22	6.07
50	+	70.00	2.10	2.33	0.21	6.03
100	–	67.62	1.57	2.16	0.22	7.26
100	+	67.95	1.70	2.38	0.23	7.11
Main effects						
Barley						
0		73.38[a]	2.06[a]	2.47	0.23	5.94[b]
50		69.90[ab]	1.98[ab]	2.34	0.22	6.05[b]
100		67.79[b]	1.64[b]	2.27	0.23	7.19[a]
Enzyme						
–		69.21	1.80	2.26	0.22	6.55
+		71.50	1.98	2.45	0.22	6.23
Pooled SEM		0.803	0.069	0.152	0.006	0.104
Sources of variation		*Significance*[2]				
Barley		**	*	NS	NS	*
Enzyme		NS	NS	NS	NS	NS
Barley × Enzyme		NS	NS	NS	NS	NS

Means within colon with different superscripts are significantly different, Duncan's least significance multiple-range test was applied to compare means. SEM = Standard error of the mean.
[1] 1 g/kg Agrozyme® a cocktail of cellulolytic, amylolytic and proteolytic enzymes, Merck Sharp and Dohme Research Laboratories
[2] ***P*<0.01; **P*<0.05; NS = *P*>0.05

Table 5. *Effects of different levels of barley (%) and enzyme supplementation on component excreta and ileal digestibilities of broilers.*

		Dry matter		Crude protein		Crude fat	
Barley	**Enzyme[1]**	**Excreta**	**Ileal**	**Excreta**	**Ileal**	**Excreta**	**Ileal**
0	–	76.24	76.43	63.34	66.09	71.16	73.71
0	+	75.11	76.28	63.89	66.39	73.45	71.48
50	–	71.31	72.81	61.27	65.53	67.29	66.89
50	+	73.77	73.86	62.19	65.76	70.78	71.02
100	–	68.30	68.43	60.01	62.37	61.38	62.73
100	+	70.37	71.29	64.98	65.17	66.63	66.84
Main effects							
Barley							
0		75.68	76.36	63.62	66.24	72.31	72.60
50		72.54	73.34	61.73	65.65	69.04	68.96
100		69.34	69.86	62.50	63.77	64.01	64.79
Enzyme							
–		71.95	72.56	61.54	64.66	66.61	67.78
+		73.08	73.81	63.69	65.77	70.29	69.78
Pooled SEM		1.653	1.813	1.293	1.430	2.436	2.330
Sources of variation		*Significance*[2]					
Barley		NS	NS	NS	NS	NS	NS
Enzyme		NS	NS	NS	NS	NS	NS
Barley × Enzyme		NS	NS	NS	NS	NS	NS

SEM = Standard error of the mean.
[1] 1 g/kg Agrozyme® a cocktail of cellulolytic, amylolytic and proteolytic enzymes, Merck Sharp and Dohme Research Laboratories
[2] NS: *P* >0.05.

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diets in which 100% of corn was replaced by barley. Otherwise, feed conversion ratio was increased by enzyme supplementation when chicks fed the corn diet. This lack of response in bird performance to dietary enzyme addition, especially at lower age, was inconsistent with other studies (Viveros et al., 1994; Esteve-Garcia et al., 1997; Svihus & Gullord, 2002; Moharrery, 2006; Onderci et al., 2008). However, it was in agreement with the observed trends in metabolizable energy content (Experiment 1), and was in general agreement with the findings of other researchers (McCracken & Bedford, 2001; Nahas & Lefrancois, 2001; Rebolé et al., 2010), who observed either no response or a negative response to the effects of enzymes on broiler performance. According to McCracken & Bedford (2001), factors such as diet composition and diet form could affect the performance response of broilers to enzyme supplementation. Differences in responses might also be due to the intrinsic properties of enzyme product (Biggs et al., 2007) or to the conditions under which the experiment was carried out (Rebolé et al., 2010).

Moharrery (2006) reported a higher percentage of breast part and carcass yield in broilers fed diets containing 35% barley. This observation was attributed to the lower deposition of fat or higher protein in these parts. Higher protein is associated with higher water, which altogether increased the carcass weight. The fat and protein contents of the breast or carcass were not analyzed in the present study. However, a similar pattern of response was observed for abdominal fat weight and carcass yield, and both were reduced as the level of barley in the diet was increased. Moreover, in the present study, the weight of small intestine was increased when chicks fed barley containing diets, in agreement with the results reported by Esteve-Garcia et al. (1997), Yu et al. (1998) and Gracia et al. (2003). It seems probable that the reduction of carcass yield was caused by an increase in the weight of intestine. It has been reported elsewhere that inclusion of fiber increased the relative weight of the different segments of the gastrointestinal tracts in birds (González-Alvarado et al., 2007; Jiménez-Moreno et al., 2009). Therefore, the higher weights of small intestine by feeding barley containing diets in the present study could be attributed to the higher level of fiber in these diets.

It has been reported by several authors (Scott & Boldaji, 1997; Gracia et al., 2003; Moharrery, 2006; Onderci et al., 2008) that replacing corn with barley in broiler diets reduced dry matter, crude protein, crude fat, and energy digestibilities. Consistent improvements in digestibility of nutrients owing to enzyme preparations have also been found in many studies with broiler chicks fed barley containing diets (Yu et al., 1998; Gracia et al., 2003; Onderci et al., 2008). Moreover, Ravindran et al. (2007) reported that enzyme addition improved the apparent ileal digestibility of protein and amino acids; as the average apparent ileal digestibility of the 18 amino acids was increased by 11.9% due to enzyme addition, ranging from 5.1% for methionine to 18.1% for threonine. However, in the present study, there were no significant differences in apparent ileal and excreta digestibilities of dry matter, crude protein, and crude fat for different levels of barley substitution for corn and enzyme inclusion in the diet. The reason for this observation is not known, as barley had significant effects on broiler performance and carcass characteristics. The low number of samples could be a relevant factor because the apparent ileal and excreta digestibilities of dry matter and crude fat decreased numerically as the level of barley increased in the diet.

It could be concluded from our findings that barley can replace up to 50% of the corn in a broiler diet from 1 to 21 d of age. This level can be increased to 100% over 21 d of age with almost comparable growth but with considerably less efficiency of feed utilization. Enzyme addition to diets containing low levels of barley appears to be questionable, because enzyme had only small or no effect on broiler performance even when added to barley containing diets.

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