Comparison of performance and digestibility characteristics of broilers fed diets containing treated hulled barley or hulless barley

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ABSTRACT: This study was performed with growing chickens (14 to 56 days of age) to evaluate the effects of feeding a barley-based diet. The treatments were maize diet (1) as a control, barley diet with (4) or without (2) the commercial enzyme β-glucanase, barley treated with rumen fluid without protozoa (3) and hulless barley (5). The effects of treatments were investigated in a 42-day trial using 360 sexed broiler chickens. In a digestibility trial, 15 male broiler chicks were used at 45 days of age. In this regard, five treatments were offered to chickens in three replications individually. The experimental design for performance investigation was a completely randomised one with a 5 × 2 factorial arrangement of treatments. Each of the five treatments was replicated three times per sex (n = 3). The levels of barley in treatments (2) to (5) were 35% during the growing (14 to 42 days) and finishing (42 to 52 days) period. At the end of trial, two birds from each pen were selected and slaughtered. Blood samples were taken just before slaughter of birds. No significant differences ($P > 0.05$) were observed between (3) to (5) treatments with maize diet in weight gains, feed intake and feed conversion, but barley with no treatment (2) showed lower weight gain compared to the enzyme treatment and hulless barley diet ($P < 0.05$). Ether extract digestibility decreased significantly in all barley diets compared with maize diet ($P < 0.05$). Digestibility of DM, CP, and NFE was lower in barley diet with no treatment, in comparison with other treatments ($P < 0.05$). Reduction of serum cholesterol was observed in birds on hulless barley diet ($P < 0.05$), but serum triacylglycerols and glucose did not show any significant differences between treatments ($P > 0.05$). Mean percentage yield of breast showed the highest percentage in barley diet with no treatment ($P < 0.05$) and abdominal fats were produced in lowest amounts in carcasses on hulless barley diets ($P < 0.05$).

Keywords: broiler; barley; hulless barley; enzyme; cholesterol; digestibility

Exogenous enzymes have been used extensively to remove anti-nutritional factors from feeds, to increase the digestibility of existing nutrients, and to supplement the activity of the endogenous enzymes of poultry (Classen et al., 1991; Bedford, 1993). Currently most of the enzymes that are used in feeds are xylanases for wheat and rye-based diets and β-glucanases for barley and oat-based diets. The targets of those enzymes are the non-starch polysaccharides (NSP) that are found in cereals; they include xylanases for xylans and β-glucanases for β-glucans. The use of NSP enzymes in the animal feed industry has greatly expanded in the last five years especially in countries like Iran, which utilizes large quantities of cereals such as barley and wheat in poultry diets. When added to diets especially for poultry, these enzymes have been shown to improve the efficiency of feed utilization, increase the rate of growth, improve the health of the gastrointestinal tract, and reduce environmental pollution due to a decreased output of manure and gases such as ammonia (Bedford, 1997; Choct, 1997; Marquardt, 1997). The arabinoxylans and β-glucans present in the endosperm cell walls of cereal grain have been identified as a major cause of poor growth rate and low nutrient digestibility (Ward and Marquardt, 1987) in broiler chickens. These anti-nutritive effects of NSPs

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are attributed to an increase in intestinal digesta viscosity (Choct and Annison, 1992b). Therefore, the addition of exogenous enzymes is necessary to reduce the anti-nutritive effects of viscous NSPs (Choct and Annison, 1992a). The NSP-degrading enzymes markedly increase the nutritive value of wheat (Choct et al., 1995) and rye (Bedford and Classen, 1993) in broiler chickens.

In ruminants, microorganisms play a role through their enzymes in digestive processes. Complete digestion of complex feeds such as hay or grain literally requires hundreds of enzymes (McAllister et al., 2001). The diversity of enzyme activities present in rumen fluid is advantageous because a single product can target a wide variety of substrates (Moharrery and Das, 2001).

Hulless barley has a higher AME and protein content than hulled barley because of the diluting effect of the fibrous hull (Classen et al., 2000). Based on chemical analysis, Edney et al. (1992) determined that hulless barley had higher crude protein (CP) than did hulled barley. Removal of the hull from barley increases its digestible energy content, but it also increases the proportion of starch.

The first objective of this study was to explore the possibility of using a practical procedure for barley treatment with rumen fluid. Furthermore, the removal of the hull is expected to result in modest increases in metabolizable energy and protein levels of hulless barley compared to regular barley. For this reason, comparison of the effects of hulless barley (the same percentage as of regular barley) or hulled barley (treated or untreated) and maize on performance and digestive characteristics of broiler chickens and evaluation of their blood metabolites and carcass characteristics were other objectives of this study.

MATERIAL AND METHODS

Animals and diets. Three hundred and sixty 1-day-old sexed commercial broiler chickens (Ross, Iranian Agency) were housed separately for each sex in floor pens containing litter composed of wood shavings and received a maize-based starter diet (Table 1). At 14 days of age, all the chickens from each sex were divided into 15 groups, 12 chickens per group. Each of the 5 experimental diets was fed to 3 groups of chickens (in each sex) for 42 days. Dietary treatments as grower and finisher diets (Table 1) consisted of:

1. Maize-based diet as a control.

2. Hulled barley-based diet without any treatment or enzyme addition.

3. The same diet as mentioned under (2) but barley was treated with rumen fluid without protozoa. The rumen fluid was collected from the rumen content in slaughterhouses and strained through four layers of cheesecloth and centrifuged once at 1 000 g for 10 min. The supernatant fluid was decanted and diluted with water (50:50). This fluid was mixed with ground barley thoroughly and transferred to a large plastic barrel and kept anerobically at about 20°C for 48 hours. Then the barrel was evacuated on a plastic sheet for drying in sunlight. This type of barley called processed barley was included in grower and finisher diet at the same amount as another type of barley for treatment No. 3.

4. The exogenous enzyme used in this treatment was the commercial powdered preparation Endofeed, Reg No. 280003 (GNC Bioferm INC. Saskatchewan, Canada, S7H 3A6) with β-glucanase activities. The enzyme preparation was added to the barley-based diet (the same percent as in treatment 2 and 3) at the level of 0.5 g/kg of diet.

5. Normal hulless barley-based diet (the same percent as in treatment 2 to 4) without any treatment or enzyme addition. The CP content in this grain was about 2% higher than in hulled barley but the removal of the hull is expected to result in modest increases in metabolizable energy, which can adjust the energy/protein levels in the same way as regular barley. This is why the same amount of hulless barley was used for comparison with hulled barley.

Feed and water were supplied *ad libitum* throughout the whole experiment. Body weights were determined at 14, 42 and 56 days of age and feed intake over these periods was recorded. Feed conversion (g feed per body mass – FC) was calculated after dividing the cumulated feed consumption for each pen to the total bird mass of that pen.

Digestion trial. A digestion trial was performed using 15 male broiler chicks from 45 to 52 days of age. It consisted of 4 days of adaptation, followed by 72 h with access to 85 g of feed from each treatment. Fifteen birds (3 replications per each diet) were housed in individual layer cages with wire bottoms. Birds had free access to water throughout the experiment. The cages were kept in a room at 22°C and approximately 58% ± 3 relative humidity. Excreta were collected for each 24-hour period for days 50, 51 and 52. Contamination, such as down and scales,

Table 1. Composition of experimental diets

Ingredients and analysis	Starter (g/kg)	Experimental diet			
		14 to 42 days		42 to 56 days	
		maize-based	barley-based[1]	maize-based	barley-based[1]
Ground yellow maize	618	485	150	615	300
Ground barley			350		350
Soybean meal (44% CP)	280	330	310	190	180
Fish meal	49.5	27	30	20	18
Plant oil	19	19	50	25	50
Wheat bran		84	55	95	50
Dicalcium phosphate	12	28	28	28	28
Oyster shell	13	10	10	10	10
Sodium chloride	1	4.5	1.5	4.5	1.5
DL-Methionine	0.5	2.5	2.5	2.5	2.5
Vitamin/mineral premix[2]	7	10	10	10	10
Analyses (calculated)[3]					
AME (KJ/kg)	12 556	11 380	11 376	12 096	12 096
Crude protein (%)	20.78	21.89	21.85	16.62	16.64
Methionine (%)	0.44	0.61	0.59	0.53	0.51
Methionine + Cysteine (%)	0.75	0.94	0.92	0.79	0.77
Lysine (%)	1.21	1.26	1.26	0.86	0.86

[1]in diets (2) to (5) the same levels of barley were used but with different types of treatment or variety

[2]the premix supplied the following vitamins and elements (mg/kg diet): retinol 3.6 (about 1.1 IU/KJ), cholecalciferol 0.075 (about 0.26 IU/KJ), biotin 1, DL-α-tocopherylacetate 10, riboflavin 10, pantothenate 20, choline 2 000, niacin 100, thiamine 10, pyridoxine 10, menadin sodium bisulphate 1.5, cyanocobalamine 0.1, folic acid 2, ethoxyquin 150, Mn 100, Fe 100, Cu 10, Co 1, I 1, Zn 100

[3]estimated from NRC (1994) composition tables, but energy values converted to the Joule unit

was carefully removed, and the excreta were stored in containers at –25°C. Excreta samples were subsequently dried in an oven at 80°C, weighed, ground through a 0.5 mm sieve, and stored in an airlock plastic vessel at 4°C until analysis.

Carcass characteristics and blood samples collection. At the end of the experiment (56 days of age), two birds of each pen were bled by cutting the carotid artery and blood was taken from this artery. The blood samples were centrifuged for 15 min at 2 500 × g, and the serum was harvested and stored at –80°C.

The carcass feather removal was accomplished in a free-action picker after subscalding at approximately 60°C. Heads and shanks were removed, and the remaining carcasses were dissected to breast, thigh, wings, neck, gizzard, liver, abdominal fat and weighed. The percentage yield of each part was calculated on the basis of carcass weight. The meat samples (*musculus pectoralis major*, *m. pectoralis minor*, and *m. sartorius*) were used for determination of fat, protein, ash and glycogen. The samples were minced twice and then homogenized and kept at –25°C.

Chemical measurements. Total fat contents of feed, meat and excreta were determined by extraction of samples with petroleum ether. The determination of nitrogen in feed and excreta was performed with the macro-Kjeldahl method. Because a part of nitrogen in excreta originates from uric acid, the faecal nitrogen should be corrected for uric acid nitrogen. In this regard, the excreta were calculated as total nitrogen minus

nitrogen in uric acid. The apparent metabolizable energy of each diet was calculated from the gross energy values of the diet and dried excreta. Gross energy values were measured using a bomb calorimeter (Shimadzu Automatic Bomb Calorimeter CA-3). The glycogen content in meat samples was measured as described by Djawdan et al. (1998).

Serum samples were also analysed for triacylglycerols using an enzymatic and colorimetric procedure (Kit 10-525, Ziestchem Diagnostic kit, Tehran, Iran) and for cholesterol by an enzymatic procedure (Kit 10-508, Ziestchem Diagnostic kit, Tehran, Iran) and for glucose by a colorimetric procedure (Kit 10-518, Ziestchem Diagnostic kit, Tehran, Iran).

Statistical analysis. The complete randomised model was used to analyse digestibility data. In this regard, five treatments were offered to chickens in three replications individually. The experimental design for performance investigations was a completely randomised one with a 5 × 2 factorial arrangement of treatments. Each of the five treatments was replicated three times per sex (n = 3). The data were analysed using a general linear model procedure of SAS (1988). Duncan's multiple range test (SAS, 1988) ($P < 0.05$) was used to test the significance of differences between means. The percentage values were transformed to arcsine and analysed, but the values that are reported were converted to the initial form. The values are given as means, and the homogeneity of variance was checked.

RESULTS AND DISCUSSION

Growth performance. Growth performance, feed intake and feed conversion are shown in Table 2. No differences ($P > 0.05$) in feed intake or feed conversion were observed through day 42 or 56. Weight gain was reduced significantly ($P < 0.05$) by treatment (2) at day 42 and 56. The barley diets which were treated with rumen fluid or commercial enzyme showed the same results as the maize-based diet and superior performance than barley without any treatment (2), indicating that the efficiency of dietary utilisation increased in chicks fed these regimens. A significant reduction in weight gain that occurred in broilers fed regimen (2) compared to regimen (5) suggested that the insoluble fibre may play its role because the β-glucan concentration in hulless barley is higher than in hulled barley.

At present there are two major types of hulless barley, normal and waxy. The normal type has the traditional ratio of amylose to amylopectin starch fractions as found in regular barley. The waxy type has a very high percentage of amylopectin starch. Markets for waxy barley are being developed.

Improvements in the performance of poultry fed diets containing barley to which enzymes had been added were first reported more than 45 years ago (Jensen et al., 1957). In the present study it was shown that the addition of enzyme to the diet (treatment No. 4) increased the weight attained

Table 2. Growth performance of broilers fed maize or barley-based diets from 14 to 42 or 56 days of age

	Treatment[1]					SEM	Sex		P*
	(1)	(2)	(3)	(4)	(5)		male	female	
Days 14 to 42									
Weight gain (g)	1 377	1 346	1 412	1 429	1 436	10.4	1 510	1 291	0.0001
Feed intake (g)	2 518	2 598	2 591	2 665	2 618	12.9	2 724	2 467	0.0001
Feed conversion	1.83	1.93	1.84	1.87	1.82	0.012	1.80	1.91	0.0058
Days 14 to 56									
Weight gain (g)	2 277^{ab}	2 185^{b}	2 252^{ab}	2 325^{a}	2 372^{a}	42.5	2 436	2 128	0.0001
Feed intake (g)	5 094	4 980	5 052	5 086	5 183	71.4	5 333	4 825	0.0001
Feed conversion	2.25	2.29	2.25	2.19	2.19	0.040	2.19	2.27	0.0291

[1](1) = maize, (2) = hulled barley, (3) = hulled barley treated with rumen fluid, (4) = hulled barley treated with enzyme, (5) = hulless barley

[ab]means in the row with different superscripts differ significantly ($P < 0.05$)

SEM = standard error of the mean

*probability

by broilers at 8 weeks of age by over 6% ($P < 0.05$). Corresponding improvements in feed conversion efficiency were shown for this treatment. The negative effect of hulled barley inclusion in the diets was not proved in this study. The reason for this aspect is partly related to the inclusion of hulled barley to the diet after 2 weeks of age. During the first 2 weeks of age the gastrointestinal tract, especially the small intestine epithelium, is not completely mature (cellularity and enzymology); for this reason the chicks could not observe any inconvenient material such as non-starch polysaccharides (NSP) in their diets (Petersen et al., 1976; Henning, 1979; McNab and Smithard, 1992). The processed barley in treatment (3) provided the same results of weight gain, feed intake and feed conversion as barley treated with the commercial enzyme. The improvement in the nutritive value of processed barley is partly connected with the rumen microbial action and partly with soaking it in the fluid. Gohl (1977) presented evidence to indicate that the stimulation of endogenous β-glucanase and its subsequent action on β-glucan, as takes place during malting (Bamforth, 1982), was one of the factors contributing to the increase in the nutritive value of barley as a result of water treatment. Beneficial alterations to the structure of starch (Potter et al., 1965) were also proposed as contributory factors.

In this study hulless barley brought interesting results compared to the other treatments, but the β-glucan content in this treatment (5) was higher than in other diets (data is not shown). The result of this study suggested that the β-glucan was not a unique factor for negative effects of barley. The combination of β-glucan along with insoluble fibre (hull) may act as a synergic status producing negative effects. Newman et al. (1985) reported the alkaline viscosity of unpearled barley to be 2.27 cp, and of pearled 1.99 cp. By removing one of the factors such as β-glucan (adding the enzyme (3) or (4)) or insoluble fibre (hulless barley) better performance is to be expected. This result is in contrast with Scott et al. (1998), who reported that the hulless barley cultivars significantly reduced excreta dry matter (DM), feed intake, 17-day body weight (BW), and increased the feed to gain ratio. They stated that the enzyme had a greater effect on the hulless variety. In agreement with the results of the present study Classen et al. (2000) reported that hulless barley had higher apparent metabolizable energy (AME) and protein content than hulled barley because of the diluting effect of the fibrous hull. They also mentioned that within hulless barley cultivars, the low fibre content was suggested to further enhance the nutritive value for broiler chickens.

The feed conversion of female broilers will usually be higher (less efficient) than in male birds of corresponding weight, after about 30 days of age. The reason for this finding is that female birds tend to deposit proportionally more fat in the carcass (Ryley et al., 1970).

Feed digestibility and metabolizable energy. Table 3 shows excreta and digestibility data in this experiment. Chicks on the maize diet (1) produced the lowest amount of moisture in excreta ($P < 0.05$). The enzyme treated barley (4) and hulless barley (5) produced similar percentages of excreta moisture and the excreta were slightly drier compared to untreated (2) and processed barley (3) ($P > 0.05$). This finding could be partly explained by the capacity of nonstarch polysaccharides to bind water (Langhout and Schutte, 1996). The increase in digesta water is thus the primary mechanism by which water-soluble nonstarch polysaccharides exert antinutritive properties (Bedford and Classen, 1993). Cellulose, hemicellulose, pectin, lignin, and digestion resistant starch have modifying effects on digesta water in the non-ruminant intestinal tract (Craig et al., 1998). Inclusive of these fibre fractions are soluble and insoluble β-glucans, which are found in higher percentages in barley diet compared to maize-based diet.

Except the fat, other nutrient digestibility shows the lowest values for untreated barley compared to other treatments ($P < 0.05$) and fat digestibility in maize-based diet (1) shows a significantly higher value in comparison with other treatments ($P < 0.05$). Various authors have suggested that the low lipid digestibility in broiler chickens fed diets with a high content of NSPs may be due to bacterial overgrowth in the small intestine and subsequent excessive deconjugation of bile acids, which reduces their efficacy in solubilizing lipids (Huhtanen and Pensack, 1965; Salih et al., 1991). The adjusted crude protein digestibility shows the highest value for hulless barley (5) and the lowest value for untreated barley (2) ($P < 0.05$). Volatile fatty acids and polyamines produced by gut bacteria have stimulatory effects on the proliferation rate and secretory activity of intestinal mucosa (Sakata, 1987; Osborne and Seidel, 1989; Furuse et al., 1991). Before correcting for the concentration of uric acid in the excreta of barley treatments (2, 3, 4, 5) no significant

Table 3. Mean values of excreta moisture and digestibility coefficients of diets (in %)

	Treatments					SEM
	(1)	(2)	(3)	(4)	(5)	
Excreta moisture	53.85^{b}	75.30^{a}	75.85^{a}	72.59^{a}	71.82^{a}	0.356
Digestibility coefficients						
Dry matter	70.53^{a}	66.13^{b}	72.23^{a}	71.27^{a}	73.13^{a}	0.011
Protein[2]	42.81^{ab}	38.46^{b}	53.16^{a}	46.45^{ab}	53.83^{a}	0.034
Corrected protein[3]	75.24^{bc}	74.75^{c}	79.60^{ab}	75.75^{bc}	81.73^{a}	0.013
Ether extract	91.33^{a}	88.73^{b}	88.13^{b}	87.63^{b}	88.57^{b}	0.006
Nitrogen free extract	77.77^{bc}	75.73^{c}	82.17^{a}	79.83^{ab}	80.67^{a}	0.008

[1](1) = maize, (2) = hulled barley, (3) = hulled barley treated with rumen fluid, (4) = hulled barley treated with enzyme, (5) = hulless barley

[ab]means in the row with different superscripts differ significantly ($P < 0.05$)

SEM = standard error of the mean

[2](nitrogen × 6.25)

[3]faecal nitrogen in the excreta was corrected as total nitrogen minus nitrogen in uric acid

difference was observed between these treatments and maize-based diet (1), but after correction for the uric acid concentration a significant difference was observed ($P < 0.05$). The reason for this result is partly explained by the excretion of nitrogen through uric acid. In this regard, decreasing uric acid by enzyme supplementation could be related to better availability and digestibility of protein and therefore it could eliminate the excretion of nitrogen as the main material of uric acid production. Consequently, a reduction in uric acid excretion may decrease the environmental contamination. In future this could lead to the lower rate of crude protein in broiler rations treated with enzyme supplementation. On the other hand, in barley-fed birds, with an increase in microbial fermentation there would be a higher loss of nitrogen, leading to a reduction in apparent nitrogen digestibility, as was seen. This result agrees with the finding of Smits et al. (1997), who demonstrated a significant reduction in apparent nitrogen digestibility after feeding higher NSP to the birds. Angkanaporn et al. (1994) demonstrated that water-soluble pentosans in the diet significantly raised the endogenous losses in broiler birds.

The apparent metabolizable energy values are presented as means in Table 4. Rumen fluid (3) and enzyme (4) treatment of barley increased the energy value from 10 054 to 11 481 and 10 837 KJ/kg, respectively. The AME value for hulless barley (5) is 1 063 KJ more than for hulled barley. It is important to note that the improvement in AME of barley-based diets following the rumen fluid or enzyme treatment is due to the improvement in nutrient (protein, fat, etc.) digestibility and not due to the availability of NSP themselves to act as an energy

Table 4. Apparent metabolizable energy ME (KJ/kg) of maize, treated or untreated barley and total diets

	Treatments					SEM
	(1)	(2)	(3)	(4)	(5)	
Total diet	12 092	11 749	12 247	12 021	12 046	342.6
Particular cereals[1]	14 008^{a}	10 054^{b}	11 481^{b}	10 837^{b}	11 117^{b}	798.7

[ab]means within a row lacking a common superscript differ ($P < 0.05$)

[1](1) = maize, (2) = hulled barley, (3) = hulled barley treated with rumen fluid, (4) = hulled barley treated with enzyme, (5) = hulless barley

SEM = standard error of the mean

Table 5. Some blood serum metabolites of chickens fed maize or barley-based diets (in mg/dl)

	Treatments[1]					SME	Sex		P^*
	(1)	(2)	(3)	(4)	(5)		male	female	
Total cholesterol	93.41[a]	79.53[b]	86.07[ab]	97.70[a]	85.14[ab]	4.36	89.85	86.26	0.3109
Triacylglycerols	56.57	54.07	55.90	54.90	53.63	8.15	48.96	61.07	0.1026
Glucose	242.6	270.1	274.6	255.5	286.5	14.4	265.3	266.5	0.9285

[1](1) = maize, (2) = hulled barley, (3) = hulled barley treated with rumen fluid, (4) = hulled barley treated with enzyme, (5) = hulless barley

[ab]means in the row with different superscripts differ significantly ($P < 0.05$)

SEM = standard error of the mean

[*]probability

source for the chicken. This result agrees with the finding of other researchers (Danicke et al., 1995; Schutte et al., 1995), who demonstrated the same result when they used wheat-based diets.

Blood serum metabolites. The data related to serum metabolites are shown in Table 5. The consumption of hulled barley-based diet significantly decreased ($P < 0.05$) total cholesterol by 15%. There were no significant differences between treatments in serum triacylglycerols and glucose. No differences between the sexes in serum total cholesterol or glucose concentration were found ($P > 0.05$). However, compared to females, male chicks showed a markedly decreased ($P = 0.1026$) concentration of serum triacylglycerols by 20%. The cholesterol-lowering activity of barley is believed to be attributable to β-glucan in the soluble fibre fraction of this cereal grain (Delaney et al., 2003). In hulled barley-fed birds the efficiency of bile acid in the digesta might be lowered, which could explain not only the low lipid digestibility (Table 3) but also the low serum cholesterol concentration as secondary features. This result agrees with the finding of other researchers who reported an increase in NSP in the intestinal content, reduced cholesterol absorption and plasma cholesterol concentration in broiler chickens (Smits et al., 1997) and hamsters (Gallaher et al., 1993; Carr et al., 1996). The experimental findings of lower serum triacylglycerol levels in male birds in comparison with female

Table 6. Effect of different treatments on the yield of parts as percentages of broiler carcass weight (in %)

	Treatments[1]					SEM	Sex		P^*
	(1)	(2)	(3)	(4)	(5)		male	female	
Fresh carcass[2]	70.27	71.40	70.02	70.84	70.04	1.654	70.54	70.49	0.9701
Thigh	30.00	28.90	29.45	28.89	29.83	0.385	29.84	28.99	0.0171
Breast	32.69[b]	34.62[a]	32.74[b]	34.24[ab]	32.75[b]	0.530	32.61	34.21	0.0014
Wings	12.16	12.17	12.19	11.97	12.58	0.247	12.25	12.18	0.7581
Neck	7.55	7.22	7.20	7.48	7.23	0.245	7.40	7.28	0.5857
Abdominal fat	2.35	1.83	2.15	2.44	1.61	0.226	1.99	2.17	0.3799
Gizzard	2.14	2.25	2.32	2.31	2.29	0.128	2.20	2.32	0.3172
Liver	3.14	3.22	3.07	3.01	3.22	0.119	3.08	3.18	0.3362

[1](1) = maize, (2) = hulled barley, (3) = hulled barley treated with rumen fluid, (4) = hulled barley treated with enzyme, (5) = hulless barley

[ab]means in the row with different superscripts differ significantly ($P < 0.05$)

[2]carcass yields as percentages of live weight

SEM = standard error of the mean

*probability

Table 7. Effect of different treatments on meat (*musculus pectoralis major, m. pectoralis minor, m. sartorius*) composition

	Treatments[1]					SEM	Sex		*P**
	(1)	(2)	(3)	(4)	(5)		male	female	
Moisture	74.96^{ab}	74.73^{ab}	73.33^{bc}	72.50^{c}	75.51^{a}	0.562	74.09	74.32	0.6563
Protein	20.91^{ab}	21.80^{a}	19.50^{b}	20.25^{ab}	19.68^{b}	0.564	20.80	20.06	0.1639
Fat	2.68 ^{b}	1.97^{b}	5.33^{a}	5.71^{a}	3.18^{ab}	0.798	3.39	4.16	0.2986
Glycogen	0.09^{b}	0.09^{b}	0.14^{a}	0.15^{a}	0.09^{b}	0.015	0.11	0.11	0.8896
Ash	1.37	1.41	1.70	1.39	1.54	0.144	1.61	1.35	0.0625

[1](1) = maize, (2) = hulled barley, (3) = hulled barley treated with rumen fluid, (4) = hulled barley treated with enzyme, (5) = hulless barley

^{ab}means in the row with different superscripts differ significantly ($P < 0.05$)

SEM = standard error of the mean

*probability

chickens are in agreement with Qureshi et al. (1983) and Konjufca et al. (1997).

Carcass characteristics. The mean percentage of carcass parts in different treatments is documented in Table 6. Except for breast parts and abdominal fat, no significant effects of treatments on carcass parts could be found. A higher percentage of breast parts in hulled barley based-fed birds may refer to lower deposition of fat or higher protein in this part. Higher protein is associated with higher water, which altogether increased the breast weight. A similar result was found for carcass yield, which was numerically higher in hulled barley based-fed birds. The results of the current study demonstrated that the NSP concentration from barley reduced abdominal fat. This result agrees with the finding of Esteve-Garcia et al. (1997), who reported that broiler diets based on barley reduced abdominal fat to 2.5% of carcass weight. Deposits of fat in the abdominal region of the broiler are considered a waste by the poultry industry. Abdominal fat is not only a loss, but also it represents an added expense for the processing effluent treatment. In further processing, it appears that the larger the quantity of abdominal fat, the lower the processing yields (Yusrizal and Chen, 2003). The effects of the birds' sex on the yield of parts are shown in Table 6. Females yielded a higher proportion of breasts ($P = 0.0014$), but a smaller proportion of thigh than males ($P = 0.0171$). This result completely agrees with Young et al. (2001), who reported the same results.

Data on the chemical composition of meat samples (*musculus pectoralis major*, *m. pectoralis minor*, and *m. sartorius*) are presented in Table 7. As the results show, higher protein and lower fat percentage in meat samples are accompanied by higher moisture content. This relationship was discussed in greater detail by Velu et al. (1972), Sibbald and Wolynetz (1986), and Wolynetz and Sibbald (1990). If the protein intake does not limit the potential of the animals to respond to changes in energy intake, the general rule is the greater the energy intake, the fatter the carcass at any weight (Griffiths et al., 1977). Glycogen content in meat samples is significantly ($P < 0.05$) highest in treated barley diets (3 and 4) and lowest and same in other treatments. Post mortem, glycogen is converted anaerobically to lactic acid, which causes a decline in pH. This decline can occur only if sufficient glycogen is available (Wal et al., 1999). It is an unfavourable indication if the pH value does not fall to 6.1 or below (Gracey, 1981).

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