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Apparent Ileal Amino Acids Digestibility of Four Varieties of Barley for Two Strains of Chickens

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Abstract: The main objective of this study was to assess the nutritional value of four varieties of barley (Beecher, Jimah 54, Jimah 51 and Jimah 58) using commercial broiler and local poultry strains. Four experimental diets were formulated, representing four different varieties of barley and were evaluated using six replicates of eight birds per cage at 21 day of age. Cages were located in an environmentally controlled room maintained under conditions suitable for birds at this age with a photo-period of 23 h in every 24 h. Diets and water were offered on ad libitum basis. On the fourth day after the adaptation to the experimental diets, feed troughs were removed from every cage for 1 h and then reintroduced for 2 h. Then the birds were killed to allow for sampling of ileal digesta, from Meckel's diverticulum to the ileal-caecal-colonic injunction. Broiler birds showed significantly ($p<0.001$) higher digestibility coefficients and digestible content of amino acids across all the barley varieties than the local birds. Out of the four barley varieties evaluated in this study, Beecher variety had the lowest amino acids digestibility coefficient and digestible content for the two bird breeds ($p<0.001$). The digestibility coefficient and digestible content of amino acids estimates for Jimah 54 was the highest across the two strains ($p<0.001$). The variability in digestibility and digestible content in barley varieties can be attributed to the high fiber levels and the presence of beta-glucan. The results suggest that the class of chickens and variety significantly influenced the apparent ileal digestibility and digestible contents of amino acids in the nutrient assessed in this study.

Key words: Ileal digestibility, amino acids, barley, starin, variety, broiler

INTRODUCTION

The future development of the poultry industry in many regions of the world depends to a large extent on the availability of feedstuffs that are suitable or can be made suitable for use in poultry feeds. Barley is one of the most extensively cultivated cereal grains in the world due to its compatible nutritional value, adaptability, controllable grain availability and market price (Farrell, 2005). Barley grain is a medium protein ingredient, which falls between oats and wheat in most characteristics and many varieties of barley are higher in protein and amino acid than in corn (National Research Council, 1994).

Barley is cultivated for human and animal consumption and new varieties of barley, adapted to local cultivation practices and environmental conditions, are constantly selected (Al-Lawati and Nadaf, 2001). There is a general lack of information on the digestible nutrient contents of new varieties. Published data on the ileal digestibility of amino acids for these varieties are scanty. The digestible nutrient content of those barley varieties is critical for selection. Amino acids and their availability must be taken into consideration, as they are extremely important for determining their inclusion rate in poultry diets.

Many published studies are available on the amino acid digestibility of feed ingredient for poultry (Raharjo and Farrell, 1984; Green *et al*., 1987; Green and Kiener, 1989; Parsons, 1991; Angkanaporn *et al*., 1996; Parsons *et al*., 1997; Ravindran *et al*., 1999, 2005; Kadim *et al*., 2002; Huang *et al*., 2005), but the data are variable probably due to differences in methodology used including the class of bird, site of measurement (excreta or ileal) and correction for endogenous losses (true or apparent).

Formulation of poultry diet depends on matching nutrient requirements with composition of dietary ingredients with emphasis on attention to nutrient availability. All diet components are important in formulation of poultry diets but significant attention should be made to the dietary amino acids because the control of protein status and digestible amino acids have been shown to increase weight gain, feed intake and improve body composition in broilers (Fernandez *et al*., 1995; Rostagno *et al*.,1995;

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Taherkhani *et al*., 2008). It has been suggested that analysis of ileal contents rather than excreta may be a reliable method for assessing amino acid digestibility in poultry diets (Ravindran *et al*., 1999). The objective of the current study was to assess the ileal amino acid digestibility coefficients of four varieties of barley using commercial broiler and local chickens.

MATERIALS AND METHODS

Barley varieties: The four varieties of barley; Beecher, Jimah 54, Jimah 51 and Jimah 58 used in the current study were developed at the research stations Jimah and Wadi Quriyat in Oman. The varieties developments have been previously described by Al-Lawati and Nadaf (2001).

Birds and housing: One hundred and twenty newly hatched chicks from each strain of Cobb 500-type broiler chickens and local chickens were housed in suspended grower cages. The cages were located in an environmentally controlled metabolism room maintained at 35°C on day 1 and reduced by 1°C per day until 22°C. Birds had free access to water and feed; lighting was maintained at a photo-period of 23 h in every 24 h. Birds were initially allocated to replicate cages was from 13 day, with live weights of birds in replicates differed by less than 10 g. Birds were fed a commercial broiler diet from day one to day 18. The birds were 19 day old at the commencement of the ileal digestibility assay.

Experimental diets and procedures: The four test ingredients, representing the four varieties of barely were ground using a laboratory hammer mill fitted with a 3 mm screen and then incorporated into semi-synthetic diets at one rate of inclusion (0.50 as proportion) as the only component containing protein/amino acids (Table 1). Other raw materials were added sequentially while the mixer was at a slow speed (to ensure effective homogensiation of all ingredients). These included the indigestible marker titanium dioxide, a vitamin/mineral premix, vegetable oil and 50:50 mixture of purified maize starch and glucose (in amounts to make diets up to 1000 g/kg). Each of the four experimental diets was evaluated with six replicates with a cage containing 5 birds (Cobb 500-type broilers) each. Experimental diets were fed *ad libitum* for four days from 19 to day 23 of age.

Table 1: Composition of experimental diets

Raw material (g/kg)	Jimah-54	Beecher	Jimah-58	Jimah-51
Barley variety	500	500	500	500
Vegetable oil	50	50	50	50
Vitamin and mineral premix*	50	50	50	50
Titanium dioxide	5	5	5	5
Starch:glucose (50:50)	395	395	395	395
Total	1000	1000	1000	1000

*Designed to meet the requirements of the young broiler chicken

On day 23, birds were starved for one hour then fed for two hours to ensure sufficient gut fill for digesta sample collection. Birds were then killed by an intra-cardial injection of sodium pentobarbitone. Following dissection of the lower small intestine, digesta sample was gently flushed with distilled water and collected into a collection vessel. Samples from birds in a cage were pooled in order to provide enough samples for chemical analysis following the procedure described by Al-Marzooqi and Wiseman (2009).

Calculations: The titanium and amino acid data were used to calculate the coefficient of apparent amino acid digestibility using the following equation as described by Al-Marzooqi and Wiseman (2009):

$$1 - (aa_{dig} * marker_{diet})/(aa_{diet} * marker_{dig})$$

Where:

aa_{dig} = Amino acid concentration in digesta;
$marker_{diet}$ = Titanium concentration in the diet;
aa_{diet} = Amino acid concentration in the diet and
$marker_{dig}$ = Titanium concentration in the digesta.

From the coefficients and the amino acid contents of the diet, the concentration of ileal apparently digestible amino acid/kg was calculated.

Chemical analysis: Samples of test ingredients and ileal digesta samples used for laboratory analysis were ground to pass through a 1 mm mesh in a micro-Wiley mill. Samples of ileal contents were freeze dried prior to grinding. Duplicate determinations of dry matter, crude protein, ether extract, crude fiber, ash and gross energy content were made on test ingredients according to AOAC (2000). Amino acid contents of duplicate of test ingredients and ileal digesta samples were carried out at Massey University Analytical Laboratory in New Zealand. Amino acids contents were determined, by using a Waters ion-exchange HPLC system, utilizing post-column ninhydrin derivatisation and fluorescence detection, following hydrolysis in 6M glass-distilled hydrochloric acid containing 0.1% phenol for 24 h at 110 + 2°C in evacuated sealed tubes. Lysozyme was used as external standard for the amino acid analysis. Beta-glucans was determined using a beta-glucan kit (cat No. 1120, Megazyme International Irland Ltd., Bray, Ireland) according to McCleary and Codd (1991). Titanium (the inert internal marker) was analyzed using a modified version of the AOAC method (Short *et al*., 1999). Chemical analyses were performed in duplicate and repeated if individual data differed by <5%.

Statistical analysis: Data were analyzed by general analysis of variance using the general linear model procedure using SAS, 2001 (SAS Institute Inc., Version 2 and 6, 2001). The experimental design was a 2 x 4 factorial with 2 breeds (Cobb 500 and local chicken) and

4 barley varieties (Beecher, Jimah 54, Jimah 51 and Jimah 58). The main parameters tested in the analysis of variance were digestibility coefficients and digestible content of amino acids. Significant differences between treatment means were assessed using the least-significant-difference procedure. Interactions between the treatments were tested using Tukey's multiple comparisons test when significant and excluded from the model when not significant ($p>0.05$).

RESULTS AND DISCUSSION

The chemical composition, amino acids and beta-glucan contents for the barely varieties are shown in Table 2. Gross energy and fat contents of the four barley varieties were similar. Beecher variety had higher fiber content (37%) and lower protein (23.5%) than Jimah 54. The variations in amino acid concentrations of barley varieties evaluated in this study were related largely to the protein level in the grain. In these grains, the amino acid concentrations generally increased with increasing protein levels. The Jimah 54 variety had higher amino acid concentrations in contrast to other barley varieties (Table 2). The mean apparent ileal digestibility and digestible contents of amino acids in Jimah 54 variety were higher for broilers chicks ($p<0.001$) than that for local strains (Table 3 and 4; respectively).

Table 2: Chemical composition, amino acids and beta-glucan contents in different varieties of barley

	Barley variety			
	Jimah-54	Beecher	Jimah-58	Jimah-51
Dry matter (g/kg DM)	914.6	934.7	932.1	933.2
Crude protein (g/kg DM)	146.7	112.1	144.7	126.5
Crude fiber (g/kg DM)	57	91.1	61.6	63
Ether extract (g/kg DM)	19.3	18.5	17.8	17.9
Ash (g/kg DM)	28.8	33.9	28.7	31.9
Gross energy (MJ/g DM)	15.85	15.72	15.9	15.27
Essential amino acids (g/kg DM)				
Threonine	4.12	3.43	3.81	3.52
Valine	6.71	5.41	5.91	5.63
Methionine	1.98	1.63	1.85	1.57
Isoleucine	4.58	3.47	4.05	3.67
Leucine	8.74	6.84	7.87	7.24
Phenylalanine	6.44	4.78	5.96	5.24
Histidine	3.36	2.68	2.83	2.62
Lysine	4.56	3.92	4.09	3.8
Arginine	5.91	4.96	5.49	4.71
Non-essential amino acids (g/kg DM)				
Aspartic acid	8.86	7.31	8.45	7.73
Tyrosine	3.52	2.95	3.48	2.96
Serine	4.78	3.82	4.39	4.07
Glutamic acid	32.47	23.67	29.73	26.41
Proline	14.07	9.90	12.74	11.31
Glycine	5.21	4.32	4.71	4.37
Alanine	5.44	4.52	4.74	4.61
Total	120.75	93.61	110.1	99.46
Anti Nutritional factor (g/kg DM)				
Beta-Glucan	37.02	39.02	38.43	38.61

For broiler birds; the overall mean amino acid digestibility coefficients (and ranges across barley variety) were: Jimah-54 0.77 (0.60-0.93); Beecher 0.66 (0.45-0.88); Jimah-58 0.73 (0.57-0.92) and Jimah-51 0.71 (0.52-0.94); whereas for local birds; the overall amino acid digestibility coefficients (and range across barley variety) were: Jimah-54 0.67 (0.49-0.83); Beecher 0.50 (0.31-0.71); Jimah-58 0.66 (0.47-0.83) and Jimah-51 0.56 (0.31-0.94).

The overall mean amino acids digestible content g/kg DM (and ranges across barley variety) for broiler birds were: Jimah-54 2.967 (0.90-14.01); Beecher 2.073 (0.73-9.46); Jimah-58 2.329 (0.69-11.57) and Jimah-51 2.271 (0.79-10.96); whereas for local birds the overall mean amino acids digestible content g/kg DM (and ranges across barley variety) were: Jimah-54 2.669 (0.72-13.39); Beecher 1.566 (0.51-8.13); Jimah-58 2.130 (0.73-10.66) and Jimah-51 2.023 (0.57-10.93).

In this study, the amino acid contents of different barley varieties are nearly similar with NRC (1994); Kadim *et al.* (2002) and Saki *et al.* (2009). In the four barley samples evaluated, Beecher variety had the lowest digestibility coefficient and digestible content in comparisons to the other barley varieties across the two breeds (Table 3 and 4; respectively). The variability in digestibility and digestible content in barley varieties can be attributed to the high fiber levels (Table 2). Similar results were suggested by Sauer *et al.* (1981) who reported that the lower amino acid digestibility in barley was due to its thicker aleurone layer, which is rich in amino acid content, but due to its higher fiber, content may not be digested well. Also, The beta-glucan contents of the barely varieties determined in this study (range from 37-39 g/kg DM; Table 2) were in similar range of thirty barley samples studied by Gandon (1995) who reported wide variation of total beta-glucan (30.9-55.5 g/kg DM). Young birds are less able to digest barley and the use of barley is limited by the presence of beta-glucan, which may vary with cultivar and growing condition (Campbell *et al.*, 1989). Beta-glucans influence barley nutritional value by increasing gut viscosity of poultry and thus reducing the availability of nutrients for digestion and absorption (Almirall *et al.*,1995). White *et al.* (1981) reported that when barley beta-glucan was added to the diet at only 10 g/kg, the viscosity of the intestinal contents increased threefold in chickens.

However, strains had significant effect on digestibility coefficients and digestible content ($p<0.001$; Table 3 and 4; respectively). Broiler birds showed significantly higher digestibility coefficients and digestible content for all the amino acids across all the barley varieties than the local birds. The reasons for improved digestion in broilers are unclear. Influences of genotype for broilers on digestion have been reported (Sørensen *et al.*, 1983; Leenstra and Pit, 1988; Jørgensen *et al.*, 1990). Other possible explanation may be that the modern fast-growing

Table 3: Apparent ileal digestibility coefficients of four varieties of barley for commercial broiler and local chickens

	Breed											
	Broiler				Local							
	Barley variety				Barley variety							
Amino acid	J-54	Beecher	J-58	J-51	J-54	Beecher	J-58	J-51	SEM	Breed	Variety	B*V
Essential amino acids												
Threonine	0.60^{a}	0.45^{ab}	0.57^{a}	0.52^{ab}	0.49^{ab}	0.31^{b}	0.47^{ab}	0.31^{b}	0.048	**	**	NS
Valine	0.79^{a}	0.65^{ab}	0.73^{a}	0.71^{a}	0.67^{ab}	0.52^{b}	0.66^{ab}	0.51^{b}	0.033	***	**	NS
Methionine	0.93^{a}	0.88^{a}	0.92^{a}	0.94^{a}	0.97^{a}	0.62^{c}	0.74^{b}	0.94^{a}	0.023	***	***	***
Isoleucine	0.77^{a}	0.66^{abc}	0.72^{a}	0.70^{a}	0.68^{ab}	0.51^{c}	0.65^{abc}	0.54^{bc}	0.031	***	**	NS
Leucine	0.81^{a}	0.72^{ab}	0.77^{a}	0.75^{a}	0.71^{ab}	0.56^{c}	0.70^{ab}	0.60^{bc}	0.028	***	**	NS
Phenylalanine	0.80^{a}	0.68^{ab}	0.77^{a}	0.74^{ab}	0.74^{a}	0.59^{b}	0.73^{ab}	0.65^{ab}	0.032	**	**	NS
Histidine	0.78^{a}	0.63^{ab}	0.73^{a}	0.69^{ab}	0.66^{ab}	0.43^{c}	0.64^{ab}	0.52^{bc}	0.039	***	**	NS
Lysine	0.80^{a}	0.69^{ab}	0.75^{ab}	0.76^{ab}	0.66^{bc}	0.51^{d}	0.66^{bc}	0.54^{cd}	0.026	***	***	*
Arginine	0.80^{a}	0.67^{ab}	0.72^{ab}	0.70^{ab}	0.68^{ab}	0.48^{c}	0.67^{ab}	0.55^{bc}	0.034	***	**	NS
Non-Essential amino acids												
Aspartic acid	0.71^{a}	0.59^{abc}	0.67^{a}	0.64^{ab}	0.58^{abc}	0.40^{c}	0.58^{abc}	0.46^{bc}	0.039	***	**	NS
Serine	0.67^{a}	0.55^{ab}	0.64^{a}	0.60^{ab}	0.58^{ab}	0.35^{c}	0.57^{ab}	0.43^{bc}	0.036	***	**	NS
Glutamic acid	0.88^{a}	0.81^{abc}	0.86^{ab}	0.83^{ab}	0.83^{ab}	0.71^{c}	0.83^{ab}	0.76^{bc}	0.021	**	**	NS
Proline	0.85^{a}	0.77^{abc}	0.83^{ab}	0.80^{ab}	0.82^{ab}	0.68^{c}	0.81^{ab}	0.73^{bc}	0.022	**	***	NS
Glycine	0.68^{a}	0.53^{ab}	0.62^{a}	0.60^{a}	0.54^{ab}	0.35^{b}	0.53^{ab}	0.37^{b}	0.043	***	**	NS
Alanine	0.76^{a}	0.62^{ab}	0.70^{a}	0.68^{a}	0.62^{ab}	0.45^{bc}	0.61^{abc}	0.44^{c}	0.037	***	**	NS
Tyrosine	0.73^{a}	0.63^{abc}	0.71^{ab}	0.69^{ab}	0.65^{abc}	0.52^{c}	0.65^{abc}	0.57^{bc}	0.029	***	**	NS
AVG	0.77	0.66	0.73	0.71	0.67	0.50	0.66	0.56				

AVG = Average digestibility of all amino acids. J = Jimah. * = p<0.05; ** = p<0.001; *** = p<0.0001; NS = Not Significant.
$^{a-d}$Within each analysis, means not sharing a common superscript are significantly different (p<0.05). B*V= Breed*Variety

Table 4: Apparent ileal digestible content of amino acids of four barely for commercial broiler and local chickens

	Breed											
	Broiler				Local							
	Barley variety				Barley variety							
Amino acid	J-54	Beecher	J-58	J-51	J-54	Beecher	J-58	J-51	SEM	Breed	Variety	B*V
Essential amino acids												
Threonine	1.22^{a}	0.85^{abcd}	0.96^{abc}	0.83^{abcd}	1.01^{ab}	0.51^{d}	0.80^{bcd}	0.57^{cd}	0.080	***	***	NS
Valine	2.57^{a}	1.84^{bcd}	1.97^{bc}	1.85^{bcd}	2.23^{ab}	1.36^{e}	1.80^{cd}	1.47^{de}	0.090	***	***	NS
Methionine	0.90^{a}	0.73^{c}	0.69^{c}	0.79^{bc}	0.72^{c}	0.49^{d}	0.73^{c}	0.84^{ab}	0.020	***	***	***
Isoleucine	1.74^{a}	1.17^{c}	1.28^{bc}	1.28^{bc}	1.53^{ab}	0.86^{d}	1.16^{c}	1.05^{cd}	0.050	***	***	NS
Leucine	3.49^{a}	2.48^{c}	2.70^{bc}	2.71^{bc}	3.08^{ab}	1.85^{d}	2.46^{c}	2.28^{cd}	0.100	***	***	NS
Phenylalanine	2.54^{a}	1.71^{bc}	1.96^{b}	1.96^{b}	2.37^{a}	1.36^{c}	1.85^{b}	1.86b	0.080	***	***	NS
Histidine	1.29^{a}	0.90^{bc}	0.92^{bc}	0.86^{bc}	1.09^{ab}	0.56^{d}	0.82^{c}	0.71^{cd}	0.050	***	***	NS
Lysine	1.79^{a}	1.43^{bc}	1.37^{bc}	1.37^{bc}	1.49^{b}	0.97^{e}	1.22^{cd}	1.07^{de}	0.050	***	***	*
Arginine	2.32^{a}	1.67^{bc}	1.64^{bc}	1.78^{bc}	1.98^{ab}	1.16^{d}	1.53^{cd}	1.47^{cd}	0.080	***	***	NS
Non-essential amino acids												
Aspartic acid	3.11^{a}	2.27^{b}	2.50^{ab}	2.39^{b}	2.53^{ab}	1.42^{c}	2.16^{b}	1.87^{bc}	0.140	***	***	NS
Serine	1.58^{a}	1.11^{bc}	1.26^{abc}	1.17^{bc}	1.37^{ab}	0.66^{d}	1.13^{bc}	0.92^{cd}	0.070	***	***	NS
Glutamic acid	14.01^{a}	9.46^{c}	11.57^{b}	10.96^{b}	13.39^{a}	8.13^{d}	10.66^{bc}	10.93^{b}	0.250	***	***	NS
Proline	5.88^{a}	3.83^{c}	4.55^{b}	4.71^{b}	5.71^{a}	3.26^{d}	4.33^{b}	4.51^{b}	0.110	**	***	NS
Glycine	1.73^{a}	1.25^{bc}	1.31^{ab}	1.20^{bc}	1.40^{ab}	0.73^{d}	1.13^{bcd}	0.85^{cd}	0.090	***	***	NS
Alanine	2.03^{a}	1.49^{b}	1.56^{b}	1.42^{b}	1.68^{ab}	0.98^{c}	1.36^{bc}	1.01^{bc}	0.080	***	***	NS
Tyrosine	1.27^{a}	0.98^{b}	1.02^{b}	1.05^{ab}	1.13^{ab}	0.75^{c}	0.94^{bc}	0.96	0.050	***	***	NS
AVG	2.967	2.073	2.329	2.271	2.669	1.566	2.130	2.023				

AVG = Average digestibility of all amino acids. J = Jimah. * = p<0.05; ** = p<0.001; *** = p<0.0001; NS = Not Significant.
$^{a-e}$ Within each analysis, means not sharing a common superscript are significantly different (p<0.05). B*V = Breed*Variety

broilers have more nutrient transport capacity and greater intestinal mass than other poultry strains (Mitchell and Simth, 1991; Nir *et al*., 1993; Uni *et al*., 1995; Jackson and Diamond, 1996). Mitchell and Smith (1991) reported that the villus surface area, absolute intestinal weight and length and duodenum weight to length ratio were higher in highly selected boilers compared with birds bred by low selection.

Conclusion: Differences in cultivar, growing season, agronomic practices or processing can cause variations in nutrient concentrations of cereals in general. The influence of variety and strains of chicken on digestibility and digestible contents of the nutrient assessed in this study was highly significant. Overall, the present study suggests that the practice of using amino acid digestibility values generated with commercial strains for local chickens may not be appropriate.

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