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Influence of Strain of Chickens on Ileal Amino Acids Digestibility of Different Protein Sources

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Abstract: The main objective of this study was to assess the nutritional value of four protein sources (soyabean meal, fish silage, sardine fish and fishmeal) using commercial broiler and local poultry strains. Four experimental diets were formulated; representing four different proteins sources and was 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 protein sources than the local birds. Out of the four protein sources evaluated in this study, fishmeal had the lowest amino acids digestibility coefficient for the two bird breeds ($p < 0.001$). The digestibility coefficient and digestible content of amino acids estimates for fish silage was the highest across the two strains ($p < 0.001$). The lower digestibility of amino acids for soyabean meal is related to the presence of; antinutritional factor, trypsin inhibitor. Fish silage shows a great potential to be used as protein supplements for poultry feeding. The results suggest that the class of chickens and protein source 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, soyabean meal, fish, silage, strain, broiler

INTRODUCTION

The poultry industry in Oman is being severely hampered by shortages of sources of concentrate feed ingredients due to limited resources of fresh water and arable land (El Hag, 1995). In Oman, the feed industry is sustained only through importation of up to 100% of feed ingredients, which increases the cost of formulated diets. Oman has a long coastal line which enables catching large amounts of fish. Many fish is exported but a large proportion is used for domestic consumption and a large amount is wasted. A way of minimizing the environmental problems generated by the high amount of fish waste is its transformation in a product to be incorporated as ingredient in animal rations (Ristics *et al.*, 2002). Fish by-products are the most important by-products available at reasonable prices in Oman. These fish by-products have the potential to be used as a high protein supplement for farm animal and poultry feeding in Oman. Sardines in Oman are traditionally dried on the beach for several days before being used as animal feed. This type of drying reduces the quality of sardines and makes them prone to insect infestation and sand contamination. Fish silage can be an effective way for

processing fish by-products and using them as a feed ingredient. In regions, where by-catch surplus catches or fish processing wastes are available, fish silage represents a possible alternative to fishmeal as a source of animal protein. Fish meal is well recognized by animal nutritionist as an excellent source of protein. However, commercial fishmeal preparation is a complicated process and is a demanding procedure including sterilization and defatting which increases the cost and may lead to protein denaturing if not carried out properly (Mikulec *et al.*, 2004). Numerous reports have been made about fish silage production and its use in animal feed as useful protein source (Green *et al.*, 1988; Machin *et al.*, 1990; Jackson *et al.*, 1984; Haaland *et al.*, 1990; Espe *et al.*, 1992). However, so far, fish silage is still not known to Oman industry and farmers, despite the scarcity of animal feed ingredients. Soyabean meal by far is a valuable commodity used widely in animal nutrition in general and poultry diets in particular due to its amino acid profile composition. The protein level in soyabean meal can be variable and this may be an indication of seed variety and or/processing conditions involving fat extraction (Veltman *et al.*, 1986).

Soybean contains a number of natural toxins and antinutritional factors, the most challenging being the trypsin inhibitor. As with most types of beans, the trypsin inhibitors will disrupt protein digestion and its presence is characterized by compensatory hypertrophy of the pancreas (McNaughton, 1981).

A major constraint of poultry production in Oman is the high cost of feeds. One way to overcome this problem is by using local ingredients available for feeding chickens. Prior to including these feed ingredients in poultry diets, their nutrition value should be evaluated. There is a general lack of information on the digestible nutrient contents of fish by-products available in Oman. Their digestible nutrient contents is critical. Amino acids and their availability must be taken into consideration, as they are extremely important for determining their inclusion rate in poultry diets. Analysis of ileal contents rather than excreta is a more reliable method for assessing amino acid digestibility in poultry. The ileal collection method has been suggested by several researchers to allow a more accurate determination of protein and amino acid digestibility (Achinewhu and Hewitt, 1979; Al-Marzooqi *et al.*, 2010a; Raharjo and Farrell, 1984; Kadim *et al.*, 2002). It has been shown to be more sensitive in detecting small differences in the digestibility of the nutrients. In addition, such procedures remove the effects of fermentation by the bacteria of the hindgut on undigested residue and the urinary influence on digestibility (Sibbald, 1987). The objective of this experiment was to assess the ileal amino acid digestibility coefficients of four protein sources using commercial broiler and local chickens.

MATERIALS AND METHODS

Sample preparation: Both soyabean meal and fishmeal were purchased from a local supplier. Batches of sardines fish were collected from the fishermen at Seeb landing beach with Indian oil sardines, *Sardinella Longiceps*, as the main species and transported to the university in cool boxes then kept frozen at (-20°C) until the time of usage. Sardine fish was freeze-dried in an Edwards drier to a constant mass for further use.

Silage production: Sardine fish silage was prepared by following the procedure described by Al-Marzooqi *et al.*, 2010a. Sardine fish silage sample was freeze-dried in an Edwards drier to a constant mass for chemical analysis and further use.

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 four protein sources (soyabean meal, fish silage, sardine fish and fishmeal) 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 homogenisation 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. 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):

$$1 - (aa_{\text{dig}} * \text{marker}_{\text{diet}}) / (aa_{\text{diet}} * \text{marker}_{\text{dig}})$$

Where:

aa_{dig} = Amino acid concentration in digesta

$\text{Marker}_{\text{diet}}$ = Titanium concentration in the diet

aa_{diet} = Amino acid concentration in the diet and

$\text{marker}_{\text{dig}}$ = 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

Table 1: Composition of experimental diets

Raw material (g/kg)	Soyabean meal	Fish silage	Sardine fish	Fish meal
Test ingredient	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

to grinding. Analysis was always carried out in duplicate. Duplicate determinations of dry matter, crude protein, ether extract, crude fiber, ash and gross energy content were made on test ingredients samples 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. Trypsin Inhibitor Activity (TIA) was measured according to the method established by Kakade *et al.* (1974). Titanium (the inert internal marker) was analysed using a modified version of the AOAC method (Short *et al.*, 1996).

Statistical analysis: Data were analyzed by general analysis of variance using the general linear model procedure using SAS (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 protein sources (soyabean meal, fish silage, sardine fish and fishmeal). 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

The chemical composition and amino acid content of the soyabean meal, fish silage, sardine fish and fishmeal is summarized in Table 2. In general fish by products had higher crude protein contents than soyabean meal. Fish silage had the highest crude protein contents 33% more than the than soyabean meal. Crude protein was lower by 29% in soyabean meal than in fish silage and fishmeal; respectively. Both fish silage and fishmeal had 80% higher fat content, determined as ether extract, than

for sardine fish and soyabean meal. Gross energy content of the soyabean meal, fish silage, sardine fish and fishmeal were 14.29, 19.99, 15.60 and 15.88 MJ/kg, respectively, which indicates that soyabean meal had 28% less gross energy than the other ingredients, respectively.

Soyabean meal had lower level of sulphur-containing amino acids than fish silage, sardine fish and fishmeal. For the most important essential amino acids for poultry performance; fish silage contained 66.1 % more methionine (16.91 vs. 5.73 g/kg DM); 24.1% more threonine (24.31 vs. 18.45 g/kg DM) and 34 % more lysine (47.3 vs. 31.23 g/kg DM) compared to soyabean meal. Both sardine fish and fishmeal had a similar content of total essential amino acids as fish silage. Fishmeal had the highest content of total non essential amino acids compared to other ingredients.

Mean digestibility coefficients and digestible contents of the individual amino acids of essential and non-essential amino acids determined in the ileum for soyabean meal, fish silage, sardine fish and fishmeal are shown in Table 3 and Table 4, respectively. The overall mean amino acids digestibility coefficients and digestible contents of fish silage were higher for both poultry strains ($p < 0.001$) in comparison to other protein sources (Table 3 and 4; respectively). In contrast, The overall mean amino acids digestibility coefficients and digestible contents of fishmeal were considerably lower than other protein sources across the two stains ($p < 0.001$) (Table 3 and 4; respectively). For the most important essential amino acids for poultry performance, fish silage had 4% more methionine (0.94 vs. 0.90), 10.2% more threonine (0.88 vs. 0.79) and 7.4% more lysine (0.95 vs. 0.88) than soyabean meal; respectively. For broiler birds; the overall mean amino acid digestibility coefficients (and ranges across protein sources) were: soyabean meal 0.85 (0.80 to 0.90); fish silage 0.90 (0.84 to 0.95); sardine fish 0.87 (0.82 to 0.94) and fishmeal 0.74 (0.64 to 0.79); whereas for local birds; the overall amino acid digestibility coefficients (and range across protein sources) were: soyabean meal 0.74 (0.64 to 0.84); fish silage 0.85 (0.79 to 0.90); sardine fish 0.82 (0.74 to 0.91) and fishmeal 0.63 (0.45 to 0.72).

The overall mean amino acids digestible content g/kg DM (and ranges across protein sources) for broiler birds

Table 2: Chemical composition, amino acids in soybean meal, fish silage, sardine fish and fish meal

Chemical composition (g/kg DM)	Soybean meal	Fish silage	Sardine fish	Fish meal
Dry matter	923.20	290.00	916.20	949.50
Crude protein	446.00	667.50	627.30	631.20
Ether extract	21.40	117.00	30.10	109.00
Crude fiber	68.60	-	-	-
Ash	115.70	157.90	282.00	190.10
Gross energy (MJ/g DM)	14.29	19.99	15.60	15.88
Essential amino acids (g/kg DM)				
Threonine	18.45	24.31	23.95	24.43
Valine	23.83	32.51	32.19	32.94
Methionine	5.73	16.91	17.48	13.94
Isoleucine	21.54	25.00	24.35	23.44
Leucine	37.12	40.76	42.12	44.51
Phenylalanine	25.74	23.18	23.11	23.94
Histidine	14.46	22.72	13.42	19.24
Lysine	31.23	47.30	39.88	43.25
Arginine	36.77	36.20	29.80	44.41
Total	214.90	269.00	246.30	270.10
Non-essential amino acids (g/kg DM)				
Aspartic acid	59.24	54.06	48.66	55.44
Tyrosine	17.23	19.66	16.37	18.37
Serine	22.14	20.10	22.12	25.10
Glutamic acid	91.96	79.33	76.05	87.40
Proline	25.33	27.75	26.38	42.49
Glycine	21.19	44.53	40.66	60.26
Alanine	23.12	43.68	39.42	47.21
Total	260.20	289.10	269.70	336.30
Anti nutritional factors (mg/g DM)				
Trypsin inhibitor	7	-	-	-

Table 3: Apparent ileal amino acids digestibility coefficients of four protein sources for commercial broiler and local chickens

Amino acids	Breed								SEM	Breed	Protein	B*P
	Broiler				Local							
	SBM	FS	SF	FM	SBM	FS	SD	FM				
Essential												
Threonine	0.80 ^b	0.88 ^a	0.85 ^{ab}	0.71 ^{cd}	0.64 ^d	0.82 ^{ab}	0.77 ^{bc}	0.58 ^e	0.017	***	***	*
Valine	0.82 ^b	0.92 ^a	0.88 ^{ab}	0.74 ^c	0.70 ^{cd}	0.86 ^{ab}	0.83 ^b	0.64 ^d	0.014	***	***	*
Methionine	0.90 ^a	0.94 ^a	0.94 ^a	0.76 ^{bc}	0.81 ^b	0.90 ^a	0.91 ^a	0.70 ^c	0.014	***	***	NS
Isoleucine	0.84 ^{ab}	0.92 ^a	0.88 ^{ab}	0.73 ^c	0.73 ^c	0.86 ^{ab}	0.83 ^b	0.64 ^d	0.017	***	***	NS
Leucine	0.85 ^b	0.93 ^a	0.88 ^{ab}	0.75 ^c	0.74 ^c	0.87 ^{ab}	0.85 ^b	0.67 ^c	0.017	***	***	NS
Phenylalanine	0.86 ^{ab}	0.92 ^a	0.89 ^{ab}	0.75 ^c	0.77 ^c	0.86 ^{ab}	0.83 ^{bc}	0.67 ^d	0.016	***	***	NS
Histidine	0.86 ^a	0.91 ^a	0.83 ^{ab}	0.74 ^{bc}	0.74 ^c	0.84 ^a	0.84 ^a	0.63 ^d	0.018	***	***	**
Lysine	0.88 ^a	0.95 ^a	0.93 ^a	0.76 ^b	0.79 ^b	0.89 ^a	0.90 ^a	0.67 ^c	0.016	***	***	NS
Arginine	0.90 ^{ab}	0.92 ^a	0.90 ^{ab}	0.79 ^c	0.84 ^{bc}	0.87 ^{ab}	0.88 ^{ab}	0.72 ^d	0.013	***	***	NS
Non-essential												
Aspartic acid	0.84 ^{ab}	0.86 ^a	0.84 ^{ab}	0.64 ^d	0.69 ^{cd}	0.80 ^{abc}	0.74 ^{bcd}	0.45 ^e	0.024	***	***	NS
Serine	0.80 ^{ab}	0.87 ^a	0.82 ^a	0.69 ^c	0.69 ^c	0.79 ^{ab}	0.74 ^{bc}	0.55 ^d	0.016	***	***	**
Glutamic acid	0.88 ^a	0.88 ^a	0.87 ^a	0.73 ^c	0.79 ^{bc}	0.86 ^{ab}	0.78 ^{bc}	0.63 ^d	0.017	***	***	NS
Proline	0.82 ^{ab}	0.84 ^a	0.83 ^{ab}	0.74 ^c	0.72 ^c	0.83 ^{ab}	0.75 ^{bc}	0.59 ^d	0.017	***	***	**
Glycine	0.80 ^{ab}	0.85 ^a	0.88 ^a	0.75 ^b	0.66 ^c	0.84 ^a	0.81 ^{ab}	0.58 ^c	0.180	***	***	**
Alanine	0.85 ^b	0.92 ^a	0.91 ^{ab}	0.77 ^c	0.73 ^{cd}	0.89 ^{ab}	0.88 ^{ab}	0.68 ^d	0.013	***	***	**
Tyrosine	0.85 ^b	0.92 ^a	0.86 ^{ab}	0.74 ^d	0.77 ^{cd}	0.84 ^b	0.84 ^{bc}	0.65 ^e	0.013	***	***	NS
AVG	0.85	0.90	0.87	0.74	0.74	0.85	0.82	0.63				

AVG: Average digestibility of all amino acids. SBM = Soyabean Meal; FS = Fish Silage; SF = Sardine Fish; FM = Fish Meal; SEM = Standard Error of Means. *p<0.05; **p<0.01; ***p<0.001; NS = Not Significant.

^{a-e}Within each analysis, means not sharing a common superscript are significantly different (p<0.05). B*P = Breed*Protein

were: soyabean meal 1.23 (0.252 to 3.926); fish silage 1.54 (0.793 to 3.361); sardine fish 1.37 (0.530 to 3.293) and fishmeal 1.38 (0.521 to 3.151); whereas for local birds the overall mean amino acids digestible content

g/kg DM (and ranges across protein sources) were: soyabean meal 1.08 (0.227 to 3.521); fish silage 1.40 (0.766 to 2.976); sardine fish 1.34 (0.538 to 3.264) and fishmeal 1.17 (0.483 to 2.735).

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

Amino acids	Breed								SEM	Breed	Protein	B*P
	Broiler				Local							
	SBM	FS	SF	FM	SBM	FS	SD	FM				
Essential												
Threonine	0.716 ^d	1.069 ^a	0.968 ^b	0.853 ^c	0.574 ^e	0.933 ^{bc}	0.937 ^{bc}	0.704 ^d	0.019	***	***	*
Valine	0.953 ^d	1.491 ^a	1.355 ^b	1.209 ^c	0.818 ^e	1.351 ^b	1.326 ^b	1.045 ^d	0.021	***	***	*
Methionine	0.252 ^e	0.793 ^a	0.779 ^{ab}	0.521 ^c	0.227 ^e	0.766 ^{ab}	0.748 ^b	0.483 ^d	0.008	***	***	NS
Isoleucine	0.883 ^c	1.148 ^a	1.028 ^b	0.844 ^{cd}	0.768 ^d	1.039 ^b	0.997 ^b	0.737 ^e	0.018	***	***	NS
Leucine	1.532 ^d	1.899 ^a	1.763 ^{ab}	1.654 ^{bc}	1.339 ^e	1.726 ^b	1.754 ^{ab}	1.475 ^{de}	0.034	***	***	NS
Phenylalanine	1.081 ^a	1.061 ^{ab}	0.976 ^{bc}	0.892 ^c	0.965 ^{bc}	0.965 ^{bc}	0.946 ^{bc}	0.792 ^d	0.020	***	***	NS
Histidine	0.603 ^d	1.039 ^a	0.530 ^{de}	0.707 ^c	0.520 ^e	0.952 ^b	0.538 ^{de}	0.598 ^{de}	0.016	***	***	*
Lysine	1.344 ^{cd}	2.252 ^a	1.758 ^b	1.616 ^b	1.207 ^d	2.123 ^a	1.695 ^b	1.431 ^c	0.031	***	***	NS
Arginine	1.613 ^{abc}	1.674 ^{ab}	1.280 ^d	1.730 ^a	1.500 ^c	1.584 ^{bc}	1.237 ^d	1.576 ^{bc}	0.024	***	***	NS
Non-essential												
Aspartic acid	2.429 ^a	2.335 ^a	1.955 ^b	1.759 ^b	2.005 ^b	1.987 ^b	1.861 ^b	1.245 ^c	0.064	***	***	*
Serine	0.861 ^b	0.963 ^a	0.786 ^{bc}	0.862 ^b	0.747 ^{cd}	0.816 ^{bc}	0.764 ^{cd}	0.683 ^d	0.019	***	***	**
Glutamic acid	3.926 ^a	3.361 ^{bc}	3.293 ^{bcd}	3.151 ^{cd}	3.521 ^b	2.976 ^{de}	3.264 ^{bcd}	2.735 ^e	0.074	***	***	NS
Proline	1.019 ^c	1.113 ^c	1.098 ^c	1.558 ^a	0.886 ^d	0.994 ^{cd}	1.102 ^c	1.244 ^b	0.024	***	***	**
Glycine	0.831 ^d	1.723 ^{bc}	1.874 ^b	2.226 ^a	0.683 ^d	1.655 ^c	1.790 ^{bc}	1.737 ^{bc}	0.037	***	***	**
Alanine	0.959 ^d	1.814 ^{ab}	1.886 ^a	1.809 ^{ab}	0.825 ^e	1.729 ^b	1.859 ^a	1.586 ^c	0.022	***	***	**
Tyrosine	0.718 ^c	0.906 ^a	0.670 ^{cd}	0.674 ^{cd}	0.650 ^{de}	0.823 ^b	0.656 ^d	0.591 ^e	0.012	***	***	*
AVG	1.23	1.54	1.37	1.38	1.08	1.40	1.34	1.17				

AVG: Average digestibility of all amino acids. SBM = Soyabean Meal; FS = Fish Silage; SF = Sardine Fish; FM = Fish Meal; SEM = Standard Error of Means. *p<0.05; **p<0.01; ***p<0.001; NS = Not Significant.

^{a-e} Within each analysis, means not sharing a common superscript are significantly different (p<0.05). B*P: Breed*Protein

DISCUSSION

Describing the nutritive value of protein in feed ingredients in terms of digestible amino acid content is closer than total amino acid content in reflecting the amount that actually can be digested, absorbed and utilized by animals and becomes available for maintenance and production purposes (McNab, 1995). In the current study, the amino acid digestibility assays were based on the ileal collection method that involved using an indigestible marker, which was included in the diet at a 0.05% concentration. This was implemented to avoid uncertainty introduced by the contamination of droppings by feathers, scurf, spelt feed and the activities of microflora in the hindgut (Parsons, 1985). All the amino acid digestibility coefficients presented in this study are apparent since no account was taken of endogenous amino acid losses. As mentioned previously, the amino acids digestibility in soyabean meal were consistently lower across the two strains of chicken than those in fish silage (Table 2).

Soyabean meals are of major importance worldwide as a plant protein constituent of diets for poultry. It is well acknowledged that limitations to their use are associated with relatively modest concentrations of protein and nutritionally essential amino acids and there is a considerable interest in selecting cultivars with improved nutritional quality (Clarke and Wiseman, 2000). However, a further area of primary significance is the presence of anti-nutritional factors, such as trypsin inhibitor, as it interferes with protein digestion. Trypsin inhibitor is heat liable and is reduced below levels likely

to cause problems, although necessary processing is associated with increased cost. The trypsin inhibitor of soybean meal used in this study is 7 mg/g (Table 3) and is above the recommended trypsin inhibitor threshold of 4 mg/g (Clarke and Wiseman, 2005). The lower digestibility of amino acids of soybean meal can be attributed to the presence of anti-nutritional factor as it can affect protein digestibility in the digestive tract of the birds. Trypsin inhibitor level varies with source of bean and processing conditions (Nitsan and Nir, 1977; Clarke and Wiseman, 2000). Many authors reported negative effects of feeding soyabean meal high in trypsin inhibitor levels to broiler chicks (Leeson and Atteh, 1996; Zhu *et al.*, 1996; Zollitsch *et al.*, 1993). It is well-known that processing conditions can markedly influence the digestibility of amino acids in soyabean meal (Parsons, 1991). Therefore, the wide variation in processing conditions of soyabean meals means that the actual amount of trypsin inhibitor ingested by poultry will vary considerably between batches.

In this study, the amino acid profiles of the fishmeal and fish silage were similar to those obtained by other authors (Machin *et al.*, 1990; Vidotti *et al.*, 2003; Geron *et al.*, 2007; Santana-Delgado *et al.*, 2008). In the four protein samples evaluated, fish silage had the highest digestibility coefficients and digestible contents for both breeds (p<0.001) in comparison to other protein sources. Similar results were suggested by Skrede and Kjos (1996) who found that the digestibility of all amino acids was higher in fish silage than in fishmeal. They reported that fish silage is a source of highly available amino acids.

The chemical composition and protein quality of fishmeal can vary greatly depending on the species of fish used (Wu and Kellems, 1984; Ponce and Gernat, 2002), freshness of the raw materials (Anderson *et al.*, 1993), conditions and length of storage (Kellenbarger 1961; Anderson *et al.*, 1993) amount of residual oil (Anderson *et al.*, 1993), processing method and handling condition (Grau and Williams, 1965; Smith and Scott, 1965; Schumaier and McGinnis, 1969; Whitacre and Latshaw, 1982), drying method and temperature (Rosselot and Lopez-Lastra, 1996) and whether the meal is made from whole fish or the waste from some other processing operation (Anderson *et al.*, 1993), thus fishmeal needs to be evaluated continuously. The utilization of local fish waste and catch surplus of fish offers a great potential to utilize these wastes as a protein source in poultry feeding which can contribute to overcoming protein shortage in areas where structural foodstuff is lacking. The advantage of fish silage production is that the proteolytic enzymes present in the fish hydrolyse the protein and fat and this autolysis is accelerated by weak or strong acids, reaching the highest activity at pH between 2 and 4. This creates conditions more suitable for enzyme activity, bone breakdown and inhibition of spoilage and pathogenic type bacteria and therefore, proliferation of microorganisms is avoided which improve the product safety to be used in animal feeding (Raa and Gildberg, 1982. In addition, fish silage has various industrial applications. It is friendly to the environment, safer, technologically simpler and more economical than the manufacture of fishmeal (Gildberg, 1993).

However, poultry 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 protein sources than the local birds. The reasons for improved digestion in broilers are unclear. Influences of genotype for broilers on digestion have been reported (Sorensen *et al.*, 1983; Leenstra and Pit, 1988; Jorgensen *et al.*, 1990; Al-Marzooqi *et al.*, 2010b). Other possible explanation may be that the modern fast-growing broilers have more nutrient transport capacity and greater intestinal mass than other poultry strains (Mitchell and Smith, 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.

In summary, the influence of protein source and class 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. The technology of fish silage production is very simple. The silage process is fast in tropical climates and the product can be used in place.

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