Chicken Meat Research and Development Committee
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FINAL REPORT

PROJECT NO. US51A

Total and Digestible Tryptophan Contents of Feedstuffs for Poultry

Principal Investigators: Associate Professor W.L. Bryden
Dr G. Ravindran
Dr V. Ravindran

Phone: 2 4655 0658
Fax: 2 4655 0693

Contact Address: Department of Animal Science,
University of Sydney,
Camden, NSW 2570

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EXECUTIVE SUMMARY

Reliable values of total and digestible tryptophan in feedstuffs for use in feed formulation matrixes are needed because tryptophan is often the third limiting amino acid in practical poultry diets. However, tryptophan is oxidatively destroyed during acid hydrolysis in routine amino acid analysis and its determination requires a separate analytical procedure. A procedure involving alkaline hydrolysis with sodium hydroxide followed by separation of tryptophan by ion exchange chromatography has recently been developed and validated for the routine analysis of tryptophan in feeds (Ravindran and Bryden, 1996). Digestible amino acid contents of 93 samples of 25 Australian feedstuffs for poultry have been surveyed and are now available to the industry (Ravindran *et al*., 1998), but digestible tryptophan values were not included this database. In the present study, the ingredient, diet and digesta samples from the above survey were analysed for tryptophan and digestibility coefficients were calculated using acid insoluble ash as the indigestible dietary marker. The content (n = 93) and apparent ileal digestibility coefficient (n = 81) of tryptophan in feedstuffs are presented in this report. These results should be considered as an addendum to the earlier survey of digestible amino acids in Australian feedstuffs. To enable this, the same sample codes are used to identify the feed samples in this report. Additional data presented herein, on eight feedstuffs, indicate that tryptophan digestibility for broilers and layers are similar.

INTRODUCTION

Tryptophan is an essential amino acid for poultry and may become limiting especially when diets are based on maize, lupins and meat and bone meal. Reliable values of total and digestible tryptophan in feedstuffs for use in feed formulation matrixes is therefore urgently needed. This will also facilitate the strategic use of commercially available synthetic, feed-grade tryptophan.

Although numerous reports are available on amino acid digestibility in ingredients for poultry (see Ravindran and Bryden, 1999), these data seldom include values for tryptophan. This is because of the analytical difficulties in the determination of tryptophan due to the labile nature of this amino acid in the presence of light and hydrogen ions. Tryptophan, unlike most other amino acids, cannot be determined by routine ion-exchange chromatography after acid hydrolysis with 6 M HCl, as it is oxidatively destroyed. It has to be analysed separately or acid hydrolysis procedures have to be modified to render tryptophan stable. Several procedures have been studied over the years, but with variable success. The methods investigated include hydrolysis (acidic, alkaline or enzymatic) of the protein, a necessary first step, followed by quantitation of tryptophan by different (chromatographic, colorimetric, fluorimetric) techniques (Friedman and Cuq, 1988). These methods are generally limited in accuracy and reproducibility, often as a result of degradation/precipitation losses during hydrolysis or interference by other amino acids or other compounds (lysinoalanine, for example) in the hydrolysate during quantitation.

A chromatographic method has been recently developed for the determination of tryptophan content in food and feed proteins (Ravindran and Bryden, 1996). The method involves separation and quantitation of tryptophan (released from protein by alkaline hydrolysis with NaOH) by isocratic ion-exchange chromatography with O-phthalaldehyde derivatisation followed by fluorescence detection. In this procedure, chromatographic separation of the tryptophan and 5-methyl tryptophan, the internal standard, is completed in 15 min, without any interference from other compounds. The precision of the method has been determined to be 1 - 4% relative standard deviation. Accuracy of this method has been validated by agreement with the value for chicken egg white lysozyme, a sequenced protein, and by quantitative recoveries after spiking with lysozyme. Peak purity checks were made by the elimination technique using gelatin, a protein that contains no tryptophan.

A compilation of digestible amino acid contents of 93 samples of 25 Australian feedstuffs for poultry has been recently published (Ravindran *et al*., 1998), but digestible tryptophan values were not included this database. The ingredient and ileal digesta samples from this survey were analysed in the present study to estimate total and digestible concentrations of tryptophan in these feed samples. An additional aim of the study was to compare the tryptophan digestibility coefficients of eight feed ingredients determined with broilers and layers.

MATERIALS AND METHODS

Digestibility assays

Survey of Australian Feedstuffs

The ingredient and ileal digesta samples from a previous survey of amino acid digestibility in Australian feedstuffs (Ravindran *et al*., 1998) were used in this study. In this survey, apparent ileal amino acid digestibility values of 93 samples representing 25 feed ingredients have been determined using five-week old broilers. The assay methodology has been previously described in detail. Briefly, different assay diets were used for the evaluation of cereal grains and protein meals. In the case of cereals, assay diets contained 91.8 % test cereal, 2 % vegetable oil and 4.2 % mineral and vitamin supplements. In the case of protein meals, assay diets were based on dextrose and contained the test feedstuff as the only source of protein. The proportions of dextrose and the test feedstuff were varied in each diet to obtain 20 % crude protein. Celite (2 %) was added to all diets as a source of acid-insoluble ash (AIA) which was used as an indigestible marker in the calculation of digestibility coefficients.

Each assay diet was offered *ad libitum* to three pens (4 birds/pen) of male broilers from 35 to 42 days of age. On day 42, all birds were euthansed by an intracardial injection of diluted sodium pentabarbitone solution, and the contents of the lower half of the ileum were obtained. Ileal digesta of birds within a pen were pooled, frozen immediately after collection, and subsequently freeze-dried. Dried ileal digesta samples were ground to pass through a 0.5 mm sieve and stored in airtight containers at -4 ^{0}C for chemical analyses.

Comparison of Digestibility in Broilers and Layers

The apparent ileal digestibility of tryptophan in eight feed ingredients was determined using 5-week old male broilers (Cobb) and 60-week old layers (Isa Brown). Standard assay procedures were employed (Ravindran *et al.*, 1998). Assay diets contained the test ingredient as the only source of protein. Celite was included in all diets as an indigestible marker. Following overnight fasting, each assay diet was fed *ad libitum* to five replicate pens (6 birds/pen for broilers and 5 birds/pen for layers) for three days, and digesta contents from the terminal ileum were collected and analysed for tryptophan and AIA.

Tryptophan analysis

Chemicals: Standard stock solutions (5 mM) of L-tryptophan (Calbiochem. Corp., La Jolla, CA 92037) and α-methyl - DL - tryptophan (Sigma Chemical Co., St.Louis, MO 63178), both dried overnight over $P_2 0_5$ under vacuum, were prepared in 0.05 M NaOH. An internal standard, 5 mM α-methyl tryptophan in 0.05 M NaOH was also prepared. A 5 M NaOH solution was prepared on the day of use. Ultrapure water was prepared for all solutions using a Milli-Q ultrapure water system (Millipore Corp., Bedford, MA 01730).

All other chemicals and reagents were of the HPLC grade and all except O-phthalaldehyde (OPA; Sigma Chemical Co., St Louis MO63178, USA) were purchased from BDH Chemicals (BDH Chemicals Australia Pty Ltd, Kilsyth, VIC 3137). The elution buffer for HPLC constituted 58.8 g tri-sodium citrate, 12.4 g boric acid, and 13 mL 4N NaOH, made upto 1 L with water and the pH adjusted to 9.3. The OPA buffer was prepared by dissolving 1.2 g OPA in 15-20 mL ethanol and mixing with 2.4 mL 3-mercaptopropionic acid and 10 mL of 10% brij-35, all then made upto 1L with OPA stock buffer. The OPA stock buffer was made of 122.1 g sodium carbonate (anhydrous), 56.4 g potassium sulfate and 40.7 g boric acid, dissolved in the same order in water and made upto 3 L. All solutions used in HPLC analysis were filtered through 0.2 µm nylon-66 membrane filters (Rainin Instrument Co., Woburn, MA 01801).

Equipment: A PASCAL type 2021 rotary high vacuum pump (John Morris Scientific Pty. Ltd., Sydney, NSW) was used for evacuation of air and a Labec autoclave (Laboratory Equipment Pty. Ltd., Sydney, NSW) for hydrolysis. Amino acid analysis

was performed using a Shimadzu amino acid analysis system (Shimadzu Corp., Kyota, Japan). It was equipped with model LC-10AD pumps, an autoinjector (SIL-10A), a temperature control module (CTO-10A), a postcolumn reaction system, a model RF-10A spectrofluorometric detector, a communication bus module (CBM-10A), a sodium cation exchange column (Shim-pack Amino-Na, I.D. 6.0 mm * 10 cm) and a data processing unit (Class - LC 10, version 1.6).

Hydrolysis Procedure: Samples were hydrolysed with NaOH in teflon containers under an atmosphere of nitrogen, according to the following procedure. Samples containing 20-30 mg protein were dispersed in 10 mL of 4.2 M sodium hydroxide containing 0.15 mM α-methyl tryptophan as internal standard, freshly prepared on the day of use. Soluble starch (20 mg) was added to samples containing little or no starch. Soluble starch serves as a protective agent as it is preferentially oxidised. A drop or two of 2-octanol was added to prevent frothing (Spies, 1967). The internal standard was added to the standard tryptophan at the same time it was added to the sample and carried through the same procedure as for the sample, except that the hydrolysis step was omitted. The medium was homogenised (in Maxi Mix II), sonicated, flushed with nitrogen, and cooled in a freezer for at least an hour. The lids of the teflon containers were then slightly opened, placed in a vacuum desiccator, and evacuated using a vacuum pump. The desiccator was then purged with nitrogen and the process repeated thrice to remove air from the samples. This is an important step in the hydrolysis procedure as any oxygen not removed would lead to oxidative losses of tryptophan. The containers were removed from the desiccator under an atmosphere of nitrogen, lids closed tightly, and the samples hydrolysed in an autoclave at 120 ^{o}C for 15 h. The hydrolysates were cooled at 4 ^{o} C, acidified to a pH 6.5 with HCl (tryptophan is stable at pH 4-7), diluted to 50 mL with sodium citrate buffer of pH 6.5 and filtered through 0.2 μm nylon 66 filter membrane into autosampler vials.

All samples were hydrolysed in duplicate and where the duplicates disagreed by more than 5% of the mean, samples were re-hydrolysed and re-analysed. Lysozyme was used as a reference material.

Analysis: Tryptophan and 5-methyl tryptophan were separated by ion exchange chromatography. Aliquots of the sample hydrolysates or standard mixture of tryptophan and 5-methyl tryptophan were injected onto the column and eluted isocratically with sodium citrate buffer of pH 9.3 at a flow rate of 0.5 mL/min and a column temperature of 65 ^{o}C. OPA was used for postcolumn derivatisation and fluorometric detection of amino acids.

Other Analyses

Nitrogen determinations were performed in duplicate by the method of Sweeney (1989), using FP-428 nitrogen determinator (LECO® Corporation, St..Joseph, MI, USA). Crude protein content of the ingredients were calculated as N x 6.25. The only exception was wheat for which a conversion factor of 5.89 was used. The AIA contents of diet, ileal digesta and excreta samples were measured after ashing the samples and treating the ash with boiling 4 M hydrochloric acid.

Calculations

The apparent ileal tryptophan digestibility coefficients were calculated using the following formula with AIA as the marker.

$$\text{Digestibility coefficient} = \frac{(\text{Trp} / \text{AIA})_d - (\text{Trp} / \text{AIA})_i}{(\text{Trp} / \text{AIA})_d}$$

where, $(\text{Trp} / \text{AIA})_i$ = ratio of tryptophan to acid-insoluble ash in ileal digesta

and $(\text{Trp} / \text{AIA})_d$ = ratio of tryptophan to acid-insoluble ash in the diet.

RESULTS

The content and apparent ileal digestibility coefficient of tryptophan in feedstuffs are presented in **Appendix Table 1**. Tryptophan content is expressed as g/100 g and on an 'as-fed' basis. For 11 feed samples, insufficient amounts of ileal digesta were available

for analysis and only the tryptophan content in the feed was determined. These results should be considered as an addendum to the compilation of digestible amino acids previously reported from our laboratory (Ravindran *et al*., 1998). To enable this, the same sample codes are used to identify the feed samples in this report.

Comparison of tryptophan digestibility values for broilers and layers are summarised in **Appendix Table 2**. The estimates for digestibility coefficients in all feedstuffs for 5-week old broilers and layers were similar ($P > 0.05$).

DISCUSSION

Tryptophan Content in Feedstuffs

Differences in origin, agronomic practices or processing may cause variation in the tryptophan content of feedstuffs. But data on the variability in the tryptophan content of commonly used feedstuffs in Australia is lacking. The levels and variability in tryptophan of 92 samples of 23 feedstuffs are presented in this report. The determined tryptophan levels are discussed in comparison with the NRC (1994) feed composition table values. It should be recognised, however, that the NRC values provide average data summarised across published sources, based on different methods of tryptophan analysis, and direct comparison with the values in this report difficult.

The tryptophan contents of the six maize samples ranged from 0.05 to 0.09 g/ 100 g. The highest value (0.09 g/ 100 g) was determined in a high-lysine maize sample, while the remaining normal maize samples contained relatively low levels of tryptophan (0.05-0.06 g/ 100 g). Similar differences in tryptophan contents between normal and high-lysine corn have been reported by other workers (Bressani, 1991; Zarkadas *et al*., 1995).

The values determined for the six sorghum samples (0.09 – 0.12 g/ 100 g) were higher than the values of 0.08 and 0.09 g/ 100 g listed by the NRC (1994) for samples containing 9 and 11 g crude protein/ 100 g, respectively. The crude protein contents of our sorghum samples ranged from 8.1 to 11.6 g/ 100 g. Tryptophan contents tended to increase with increasing levels of protein in the grain, consistent with earlier reports from our laboratory. Ravindran and Bryden (1997), analysing sorghum grain samples with protein levels ranging from 5.9 to 13.0 g/ 100 g, found that two-thirds of the variation in

tryptophan content can be explained by differences in protein levels. In this study, the tryptophan content in sorghum varied from 0.07 to 0.11 g/ 100 g.

Tryptophan content of the 24 wheat samples ranged from 0.09 to 0.18 g/ 100 g, depending largely on the protein content of the grain. The average tryptophan content of samples containing < 10, 10-12, 12-14 and > 14 g crude protein (N x 5.89)/ 100 g were 0.10, 0.12, 0.15 and 0.16 g/ 100 g, respectively. These values compare closely with the values of 0.12 and 0.16 g/ 100 g listed by NRC (1994) for wheats containing 10 and 13 g crude protein/ 100 g, respectively.

Tryptophan levels determined in millrun and rice polishings were comparable to those listed by NRC (1994), while our values for barley and triticale were slightly higher.

The average tryptophan level (0.64 g/ 100 g) determined for soybean samples in our study was lower than the value (0.74 g/ 100 g) listed by NRC (1994). However, considerable variability in tryptophan contents (0.58 - 0.71 g/ 100 g) was observed in the nine soyabean meal samples analysed, and these values agree well with those reported by other workers (Bolton and Blair, 1974; McNab and Scougall, 1982; Sato *et al*., 1984; Pinter-Szakacs and Molnar-Perl, 1990; Adeola, 1998). Tryptophan content in cottonseed meal samples (0.46 – 0.51 g/ 100 g) compares well with the NRC (1994) values (0.47 – 0.52 g/ 100 g). The average values for locally available canola meal (0.38 g/ 100 g) and sunflower meal (0.36 g/ 100 g) were, however, lower than those reported by NRC (1994). Reasons for the low tryptophan concentration in these samples are unclear, but may be related to processing methods.

With the exception of lupins, tryptophan values in grain legumes agreed well with published values (NRC, 1994; Peterson and Mackintosh,1994). The tryptophan contents determined for lupin samples in our study were lower than the values of 0.32 – 0.37 g/ 100 g reported by Peterson and Mackintosh (1994).

Tryptophan levels in blood meal, fish meal, casein and maize gluten meal compared closely with NRC (1994) values. However, the levels determined in meat meal and, meat and bone meal were substantially lower than the NRC (1994) values. Differences in the composition of raw materials used and rendering conditions may have been responsible for the lower tryptophan levels in locally produced meat by-products. No tryptophan was detected in the gelatin sample analysed.

Ileal Digestibility of Tryptophan

There is a paucity of information on tryptophan digestibility in feedstuffs for poultry. In particular, no comparable data is available on digestibility values at the ileal level. To our knowledge, this is the first report on ileal tryptophan digestibility for poultry.

The average ileal tryptophan digestibility in maize, sorghum and triticale were similar, but tryptophan in wheat was found to be more digestible. Interestingly, variation in trytophan digestibility among samples within cereal type was considerably smaller compared to those noted for tryptophan content. Grain protein level had no influence on tryptophan digestibility. For example, ileal tryptophan digestibility in wheat samples containing < 10, 10-12, 12-14 and > 14 g crude protein / 100 g were 81, 82, 84 and 83 %, respectively.

Among the plant protein supplements, average tryptophan digestibility in soyabean meal (84 %) and sunflower meal (81 %) were higher than those in canola meal (73 %) and cottonseed meal (75 %). The ileal digestibility value of 84 % determined for soyabean meal in our study was similar to the apparent ileal digestibility value of 85 % for growing pigs (Knabe *et al*., 1989). It is of interest to note that the digestibility estimate for the full-fat canola sample (86 %) was higher than those determined for canola meal samples (73 – 80 %). This observation may suggest of possible adverse processing conditions on tryptophan digestibility. Among the grain legumes, tryptophan in lupins (both *Angustifolius* and *Albus*) were better digested than those in chickpeas, fababeans, and field peas.

The amino acid digestibilities in fish meal and blood meal were substantially higher than those in meat and bone meal, meat meal and feather meal. Marked variation in amino acid digestibilities was also observed among samples of specific animal protein meals, highlighting significant batch-to-batch differences.

Broiler Versus Layer Comparison

We are not aware of any published reports comparing digestibility of amino acids in feedstuffs for broilers and layers. The results of our study indicate that tryptophan digestibility for broilers and layers in the eight feedstuffs tested were similar. One might have expected layers to better digest the protein and amino acids, at least in the poorly

digestible ingredients, owing to differences in gut development and digesta retention time.

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TABLE 1

Dry matter, crude protein and contents (g/ 100 g as received) and ileal digestibility coefficients of tryptophan in feed ingredients for broilers.

Code	Feedstuff	DM (%)	CP (%)	Tryptophan content	Digestibility
Cereals					
B01	Barley	89.6	8.5	0.11	-
M01	Maize	89.1	7.6	0.05	0.72
M02	Maize	88.5	8.1	0.06	0.70
M03	Maize	91.9	8.1	0.06	0.75
M04	Maize	90.5	7.8	0.06	0.66
M05	Maize	90.2	7.9	0.06	0.71
M06	Maize, high lysine	92.0	9.8	0.09	0.70
S01	Sorghum	90.8	11.6	0.11	0.74
S02	Sorghum	9.9	11.1	0.12	0.72
S03	Sorghum	91.1	8.1	0.09	0.76
S04	Sorghum	88.4	10.3	0.10	0.80
S05	Sorghum	87.9	11.0	0.10	0.75
S06	Sorghum	90.6	7.1	0.07	0.71
T01	Triticale	90.5	10.2	0.10	0.76
T02	Triticale	91.2	10.7	0.10	0.76
T03	Triticale	90.1	10.6	0.09	0.74
W01	Wheat	90.1	9.4	0.10	0.85
W02	Wheat	90.7	9.2	0.12	0.82
W03	Wheat	92.1	11.8	0.13	0.79
W04	Wheat, new season	91.7	13.7	0.17	0.84
W05	Wheat, old season	92.0	12.5	0.15	0.85

TABLE 1 (contd)

Dry matter, crude protein and contents (g/ 100 g as received) and ileal digestibility coefficients of tryptophan in feed ingredients for broilers.

Code	Feedstuff	DM (%)	CP (%)	Tryptophan content	Digestibility
W06	Wheat, Warbler	93.4	16.2	0.18	0.81
W07	Wheat, Triller	89.9	8.8	0.10	0.78
W08	Wheat, Currawong	91.5	10.1	0.13	0.78
W09	Wheat, Lowan	90.1	10.1	0.12	0.83
W10	Wheat, Lawson	92.3	10.7	0.11	0.85
W11	Wheat, Harvey	91.0	10.4	0.13	0.82
W12	Wheat, Broadbent	92.6	11.8	0.14	0.83
W13	Wheat, Murray Bridge	93.2	10.5	0.13	0.85
W14	Wheat, Tailem Bent	93.6	9.0	0.10	0.77
W15	Wheat, Bouchier	91.0	12.3	0.14	0.82
W16	Wheat	92.7	9.3	0.12	0.85
W17	Wheat	92.4	12.1	0.15	0.85
W18	Wheat	93.3	15.8	0.16	0.84
W19	Wheat	90.5	14.9	0.15	0.84
W20	Wheat	92.0	15.2	0.16	0.83
W21	Wheat	90.6	15.1	0.15	0.82
W22	Wheat	89.9	10.9	0.12	0.80
W23	Wheat	90.4	10.8	0.11	0.81
W24	Wheat, Meering	88.9	9.6	0.09	0.78
Cereal by-products					
MM01	Millrun	92.1	15.1	0.21	0.76
RP01	Rice pollard	90.5	12.9	0.15	0.65

TABLE 1 (contd)

Dry matter, crude protein and contents (g/ 100 g as received) and ileal digestibility coefficients of tryptophan in feed ingredients for broilers.

Code	Feedstuff	DM (%)	CP (%)	Tryptophan content	Digestibility
Oilseed meals					
CM01	Canola meal, full-fat	91.7	26.6	0.36	0.86
CM02	Canola meal	92.9	35.1	0.39	0.80
CM03	Canola meal	91.7	35.0	0.45	0.77
CM04	Canola meal	92.3	38.8	0.52	0.79
CM05	Canola meal	92.3	29.1	0.50	0.80
CM06	Canola meal	90.6	35.5	0.37	0.73
CM07	Canola meal	89.2	29.7	0.44	0.78
CSM01	Cottonseed meal	92.6	38.4	0.50	0.76
CSM02	Cottonseed meal	91.6	39.6	0.46	0.75
CSM03	Cottonseed meal	93.2	40.0	0.48	0.76
CSM04	Cottonseed meal	90.1	38.1	0.51	0.74
SBM01	Soyabean meal	90.2	46.3	0.61	0.87
SBM02	Soyabean meal	92.8	46.7	0.58	0.85
SBM03	Soyabean meal	91.5	48.3	0.64	0.83
SBM04	Soyabean meal	90.9	49.0	0.71	0.84
SBM05	Soyabean meal	92.6	48.7	0.69	0.83
SBM06	Soyabean meal	92.3	49.1	0.70	0.81
SBM07	Soyabean meal	89.8	44.8	0.59	0.84
SBM08	Soyabean meal	90.2	47.7	0.61	-
SBM09	Soyabean meal	92.1	46.4	0.62	0.85

TABLE 1 (contd)

Dry matter, crude protein and contents (g/ 100 g as received) and ileal digestibility coefficients of tryptophan in feed ingredients for broilers.

Code	Feedstuff	DM (%)	CP (%)	Tryptophan content	Digestibility
SM01	Sunflower meal	91.0	34.6	0.36	-
SM02	Sunflower meal	93.5	36.6	0.39	0.82
SM03	Sunflower meal	90.6	31.0	0.34	0.80
Grain Legumes					
CP01	Chick pea	93.0	21.3	0.18	0.71
FB01	Faba bean	92.3	23.8	0.19	0.63
P01	Field pea	90.6	22.9	0.18	0.75
P02	Field pea	91.1	21.6	0.20	0.63
L01	Lupin, *angustifolius*	92.0	30.4	0.26	0.77
L02	Lupin, *angustifolius*	92.6	34.0	0.27	0.78
L03	Lupin, *angustifolius*	92.9	29.9	0.25	0.82
L04	Lupin, *angustifolius*	90.7	28.8	0.28	0.79
L05	Lupin, *albus*	93.5	34.7	0.28	0.83
Animal Protein Meals					
BM01	Blood meal	92.7	91.3	1.35	-
BM02	Blood meal	91.9	89.7	1.28	0.84

TABLE 1 (contd)

Dry matter, crude protein and contents (g/ 100 g as received) and ileal digestibility coefficients of tryptophan in feed ingredients for broilers.

Code	Feedstuff	DM (%)	CP (%)	Tryptophan content	Digestibility
FTM01	Feather meal	92.9	87.1	0.45	0.52
FM01	Fish meal	92.9	63.8	0.51	0.81
FM02	Fish meal	92.1	61.6	0.64	0.72
FM03	Fish meal	90.8	58.9	0.50	-
MM01	Meat meal	91.2	55.7	0.27	0.57
MM02	Meat meal	92.6	54.6	0.24	-
MM03	Meat meal	92.6	54.0	0.30	0.68
MBM01	Meat and bone meal	91.8	49.0	0.19	0.56
MBM02	Meat and bone meal	92.0	47.8	0.26	0.60
MBM03	Meat and bone meal	92.9	49.9	0.26	0.70
Miscellaneous					
MIS01	Biscuit meal	92.9	10.4	0.10	-
MIS02	Casein	93.1	87.0	1.18	0.97
MIS03	Casein	92.0	87.9	1.04	-
MIS04	Casein	92.9	87.6	1.06	-
MIS05	Dogfood scrap meal	92.7	23.1	0.22	-
MIS06	Gelatin	92.1	88.2	0.00[1]	-
MIS07	Maize gluten	91.9	64.3	0.35	-

[1]Tryptophan was not detected in gelatin.

TABLE 2

Tryptophan content and digestibility coefficient of eight feedstuffs determined with 5-week old broilers and 60-week old laying hens

Ingredient	Tryptophan content (g/100 g as fed basis)	Digestibility coefficient		
		Broilers	Layers	Pooled SEM[1]
Maize	0.056	0.698	0.696	0.033
Sorghum	0.120	0.743	0.756	0.009
Wheat	0.134	0.750	0.737	0.039
Millmix	0.221	0.785	0.805	0.005
Soyabean meal	0.706	0.879	0.877	0.006
Canola meal	0.428	0.816	0.822	0.022
Cottonseed meal	0.501	0.699	0.715	0.007
Meat meal	0.283	0.724	0.744	0.014

[1] Differences in tryptophan digestibility between broilers and layers are not statistically significant ($P > 0.05$) for any of the ingredients.