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Full Length Research Paper

Evaluation of protein and energy quality of poultry by-product meal using poultry assays

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In the present study, two experiment were conducted to evaluate three poultry by-product meal (PBM; A, B and C), that is produced in commercial rendering plants. In first experiment, true amino acids (AA) digestibility and TMEn of the PBM were determined using the precision-fed cecectomized rooster. In second experiment, 1 week old male chicks were fed from 8 to 21 days of age with a corn-SBM diet or diets containing 5 or 10% PBM C formulated to be equal in total or digestible AA to the corn-SBM diet. TMEn and true amino acid digestibility varied among PBM (P < 0.05). Mean true digestibility coefficients (percentages) for AA in PBM A, B, and C were 81.75, 67.80 and 66.31, respectively. Feed efficiency of chick fed diet containing 5 or 10% PBM C on a digestible AA basis or 5% PBM C on a total AA basis was not significantly different (P > 0.05) than that of the chicks fed the corn-SBM diet. The results of this study indicated that PBM has substantial nutritional value for poultry and diets containing 10% PBM in chick diets had no detrimental effects on performance if the diets were formulated to contain adequate levels of digestible AA.

Key words: Energy, protein quality, poultry by-product meal.

INTRODUTION

Similar to meat meal, poultry by-product meal (PBM) is produced essentially from waste generated during poultry meat processing. Since only one animal species is used, poultry by-product meal would be expected to be more homogeneous than meat meal and contain lower levels of calcium and phosphorus (Leeson and Summers, 1997). However, compositional variability of this product can arise from the inclusion of feathers, blood and viscera, with the former product necessitating higher cooking temperatures in order to hydrolyse the keratin proteins.

Research showed that PBM has substantial nutritional value for poultry; however, the nutritional quality may vary greatly among samples (Escalano and Pesti, 1986; Pesti, 1987; Han and Parsons, 1990; Hassanabadi et al., 2008). The presence of a significant amount of feathers can markedly influence the order of amino acid limitation in poultry by-product meals. Main and Doghir (1981, 1982) found that methionine and lysine were the first and second-limiting amino acids, respectively. In contrast, Wang and Parsons (1998) used a more conventional sample and reported that the order of amino acid limitation was sulphur amino acids, tryptophan, threonine and lysine. A partial explanation for the different findings between the two laboratories is that the sample evaluated by Main and Doghir (1981, 1982) contained 3.73% cystine, which was indicative of a high proportion of feather protein. Other experiments have shown that the digestibilities of amino acids (AA) in the PBM vary among different samples and were lower than that of soybean meal (NRC, 1994; Han and Parsons, 1990).

Previous work showed that dietary inclusion of 5% PBM did not significantly affect chick growth in comparison to a corn-soybean meal diet (Gohl, 1981; Escalano and Pesti, 1987; Pesti, 1987; Hassanabadi et al., 2008). However, with a higher inclusion rate of 10 or 15% PBM in those study, growth and feed efficiency were decreased below that of chicks fed a corn-SBM diet. Because all diets (diets containing 10 or 15% of PBM and

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Table 1. Processing procedure for poultry by- product (PBM).

Meal	Processing time and temperature	
	Time (min)	Temperature (℃)
PBM A	200 - 220	115
PBM B	170 - 190	165
PBM C	180 - 200	135

Table 2. Chemical composition of poultry by-product meals[1].

Components	Poultry by-product sample		
	A (%)	B (%)	C(%)
Moisture	8.84	1.91	9.16
Crude protein	57.60	62.44	50.48
Crude fat	19.72	22.21	22.80
Ash	6.04	6.18	10.65
Calcium	1.35	1.70	1.80
Phosphorus	0.83	1.36	1.57
Amino acids			
Asp	4.59	4.99	3.90
Thr	2.45	2.68	1.95
Ser	3.01	3.36	2.54
Glu	6.97	7.38	5.65
Ala	3.20	3.67	2.83
Cys	1.14	1.31	0.95
Val	4.05	4.20	2.73
Met	1.11	1.20	0.97
Ile	2.80	2.97	2.14
Leu	5.00	5.34	3.97
Tyr	2.00	2.17	1.53
Phe	3.57	3.79	3.12
His	1.17	1.20	1.17
Lys	2.47	2.34	1.86
Arg	4.09	4.31	3.17

corn-SBM diet) were formulated on a total AA basis and the digestibilities of the AA in the PBM were lower than those in corn and soybean meal (NRC, 1994), therefore, reduced chick performance obtained with the 10 or 15% PBM diets was hypothesized to be due to differences in digestible AA levels among the diets.

Therefore, the objective of this study was to determine the protein and energy quality of three PBM, as well as evaluated the performance of chicks fed diets containing 5 and 10% PBM (PBM C) formulated on a total AA basis versus a digestible AA basis in comparison with a corn-SBM diet.

MATERIALS AND METHODS

Three PBM (A, B, and C) were obtained from commercial rendering plants that used different processing system, times and temperatures (Table 1). The PBM samples contain feathers, blood and viscera, that processed using continuous cooking system under pressure in an attempt to hydrolyze of the feathers and increase of their digestibility. All samples were analyzed for DM, N, ether extract, ash, Ca, and P according to the procedures of the Association of Official Analytical Chemists (2000). Amino acid concentrations in the PBM were determined using ion-exchange chromatography following hydrolysis in 6 N HCl for 22 h at 110℃ (Spackman et al., 1958). Analyses of methionine and cystine were conducted following performic acid oxidation by the method of Moore (1963) except that samples were diluted with water and lyophilized to remove excess performic acid. Gross energy was determined using a bomb calorimeter. The chemical compositions of the PBM are presented in Table 2.

True digestibility assay

This experiment was conducted to determine the true digestibility of amino acids and TME_n of PBM. Mature single comb white leghorn roosters approximately 45 weeks of age were used. The birds were housed in an environmentally regulated room and kept in individual cages with raised wire floors and subjected to a photoperiod of 16 h light and 8 h dark daily. Feed and water were supplied for *ad libitum* access before the beginning of the experiments. Cecectomy was performed according to the procedure of Parsons (1985) when the birds were 25 weeks of age. All roosters were given at least 8 weeks to recover from surgery prior to being used in experiments. The assay procedure was described by Sibbald (1986). Following a 24 h period without feed, Cecectomized roosters were given 30 g of a PBM through crop intubation. Additional roosters were deprived of feed throughout the experimental period to measure endogenous excretion of DM, energy, N, and AA. Four roosters were assigned to each treatment. A plastic tray was placed under each cage and excreta were collected quantitatively for 48 h after crop intubation. The excreta samples were lyophilized, weighed, and ground to pass through a 60-mesh screen. Gross energy, N, and AA concentrations were determined on at least four replicates of each individual sample of excreta according to the procedures described previously. True digestibilities of AA were calculated according to the method of Sibbald (1979), and TMEn was calculated by the method of Parsons et al. (1982).

Chick assay

One-week-old male chicks resulting from the cross of New Hampshire males and Columbian Plymouth Rock females were used in chick assays. Chicks were housed in thermostatically controlled starter batteries with raised wire floors in an environmentally regulated room. Feed and water were supplied for *ad libitum* consumption and light was provided 24 h daily. The chicks were fed a 24% CP corn-SBM pretest diet during the first 7 days posthatching. Following an overnight period without feed, the chicks were weighed, wing-banded, and allotted to dietary treatments as described by Sasse and Baker (1973).

Chick assay was conducted to evaluate growth performance of chicks fed diets containing 5 or 10% PBM C formulated on a total or digestible AA basis (Table 3) compared to a corn-SBM diet. The analytical values for the PBM C in Table 2 and NRC (1994) table's values for corn and SBM were used for the diet formulations. The diets containing PBM C were formulated to contain levels of total AA or digestible AA equal to the levels in the corn-SBM diet or equal to the NRC (1994) total AA requirement, whichever was lower. All diets were formulated to provide 21.5% protein and 3200 kcal TMEn/kg and to meet all other NRC (1994) nutrient requirements. The five diets were fed to four replicate of seven male chicks from 8 to 21 d posthatching.

Statistical analyses

Data from both true digestibility assay and chick assay were subjected to ANOVA for completely randomized designs using SAS (SAS Institute, 1985). Statistical significance of differences among treatments was assessed using the Duncan's test (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

The results herein indicate that the nutritional value of the PBM can vary greatly. For example the CP, fat, and ash content of our three samples varied from 50 to 62%, 19 to 22% and 6 to 10%, respectively. It is possible that differences in dry matter content of PBM may have been partially responsible for the variation in protein content among the meals. When comparing the composition of our PBM to the one evaluated by Han and Parsons (1990), all of our PBM were similar in CP, higher in fat and lower in ash. Moreover, the CP and fat contents of our PBM were similar and higher, respectively, to those reported by NRC (1994). This variability among the PBM could be due to differences in raw material composition and processing system.

True digestibility of the 15 measured amino acids and TME_n varied among the PBM (Table 4). Digestibility also varied among the amino acids, with digestibility of cystine being substantially lower than that of all other amino acids. Digestibilities of all amino acids were significantly higher ($P < 0.05$) for PBM A (81.75%) than PBM B (67.80%) and C (66.31%). The greatest digestibility of essential amino acids among PBM was for arginine. Digestibility of most amino acids in PBM A was generally similar to that of poultry by-product meal evaluated by Han and Parsons (1990) and NRC (1994) values. However, digestibility value of amino acids for PBM B and C were lower than the NRC (1994) values for poultry by-product meal.

The results of amino acid digestibility assay indicated that the protein quality of PBM can vary greatly. The lower values for PBM B and C suggest that the type of processing system may be a contributing factor to the variation in protein quality. Systems were used for PBM B or C in an attempt to at least partially hydrolyze the feathers and improve their utilization. However, the low amino acid digestibility of PBM B and C compared to that of PBM A suggest that the processing system used for PBM B or C may have heat-damaged the non feather protein in this meals. It is also possible that differences in raw material composition may have been partially responsible for the variation in protein quality among the PBM.

Among amino acids, digestibility of cystine was substantially lower than that of all other amino acids. Feather content of PBM has a high proportion of keratin protein inclusion of cystine disulfide bonds (Papadopoulos et al., 1985). Under conditions of prolonged exposure to high pressure and temperature during commercial processing, some of the cystine will be converted to the atypical sulfur amino acid lanthionine (Baker et al., 1981). Lanthionine has been reported to be absorbed by chicks, but it generally has decreased amino acid digestibility (Baker et al., 1981; Han and Parsons, 1991).

The TME_n content of PBM C was lower then that of PBM A and B (Table 4). The variation in TME_n among the PBM can largely be explained by difference in ash content. Consequently, the variation in efficiency of energy utilization (TME_n/gross energy; 66, 60 and 61% for PBM A, B and C, respectively) among the PBM was much less than that of TME_n. The mean TMEn of the three PBM was 3528 Kcal/kg and was higher than the NRC (1994) values for poultry by-product meal. This

Table 3. Composition of diets containing PBM C formulated on a total or digestible amino acid base.

Ingredient and composition	Level of PBM C					
	0% PBM C[1]	5% PBM C[1]	10% PBM C[1]	0% PBM C[2]	5% PBM C[2]	10% PBM C[2]
Corn grain, ground	52.39	55.47	58.59	52.39	55.57	58.75
Soybean meal (44 % CP)	38.43	31.96	25.44	38.43	31.85	25.21
PBM C	0	5.00	10.00	0	5.00	10.00
Soybean oil	4.74	3.47	2.19	4.74	3.44	2.14
Dicalcium phosphate	1.45	1.16	0.88	1.45	1.16	0.88
Ground Limestone	1.70	1.64	1.59	1.70	1.64	1.59
Iodized Salt	0.47	0.42	0.37	0.47	0.42	0.37
Vitamin mix[3]	0.25	0.25	0.25	0.25	0.25	0.25
Trace Minerals mix[4]	0.25	0.25	0.25	0.25	0.25	0.25
Choline-Cl (60%)	0.10	0.10	0.10	0.10	0.10	0.10
L-Lys HCL	-	0.08	0.17	-	0.11	0.23
DL-Met	0.22	0.20	0.17	0.22	0.21	0.23
Calculated or analytical composition[5]						
TME_n (kcal/kg)	3200	3200	3200	3200	3200	3200
Crude protein	21.50	21.50	21.50	21.50	21.50	21.50
Crude fat	6.99	6.95	6.89	6.99	6.92	6.83
Calcium	1.00	1.00	1.00	1.00	1.00	1.00
Avail. Phosphorus	0.45	0.45	0.45	0.45	0.45	0.45
Sodium	0.20	0.20	0.20	0.20	0.20	0.20
Arg	1.40	1.37	1.34	1.26	1.21	1.16
His	0.82	0.81	0.8	0.76	0.73	0.72
Ile	1.16	1.14	1.13	1.06	1.04	1.02
Leu	2.07	2.08	2.09	1.89	1.86	1.83
Lys	1.17	1.17	1.17	1.05	1.05	1.05
Met + Cys	0.90	0.90	0.90	0.81	0.81	0.81
Phe + Tyr	2.17	2.16	2.15	1.97	1.93	1.89
Thr	0.81	0.82	0.82	0.73	0.71	0.69
Val	1.25	1.27	1.28	1.16	1.12	1.10
Trp	0.31	0.29	0.26	0.28	0.25	0.23

[1]Diets formulated to meet or exceed the NRC (1994) total amino acid requirements.[2]Diets formulated to meet or exceed the NRC (1994) digestible amino acid requirements.[3]Provided per kilogram of diet: vitamin A, 9000 IU; cholecalciferol, 2000 IU; vitamin E, 18 IU; vitamin B12, 0.015 mg; riboflavin, 6.6 mg; d-pantothenic acid, 10 mg; niacin, 30 mg; menadione sodium bisulfite, 3 mg.[4]Provided as milligrams per kilogram of diet: manganese, 100 from manganese oxide; iron, 50 from iron sulfate; zinc, 100 from zinc oxide; copper, 10 from copper sulfate; iodine, 0.99 from ethylene diamine dihydroiodide; selenium, 0.2 from sodium selenite.[5]All values except corn and soybean meal were analyzed values. The values for corn and soybean meal were derived from the NRC (1994).

difference in TME_n could be due to fat content of our PBM (21%) than that of poultry by- product meal (13%) evaluated by NRC (1994).

In chick assay, daily weight gain and daily feed intake of chicks were similar among all treatments (Table 5). Feed efficiency of chick fed diets containing 5% PBM C on a total or digestible AA basis was not significantly different (P > 0.05) than that of the chicks fed the corn-SBM diet. Previous work also showed that dietary inclusion of 5% PBM did not significantly affect chick growth in comparison to a corn-soybean meal diet (Gohl, 1981; Escalano and Pesti, 1987; Pesti, 1987; Hassanabadi et al., 2008). Dietary inclusion of 10% PBM C on a total AA basis depressed feed efficiency in comparison to the corn-SBM diet (P < 0.05). However, feed efficiency of chick fed diet containing 10% PBM C on a digestible AA basis was not significantly different (P > 0.05) than that of the chicks fed the corn-SBM diet. Therefore, it seems formulating diets containing 10% PBM on a digestible AA basis resulted in improved chick performance (P < 0.05) compared to that achieved from formulation on a total AA basis. Previous studies on cottonseed meal (Fernandez et al., 1995), poultry by-product meal and feather meal (Rostagno et al., 1995)

Table 4. The TMEn and true digestibility coefficients of amino acids in poultry by- product meal[1].

	Poultry by-product sample			
Variable	**A**	**B**	**C**	**SEM**
TME_n (kcal/kg)	3673.7 [a]	3657.2 [a]	3254.4 [b]	99.5
Asp(%)	72.02 [a]	57.12 [b]	48.92 [b]	2.76
Thr(%)	84.46 [a]	69.08 [ab]	58.11 [b]	5.93
Ser(%)	85.41 [a]	65.77 [b]	72.65 [ab]	4.98
Glu(%)	80.04 [a]	60.55 [b]	60.29 [b]	4.76
Ala(%)	82.57 [a]	68.57 [b]	67.07 [b]	3.23
Cys(%)	60.11 [a]	45.15 [b]	46.31 [b]	2.62
Val(%)	85.46 [a]	69.69 [ab]	58.91 [b]	5.95
Met(%)	84.30 [a]	68.25 [b]	66.15 [b]	3.35
Ile(%)	85.93 [a]	79.66 [a]	79.77 [a]	2.08
Leu(%)	84.27 [a]	67.80 [b]	70.47 [b]	3.43
Tyr(%)	86.88 [a]	74.21[ab]	71.87 [b]	4.09
Phe(%)	86.20 [a]	70.39 [b]	79.98 [ab]	3.29
His(%)	81.61 [a]	73.89 [b]	72.09 [b]	2.46
Lys(%)	77.48 [a]	73.24 [ab]	63.61 [b]	3.13
Arg(%)	89.59 [a]	73.68 [b]	78.51 [ab]	3.83
Mean (%)	81.75	67.80	66.31	

[a–b] Means within a row with no common superscript differ significantly ($P < 0.05$).[1]Data are means of four cecectomized roosters.

Table 5. Growth performance of chicks fed a corn-soybean meal diet or diets containing poultry by- product meal C (PBM C) formulated on a total or digestible amino acid (AA) basis[1].

Dietary treatment [2]	Formulation method	Daily weight gain (g)	Daily feed intake (g)	Feed: gain (g: g)
1. Corn soybean meal		36.11 [a]	60.10 [a]	1.665 [b]
2. 5 % PBM C	Total AA	35.36 [a]	59.20 [a]	1.676 [ab]
3. 10 % PBM C	Total AA	33.53 [a]	59.07 [a]	1.759 [a]
4. 5 % PBM C	Digestible AA	35.79 [a]	59.68 [a]	1.668 [b]
5. 10 % PBM C	Digestible AA	34.92 [a]	60.78 [a]	1.740 [ab]
SEM		1.13	1.28	0.02

[a–b] Means within a column with no common superscript differ significantly ($P < 0.05$).[1] Means of four groups of seven male chicks from 8 to 21 d posthatching; average initial weight was 107.5 g.[2] All diets supplied 21.5% CP and 3200 Kcal TMEn/kg.

have also shown that formulation of poultry diets on a digestible AA basis is superior to formulation on a total AA basis when using ingredients that have AA digestibilities contents lower than those in corn and SBM.

The results of this study further confirm earlier studies (Main and Doghir, 1981, 1982; Escalano and Pesti, 1986; Pesti, 1987; Han and Parsons, 1990; Hassanabadi et al., 2008) that PBM has substantial nutritional value for poultry; however, the nutritional quality may vary greatly among samples. Moreover, our results indicate that formulation of poultry diets containing PBM on a digestible AA basis is superior to formulation of diets on a total AA basis. Thus, as much as 10% of PBM could be included in chick diets with no detrimental effects on performance if the diets were formulated to contain adequate levels of digestible AA.

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