IJAS Iranian Journal of Applied Animal Science

Dietary Formulation with Poultry by-Product Meal on a Total Amino Acid *vs*. a Digestible Amino Acid Basis

Research Article

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Received on: 11 Dec 2013
Revised on: 11 Feb 2014
Accepted on: 15 Feb 2014
Online Published on: Dec 2014

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Online version is available on: www.ijas.ir

ABSTRACT

Previous results indicated that performance of chicks fed a high level (10%) of poultry by-product meal (PBM) was lower than performance of chicks fed a corn-soybean meal (SBM) diet. The latter difference was hypothesized to be due to variation in digestible amino acid (AA) levels among the diets. This study evaluated diets containing PBM formulated on equivalent total AA basis *vs*. an equivalent digestible AA basis compared to a corn-SBM diet. In this study, 7 days old male chicks were fed from 8 to 21 and 21 to 42 days of age with a corn-SBM diet or diets containing 5 or 10% PBM formulated to be equal in total or digestible AA to the corn-SBM diet. From 8 to 21 days post hatch, chicks fed 10% PBM diet formulated on a total AA basis had significantly lower ($P<0.05$) feed efficiency than chicks consuming the corn-SBM diet. However, formulating diets containing 5 or 10% PBM on a digestible AA basis yielded growth performance equivalent to chicks fed the corn-SBM diet. From 21 to 42 days of age, chicks fed diets containing 5 or 10% PBM formulated on a total AA had significantly lower ($P<0.05$) weight gain and feed efficiency than chicks consuming the corn-SBM diet. Diets containing PBM formulated on a digestible AA yielded growth performance equivalent to chicks fed the corn-SBM diet. The results of this study indicated that formulation of diets containing PBM on a digestible AA basis is superior to formulation on a total AA basis and that 10% inclusion of PBM in chick diets had no detrimental effects on performance if the diets were formulated to contain adequate levels of digestible AA.

KEY WORDS amino acid digestibility, chick, poultry by-product meal.

INTRODUCTION

The emphasis of feed formulation is to most economically provide nutrients such as energy and amino acids (AA) in amounts that meet the requirements of animals from ingredients that are available. Many feed ingredients used in poultry production can vary in nutrient content and digestibility (Parsons *et al*. 1997; Spiehs *et al*. 2002). One of the most important nutrients in diet formulations is protein or AA. Requirements of AA are often based on the total analytical levels of AA in feed ingredients; however, the amounts of total AA contained in feed ingredients are often much higher than the amounts that are digestible (NRC, 1994). Consequently, formulation of poultry diets based on digestible AA should be superior to formulation based on total AA. The latter has been shown in a limited number of studies (Fernandez *et al*. 1995; Rostagno *et al*. 1995). Further work showed that PBM has substantial nutritional value for poultry; however, the nutritional quality may be variable (Main and Doghir, 1981; Main and Doghir, 1982; Han and Parsons, 1990; Elkin, 2002). We have previously shown that the digestibility of AA varies among PBM due to processing systems and temperatures (Jafari *et al*. 2011). Previous work showed that dietary inclusion of 5% PBM

did not significantly affect chick growth in comparison to the corn-SBM diet (Gohl, 1981; Escalona and Pesti, 1987; Hassanabadi *et al*. 2008). However, with a higher inclusion rate of 10 or 15% PBM in those studies, growth and feed efficiency were decreased below that of chicks fed a corn-SBM diet. The 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, because all diets were formulated on a total AA basis and the digestibilities of the AA in the PBM were found to be substantially lower than those in corn and soybean meal (NRC, 1994). Therefore, the objective of this study was to evaluate the performance of chicks fed diets containing 5 or 10% PBM formulated on a total AA basis versus a digestible AA basis in comparison with a corn-SBM diet from 8 to 21 and 21 to 42 days of age.

MATERIALS AND METHODS

Ingredient analyses

The PBM was obtained from commercial rendering plants and contains feathers, blood and viscera, processed using continuous cooking system under pressure in an attempt to hydrolyze of the feathers and increase their digestibility. PBM sample were analyzed for dry matter (DM), N, ether extract (EE), ash, Ca, and P according to the procedures of the AOAC. (2000). AA concentrations in the PBM were determined using ion-exchange chromatography following hydrolysis in 6 N HCl for 22 h at 110 ˚C (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 the excess of performic acid. The chemical compositions of the PBM are presented in Table 1. The true metabolizable energy corrected to zero nitrogen balance (TMEn) and true digestible AA coefficients of the PBM were determined using the precision-fed cecectomized rooster assay (Parsons, 1985). 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 assays

Seven days 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% crude protein (CP) corn-SBM pretest diet during the first 7 days post hatching.

Following an overnight period without feed, the chicks were weighed, wing-banded, and allotted to dietary treatments as described by Sasse and Baker (1973).

Table 1 Chemical composition of poultry by-product meal[1]

Components	(%)
Moisture	9.16
Crude protein	50.48
Crude fat	22.80
Ash	10.65
Calcium	1.80
Phosphorus	1.57
Amino acids[2]	
Asp	3.90 (1.91)
Thr	1.95 (1.13)
Ser	2.54 (2.81)
Glu	5.65 (3.40)
Ala	2.83 (1.90)
Cys	0.95 (0.44)
Val	2.73 (1.60)
Met	0.97 (0.64)
Ile	2.14 (1.71)
Leu	3.97 (2.80)
Tyr	1.53 (1.03)
Phe	3.12 (2.50)
His	1.17 (0.84)
Lys	1.86 (1.18)
Arg	3.17 (2.49)
TMEn (kcal/g)	3.254

[1] Expressed on air-dry basis.
[2] Values not in parentheses are total amino acid concentrations; values in parentheses are digestible amino acid concentrations. Digestible amino acid values were determined using the precision fed cecectomized rooster assay, with four roosters per sample.

Chick assay was conducted to evaluate growth performance of chicks fed diets containing 5 or 10% PBM formulated on a total or digestible AA basis compared to a corn-SBM diet from 8 to 21 (Table 2) and 21 to 42 days of age (Table 3). The analytical values for the PBM in Table 1 and NRC (1994) table's values for corn and SBM were used for the diet formulations. The diets containing PBM 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% (8 to 21 days) or 20% (21 to 42 days) crude 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 and 21 to 42 days post hatching.

Statistical analysis

Data from chick assay was subjected to ANOVA for completely randomized designs using SAS® (SAS, 1996). Statistical significance of differences among treatments was assessed using the Duncan's test (Steel and Torrie, 1980).

Table 2 Composition of diets containing poultry by-product meal (PBM) formulated on a total or digestible amino acid base from 8 to 21 days of age

Ingredient and composition	Level of PBM					
	0% PBM[1]	5% PBM[1]	10% PBM[1]	0% PBM[2]	5% PBM[2]	10% PBM[2]
	(%)					
Corn grain, ground	52.39	55.47	58.59	52.39	55.56	58.75
Soybean meal (44% CP)	38.43	31.96	25.44	38.43	31.85	25.21
PBM	0.00	5.00	10.00	0.00	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]						
TMEn (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. Diets containing 0% PBM based on total or digestible AA was same diet, alone the digestibility of AA was different.
[3] Provided per kilogram of diet: vitamin A: 9000 IU; vitamin E: 18 IU; vitamin B_{12}: 0.015 mg; Cholecalciferol: 2000 IU; Riboflavin: 6.6 mg; D-pantothenic acid: 10 mg; Niacin: 30 mg and 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 and Selenium: 0.2 from sodium selenite.
[5] All values except corn and soybean meal were analyzed values. The values for corn and SBM were derived from the NRC (1994).

RESULTS AND DISCUSSION

From 8 to 21 days of age, weight gain and daily feed intake of chicks were similar among all treatments (Table 4). Feed efficiency of chick fed diets containing 5% PBM on a total or digestible AA basis was not significantly different (P>0.05) than the chicks fed with the corn-SBM diet. Dietary inclusion of 10% PBM 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 on a digestible AA basis was not significantly different (P>0.05) than the chicks fed with the corn-SBM diet. Other research also showed that chick growth was not affected by dietary inclusion level of 5% PBM in comparison with corn-SBM diet, especially in chicks less than 21 days of age (Gohl, 1981; Escalona and Pesti, 1987; Hassanabadi *et al*. 2008).

However, higher inclusion level of PBM (10 or 15%) on a total AA in those studies, decreased performance below that of chicks fed with the corn-SBM diet, because the digestibilities of the AA in the PBM were lower than those in corn and SBM (Table 1). From 21 to 42 days of age, chicks fed diets containing 5 or 10% PBM on a total AA basis depressed weight gain and feed efficiency (P<0.05) compared to the corn-SBM diet; however chick performance fed diets containing 5 or 10% PBM on a digestible AA basis were not significantly different (P>0.05) than those of chicks fed the corn-SBM diet (Table 5).

Also single degree of freedom contrasts for feed efficiency from 21 to 42 days of age for diets containing PBM on a digestible AA bases *vs*. their corresponding total AA diets were significant (P<0.05). At 8 to 42 days of age, weight gain and daily feed intake of chicks were similar among all treatments.

Table 3 Composition of diets containing poultry by-product meal (PBM) formulated on a total or digestible amino acid base from 21 to 42 days of age

Ingredient and composition	Level of PBM					
	0% PBM[1]	5% PBM[1]	10% PBM[1]	0% PBM[2]	5% PBM[2]	10% PBM[2]
	(%)					
Corn grain, ground	58.54	61.44	64.57	58.54	61.56	64.76
Soybean meal (44 % CP)	34.04	27.76	21.23	34.04	27.59	20.96
PBM	0.00	5.00	10.00	0.00	5.00	10.00
Soybean oil	3.62	2.4	1.12	3.62	2.36	1.05
Dicalcium phosphate	1.24	0.96	0.67	1.24	0.96	0.67
Ground limestone	1.55	1.5	1.44	1.55	1.50	1.44
Iodized salt	0.34	0.29	0.24	0.34	0.29	0.24
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	0.1	0.10	0.10	0.10	0.10
L-Lys HCL	-	-	0.09	-	0.04	0.16
DL-Met	0.07	0.05	0.04	0.07	0.10	0.12
Calculated or analytical composition[5]						
TMEn (kcal/kg)	3200	3200	3200	3200	3200	3200
Crude protein	20.00	20.00	20.00	20.00	20.00	20.00
Crude fat	6.08	6.08	6.02	6.08	5.96	6.04
Calcium	0.90	0.90	0.90	0.9	0.9	0.9
Avail. phosphorus	0.40	0.40	0.40	0.4	0.4	0.4
Sodium	0.15	0.15	0.15	0.15	0.15	0.15
Arg	1.29	1.27	1.23	1.16	1.11	1.06
His	0.78	0.78	0.77	0.71	0.7	0.69
Ile	1.08	1.08	1.07	0.99	0.98	0.96
Leu	1.99	2.00	2.01	1.81	1.79	1.75
Lys	1.00	1.00	1.00	0.90	0.90	0.90
Met + Cys	0.72	0.72	0.72	0.67	0.67	0.67
Phe + Tyr	2.03	2.03	2.02	1.83	1.81	1.78
Thr	0.76	0.76	0.76	0.68	0.67	0.65
Val	1.18	1.2o0	1.22	1.08	1.07	1.04
Trp	0.28	0.26	0.23	0.26	0.24	0.22

[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. Diets containing 0% PBM based on total or digestible AA was same diet, alone the digestibility of AA was different.
[3] Provided per kilogram of diet: vitamin A: 9000 IU; vitamin E: 18 IU; vitamin B_{12}: 0.015 mg; Cholecalciferol: 2000 IU; Riboflavin: 6.6 mg; D-pantothenic acid: 10 mg; Niacin: 30 mg and 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 and Selenium: 0.2 from sodium selenite.
[5] All values except corn and soybean meal were analyzed values. The values for corn and SBM were derived from the NRC (1994).

Table 4 Performance of chicks fed a corn-soybean meal (SBM) diet or diets containing poultry by-product meal (PBM) formulated on a total or digestible AA basis from 8 to 21 days of age[1]

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

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
[1] Means of four groups of seven male chicks from 8 to 21 days post hatching; average initial weight was 107.5 g.
[2] All diets supplied 21.5% CP and 3200 kcal TMEn/kg.
[3] Single degree of freedom contrasts were not significant (P>0.05) for feed efficiency for treatments 2 and 3 *vs*. 4 and 5.
SEM: standard error of the means.

Feed efficiency of chicks fed diets containing PBM on a digestible AA was better than those of chicks fed the diets based on total AA (Table 6). However, feed efficiency of diet containing 10% PBM on a digestible AA basis still yielded performance that was inferior to the corn-SBM diet.

The explanation for the latter differences is unknown, but there are several possible reasons. First, the true digestibility assay may have overestimated the amounts of Met, Cys or Lys that were bioavailable for protein synthesis, particularly in early age of chicks (to 21 days of age).

Table 5 Performance of chicks fed a corn-soybean meal (SBM) diet or diets containing poultry by-product meal (PBM) formulated on a total or digestible AA basis from 21 to 42 days of age[1]

Dietary treatment[2]	Formulation method	Daily weight gain (g)	Daily feed intake (g)	Feed: gain (g:g)[3]
1. Corn-SBM	-	77.07[a]	148.8	1.931[a]
2. 5 % PBM	Total AA	70.05[b]	144.5	2.064[b]
3. 10 % PBM	Total AA	70.08[b]	146.9	2.097[b]
4. 5 % PBM	Digestible AA	75.83[ab]	146.7	1.935[a]
5. 10 % PBM	Digestible AA	74.99[ab]	149.1	1.988[a]
Pooled SEM	-	1.98	3.3	0.02

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
[1] Means of four groups of seven male chicks from 21 to 42 days post hatching.
[2] All diets supplied 20% CP and 3200 kcal TMEn/kg.
[3] Single degree of freedom contrasts were significant (P<0.05) for feed efficiency for treatments 2 and 3 *vs*. 4 and 5.
SEM: standard error of the means.

Table 6 Performance of chicks fed a corn-soybean meal (SBM) diet or diets containing poultry by-product meal (PBM) formulated on a total or digestible AA basis from 8 to 42 days of age[1]

Dietary treatment	Formulation method	Daily weight gain (g)	Daily feed intake (g)	Feed: gain (g:g)[2]
1. Corn-SBM	-	60.68	113.35	1.868[a]
2. 5 % PBM	Total AA	56.18	110.39	1.966[bc]
3. 10 % PBM	Total AA	55.46	111.78	2.017[c]
4. 5 % PBM	Digestible AA	59.81	111.90	1.871[a]
5. 10 % PBM	Digestible AA	58.97	113.67	1.930[b]
Pooled SEM	-	1.41	2.25	0.02

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
[1] Means of four groups of seven male chicks from 8 to 42 days post hatching.
[2] Single degree of freedom contrasts were significant (P<0.05) for feed efficiency for treatments 2 and 3 *vs*. 4 and 5.
SEM: standard error of the means.

Batterham (1992) and Fernandez and Parsons (1996) reported that AA digestibility assays may overestimate AA bioavailability in some cases. Second, the precision fed rooster assay may have overestimated the TMEn value of the PBM for chicks relative to the corn and SBM. The explanation seems possible, because the differences in performance from the PBM diets *vs*. the corn-SBM diet were much greater for feed efficiency than for growth. Other studies also showed that the AA digestibility values for some ingredients that determined by rooster assay had greater than those determined by standardized ileal amino acid digestibility assay in broilers (Garcia *et al*. 2007; Adedokun *et al*. 2009; Kim *et al*. 2011).

However, the single degree of freedom contrasts from 8 to 42 days of age for diets containing PBM on a digestible AA bases *vs*. their corresponding total AA diets were significant (P<0.05) for feed efficiency, further indicating that formulation of diets based on digestible AA yielded better growth performance than the formulation of diets based on total AA.

CONCLUSION

Therefore, it seems that formulating diets containing 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. Moreover, our results indicate that up to 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. Previous studies on cottonseed meal (Fernandez *et al*. 1995), PBM and feather meal (Rostagno *et al*. 1995) 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.

ACKNOWLEDGEMENT

We wish to thank Dr. Ghahri (assistant professor of Islamic Azad University of Urmia branch) for providing research facilities for this investigation.

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