Effects of Overprocessing on the Nutritional Quality of Peanut Meal

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ABSTRACT Two experiments were conducted to evaluate the effects of overprocessing by autoclaving on the *in vivo* protein quality and *in vitro* protein solubility in 0.2% KOH of solvent-extracted peanut meal containing 48% protein. The peanut meal was autoclaved at 120 C and 105 kPa for 0, 20, 30, 40, 50, 60, or 90 min. *In vivo* protein quality of the autoclaved peanut meal was evaluated in chicks fed corn-peanut meal diets (22.5% protein) from 8 to 22 d of age and in adult cecectomized roosters using a precision-fed amino acid digestibility assay. Chick performance was significantly decreased when peanut meal had been autoclaved ($P < 0.05$) 60 min or more in one experiment and by 40 min or more in the other experiment. True digestibility of amino acids in peanut meal also decreased as autoclaving time increased. The effect of autoclaving was greatest for lysine, wherein digestibility was 87, 72, 68, and 57% for peanut meal autoclaved for 0, 30, 60, or 90 min, respectively. Protein solubility of peanut meal in 0.2% KOH decreased from 78 to 56% as autoclaving time increased from 0 to 90 min. Protein solubility values of 70% or lower were indicative of decreased *in vivo* peanut meal quality. The results of this study indicated that overprocessing by autoclaving reduces the protein quality of peanut meal and that protein solubility in KOH is a useful *in vitro* index of overprocessing.

(*Key words*: peanut meal, protein solubility, amino acid digestibility, chick, poultry)

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INTRODUCTION

Peanut meal (PNM) is a feed ingredient often used in poultry rations in many countries. Peanut meal protein is deficient in Lys and Met (Grau, 1946; Driggers and Tarver, 1958; Douglas and Harms, 1959; Anderson and Warnick, 1965) and possibly other amino acids (Waldroup and Harms, 1963). As reported by Heuser *et al.* (1946), Driggers and Tarver (1958), and Carew *et al.* (1988), high levels of PNM can be used successfully in broiler chicken diets if adequate levels of dietary Lys and Met are provided. However, Douglas and Harms (1959) and Waldroup and Harms (1963) reported that amino acid-supplemented PNM diets yielded chick performance that was generally inferior to that obtained with a corn-soybean meal diet. The latter authors further reported that protein quality varied between two different samples of PNM.

The inconsistency in response among studies to the use of PNM may be related to the protein quality of the PNM used. Peanuts are crushed industrially for oil and cake by hydraulic prepressing, continuous horizontal screw-pressing (expelling), or prepress solvent extraction (Rosen, 1958). Because the processing involves heating, it is possible that the protein quality of PNM could be reduced in some instances due to overcooking. It has been shown that excess heating of oilseed meals such as soybean meal, canola meal, and sunflower meal decreases *in vivo* availability of some amino acids, particularly Lys (Hancock *et al.*, 1990; Parsons *et al.*, 1992; Anderson-Hafermann *et al.*, 1993; Zhang and Parsons, 1994). Thus, overprocessing of PNM could greatly affect its nutritional value, especially because PNM protein is very deficient in Lys.

Protein solubility in KOH has been reported to be a good indicator of reduced protein quality in overprocessed soybean meal (Araba and Dale, 1990; Parsons *et al.*, 1991) and also is useful for detecting overprocessed canola meal (Anderson-Hafermann *et al.*, 1993) and sunflower meal (Zhang and Parsons, 1994). However, its usefulness as an indicator of protein quality for overprocessed PNM has not been evaluated. The objectives of the present study were to determine the effect of overprocessing on *in vivo* protein quality of PNM and the usefulness of protein solubility in KOH as an indicator of reduced *in vivo* protein quality due to overprocessing of PNM.

MATERIALS AND METHODS

The peanut meal used in all experiments was obtained as a single batch from a commercial solvent extraction processing plant.[2] For overprocessing of the

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PNM, a thin layer (1.25 cm in depth) was placed on metal trays, covered tightly with aluminum foil, and autoclaved at 121 C and 105 kPa for increasing amounts of time from 0 to 90 min.

Protein solubility of the unautoclaved and autoclaved PNM in 0.2% KOH was determined by the method described by Parsons *et al.* (1991). Amino acid concentrations in the PNM and excreta from the digestibility trials described below were determined in duplicate or triplicate using ion-exchange chromatography[3] following hydrolysis in 6 *N* HCl for 22 h at 110 C (Spackman *et al.*, 1958). Analyses of Met and Cys were conducted separately following performic acid oxidation by the method of Moore (1963), except that samples were diluted with water and lyophilized to remove excess performic acid following the 16-h oxidation period. Crude protein levels were determined by the macro-Kjeldahl method (Association of Official Analytical Chemists, 1980).

Experiments 1 and 2 were conducted to evaluate the effect of overprocessing on *in vivo* protein quality of PNM for chicks and to evaluate the KOH assay as an indicator of overprocessing. Male chicks, obtained by crossing New Hampshire males and Columbian Plymouth Rock females, were housed in thermostatically controlled starter batteries with raised wire floors and provided with water and feed for *ad libitum* consumption. Uniform light was provided 24 h/d. The chicks were fed a 23% CP corn-soybean meal diet during the first 7 d posthatching. After being deprived of feed overnight, chicks were weighed, wing-banded, and assigned to dietary treatments by the procedure of Sasse and Baker (1974).

In Experiment 1, corn-PNM diets containing 22.5% CP (Table 1) were prepared from PNM autoclaved for 0, 30, 60, or 90 min. In Experiment 2, corn-PNM diets were prepared from PNM autoclaved for 0, 20, 30, 40, 50, or 60 min. The corn-PNM diets were formulated to be slightly deficient in Lys (1.00%) to increase sensitivity for detecting adverse effects of overprocessing on protein quality of PNM. Each of the diets in both experiments was fed to three replicate groups of five male chicks from 8 to 22 d posthatching. Body weight and feed intake of each replicate group were measured at the termination of the experiments, and weight gain and feed efficiency (gain:feed ratio) were calculated.

Experiment 3 was conducted to determine the true digestibilities of amino acids in PNM autoclaved for 0, 30, 60, or 90 min. The precision-fed cockerel assay of Sibbald (1986), with some modifications, was used for determining the digestibility values. At 25 wk of age, Single Comb White Leghorn cockerels were cecectomized as previously described (Parsons, 1985) and were not used in digestibility trials for at least 8 wk following surgery. The birds were housed in individual cages with raised wire floors in an environmentally regulated room having a 24-h light photoperiod. Feed and water were provided for *ad libitum* consumption except when the birds were used in a digestibility assay. Following 24 h of feed deprivation, five cockerels were given 30 g of a PNM sample via crop intubation. To estimate endogenous amino acid excretion, the same number of cockerels were deprived of feed for the duration of the digestibility assay. Excreta were quantitatively collected on plastic trays placed under each cage for 48 h. The excreta were frozen, lyophilized, weighed, ground to pass through a 60-mesh screen, and analyzed for amino acid content as described previously. True digestibility of amino acids was calculated by the method of Sibbald (1979), with digestibility referring to the amount of dietary amino acid not appearing in the feces plus urine.

The chick performance data, amino acid digestibility values, and KOH protein solubility values obtained in the experiments were analyzed by ANOVA for completely randomized designs (Steel and Torrie, 1980) using algorithms generated by the SAS Institute (1982). Differences among treatment means were assessed using the least significant difference test (Steel and Torrie, 1980). Regression analysis was also used to evaluate the chick performance response to autoclaving of PNM (Steel and Torrie, 1980).

TABLE 1. Composition of the corn-peanut meal basal diet

Ingredients and analysis	Percentage
Peanut meal (47.8% CP)	36.06
Corn (8.0% CP)	59.48
Dicalcium phosphate	1.39
Ground limestone	1.62
Choline·Cl (60%)	0.10
Iodized salt	0.40
Vitamin premix[1]	0.20
Trace mineral premix[2]	0.15
L-Lys·HCl	0.29
DL-Methionine	0.26
L-Threonine	0.05
Analysis[3]	
CP	22.5
ME_n, kcal/kg	2,800
Methionine + cystine	0.90
Lys	1.00
Ca	1.00
Available P	0.45

[1]Provided per kilogram of diet: vitamin A (as retinyl A acetate), 4,400 IU; cholecalciferol (as activated animal sterol), 1,000 IU; vitamin E (as DL-α-tocopheryl acetate), 11 IU; vitamin B_{12}, 0.01 mg; riboflavin, 4.41 mg; d-pantothenic acid, 10 mg; niacin, 22 mg; menadione sodium bisulfite, 2.33 mg.

[2]Provided as milligrams per kilogram of diet: manganese, 75 from manganese oxide; iron, 75 from iron sulfate; zinc, 75 from zinc oxide; copper, 5 from copper sulfate; iodine, 0.35 from ethylene diamine dihydroiodide; selenium, 0.2 from sodium selenite.

[3]Crude protein is based on analytical values. Amino acids, ME_n, Ca, and available P values are calculated values based on table values from the National Research Council (1984).

[3]Beckman Model 6300 amino acid analyzer, Beckman Instruments Corp., Palo Alto, CA 93402.

TABLE 2. Effect of autoclaving peanut meal on chick performance and protein solubility, Experiment 1

Diet	Autoclaving time	Weight gain[1,2]	Gain:feed ratio[1,2]	Protein solubility[2,3]
	(min)	(g)	(g:g)	(%)
Corn-peanut meal, 22% CP	0	277[a]	0.569[a]	78[a]
	30	263[a]	0.564[a]	71[b]
	60	240[b]	0.525[b]	66[c]
	90	198[c]	0.475[c]	56[d]
Pooled SEM		4.5	0.013	1.0

[a-d]Means within a column with no common superscript differ significantly ($P < 0.05$).

[1]Values are means of three replicate groups of five male chicks from 8 to 22 d of age; average initial weight was 85.8 g.

[2]Linear effect of autoclaving ($P < 0.001$).

[3]Solubility of peanut meal protein in 0.2% KOH. Values are means of triplicate analyses.

RESULTS

Increasing autoclaving time in Experiment 1 resulted in a linear decrease ($P < 0.05$) in weight gain, feed efficiency, and protein solubility (Table 2). In comparison to the unautoclaved PNM, autoclaving for 60 min or more significantly reduced ($P < 0.05$) weight gain and feed efficiency. Protein solubility decreased as PNM was autoclaved for 30 min, and autoclaving for 60 and 90 min each caused further reductions ($P < 0.05$) in protein solubility. Compared with the unautoclaved PNM, the reductions at 90 min were 29, 17, and 28% for weight gain, feed efficiency, and protein solubility, respectively.

Experiment 2 was conducted to determine the effect of autoclaving times intermediate to those used in Experiment 1. Autoclaving PNM for 40, 50, or 60 min reduced chick performance ($P < 0.05$) to a similar extent (Table 3). Protein solubility in 0.2% KOH decreased linearly from 0 to 40 min. No further reduction in protein solubility was observed at 50 and 60 min of autoclaving.

The effect of autoclaving time on total amino acid concentrations in PNM is shown in Table 4. Ninety minutes of autoclaving reduced the Lys concentration by 24% below that obtained for the unautoclaved meal ($P < 0.05$). Autoclaving had much less effect on the concentration of the other amino acids, although the Arg concentration was reduced by 12% from 90 min of autoclaving. The average reductions for amino acids other than Lys when PNM was autoclaved for 30, 60, or 90 min were 3, 3, and 4%, respectively, compared with 10, 16, and 24% for Lys, respectively.

As shown in Table 5, the true digestibility of Lys, expressed as a proportion of the analyzed Lys in the unautoclaved PNM, decreased markedly ($P < 0.05$) for each 30-min increase in autoclaving time (Experiment 3). The largest decrease occurred for the first 30 min of autoclaving. The digestibility of the analyzed Lys remaining after autoclaving was also significantly decreased as autoclaving time increased ($P < 0.05$). The effects of autoclaving on digestibility of most other

TABLE 3. Effect of autoclaving peanut meal on chick performance and protein solubility, Experiment 2

Autoclaving time	Weight gain[1]	Gain:feed ratio[1]	Protein solubility[2]
(min)	(g)	(g:g)	(%)
0	284[a]	0.580[a]	78[a]
20	287[a]	0.574[a]	75[b]
30	291[a]	0.583[a]	71[c]
40	273[b]	0.551[b]	67[d]
50	272[b]	0.547[b]	68[d]
60	265[b]	0.549[b]	67[d]
Pooled SEM	3.4	0.008	0.9

[a-d]Means within a column with no common superscript differ significantly ($P < 0.05$).

[1]Values are means of three replicate groups of five male chicks from 8 to 22 d of age; average initial weight was 91.4 g.

[2]Solubility of peanut meal protein in 0.2% KOH. Values are means of triplicate analyses.

TABLE 4. Effect of autoclaving on analyzed amino acid concentrations in peanut meal[1]

Amino acid	Minutes autoclaved 0	30	60	90
	(%)			
Aspartic acid	6.36	6.15	6.15	6.30
Threonine	1.31	1.31	1.32	1.31
Serine	2.56	2.42	2.42	2.42
Glutamic acid	10.15	10.08	10.12	10.10
Proline	2.12	2.00	2.01	1.99
Glycine	2.88	2.81	2.85	2.84
Alanine	1.91	1.89	1.90	1.90
Cystine	0.69	0.67	0.66	0.69
Valine	1.91	1.72	1.75	1.73
Methionine	0.47	0.46	0.47	0.48
Isoleucine	1.60	1.44	1.47	1.47
Leucine	3.10	3.01	3.01	3.03
Tyrosine	1.42	1.48	1.44	1.44
Phenylalanine	2.35	2.28	2.29	2.80
Histidine	1.10	1.05	1.04	1.03
Lysine	1.66	1.49	1.39	1.26
Arginine	5.90	5.60	5.43	5.19

[1]90% DM basis. Amino acid analyses performed in triplicate; mean coefficient of variation for amino acid analyses within samples was 3.5%.

TABLE 5. Effect of autoclaving on true digestibility of amino acids in peanut meal, Experiment 3[1]

Amino acid	Minutes autoclaved 0	30	60	90	Pooled SEM
	(%)				
Lysine	87[a] (87[a])[2]	72[d] (83[b])	68[e] (81[b])	57[f] (76[c])	1.3
Threonine	88[a]	80[b]	78[b]	76[b]	1.5
Cystine	75[a]	67[ab]	67[ab]	60[b]	3.0
Valine	96[a]	88[b]	88[b]	85[c]	1.0
Methionine	81	76	76	78	3.0
Isoleucine	96[a]	88[b]	88[b]	85[c]	0.9
Leucine	96[a]	95[a]	94[ab]	92[b]	0.9
Phenylalanine	95[a]	89[b]	89[b]	87[b]	1.3
Histidine	88[a]	84[bc]	85[b]	82[c]	1.1
Arginine	89[a]	80[b]	78[b]	74[c]	1.3

[a–f]Means within a row with no common superscript differ significantly ($P < 0.05$).

[1]Values are means of five individual cecectomized cockerels expressed as a percentage of the analyzed amino acid content in the unautoclaved peanut meal.

[2]Values in parentheses are digestibility of lysine expressed as a percentage of the analyzed lysine in peanut meal remaining after autoclaving.

amino acids were significant but less than those observed for Lys. Digestibility of Thr, Val, Ile, Phe, His, and Arg were significantly decreased at 30 min of autoclaving. Digestibility of Val, Ile, and Arg were reduced further ($P < 0.05$) at 90 min of autoclaving. Digestibility of Cys and Leu were significantly decreased at 90 min of autoclaving. Met digestibility was not significantly affected ($P > 0.05$), even with 90 min of autoclaving.

DISCUSSION

The results herein showed that overprocessing by autoclaving markedly influences *in vivo* protein quality of PNM. Overprocessing decreased both growth performance of chicks and digestibility of amino acids in adult cockerels. The greater effects of overprocessing on Lys than on other amino acids is in agreement with recent studies on soybean meal (Parsons *et al.*, 1992), canola meal (Anderson-Hafermann *et al.*, 1993), and sunflower meal (Zhang and Parsons, 1994). Much of the reduction in digestible Lys can probably be attributed to Maillard reaction products formed during autoclaving (Hurrell, 1990). The large decreases in analyzed Lys by autoclaving indicated Lys destruction, probably due to formation of advanced Maillard reaction products. The latter situation may have also occurred for arginine because its analyzed concentration was also reduced as autoclaving time increased. The reduced digestibility of the analyzed Lys remaining after autoclaving further suggested that early Maillard reaction products were also formed. The latter products are recoverable during amino acid analysis (acid hydrolysis and ion-exchange chromatography) but are not available for *in vivo* protein synthesis (Carpenter, 1973). Many of the early Maillard reaction products can be absorbed intestinally but then are often excreted unchanged in the urine (Hurrell, 1990).

The present study clearly showed that protein solubility in KOH decreased as PNM was overcooked by autoclaving. Similar results have been reported for soybean meal (Araba and Dale, 1990; Parsons *et al.*, 1991), canola meal, (Anderson-Hafermann *et al.*, 1993), and sunflower meal (Zhang and Parsons, 1994). The effect of autoclaving on protein solubility of PNM was somewhat less than that observed previously in our laboratory for soybean meal (Parsons *et al.*, 1991). The difference probably resulted because the PNM was autoclaved while covered tightly with aluminum foil, whereas the soybean meal was autoclaved uncovered in the earlier study. The results of the present study indicated that protein solubility in KOH is a useful index of overprocessing of PNM, and protein solubility values of approximately 70% or lower are indicative of overprocessed PNM. This critical limit is similar to that for soybean meal (Araba and Dale, 1990).

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