Nutritional Evaluation of Dried Tomato Seeds

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ABSTRACT Two samples of tomato seeds, a by-product of the tomato canning industry were evaluated to determine proximate analysis, amino acid content, and digestibility, TME_n, and protein efficiency ratio. Tomato seeds were also used to replace corn and soybean meal (SBM) in a chick diet on an equal true amino acid digestibility and TME_n basis. Tomato seeds were found to contain 8.5% moisture, 25% CP, 20.0% fat, 3.1% ash, 35.1% total dietary fiber, 0.12% Ca, 0.58% P, and 3,204 kcal/kg of TME_n. The total amounts of methionine, cystine, and lysine in the tomato seeds were 0.39, 0.40, and 1.34%, respectively, and their true digestibility coefficients, determined in cecectomized roosters, were 75, 70, and 54%, respectively. The protein efficiency ratio (weight gain per unit of protein intake) value when fed to chicks at 9% CP was 2.5 compared to 3.6 for SBM ($P \leq 0.05$). When corn-SBM diets were formulated on an equal true amino acid digestibility and TME_n basis, up to 15% tomato seeds could replace corn and SBM without any adverse affects on chick weight gain, feed intake, or gain:feed ratio from 8 to 21 d posthatch. Tomato seeds at any level in the diet did not significantly affect skin pigmentation. Although the protein quality of tomato seeds may not be as high as SBM, tomato seeds do contain substantial amounts of digestible amino acids and TME_n. When formulating diets on a true digestible amino acid and TME_n basis, tomato seeds can be supplemented into chick rations at up to 15% without any adverse affects on growth performance.

(*Key words*: amino acid digestibility, metabolizable energy, poultry, tomato seed)

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INTRODUCTION

The USDA reported that nearly ten million tons of tomatoes were processed in the United States in 1997 (USDA, 2001). Approximately 10 to 30% of the raw weight is not used for human consumption and results in waste (Ben-Gera and Kramer, 1969; Geisman, 1981). Increasing environmental concerns and legislation have promoted research into alternate methods of tomato waste disposal. Of the one to three million tons of tomato waste produced each year in the United States, approximately 50% of that waste is in the form of tomato seeds (TS; Eggers and Geisman, 1976). Proximate analysis has shown appreciable amounts of nutrients to be found in TS (Carlson et al., 1981; Geisman, 1981; Brodowski and Geisman, 1980; Tsatsaronis and Boskou, 1975). Some studies have determined the feasibility of feeding tomato waste to poultry. Dried tomato pulp (skins, seeds, and core) was fed to laying hens at an inclusion rate of 12%, resulting in similar egg production, feed consumption, feed efficiency, egg weight, and shell thickness in comparison to hens fed a corn-soybean meal (SBM) control diet (Dotas et al., 1999). In another experiment, 8 or 15% tomato meal (undefined contents) was included in diets fed to laying hens without negative effects on hen weight, egg number, shell quality, egg shape index, feed consumption, and mortality, but yolk color score was significantly increased (Yannakopoulos et al., 1992). Squires et al. (1992) treated tomato cannery wastes (undefined contents) with heat, water, acid, and alkali without affecting performance when included at 10 or 20% in the diet in one experiment and showed increases in chick gain and feed efficiency with alkali treatment of tomato cannery waste in another experiment. Ammerman et al. (1965) substituted dried tomato pulp (dried whole tomatoes) for alfalfa meal at 3% in chick diets without adverse effects on growth performance and fat deposition, but did significantly reduce skin or shank color. Although tomato by-products have been evaluated in poultry production to a limited extent, little to no work has been carried out to determine the protein quality, amino acid (AA) digestibility, and TME_n of TS. Most of the previous studies only evaluated replacement of corn or SBM or both with tomato products, but none of those studies evaluated the replacement of corn and SBM with TS on an equal TME_n and true digestible AA basis. In addition, the previous studies evaluated tomato by-products varying in composition and not TS per se. Thus, it was the objective of these experiments to

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Abbreviation Key: AA = amino acids; NPR = net protein ratio; PER = protein efficiency ratio; SBM = soybean meal; TS = tomato seeds.

determine the protein quality (protein efficiency ratio and net protein ratio), true AA digestibility, and TME_n for cleaned, screened TS and to evaluate replacement of corn and SBM with TS on an equal TME_n and true digestible AA basis in chick diets.

Materials and Methods

Tomato Seeds

Two shipments of TS were obtained from Zacky Farms.[2] The seeds had been obtained by screening air-dried, mixed tomato waste to remove the majority of the tomato skins and other waste material at the processing plant. The seeds were then sent to our laboratory and subsequently ground in a Hammermill to pass through a 1-mm screen. Both shipments of TS were evaluated to determine proximate analysis, true AA digestibility, and TME_n, as described below. The first (Sample 1) and second (Sample 2) shipments of TS were also evaluated in the first and second chick assays, respectively, as described below.

Precision-fed Rooster Assays and Proximate Analysis

Both samples of TS were assayed for true amino acid digestibility and TME_n, using the precision-fed cecectomized rooster assay (Douglas et al., 1997). A subsample of the second TS sample was also assayed for TME_n using conventional roosters at the Pergamino poultry research station of the Instituto Nacional de Tecnologia Agropecuaria, Buenos Aires, Argentina, using the same procedure or method. Four roosters were tube-fed each TS sample in the rooster assays. The TS were analyzed for moisture content, CP, crude fat, ash, Ca, and P using methods of the AOAC (1980) and total dietary fiber by the method of Prosky et al. (1984).

Chick Experiments

Eight-day-old male chicks resulting from the cross of New Hampshire males and Columbian Plymouth Rock females were used in both chick experiments. Chicks were housed in an environmentally regulated room in thermostatically controlled starter batteries with raised wire floors. Feed and water were supplied ad libitum and continuous light was provided for the duration of the experiment. The chicks were fed a 23% CP corn-SBM pretest diet that met or exceeded all NRC (1994) nutrient requirements during the first 7 d posthatch. Following overnight fasting, the chicks were weighed, allotted to groups of five chicks so that mean BW of each group was similar, wing-banded, and allotted to dietary treatments as described by Boomgaardt and Baker (1971).

The first chick experiment was conducted to evaluate the protein quality of TS using protein efficiency ratio

[2]Traver, CA.

TABLE 1. Composition of the N-free basal diet, Experiment 1

Ingredient	Experiment 1
	(%)
Cornstarch	59.48
Dextrose	29.74
Soybean oil	5.00
Mineral mix[1]	5.37
Vitamin mix[2]	0.20
Choline·Cl	0.20
DL-Tocopheryl acetate	0.002
Ethoxyquin	0.0125

[1]Mineral mix provided the following (per kg of diet): $CaCO_3$, 3 g; $Ca_3(PO_4)$, 28 g; K_2HPO_4, 9 g; NaCl, 8.89 g; $ZnCO_3$, 0.1 g; $CuSO_4·H_2O$, 0.02 g; $MgSO_4·7H_2O$, 3.5 g; ferric citrate, 0.5 g; $MnSO_4·H_2O$, 0.65 g; H_3BO_3, 9 mg; $Na_2MoO_4·2H_2O$, 9 mg; KI, 40 mg; $CoSO_4·7H_2O$, 1 mg; Na_2SeO_3, 0.215 mg.

[2]Vitamin mix provided the following (per kg of diet); thiamin·HCl, 20 mg; niacin, 50 mg; riboflavin, 10 mg; D-Ca pantothenate, 30 mg; vitamin B_{12}, 0.04 mg; pyridoxine·HCl, 6 mg; D-biotin, 0.6 mg; folic acid, 4 mg; menadione dimethyl-pyridinol bisulfite, 2 mg; ascorbic acid, 250 mg; cholecalciferol, 15 μg; retinyl acetate, 1.789 μg.

(PER) and net protein ratio (NPR) values. A nitrogen-free diet was formulated (Table 1) with TS Sample 1 replacing the cornstarch/dextrose mixture to provide 0, 3, 6, and 9% CP. Soybean meal also replaced cornstarch/dextrose in the nitrogen-free diet to provide 9% CP, resulting in five dietary treatments. Diets 1 to 4 contained 0, 12.25, 24.50, and 36.75% TS, respectively, while Diet 5 contained 18.75% SBM. The five dietary treatments were fed to four replicate groups of five male chicks from 8 to 17 d posthatch. Individual chick weights and feeder weights were recorded at the beginning and end of the experimental period. Chick weight gain, feed intake, gain:feed ratio, PER, and NPR were calculated on a per pen basis. Protein efficiency ratio was calculated by the equation:

$$\text{PER} = \text{weight gain/protein intake.}$$

Net protein ratio was calculated by the equation:

$$\text{NPR} = (\text{weight gain} - \text{weight gain of chicks fed N-free diet})/\text{protein intake.}$$

The second chick experiment evaluated the replacement of corn and SBM in a corn/SBM basal diet with 0, 5, 10, 15, or 20% TS (Sample 2) on an equal TME_n and true digestible AA basis. The TME_n and digestible AA values used for the TS were those values determined in the conventional (Argentina) and cecectomized (Illinois) rooster assays, respectively, described earlier. For corn and SBM, CP was analyzed prior to initiation of the experiment (8.5% for corn, 46.3% for SBM), total AA concentrations and TME_n were estimated using tables of the NRC (1994) and digestible AA concentrations were calculated using the digestibility coefficients in Table 9-6 of the NRC (1994). All diets (Table 2) containing TS were formulated to be equal in digestible AA to the corn/SBM diet (0% TS) unless the digestible AA level exceeded NRC (1994) total AA requirements. The five diets were fed to six replicate groups of five male chicks from 8 to 21 d post-

TABLE 2. Composition of corn/soybean meal (SBM) diets containing tomato seeds (TS) formulated on an equal TME_n and digestible amino acid basis, Experiment 2[1]

Ingredient	Corn/SBM	5% TS	10% TS	15% TS	20% TS
	(%)				
Ground corn	55.32	52.46	49.70	46.85	44.10
Soybean meal	35.95	33.50	30.90	28.45	25.85
Tomato seeds	—	5.00	10.00	15.00	20.00
Soybean oil	4.40	4.40	4.40	4.40	4.40
Ground limestone	1.17	1.17	1.20	1.20	1.20
Dicalcium phosphate	2.04	2.05	2.00	2.00	2.00
Salt	0.40	0.40	0.40	0.40	0.40
Vitamin mix[2]	0.20	0.20	0.20	0.20	0.20
Trace mineral mix[3]	0.15	0.15	0.15	0.15	0.15
DL-Met	0.22	0.24	0.25	0.26	0.28
L-Lys·HCl	—	0.05	0.11	0.16	0.22
L-Thr	—	0.02	0.04	0.06	0.08
L-Val	—	0.01	0.05	0.07	0.10
L-Ile	—	—	0.01	0.04	0.06
L-Arg	—	—	—	—	0.03
Cellulose	—	0.20	0.44	0.61	0.78
Choline chloride	0.10	0.10	0.10	0.10	0.10
Bacitracin premix[4]	0.05	0.05	0.05	0.05	0.05
Calculated composition					
CP	21.5	21.5	21.5	21.5	21.5
Ca	1.00	1.00	1.00	1.00	1.00
Nonphytate P	0.50	0.50	0.50	0.50	0.50
Digestible Arg	1.34	1.31	1.28	1.26	1.26
Digestible His	0.53	0.51	0.49	0.47	0.45
Digestible Ile	0.85	0.82	0.81	0.81	0.80
Digestible Leu	1.75	1.69	1.62	1.56	1.49
Digestible Lys	1.08	1.08	1.08	1.08	1.08
Digestible Met + Cys	0.82	0.82	0.82	0.82	0.82
Digestible Phe + Tyr	1.75	1.68	1.61	1.54	1.46
Digestible Thr	0.73	0.73	0.73	0.73	0.73
Digestible Val	0.92	0.90	0.91	0.90	0.90
Digestible Trp	0.30	0.28	0.26	0.24	0.22
TME_n (kcal/kg)	3,200	3,200	3,200	3,200	3,200

[1]Diets containing TS (Sample 2, Tables 3 and 4) were formulated to be equal in digestible amino acids to the corn/SBM diet unless the digestible amino acid level exceeded NRC (1994) total amino acid requirements. The TME_n and digestible amino acid values used for the TS were those determined in conventional (Argentina) and cecectomized (Illinois) rooster assays, respectively. Corn and SBM samples were analyzed for CP prior to the experiment with the analyzed values, 8.5 and 46.3%, respectively, used to formulate diets.

[2]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.

[3]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.

[4]Bacitracin methylene disalacylate (5.5%).

hatch. Individual chick weights and feeder weights were recorded at the beginning and end of the experimental period. Chick weight gain, feed intake, and gain:feed were calculated on a per pen basis. At the end of the experiment, skin pigmentation was determined from the right shank of each chick by two individuals using a Roche color score fan.

Statistical Analysis

Data from both chick experiments were subjected to ANOVA for completely randomized designs using SAS software (SAS Institute, 1985). Statistical significance of differences among treatments was assessed using the least significant difference test (Steel and Torrie, 1980), with significance differences determined at ($P \leq 0.05$). Regression analysis was also used to determine linear and quadratic relationships in the chick experiments. For the rooster digestibility assays, a standard error was calculated for each mean value for TME_n and AA digestibility.

RESULTS AND DISCUSSION

The composition of the two TS samples is shown in Table 3. Both samples were found to contain approximately 25% CP. This level of CP is comparable to CP levels found by Liadakis et al. (1995), Latlief and Knorr (1983), Geisman (1981), and Tsatsaronis and Boskou (1975), but lower than values reported by Yaseen et al. (1991) and Carlson et al. (1981). The TS evaluated in our study were found to contain 20.0% fat, which was similar to some reports (Carlson et al., 1981; Liadakis et al., 1995) but lower than others (Tsatsaronis and Boskou, 1975;

TABLE 3. Chemical composition of tomato seeds[1]

Component	Sample 1	Sample 2
	(%)	
Moisture	7.4	9.6
CP	24.5	25.0
Crude fat	20.1	19.9
Ash	3.0	3.1
Total dietary fiber	33.9	36.3
Ca	0.110	0.112
P	0.577	0.580
Amino acids[2]		
Asp	2.79 (1.75)	2.40 (1.37)
Thr	0.90 (0.74)	0.73 (0.56)
Ser	1.28 (0.95)	1.16 (0.72)
Glu	5.01 (3.92)	4.29 (3.28)
Pro	1.29 (0.95)	1.44 (1.09)
Ala	1.11 (0.78)	1.12 (0.73)
Cys	0.43 (0.30)	0.37 (0.26)
Val	1.16 (0.83)	1.01 (0.65)
Met	0.44 (0.35)	0.34 (0.24)
Ile	1.04 (0.74)	0.89 (0.59)
Leu	1.66 (1.25)	1.41 (0.95)
Tyr	0.98 (0.57)	0.82 (0.25)
Phe	1.25 (1.07)	1.04 (0.90)
His	0.61 (0.42)	0.49 (0.34)
Lys	1.48 (0.85)	1.19 (0.62)
Arg	2.43 (1.85)	1.84 (1.25)

[1]Expressed on an air-dry basis.

[2]Values not in parentheses are total amino acid concentrations, and values in parentheses are digestible amino acid concentrations. Digestible amino acid values were calculated using the amino acid digestibility coefficients in Table 4.

Geisman, 1981; Yaseen et al., 1991). The TS contained 0.11% Ca and 0.58% P on an air-dry basis, slightly lower than previously reported values (Tsatsaronis and Boskou, 1975). The differences in CP, fat, Ca, and P values between our study and some others could be due to different tomato cultivars, growing conditions and processing methods (i.e., the amount of seeds, pulp, and skins in the waste by-product). Total and true digestible AA concentrations are shown in Table 3 for both samples of TS. The total AA concentrations for TS are similar to previously reported values (Tsatsaronis and Boskou, 1975; Latlief and Knorr, 1983). True AA digestibility coefficients and TME_n values for both TS samples are shown in Table 4. The true AA digestibility coefficients for essential amino

TABLE 4. True amino acid digestibility coefficients and TME_n for two tomato seed samples

	Sample 1		Sample 2	
Component	Mean	SE	Mean	SE
	(%)			
Amino acids[1]				
Asp	63	1.5	57	0.9
Thr	82	1.2	77	1.5
Ser	74	1.4	62	1.4
Glu	78	0.9	76	0.8
Pro	73	1.3	75	1.8
Ala	71	1.8	65	0.6
Cys	71	2.1	69	5.6
Val	72	1.9	64	0.8
Met	78	1.6	72	1.6
Ile	71	1.5	66	0.5
Leu	75	1.3	67	0.8
Tyr	58	2.0	30	3.7
Phe	85	1.0	86	0.7
His	69	1.9	69	1.7
Lys	57	1.9	52	1.2
Arg	76	0.6	68	4.7
Mean	68		63	
TME_n, (kcal/kg)[1]	3,024	65	2,884	29
TME_n, (kcal/kg)[2]			3,204	21

[1]Mean of four cecectomized roosters determined at the University of Illinois, expressed on an air-dry basis.

[2]Mean of four conventional roosters determined at INTA in Argentina, expressed on an air-dry basis.

TABLE 5. Growth performance of chicks fed different protein levels from tomato seeds (TS) and soybean meal (SBM), Experiment 1[1]

Treatment	Weight gain (g)	Gain:feed (g/kg)	PER[2] (g/g)	NPR[3] (g/g)
N-free diet	-16.8^{e}	-273^{d}	—	—
3% CP from TS	-6.6^{d}	-73^{c}	-2.43^{c}	3.64^{b}
6% CP from TS	27.4^{c}	176^{b}	2.92^{ab}	4.72^{a}
9% CP from TS	36.6^{b}	224^{b}	2.49^{b}	3.64^{b}
9% CP from SBM	56.5^{a}	308^{a}	3.56^{a}	4.62^{a}
Pooled SEM	3	18	0.33	0.23

[a–e]Means within columns with no common superscript differ significantly ($P \leq 0.05$).

[1]Means of four groups of five male chicks, average initial weight = 87 g.

[2]PER (protein efficiency ratio) = weight gain of chicks divided by protein intake.

[3]NPR (net protein ratio) = (weight gain of chicks minus weight gain of chicks fed a N-free diet) divided by protein intake.

acids ranged from 54% for Lys to 86% for Phe (average of the two samples). The TME_n of the TS was found to be 2,954 kcal/kg as measured in cecectomized birds and 3,204 kcal/kg measured in conventional birds. The TME_n value generated from cecectomized birds is approximately 8% lower than the TME_n value measured from conventional birds. This type of difference has been reported previously for other feed ingredients (Parsons, 1985; Han and Parsons, 1990) and may be due to less hindgut microbial fermentation of the fiber in the TS in cecectomized birds.

The results of the first chick experiment for protein quality assessment are shown in Table 5. Diets containing 0 or 3% CP from TS resulted in weight loss of the chicks. Increasing CP level from TS resulted in linear increases in chick weight gain and gain:feed ratio and quadratic responses in both PER and NPR. The quadratic response resulted because PER and NPR values at 9% CP were lower than those at 6% CP. The decrease at 9% CP may be due to the high (36.5%) inclusion of TS needed to generate a 9% CP level. Previous studies utilizing poultry have not included TS at a level higher than 20% of the diet. Thus, the high 36.5% level of TS may have had a negative or growth-depressing effect, possibly due to some unknown antinutritional factor. This hypothesis is supported by the results of our second chick experiment where a 20% level of TS caused a significant growth depression. Chicks fed 9% CP from SBM had significantly higher weight gain, gain:feed ratio, PER, and NPR values than did those fed 9% CP from TS. The lower PER and NPR values indicate that TS may have a lower protein quality than SBM. However, at least part of the difference in PER and NPR of TS vs. SBM may be due to a possible growth-depressing effect of the high level of TS, as discussed earlier. Calculation of a chemical score for TS and SBM, based on digestible amino acids per unit of CP compared to NRC (1994) requirements for chicks from 0 to 3 wk, indicated that TS, like SBM, is first limiting in SAA and its degree of deficiency (score) is similar to that of SBM.

In the second chick experiment where TS replaced corn and SBM on an equal true digestible AA and TME_n basis, no significant negative effect of TS in weight gain or feed efficiency was observed among diets with up to 15% TS (Table 6). Feed efficiency did show a quadratic response to TS, with 5, 10, and 15% TS resulting in the highest feed efficiency. Inclusion of TS at 20% resulted in a significant reduction in chick weight gain. These results agree with previous research in laying hens (Yannakopoulos et al., 1992) where 15% TS showed no significant reductions in hen weight gain, number of eggs laid, feed consumption, feed efficiency, mean egg weight, shell deformation, egg shape index, or yolk weight. Other studies (Squires et al., 1992; Dotas et al., 1999) have shown that tomato pulp or

TABLE 6. Growth performance and skin pigmentation of chicks fed a corn/soybean meal (SBM) diet containing various amounts of tomato seeds (TS) on a digestible amino acid and TME_n basis, Experiment 2[1]

Treatment[2]	Weight gain (g)	Gain:feed (g/kg)	Shank score[3]
Corn/SBM	340^{ab}	673^{ab}	3.3
Corn/SBM + 5% TS	338^{ab}	694^{a}	3.2
Corn/SBM + 10% TS	347^{a}	693^{a}	3.4
Corn/SBM + 15% TS	336^{b}	693^{a}	3.5
Corn/SBM + 20% TS	323^{c}	658^{b}	3.4
Pooled SEM	4	8	0.2

[a–c]Means within columns with no common superscript differ significantly ($P \leq 0.05$).

[1]Means of six groups of five male chicks, average initial weight = 91 g.

[2]Diets formulated to contain 3,200 kcal of TME_n per kilogram and 21.5% CP.

[3]Shank pigmentation score determined using a Roche color score fan.

waste can be fed safely to laying hens and broiler chicks. Dotas et al. (1999) and Yannakopoulos et al. (1992) both reported that tomato by-products may have a positive effect on the yolk color in laying hens. In contrast, two studies conducted by Ammerman et al. (1965) showed a decrease in skin or shank pigmentation when tomato pulp was substituted for alfalfa meal at 3% in both laying hen and broiler diets. In our experiment, the inclusion of TS up to 20% did not affect shank skin pigmentation in the chicks (Table 6). Egg yolk coloration may be a more sensitive measure of pigment status in laying hens than shank color is in chicks or the pigments present in TS are not stored in the skin/shank regions of poultry.

Our results indicate that dried TS from tomato cannery waste have appreciable amounts of digestible AA and TME_n. Although the protein quality (PER) of TS may be lower than SBM, up to 15% TS can be used in chick rations from 8 to 21 d posthatch without adverse affects on chick weight gain and gain:feed ratio when diets are formulated on an equal digestible AA and TME_n basis. When economics permit, TS can be a viable ingredient in poultry rations.

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