NUTRITIONAL EVALUATION OF GRAIN AMARANTH FOR GROWING CHICKENS

Nuket Acar*, Pran Vohra* Becker**, G.D. Hanners**

and R.M. Saunders**

SUMMARY

Grain amaranth can be used in place of corn in the diets of growing chickens. Grain and its milling fractions contain some heat-labile antinutrients. Popped grain were not as nutritious as autoclaved whole grain. AME values of the autoclaved whole grain flour, fat-free flour, perisperm, bran and popped grain flour were 11.46, 11.38, 11.71, 12.00 and 11.50 kj/g, respectively.

INTRODUCTION

Amaranth, genus *Amaranthus*, is a rapidly growing, high yielding plant that utilizes C-4 photosynthetic pathway (Downton, 1973). It tolerates arid and wet climates. The genus includes about. 50 species native to tropics, but mostly grown in Mexico, Guatemala, India, Nepal, Indonesia, China and Nigeria. A few of the commonly grown species for their cereal grain are *Amaranthus caudatus*, *A. cruentus*, *A. edulis*, *A. hybridus* and *A. hypochondriacus*. The protein content of grain amaranth varies from 11% to 22%. However, grain amaranth also contain heat-labile antinutrients (Cheeke and Bronson, 1980; Saunders. 1986; Tillman and Waldroup, 1986). A number of reports are available on their amino acid profiles (Carlsson, 1980; Connor et al., 1980, Senft, 1980; Afolabi et al., 1981; Waldroup et al., 1985, Saunders, 1986; Laovoravit et al., 1986). The protein of grain amaranth is better balanced in S-containing amino acids and lysine than of other cereals such as rice, wheat or maize (Senft, 1980).

Grain amaranth are deficient in thiamin (Betschart et al., 1981; Becker et al., 1981; Laovoravit et al., 1986). Linoleic acid content is high and of linolenic acid low (Becker et al., 1981). Dark colored varieties have a higher tannin content than the light colored varieties. Phytate content (0.52%-0.61%) is higher in grain amaranth than in rice and millets but less than corn and wheat (Lorenz et al., 1984)

Waldroup et al. (1985) and Tillman and Waldroup (1986) assigned metabolizable energy values of 14.54 mj/kg (3.475 kcal/g) to the varieties *A. cruentus* and *A. hypochondriacus* based on their chemical composition. A value of 12.32 mj/kg (2.92 kcal/g) for metabolizable energy of heat-processed *A. edulis* was reported by Connor et al. (1980), and a value of 11.97 mj/kg

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* Department of Avian Sciences, University of California, Davis, CA 95616

** Food Quality Research Unit, Western Regional Research Center, USDA, Berkeley, CA 94710

(2.86 kcal/g) for autoclaved A. cruentus was obtained by Laovoravit et al.(1986) by a fast method (Vohra at al., 1982). These values need further confirmation.

Betschart et al. (1981) processed grain amaranth to obtain various fractions such as seed coat-embryo and perisperm, and also popped whole grain, and compared their feeding value for rats. Whole grain amaranth, heated or unheated, and perisperm were inferior to popped amaranth. Seed coat-embryo was intermediate, but all of them were still inferior to casein diet for supporting the growth of rats.

The present study evaluates the nutritive value of grain amaranthus, popped grain and some milling fractions for growing chickens.

MATERIALS AND METHODS

Grain amaranth was harvested in Mexico in 1985. The grain were ground in a Morehouse Model 530 stone mill set at a gap of 0.483 mm (0.019") to provide whole flour. The milling and fractionation procedures have been described by Becker et al. (1986). The coarsely ground flour was sieved through a Sweco vibrating sifter using a #20 screen. The bran and the embryo passed through leaving the perisperm on the screen. The fat-free flour was obtained by extraction of the whole flour with hexane. The samples were autoclaved for 15 minutes at 121° C (15 p.s.i.) in layers of about 2.5 cm. thickness in trays. The grain were popped at a temperature of 245° C in a gas fired hot air popper. The popped grain were then ground in the Morehouse stone mill. All the samples, raw and autoclaved, were stored until used in plastic bags in a room without any temperature control.

Proximate analysis for dry matter (DM), crude protein (CP), ether extract (EE), crude fiber (CF) and ash of the samples was carried out following the procedures outlined in A.O.A.C. (1975). Nitrogen free extract (NFE) was estimated from these analyses. Neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin and cellulose were determined as described by Goering and Van Soest (1975). Available carbohyudrates (Avail. CHO) were determined using the procedure of Southgate (1967).

Amino acid profiles of the samples were determined by an ion-exchange method using a Durrum amino acid analyzer, model D-500 (Becker et al., 1986).

Day-old broiler (Hubbard) type chicks were purchased from A & M Hatchery, Santa Rosa, CA. After banding and weighing, the chicks were randomly distributed into wire-floor battery cages, each cage containing 6 chicks of about same average group weight. The temperature in the battery was maintained at 35° for the first week, then reduced to 32.2° in the second and 29.4° in the 3rd week. The feed and tap water were available all the time.

The diets were formulated to contain about the same amount of apparent metabolizable energy (AME or ME) and CP. A value of 2.86 kcal ME/g (Laovoravit et al., 1986) was assigned to amaranth and its fractions. The composition of the diets used in this study is given in Table 4.

The body weights of individual birds and the group food intake were recorded twice each week.

The apparent metabolizable energy of the ingredients and the diets were determined by a fast method (Vohra et al., 1982).

The data were subjected to analysis of variance to determine any statistical significance (MSTAT, 1982). The significantly different means were ranked by least significant difference (LSD) method.

RESULTS AND DISCUSSION

Crude protein tended to concentrate in the bran-embryo fraction of the whole flour than in perisperm (Table 1). The reverse was true for NFE.

Table 1. Proximate analysis of raw and autoclaved amaranth samples and of corn and soybean meal (as fed basis)

Ingredient	DM %	CP %	EE %	CF %	Ash %	NFE %
Amaranth						
Whole flour, raw	90.03	17.25	7.23	1.76	2.70	71.06
Whole flour, auto.	89.95	15.13	7.14	1.72	2.56	73.45
Perisperm, raw	90.39	10.95	4.59	0.72	1.58	82.16
Perisperm, auto.	89.75	9.60	5.03	0.68	1.32	83.37
Bran, raw	91.80	29.60	13.70	1.97	5.57	49.16
Bran, auto.	91.34	25.80	15.37	2.05	4.79	51.99
Fat-free flour, raw	91.60	17.31	0.91	2.43	2.54	76.81
Fat-free f;our, auto.	90.37	16.31	2.18	2.47	2.33	76.89
Popped amaranth flour	94.35	16.81	7.50	2.85	2.58	70.26
Corn	88.12	8.11	4.25	1.72	3.05	82.87
Soybean meal	89.88	47.4	3.90	2.87	1.07	44.76

The data on the analyses of the carbohydrate complex and lignin suggest that a significantly higher value for NDF was obtained by autoclaving of whole amaranth flour, fat free flour, perisperm and bran (Table 2) for some unexplained reasons. An increase in ADF, lignin and cellulose was only observed for whole amaranth flour.

Heat involved in popping grain amaranth reduced its total lysine (Table 3). This has also been observed by Pant (1985) using a microbiological method and by Tovar and Carpenter (1982) by a dye-binding method. It is doubtful that the three methods are measuring the same entity.

Table 2. Carbohydrate complex and lignin content of raw and autoclaved amaranth samples and of corn and soybean meal (as fed basis)

Ingredient	NDF %	ADF %	Lignin %	Cellulose %	Avail. CHO %
Amaranth					
Whole flour, raw	9.59	5.75	2.57	3.12	69.13
Whole flour, auto.	18.12*	7.24*	3.42*	3.79*	71.20
Perisperm, raw	6.27	3.50	1.77	1.95	81.15
Perisperm, auto.	13.87*	3.79	2.27	2.11	81.32
Bran, raw	20.63	12.73	6.39	5.56	35.20
Bran, auto.	27.05*	12.63	5.88	6.29	43.68
Fat-free flour, raw	8.22	4.29	1.79	2.60	70.27
Fat-free flour, auto.	10.33*	4.30	1.77	2.64	75.54
Popped grain flour	23.40	9.80	5.62	4.08	70.00
Corn	18.05	3.87	0.96	3.04	80.34
Soybean meal	14.10	5.66	0.82	4.07	40.28

* Significantly different from the raw ($P<0.05$)

Table 3. Amino acid profiles of raw amaranth samples

	Whole flour	Fat-free flour	Perisperm	Bran	Popped grain
Crude protein,%	17.25	17.81	10.95	29.60	16.81
Amino acid	g/100 g protein				
Alanine	3.06	2.96	3.13	3.71	3.23
Arginine	7.69	7.16	6.95	8.98	7.60
Aspartic acid	7.25	6.90	7.56	7.67	7.35
Cysteine	2.31	2.03	2.22	2.49	2.16
Glutamic acid	14.38	13.61	13.53	17.28	15.15
Glycine	6.59	6.53	6.93	7.13	6.72
Histidine	2.33	2.14	2.16	2.56	2.61
Isoleucine	3.40	3.21	3.51	3.60	3.53
Leucine	5.02	4.62	5.11	5.14	5.11
Lysine	4.82	4.59	4.99	5.01	3.53
Methionine	2.08	2.19	2.08	2.48	1.99
Phenylalanine	3.91	3.52	3.92	4.17	3.94
Proline	3.53	3.50	3.46	4.73	3.72
Serine	5.50	5.51	5.46	6.10	5.37
Threonine	3.16	3.05	3.28	3.43	3.30
Tyrosine	3.51	3.66	3.79	4.01	3.67
Valine	3.98	3.73	3.93	4.18	4.20

As the level of CP in perisperm is only 10%, about 10% extra soybean meal was added the the diet containing this fraction to obtain the same level of protein as in other amaranth diets (Table 4).

Table 4. Composition of the diets for nutritional evaluation of amaranth samples

Ingredient	Diet					
		Amaranth				
	Control corn-soy	Whole flour	Fat-free flour g/kg	Peri-sperm	Bran	Popped flour
Corn	500.0	-	-	-	-	-
Whole flour	-	614.6	-	-	-	-
Fat-free flour	-	-	621.0	-	-	-
Perisperm	-	-	-	495.0	-	-
Bran	-	-	-	-	353.0	-
Popped flour	-	-	-	-	-	611.0
Soybean meal	400.0	275.4	271.4	377.7	285.4	276.7
Starch	-	-	-	-	189.3	-
Soybean oil	40.0	60.0	60.0	70.0	70.0	60.0
$CaHPO_4.2H_2O$	22.0	22.0	22.0	22.0	22.0	22.0
$CaCO_3$	10.0	10.0	10.0	10.0	10.0	10.0
NaCl	5.0	5.0	5.0	5.0	5.0	5.0
$MnSO_4.H_2O$	0.2	0.2	0.2	0.2	0.2	0.2
ZnO	0.1	0.1	0.1	0.1	0.1	0.1
Vitamin mix	10.0	10.0	10.0	10.0	10.0	10.0
Sand	10.7	-	-	8.0	-	-
Methionine	2.0	-	-	2.0	-	-
Lysine	-	-	-	-	-	5.0
Calculated						
ME, kcal/kg	3060	2980	2990	2990	3030	2990
CP, %	23.66	23.70	23.61	23.32	23.67	23.25
Lysine, %	1.39	1.37	1.34	1.45	1.40	1.63
Met + cys, %	0.96	0.86	0.84	1.02	0.92	0.82

Vitamin mix supplied the following in the diet (mg/kg): biotin, 0.5; Ca-pantothenate, 30; folic acid, 5; menadione, 10; niacin, 120; pyridoxine HCl, 10; riboflavin, 10; thiamin HCl, 10; vitamin B_{12}, 0.01; BHT, 1000; choline (60%), 1660; vitamin A, 10,000 IU; vitamin D_3, 4,500 ICU; vitamin E, 88 IU.

As the diets were fortified with thiamin, no deficiency symptoms associated with this vitamin (Conner et al., 1980; Lavafovit et al,, 1986) were observed. The presence of heat-labile toxicants is confimed in grain amaranth in the present study. The autoclaving of grain amaranth significantly ($P<0.05$) improved their nutritive value for chickens (Series 1, Table 5) and the gain in body weight of chickens fed autoclaved whole amaranth flour or bran was not significantly lower from that on control diet. Diet incorporating autoclaved fat-free amaranth flour was inferior to the control diet. The

Table 5. Effect of grain amaranth and fractions on gain in body weight, feed consumption and feed efficiency of growin chickens

Dietary treatment	Bodyweight gain, g (G)	Feedintake g (F)	Feed eff. F/G
Series 1, 18 days			
Control	424ab	523ab	1.23cd
Whole flour, raw	203e	362d	1.79a
Whole flour, auto.	397bc	523ab	1.32cd
Fat-free flour, raw	206e	368d	1.79
Fat-free flour, auto.	380c	490b	1.30cd
Perisperm, raw	269d	388d	1.45bc
Perisperm, auto.	464a	547a	1.18d
Bran, raw	269d	435c	1.62ab
Bran, auto.	399c	506ab	1.27cd
Series 2, 17 days			
Control	363a	442a	1.22b
Whole flour, auto.	353a	453a	1.29b
Popped grain flour	200b	321b	1.62a

a to e Means within the same column with different letters in each series differ significantly ($P<0.05$)

gain in body weight of chicks fed autoclaved perisperm diet or the control diet did not differ significantly, but was significantly higher than on any other autoclaved amaranth . fraction.

The usefulness of autoclaved whole amaranth flour was further confirmed as is evident from the data of Series 2 (Table 5). The gain in weight of chickens on this diet did not differ significantly from that on control diet. However, the chicks fed popped grain amaranth diet were significantly lighter. The calculated levels of arginine, lysine and methionine plus cysteine in all the diets met the NRC (1984) requirements, but autoclaving may have reduced the protein quality of grain amaranth and its fractions, especially the lysine content. The effect of supplementation of these diets with lysine deserves further study.

The feed efficiency for chickens fed autoclaved amaranth samples was not significantly different from those fed the control diet,

The average feed intake of the roosters for AME determination by the fast method was 58.4 ± 11.7 g and the average excreta were 19.7 ± 5.2 g. The AME values for inmgredients used in this study are given in Table 6. Autoclaved perisperm had a significantly (2.80 kcal /g) lower AME value than the raw sample (3.28 kcal/g). The AME values for other amaranth samples were not significantly influenced by autoclaving.

Table 6. Apparent metabolizable energy values of grain amaranth, some fractions, corn, soybean meal and of chicken starter diet by fast method (as fed basis)

Test ingredient	Dry matter, %	App. metabolizable energy kcal/g	(kj/g)
Chicken starter diet	89.2	2.99	12.51
Corn	90.0	3.09	12.93
Soybean meal	91.4	2.43	10.17
Amaranth			
whole flour, raw	88.7	2.85	11.92
Whole flour, auto.	90.0	2.74	11.48
Fat-free flour, raw	90.6	2.80	11.71
Fat-free flour, auto.	92.6	2.72	11.38
Perisperm, raw	89.2	3.28*	13.72*
Perisperm, auto.	90.3	2.80	11.71
Bran, raw	89.3	2.73	11.42
Bran, auto.	90.5	2.87	12.00
Popped flour	92.3	2.75	11.51

* significantly ($P<0.05$) different from other values.

These determined values were used to calculate the AME of the diets used in this study (Table 4). The AME of these diets (except popped grain) were also determined by the fast method and the data are compared with the calculated values in Table 7.

Table 7. AME values of test diets as determined by fast method and as calculated (as fed basis) from the AME values of the ingredients as given in Table 6

Diet	Dry matter %	AME, kcal/g Determined	Calculated
Control	91.2	3.00 ± 0.04	2.97
Amaranth			
Whole flour, raw	91.1	3.02 ± 0.02	3.01
Whole flour, auto.	91.2	3.00 ± 0.01	2.95
Fat-free flour, raw	91.0	2.90 ± 0.03	2.99
Fat-free flour, auto.	91.2	2.84 ± 0.08	2.94
Perisperm, raw	91.1	3.24 ± 0.10*	3.23
Perisperm, auto.	91.3	3.01 ± 0.02	3.00
Bran, raw	91.3	2.87 ± 0.02	3.04
Bran, auto.	91.8	2.91 ± 0.02	3.09

* Significantly ($P<0.05$) different from other values.

The observed and calculated values from the data by fast method are in close agreement.

The results of this study indicate that autoclaved grain amaranth and its perisperm fraction may be used in diets for chickens to replace corn.

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