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Studies on the Nutritional Value of Sorghum Grains with Varying Tannin Contents for Chicks

1. GROWTH STUDIES[1]

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ABSTRACT Studies were conducted on the performance of chicks fed diets containing either a bird resistant sorghum (BR64) or an intermediate bird resistant sorghum (NK300) as compared with that observed when chicks were fed diets containing a bird susceptible sorghum (RS610) or corn as the cereal grain. Chicks fed sorghum BR64 exhibited poorer growth and feed conversion as compared with chicks fed sorghum RS610. In general, the performance of chicks fed sorghum NK300 was intermediate between the other two sorghums. Chicks fed the corn diets consistently exhibited superior weight gains and, in some cases, superior feed conversion as compared with chicks fed the various sorghum containing diets.

Weight gains and feed conversion were decreased when tannic acid was added to the corn, sorghum RS610 and sorghum NK300 diets to the level found in the sorghum BR64 diet. The performance of chicks fed the corn and sorghum RS610 diets with added tannic acid was still superior to those of chicks fed the BR64 or the NK300 diet with added tannic acid. These results suggest that the poor performance of chicks fed the latter two diets was not due solely to the presence of tannic acid.

Chicks adapted to a high tannin diet during 1–21 days of age and fed the high tannin diet from 21 to 35 days showed weight gains of 54.7% and an increase in feed required per gram gain of 60.6% as compared with adapted chicks fed a low tannin diet from 21 to 35 days. Chicks fed a low tannin diet from 1 to 21 days of age and switched to a high tannin diet from 21 to 35 days exhibited weight gains of 43.5% and an increase in feed required per gram gain of 85.1% as compared with non-adapted chicks fed a low tannin diet from 21 to 35 days.

Similar weight gains and feed conversions were noted when essential amino acids were added to corn and sorghum RS610 diets to raise the levels to those found in the other grain. A significant improvement in weight gain and feed conversion as compared with chicks fed an unsupplemented diet was noted when chicks were fed a sorghum BR64 diet with essential amino acids added up to the levels found in corn. Weight gain, but not feed conversion, of chicks fed the supplemented sorghum BR64 diet was equal to that of chicks fed the unsupplemented RS610 diet, but chick performance was poorer than that observed with an unsupplemented corn diet, a supplemented corn diet or a supplemented RS610 diet.

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THE nutritional value of bird resistant sorghum grains containing higher than normal levels of tannic acid has been studied by several workers. Sorghum grains have, in many cases, been substituted on an equal weight basis for part of the corn in practical poultry rations containing approximately 20% or more of protein. In such cases, growth of chicks often was only slightly depressed, if at all, from feeding the bird resistant sorghum grains; however, in most cases feed conversion was depressed in comparison to diets containing corn or non-bird resistant sorghum grain (Damron *et al.*, 1968; Stephenson *et al.*, 1968).

Several studies (Chang and Fuller, 1964; Fuller *et al.*, 1966, 1967; and Conner *et al.*, 1969) have shown that additions of methionine, choline and other methyl group donors helped overcome growth depressions due to lower levels of tannic acid and partially alleviate the growth depression due to higher levels of dietary tannic acid. These same dietary supplements also increased the growth of chicks fed diets containing little or no tannic acid. Studies by Vohra *et al.* (1966) indicated no positive effect from the addition of methyl

[1] Journal paper no. 4790, Purdue University, Agricultural Experiment Station.

group donors to diets containing tannic acid; however, subsequent studies by these workers (Rayudu *et al.*, 1970) suggested that approximately 40–50% of the growth depression caused by the addition of 1% tannic acid to the diet could be alleviated by the addition of methionine alone or in combination with other methyl group donors.

Vohra *et al.* (1966) concluded that the depression in growth due to feeding tannic acid could not be entirely explained by a depression in feed intake. These workers noted that a dietary addition of 2% tannic acid resulted in a decrease in growth, feed conversion, metabolizable energy of the diet and percent retention of nitrogen. Stephenson *et al.* (1968) observed wide differences in amino acid availabilities of various varieties of yellow and brown sorghum grains and concluded that color classification was not an accurate index as far as feeding value was concerned.

The present study was conducted to investigate the nutritional value of sorghum grains with varying tannin contents when added to chick diets containing sub-optimal levels of protein. Growth and feed conversion data from chicks in this study are presented in the present paper. The results of amino acid availability studies are presented in a subsequent paper (Rostagno *et al.*, 1973).

EXPERIMENTAL PROCEDURE

Four experiments were conducted to study the performance of chicks fed sorghum grain diets which contained varying amounts of tannic acid supplied from both endogenous and exogenous sources. Male, White Mountain chicks were randomly allotted to treatments at 1 day of age. The chicks were wing banded, weighed and placed in electrically heated battery brooders with raised wire floors. Replicates were assigned to batteries so that no two replicates of a treatment could appear in the same battery or the same deck level of another battery. Feed and water were provided *ad libitum*.

The protein contents of the sorghum grains, corn and soybean meal were determined using standard procedures (A.O.A.C., 1960) and are presented in Tables 1, 2 and 4. The amino acid composition of these ingredients was determined by ion exchange chromatography[2] following sample preparation as described by Cromwell *et al.* (1967). Norleucine was added to each sample as an internal standard.

The tannic acid equivalents of the sorghum grains were determined by the Folin-Denis Method as described by Burns (1963). The tannic acid equivalent values of the sorghum grains used in Experiment 2 were as follows: bird resistant sorghum BR64, 1.57%; intermediate bird resistant sorghum NK300, 0.66%; and bird susceptible, regular sorghum RS610, 0.37%. Corn was considered to have 0% tannic acid equivalent.

A subjective leg score was used in Experiment 3 and 4 on five week old chicks to attempt to evaluate the extent of observed leg abnormalities. The leg scores were assigned as follows: 1—normal; 2—mild distortion; 3—severe distortion; and 4—inability to stand.

In Experiment 1, sorghum grains RS610, BR64 and NK300 were compared with each other on an equal weight and on an isonitrogenous basis and with corn on an equal weight basis using diets containing sub-optimal protein levels (Table 1). Three replicate groups of 9 chicks each were fed the various diets for a 14-day period.

In Experiment 2, sorghum grains RS-610, BR64 and NK300 from a second

[2] Technicon Amino Acid Analyzer, Technicon Corporation, Ardsley, New York.

TABLE 1.—*Composition of the diets, chick weight gain and feed conversions (Experiment 1)*

Ingredients (%)	Diets					
	1	2	3	4	5	6
Sorghum RS 610 (9.7)[1]	68.00	—	—	—	—	—
Sorghum BR 64 (9.0)	—	73.25	68.00	—	—	—
Sorghum NK 300 (9.1)	—	—	—	72.25	68.00	—
Corn (8.2)	—	—	—	—	—	68.00
Glucose monohydrate	5.25	—	5.25	1.00	5.25	5.25
Soybean meal (52.4)	16.50	16.50	16.50	16.50	16.50	16.50
Corn oil	5.00	5.00	5.00	5.00	5.00	5.00
Premix[2]	5.25	5.25	5.25	5.25	5.25	5.25
Total protein (%)	15.25	15.24	14.77	15.24	14.86	14.10
Weight gain (g.)[3]	102[b]	74[a]	73[a]	102[b]	96[b]	143[a]
Feed/gain ratios[3]	1.86[ab]	2.39[a]	2.44[a]	2.02[b]	2.04[b]	1.71[a]

[1] Figures in parentheses represent the protein contents expressed as a percentage of air-dried feedstuff.
[2] The premix provided the following ingredients (in %): dicalcium phosphate, 2.1; limestone, 1.5; sodium chloride (iodized), 0.45, manganese sulfate (70%), 0.05; zinc oxide, 0.006; butylated hydroxytoluene, 0.013%; vitamin supplement, 1.131. The vitamin supplement provided the following (in units/kg.): choline chloride, 2000 mg.; vitamin A, 5000 I.U.; vitamin D_3, 2250 I.C.U.; riboflavin, 8.8 mg.; calcium pantothenate, 17.6 mg; niacin, 39.6 mg; d-alpha tocopherol acetate, 8.8 I.U.; menadione sodium bisulfite, 1.4 mg; vitamin B_{12}, 11.0 μg; penicillin, 6.5 mg.
[3] Mean values for 14 day old chicks. Means bearing the same superscripts are not significantly different ($P>0.05$).

year's crop were compared with each other on an equal weight and on an isonitrogenous basis and with corn on an equal weight basis (Table 2). Also, commercially available tannic acid[3] was added to the corn, sorghum RS610 and NK300 diets to bring them to the level supplied by sorghum BR64. These diets were compared on an equal weight basis. Four replicate groups of 9 chicks each were fed the various diets for a 21-day period.

Experiment 3 was designed to test the possibility that older birds which had previously been fed a high tannin diet are less susceptible to the detrimental effects of sorghum BR64 than birds reared for 3 weeks on a corn-soybean meal diet. Chicks were divided into 2 groups at one day of age and fed either a corn-soybean meal diet (Diet 1, Table 2) or a sorghum BR64-soybean meal diet (Diet 4, Table 2) for a pre-experimental period of 3 weeks. At this time, each group was divided into two subgroups composed of 3 replicates of 10 chicks each and fed either a high tannin sorghum BR64-soybean meal diet (Diet 4, Table 2) or a low tannin sorghum RS610-soybean meal diet (Diet 5, Table 2) for 2 weeks. Leg score values of the chicks at 5 weeks of age were determined as previously described.

The effect on chick performance of supplementing diets containing sorghum grains RS610 and BR64 with essential amino acids to raise them to the levels supplied by corn and of supplementing a corn diet with essential amino acids up to the level supplied by sorghum RS610 was studied in Experiment 4. The effect of autoclaving the 2 sorghum grains for 30 minutes at 17 p.s.i. was also investigated. The cereal grains were added at 70% of the diet and the different diets were made isonitrogenous by varying the amounts of glutamic acid and glucose monohydrate added (Table 4). Tryptophan was not considered in this experiment since no

[3] Tannic Acid, Fluffy Powder, Sigma Chemical Co., St. Louis, Missouri.

TABLE 2.—*Composition of the diets, chick weight gains and feed conversion (Experiment 2)*

Ingredients (%)	Diets								
	1	2	3	4	5	6	7	8	9
Corn (9.4)[1]	72.12	—	—	—	—	—	—	—	72.12
Sorghum RS 610 (10.5)	—	72.12	—	—	60.95	—	72.12	—	—
Sorghum NK 300 (9.7)	—	—	72.12	—	—	65.78	—	72.12	—
Sorghum BR 64 (8.9)	—	—	—	72.12	—	—	—	—	—
Tannic acid	—	—	—	—	—	—	0.86	0.65	1.13
Glucose monohydrate	1.13	1.13	1.13	1.13	12.30	7.47	0.27	0.48	—
Soybean meal (49.0)	16.50	16.50	16.50	16.50	16.50	16.50	16.50	16.50	16.50
Corn oil	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Premix[2]	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25
Total protein (%)	15.00	15.70	15.10	14.50	14.50	14.50	15.70	15.10	15.00
Tannic acid Eq. (%)	—	0.27	0.48	1.13	0.23	0.43	1.13	1.13	1.13
Weight gain (g.)[3]	282^{a}	202^{b}	146^{fg}	113^{e}	187^{bc}	122^{efg}	149^{df}	69^{h}	170^{cd}
Feed gain ratios[3]	1.90^{a}	1.90^{a}	2.46^{bc}	2.81^{c}	2.01^{ab}	2.61^{c}	2.20^{ab}	3.50^{d}	2.14^{ab}

[1] Figures in parentheses represent the protein contents expressed as a percentage of air-dried feedstuff.
[2] See footnote 2, Table 1.
[3] Mean values for 21 day old chicks. Means bearing the same superscripts are not significantly different ($P>0.05$).

values for the amounts present in the cereal grains used in this study were available. Four replicate groups of 8 chicks each were fed the various diets for a 21-day period. Chicks fed the diets containing sorghum RS610 (Diet 2) and sorghum BR64 (Diet 5) were fed to 5 weeks of age to study the leg abnormality previously noted in Experiment 3.

Final chick weight gains and feed conversions were analyzed using the analysis of variance (Steel and Torrie, 1960). The treatment × replication interaction was used as the error term to test main effects. The Newman-Keuls multiple range test was used to test individual treatment differences (Steel and Torrie, 1960).

RESULTS AND DISCUSSION

When normal corn was compared with sorghum RS610, BR64 and NK300 on an equal weight basis in Experiment 1, better weight gains and feed conversion were observed by chicks fed the corn diet (Table 1). The bird resistant sorghum BR64, when compared on either an equal weight or isonitrogenous basis, produced poorer weight gains and feed conversion than sorghums RS610 and NK300. These result are in agreement with the findings of Chang and Fuller (1964) and Connor *et al.* (1969) who observed that feeding sorghum grains with high tannin contents reduced weight gains. In this experiment, the intermediate bird resistant sorghum NK300 resulted in similar weight gains but somewhat poorer feed conversion as compared with chicks fed the sorghum RS610 diet.

In Experiment 2, chicks fed the corn diet gained significantly more weight ($P<0.05$) than did chicks fed the sorghum RS610 diet; however, feed conversion of the two groups of chicks was similar (Table 2). When sorghum RS610 and BR64 were compared either on an equal weight or equal nitrogen basis, significantly better weight gains and feed conversions ($P<0.05$) were observed by chicks fed the sorghum RS610 diets. In this experiment, sorghum NK300 did not support equal chick performance as compared with sorghum RS610. In comparison with sorghum BR64, it supported better chick performance when compared

on an equal weight basis; however, chick performance was not greatly different when the two grains were compared on an equal nitrogen basis.

The addition of tannic acid to the sorghum RS610, sorghum NK300 and corn diets so that all diets contained similar levels of tannic acid as that supplied by the sorghum BR64 diet resulted in marked decreases in weight gain and feed conversion as compared with the respective diets without added tannic acid. Even though chick performance decreased as a result of the addition of tannic acid to the diet, chicks fed the corn and sorghum RS610 diets with added tannic acid still produced superior weight gains and feed conversions as compared with chicks fed the sorghum BR64 and NK300 diets containing the same amount of tannic acid. These results suggest that the poor performance of chicks in the latter two groups was not due solely to the presence of tannic acid. An explanation for the drastic effects noted from the addition of tannic acid to the NK300 diet is not apparent.

Experiment 3 was undertaken to investigate the possibility that older chicks which had become adapted to a high tannin diet might perform better during the subsequent feeding of the diet than would chicks reared on a low tannin diet. Chicks fed the sorghum BR64 diet from 21 to 35 days (Treatments 1 and 3, Table 3) showed much poorer weight gains and feed conversion than chicks fed the sorghum RS610 diets (Treatments 2 and 4). Since the initial 3 week body weights of chicks in Treatments 1 and 2 were greatly different from those of Treatments 3 and 4, the performance of chicks was compared by expressing the weight gains and feed conversions for chicks fed the high tannin treatments (1 and 3) as a percentage of their respective low tannin treatments (2 and 4). The chicks adapted to the high tannin diet and fed the high tannin diet from 21 to 35 days of age (Treatment 3) showed weight gains of 54.7% and an increase in feed required per gram gain of 60.6% as compared with their low tannin controls (Treatment 4). The non-adapted

TABLE 3.—*Effect of age and dietary tannin level on weight gain, feed conversion, and leg score of chicks (Experiment 3)*

Treatments[1]		Initial weight	Weight[2] gain	Feed/ gain[2]	Leg[2,3] score
Weeks 0–3	Weeks 3–5	g.	g.		
1. Corn	BR 64	319	96[c]	5.20[c]	1.17[a]
2. Corn	RS 610	324	221[a]	2.81[a]	1.53[ab]
3. BR 64	BR 64	148	88[c]	3.71[b]	1.83[b]
4. BR 64	RS 610	156	161[b]	2.13[a]	1.63[b]

[1] Day old chicks were divided into two groups and fed either a corn-soybean meal diet (low tannin, Diet 1, Experiment 2) or a sorghum BR 64-soybean meal diet (high tannin, Diet 4, Experiment 2) for a pre-experimental period of 3 weeks at which time each group was divided in two subgroups and were fed either a sorghum BR 64-soybean meal diet (high tannin, Diet 4, Experiment 2) or a sorghum RS 610-soybean meal diet (low tannin, Diet 5, Experiment 2) for two additional weeks.

[2] Mean values for 35 day old chicks. Means with the same lettered superscript in a vertical column are not statistically different ($P<0.05$).

[3] Values assigned for leg condition: 1.—Normal; 2.—Mild distortion; 3.—Severe distortion; 4.—Inability to stand.

TABLE 4.—*Effect of essential amino acid (EAA) supplementation of sorghum and corn grain on weight gain, feed conversion, and leg score of chicks (Experiment 4)*[1,2]

Treatments	Weight Gain	Feed/ Gain	Leg[3] Score
	g.	g.	
1. Corn (9.6%)[4]	291[a]	1.81[ae]	—
2. Sorghum RS 610 (10.5%)	225[b]	1.89[ae]	1.16[b]
3. Sorghum RS 610+EAAs[5]	265[a]	1.77[a]	—
4. Corn+EAAs[6]	274[a]	1.81[ae]	—
5. Sorghum BR 64 (8.9%)	103[d]	2.89[f]	2.29[a]
6. Sorghum BR 64+EAAs[7]	226[b]	2.22[d]	—
7. Sorghum RS 610 autoclaved	234[b]	1.98[e]	—
8. Sorghum BR 64 autoclaved	115[d]	2.83[f]	—

[1] Weight gain, and feed efficiency determined at the end of the 3rd week. Leg score determined at the end of the 5th week. Means with the same lettered superscript in a vertical column are not statistically different ($P<0.05$).

[2] The basal diet contained the following (in %): cereal grain, 70.00; soybean meal (49%), 16.50; corn oil, 5.00; premix (see footnote 2, Table 1) 5.25; glucose monohydrate, variable; amino acid, variable; and glutamic acid, variable.

[3] Values assigned for leg condition: 1.—Normal; 2.—Mild distortion; 3.—Severe distortion; 4.—Inability to stand.

[4] Figures in parentheses represent the protein contents expressed as a percentage of air-dried feedstuff.

[5] Essential amino acids added to the sorghum RS 610 diet to bring them up to the level of the corn diet (diet 1): glycine, .035%; cystine, .056%; methionine, .049%; leucine, .035%; lysine, .064%; histidine, .049% and arginine, .084%.

[6] Essential amino acid added to the corn diet to bring them up to the level of the sorghum RS 610 diet (diet 2): threonine, .014%, valine, .021% and isoleucine, .028%.

[7] Essential amino acids added to the sorghum BR 64 diet to bring them up to the level of the corn diet (diet 1): glycine, .035%; cystine, .049%, methionine, .042%, leucine, .098%; phenylalanine, .028%; lysine, .064%; histidine, .042%; and arginine, .077%.

chicks fed the high tannin diet from 21 to 35 days of age (Treatment 1) showed weight gains of 43.5% and an increase in feed required per gram gain of 81.5% as compared to their low tannin controls (Treatment 2). These results suggest that the chicks which were adapted to the high tannin diet were able to perform better on the high tannin diet than were those reared for the first 21 days on a corn-soybean meal diet.

By the end of the fifth week of the experiment, a leg abnormality which included either a bowing of the legs or a perosis-like condition was noted in several chicks. A leg score was therefore determined in an attempt to evaluate the extent of the abnormality (Table 3). The leg score values of chicks fed the sorghum BR64 diet for the first 21 days (Treatments 3 and 4) showed a trend toward higher values (increased incidence of leg abnormalities) than chicks fed the corn diet (Treatments 1 and 2) for the same period. These differences were statistically significant ($P<0.05$) only for Treatments 3 and 4 as compared with Treatment 1. The highest value noted was in chicks fed the sorghum BR64 diet for the entire 35-day period. The leg score value observed in Treatment 2 was due to several chicks with a mild leg condition, whereas in Treatments 3 and 4 chicks with severe leg problems including some which could not stand were noted.

The effects of essential amino acid supplementation of sorghum grains and corn on weight gains and feed conversion were studied in Experiment 4 (Table 4). As noted in previous experiments, the corn diet resulted in better weight gain and feed conversion as compared with those of chicks fed the sorghum RS610 or BR64 diets. Supplemental essential amino acids were added to the three diets so that the levels in the corn and sorghum diets were raised to the level found in the other grain. No attempt was made to equalize excesses of amino acids in one grain above those found in the other. When amino acids were added to the sorghum RS610 and corn diets (Diets 3 and 4, respectively) similar weight gains and feed conversion were noted. The performance of chicks fed the corn and sorghum RS610 amino acid supplemented diets was not significantly different ($P>0.05$) from that of chicks fed the corn diet without added amino acids (Diet 1), but weight gains were significantly improved ($P<0.05$) as compared with chicks fed the RS610 diet without added amino acids (Diet 2).

When the sorghum BR64 diet was supplemented with essential amino acids up to the levels found in the corn diet, weight gain and feed conversion were significantly improved ($P<0.05$) as compared with the unsupplemented sorghum BR64 diet. The weight gain of chicks fed the supplemented BR64 diet was equal to that of chicks fed the unsupplemented sorghum RS610 diet, but feed conversion was still significantly poorer. The performance of chicks fed the supplemented sorghum BR64 diet was poorer than that of chicks fed the corn diet or the corn or sorghum RS610 diets which were supplemented with essential amino acids. The results of this experiment suggest that poor digestibility may be one of the causes for the poor performance noted in chicks fed sorghum BR64. Chang and Fuller (1964) obtained equal growth rates in chicks when a low and a high tannin diet were supplemented with choline and methionine, but feed efficiency was poorer in chicks fed the high tannin sorghum diet. Sanford *et al.* (1968) observed that supplementing sorghum grain diets (17% protein) with lysine and methionine resulted in equal chick growth as compared with chicks fed corn diets. However, the

corn diet showed better growth than the sorghum diets without amino acid supplementation.

Autoclaving sorghums RS610 and BR64 did not result in a significant improvement in weight gain or feed conversion when compared with those of chicks fed the non-autoclaved RS610 and BR64 diets, respectively.

Chicks fed the unsupplemented sorghum RS610 and BR64 diets were maintained on these diets for 5 weeks. The leg score of chicks fed the sorghum BR64 diet was significantly higher ($P<0.05$) at the end of this period as compared with chicks fed the RS610 diet. The causative factor(s) involved in the appearance of this leg abnormality is presently unknown. All diets were supplemented with 1.5 to 2 times the chick's requirement (National Research Council, 1971) for manganese, choline and niacin in addition to the amounts present in the other ingredients. No additional biotin was added to any of the diets, however.

The poorer performance of chicks fed the bird resistant sorghum BR64 diets as compared with chicks fed sorghum RS610 with tannic acid added equal to that present in the sorghum BR64 diet would suggest that the endogenous tannic acid in sorghum BR64 is not the only factor responsible for the poor chick performance. Although the weight gain of chicks fed the sorghum BR64 diet supplemented with essential amino acids was equal to that of chicks fed an unsupplemented sorghum RS610 diet in Experiment 4, feed conversion was still significantly poorer ($P<0.05$). These results suggest that even though the total amino acid composition of the supplemented sorghum BR64 diet was as good or better than that of the unsupplemented RS610 diet, the amounts of amino acid available to the chick were probably lower. Vohra *et al.* (1966) observed a reduction in nitrogen retention as a result of adding 2% tannic acid to the diet. The amino acid availabilities of the three sorghum grains studies used in these experiments plus another bird resistant sorghum will be considered in a subsequent paper (Rostagno *et al.*, 1973).

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