AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY

1. SUBJECT CLASSIFICATION
A. PRIMARY: Agriculture
B. SECONDARY: Poultry

2. TITLE AND SUBTITLE
Nutritional value of high lysine sorghum grain for the chick

3. AUTHOR(S)
Featherston, W.R.; Rogler, J.C.; Axtell, J.D.; Oswalt, D.L.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1974	5 p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Agronomy Department, Purdue University, Lafayette, Indiana 47967

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)
(In Poultry science, v.4, no.4, p.1221-1225)

9. ABSTRACT

Growth studies were conducted with day-old chicks to compare the nutritional quality of a high lysine sorghum grain (IS11758) with two low-tannin commercial sorghum grains (RS671 and RS610) in diets containing various protein levels. When the sorghum grains were compared on either an equal weight or equal protein level in diets in which all the protein was supplied by the sorghum grains, the high lysine sorghum produced weight gains of approximately three times those noted with the commercial ("normal") sorghum and with approximately 50% less feed required per unit grain. Supplementation of the normal sorghum diet with lysine to equal the level supplied by the high lysine sorghum resulted in similar chick growth and feed efficiency. These results indicate that the improved performance of chicks fed high lysine sorghum was due solely to its higher lysine content. Chicks fed the high lysine sorghum diets supplemented with safflower meal or soybean meal to a 15% protein level grew 2.5 and 1.9 times faster, respectively, and were significantly more efficient in feed utilization than their corresponding counterparts fed normal sorghum diets. These results indicate that the nutritional quality of high lysine sorghum grain is markedly superior to that of two commercial sorghum grains.

10. CONTROL NUMBER
PN-AAB-923

11. PRICE OF DOCUMENT

12. DESCRIPTORS
Chickens
Lysine
Nutritive value
Sorghum

13. PROJECT NUMBER

14. CONTRACT NUMBER
CSD-1175 Res.

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

CSD-1175 Res
PN-AAB-923

Nutritional Value of High Lysine Sorghum Grain for the Chick[1]

W. R. FEATHERSTON, J. C. ROGLER, J. D. AXTELL AND D. L. OSWALT
Departments of Animal Sciences and Agronomy, Purdue University, West Lafayette, Indiana 47907

(Received for publication November 15, 1974)

ABSTRACT Growth studies were conducted with day-old chicks to compare the nutritional quality of a high lysine sorghum grain (IS11758) with two low-tannin commercial sorghum grains (RS671 and RS610) in diets containing various protein levels. When the sorghum grains were compared on either an equal weight or equal protein level in diets in which all the protein was supplied by the sorghum grains, the high lysine sorghum produced weight gains of approximately three times those noted with the commercial ("normal") sorghum and with approximately 50% less feed required per unit gain. Supplementation of the normal sorghum diet with lysine to equal the level supplied by the high lysine sorghum resulted in similar chick growth and feed efficiency. These results indicate that the improved performance of chicks fed high lysine sorghum was due solely to its higher lysine content.

Chicks fed the high lysine sorghum diets supplemented with safflower meal or soybean meal to a 15% protein level grew 2.5 and 1.9 times faster, respectively, and were significantly more efficient in feed utilization than their corresponding counterparts fed normal sorghum diets.

These results indicate that the nutritional quality of high lysine sorghum grain is markedly superior to that of two commercial sorghum grains.

POULTRY SCIENCE 54: 1220-1225, 1975

INTRODUCTION

SINGH and Axtell (1973) reported the discovery in the World sorghum collection of two floury lines of sorghum grain of Ethiopian origin, IS11167 and IS11758, which were high in lysine and contained relatively high levels of protein. The average whole grain lysine concentrations of the high lysine lines IS11167 and IS11758 were 3.34 and 3.13 (g./100 g. protein) at 15.7 and 17.2% protein, respectively. Inheritance studies suggested that the increased lysine concentration of each line was controlled by a single recessive gene.

In growth studies where sorghum provided all the dietary protein, weanling rats demonstrated three times greater weight gain with sorghum IS11758 and two times greater gains with sorghum IS11167 than was noted from normal sorghum lines (Singh and Axtell, 1973). A two-fold improvement in feed effi-

1. Journal Paper Number 5721, Purdue University Agricultural Experiment Station. This investigation supported in part by the U.S. Agency for International Development under contract csd/1175—"Inheritance and Improvement of Protein Quality and Content of *Sorghum bicolor* (Linn.) Moench."

TABLE 1.—*Protein and amino acid composition of sorghum grain used in chick studies*[1]

	Experiment 1				Experiments 2 and 3			
	RS671		IS11758		RS610		IS11[illegible]	
	%	g./100 g. protein	%	g./100 g. protein	%	g./100 g. protein	%	g./100 g. protein
Protein	11.54	—	13.62	—	11.93	—	12.19	—
Lysine	0.25	2.15	0.48	3.52	0.24	2.06	0.45	3.67
Histidine	0.27	2.38	0.32	2.33	0.27	2.30	0.29	2.39
Arginine	0.44	3.78	0.70	5.15	0.42	3.56	0.64	5.27
Aspartic acid	0.87	7.51	1.10	8.10	0.86	7.25	1.03	8.48
Threonine	0.39	3.39	0.49	3.64	0.37	3.15	0.43	3.52
Serine	0.55	4.74	0.66	4.87	0.54	4.53	0.57	4.67
Glutamic acid	2.21	19.24	2.43	17.82	2.70	22.62	2.12	17.39
Proline	0.95	8.23	0.95	6.95	1.24	10.37	0.98	8.08
Glycine	0.41	3.55	0.64	4.72	0.37	3.09	0.48	3.90
Alanine	1.15	9.95	1.17	8.57	1.12	9.43	0.98	8.03
Valine	0.59	5.10	0.73	5.38	0.63	5.27	0.66	5.41
Cystine	0.29	2.49	0.28	2.08	0.22	1.84	0.25	2.08
Methionine	0.16	1.36	0.18	1.31	0.08	0.64	0.17	1.39
Isoleucine	0.47	4.11	0.60	4.41	0.49	4.11	0.49	4.01
Leucine	1.66	14.43	1.68	12.31	1.57	13.20	1.25	10.27
Tyrosine	0.41	3.54	0.45	3.27	0.34	2.87	0.40	3.32
Phenylalanine	0.67	5.82	0.72	5.32	0.57	4.80	0.55	4.54

[1]The protein values are the averages of 4 determinations per grain while the amino acid values are the averages of two determinations from separate hydrolyzate[illegible].

ciency was observed when sorghum IS11758 was compared with sorghum IS2319, a sorghum line considered to be of above average nutritional quality.

The present studies were conducted to evaluate the nutritional value of the high lysine sorghum IS11758 in the diet of young chicks. Grain from two separate plantings of sorghum IS11758 grown in Puerto Rico during the first half of 1974 was fed in three experiments with day-old chicks.

EXPERIMENTAL PROCEDURE

Male White Mountain chicks were randomly allotted to treatments at one day of age. Chicks were weighed, wing banded and placed in electrically heated battery brooders with raised wire floors. Five chicks were placed in each pen in Experiment 1 with four replicates per treatment. Seven chicks per replicate and 4 replicates per treatment were used in Experiments 2 and 3. No two replicates of the same treatment appeared in the same battery or the same deck level of another battery. Feed and water were provided *ad libitum* during these 18-day studies.

The protein and amino acid contents of the sorghum grains are shown in Table 1. Protein content was determined by the Kjeldahl procedure (A.O.A.C., 1960). In addition, duplicate samples of the sorghum grains were hydrolyzed with 6 N HCl in evacuated sealed tubes at 110° C. for 24 hours. After evaporation of the HCl *in vacuo*, the hyrolyzates were dissolved in sodium citrate buffer. The amino acid concentrations were determined by ion exchange chromatography using a Technicon amino acid analyzer.

In Experiment 1, the high lysine sorghum IS11758 was compared with a low-tannin commercial sorghum RS671 (hereafter referred to as normal sorghum). The two grains were evaluated under several dietary conditions (Table 2). The sorghum grains were compared on an equal weight basis in diets 1-4 with the sorghum grain providing all the protein in the diet. Diets 3 and 4 were supplemented with 0.2% DL-methionine. In diet 5, normal sorghum grain was supplemented with

TABLE 2.—*Composition of diets and the effect of sorghum grains RS671 and IS11758 (high lysine) on weight gain and feed conversion of chicks (Experiment 1)*

Ingredients (%)	Diets 1	2	3	4	5	6	7	8
Sorghum RS671	92.05	—	91.85	—	86.80	70.65	—	66.75
Sorghum IS11758	—	92.05	—	91.85	—	—	70.65	—
Soybean meal	—	—	—	—	5.05	21.20	21.20	25.10
DL-methionine	—	—	0.20	0.20	0.20	0.20	0.20	0.20
Soybean oil	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Constant ingredients[1]	4.95	4.95	4.95	4.95	4.95	4.95	4.95	4.95
Total protein (%)	10.6	12.5	10.8	12.7	12.7	18.6	20.0	20.0
Weight gain (g.)[2]	13.9[d]	37.6[c]	14.3[d]	41.2[c]	58.1[c]	245.9[b]	283.0[a]	284.4[a]
Feed/gain ratios[2]	6.74[a]	3.57[c]	6.02[b]	3.37[c]	2.91[c]	1.58[d]	1.53[d]	1.52[d]

[1]The constant ingredients provided the following (in %): dicalcium phosphate, 2.5; limestone, 1.0; sodium chloride (iodized), 0.45; manganese sulfate·H_2O, 0.01692; zinc oxide, 0.006; ferrous sulfate, 0.020; butylated hydroxytoluene, 0.0125; sodium selenite, 0.22 p.p.m.; and the following vitamins in units/kg. of diet: choline chloride, 1500 mg.; vitamin A, 15,000 I.U.; vitamin D_3, 1200 I.C.U.; d-alpha tocopherol acetate, 17.6 I.U.; menadione sodium bisulfite, 2.0 mg.; riboflavin, 9.0 mg.; thiamine, 6.0 mg.; calcium pantothenate, 20.0 mg.; niacin, 50.0 mg.; pyridoxine, 8.0 mg.; folic acid, 2.0 mg.; biotin, 0.3 mg.; inositol,1000 mg.; vitamin B_{12}, 20 μg.

[2]Mean values for 18 day-old chicks. Means bearing the same superscripts are not significantly different ($P > 0.05$).

TABLE 3.—*Composition of diets and the effect of sorghum grains RS610 and IS11758 (high lysine) on weight gains and feed conversion of chicks fed 15% protein diets (Experiment 2)*

Ingredients (%)	Diets 1	2	3	4	5	6
Sorghum RS610	77.12	—	79.17	79.17	—	—
Sorghum IS11758	—	75.47	—	—	77.44	77.44
Safflower meal (42.9)	13.50	13.50	—	—	—	—
Soybean meal (49.0)	—	—	11.30	11.30	11.30	11.30
DL-methionine	—	—	—	0.15	—	0.15
Glucose monohydrate	—	1.65	0.15	—	1.88	1.73
Soybean oil	5.00	5.00	5.00	5.00	5.00	5.00
Constant ingredients[1]	4.38	4.38	4.38	4.38	4.38	4.38
Weight gain (g.)[2]	24.8[d]	60.6[c]	100.1[b]	105.0[b]	186.2[a]	199.8[a]
Feed/gain ratios[2]	3.50[a]	2.84[b]	2.16[c]	2.11[c]	2.00[d]	1.89[e]

[1]The constant ingredients provided the following (in %): dicalcium phosphate, 2.25; limestone, 1.00; sodium chloride (iodized), 0.45; manganese sulfate, 0.05; zinc oxide, 0.006; butylated hydroxytoluene, 0.0125; and the following vitamins in units/kg. of diet: choline chloride, 1300 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.

[2]Mean values for 18 day-old chicks. Means bearing the same superscripts are not significantly d[illegible]nt ($P > 0.05$).

soybean meal and DL-methionine to an equal dietary protein level found in the high lysine sorghum diet. The high lysine sorghum was also fed in a 20% protein diet supplemented with soybean meal and DL-methionine (diet 7). Chicks fed this diet were compared with those fed a normal sorghum diet containing an equal weight of sorghum (18.6% protein; diet 6) and with chicks fed a normal sorghum diet supplemented with soybean meal (diet

TABLE 4.—*Composition of diets and the effect of sorghum grains RS610, IS11758 and lysine supplementation on weight gain and feed conversion of chicks (Experiment 3)*

Ingredients (%)	Diets 1	2	3
Sorghum RS610	91.36	91.36	—
Sorghum IS11758	—	—	89.40
L-lysine·HCl	—	0.21	—
Diammonium citrate	0.26	—	0.26
Glucose monohydrate	0.04	0.09	2.00
Soybean oil	3.00	3.00	3.00
Constant ingredients[1]	5.34	5.34	5.34
Total protein (%)	10.90	10.90	10.90
Dietary lysine (%)	0.22	0.39	0.39
Weight gain (g.)[2]	14.5[b]	48.0[a]	50.8[a]
Feed/gain ratios[2]	5.95[b]	3.05[a]	3.25[a]

[1]The constant ingredients were identical to those used in Experiment 1 (Table 2) with the exception that in this experiment they contained 0.39% glucose monohydrate as a carrier for some vitamins.
[2]Mean values for 18 day-old chicks. Means bearing the same superscripts are not significantly different ($P > 0.05$).

8) to make it isonitrogenous to the high lysine sorghum diet.

In Experiment 2, high lysine sorghum was compared to a low-tannin commercial sorghum RS610 (normal sorghum). All diets were formulated to contain 15% protein (Table 3). Safflower meal was used as a supplemental protein source in diets 1 and 2 with equal protein in the two diets being supplied by the two sorghum grains. Soybean meal with and without 0.15% DL-methionine was used as the supplemental protein in diets 3-6. A similar amount of protein from the sorghum grains being tested was present in the four diets.

The same grains studied in Experiment 2 were also fed in Experiment 3. Normal sorghum (diet 1, Table 4) was compared on an isonitrogenous basis with high lysine sorghum (diet 3) in diets in which sorghum provided all the protein in the diet. All diets contained 10.90% protein. Diet 1 contained 0.22% lysine while diet 3 contained 0.39% lysine. Diet 2 contained an equal amount of protein from normal sorghum as diet 1, but was supplemented with L-lysine·HCl to a dietary lysine level of 0.39%. Diammonium citrate was added to the diets not containing supplemental lysine to keep all diets isonitrogenous.

Analysis of variance (Steel and Torrie, 1960) was used to statistically analyze final chick weight gain and feed conversion. In testing the main effects, the treatment × replication interaction was used as the error term. Individual treatment differences were tested by the Newman-Keuls multiple range test (Steel and Torrie, 1960).

RESULTS AND DISCUSSION

Chicks fed the diets in which high lysine sorghum provided all the dietary protein grew approximately three times more rapidly and required almost 50% less feed per unit weight gain than chicks fed the diets in which normal sorghum provided all the dietary protein in Experiment 1 (Table 2). Supplementation of the two sorghum grain diets with 0.2% DL-methionine had little beneficial influence on chick performance. Calculations of the amino acid contents of the grains expressed as a percent of the chick's requirement as reported by Sasse and Baker (1973) indicated that lysine was the limiting amino acid in both diets with the normal sorghum diet being more

deficient in lysine than the high lysine sorghum diet. Supplementation of the normal sorghum diet with soybean meal (diet 5) to an equal protein level as that provided by the high lysine sorghum resulted in significantly improved ($P < 0.05$) chick performance as compared with the unsupplemented diet. The performance of chicks fed diet 5 as compared with that of chicks fed diet 4 suggests that soybean meal has a higher biological value than the high lysine sorghum grain; however, the differences were not statistically significant ($P > 0.05$).

When the two sorghum grains were compared on an equal weight basis at protein levels closer to the chick's requirement, significantly greater ($P < 0.05$) weight gain was observed with the high lysine sorghum (diet 7) than with normal sorghum (diet 6). The improved feed efficiency noted with diet 7 was not statistically ($P > 0.05$) different from that noted with diet 6. No differences in weight gain or feed efficiency were noted when additional soybean meal was added to the diet in place of some normal sorghum (diet 8) to make the diet isonitrogenous with the high lysine sorghum diet.

Safflower meal is severely limiting in lysine for normal chick growth, but otherwise contains a satisfactory balance of amino acids (Valadez *et al.*, 1965). It was therefore used as a source of supplemental protein in two diets in Experiment 2 in which high lysine sorghum was compared with a commercial sorghum RS610 (Table 3). An equal amount of protein was supplied by the two sorghum grains with glucose being added to the high lysine sorghum diet to maintain the two diets at isonitrogenous levels. All diets in this experiment contained 15% protein. Chick growth was poor with both grains, but chicks fed the high lysine sorghum grew approximately 2.5 times faster than chicks fed the normal sorghum diet.

Significantly improved ($P < 0.05$) weight gain and feed efficiency were noted with chicks fed the high lysine sorghum-soybean meal diets (diets 5 and 6) as compared with those of chicks fed the normal sorghum-soybean meal diets (diets 3 and 4). Supplementation of the normal sorghum diet with 0.15% DL-methionine had little effect on chick weight gain or feed efficiency. Supplementation of the high lysine sorghum diet with 0.15% DL-methionine resulted in a significant improvement ($P < 0.05$) in feed efficiency and a slight, but not statistically significant ($P > 0.05$), increase in chick weight gain. Calculations of the dietary amino acid contents using a composite of published values for soybean meal and expressing the results as a percent of the requirement as reported by Sasse and Baker (1973) indicated that with the normal sorghum-soybean meal diets, lysine was the most limiting amino acid. With the high lysine sorghum-soybean meal diet, lysine and methionine appeared to be approximately equally limiting.

The three diets fed in Experiment 3 contained only sorghum grain protein and all diets were isonitrogenous (Table 4). One of the two normal sorghum diets (diet 2) was supplemented with L-lysine·HCl to provide a similar dietary level as that provided by the high lysine sorghum. Chicks fed the high lysine sorghum diet or the normal sorghum diet with added lysine grew approximately 3.5 times faster and with nearly 50% less feed per unit weight gain than chicks fed the unsupplemented normal sorghum diet. The performance of chicks fed the high lysine sorghum and lysine supplemented normal sorghum diets was similar. These results indicate that the improved performance of chicks fed the high lysine sorghum diets as compared with chicks fed the normal sorghum grain diets was due solely to its higher lysine content.

The prospects for improvement of the nutritional quality of sorghum grain through the introduction of the high lysine gene(s) would appear to be excellent. Studies by

Singh and Axtell (1973) suggested that the increased lysine concentration was controlled by a single recessive gene. The high lysine sorghum grain IS11758 is dented and possesses a floury endosperm which may present certain agronomic problems. The major task facing sorghum breeders will be the introduction of the high lysine gene(s) into agronomically desirable lines of sorghum grain.

REFERENCES

A.O.A.C., 1960. Methods of Analysis (9th Ed.). Association of Official Agricultural Chemists, Washington, D.C.

Sasse, C. E., and D. H. Baker, 1973. Modification of the Illinois reference standard amino acid mixture. Poultry Sci. 52: 1970-1972.

Singh, R., and J. D. Axtell, 1973. High lysine mutant gene (hl) that improves protein quality and biological value of grain sorghum. Crop Sci. 13: 535-539.

Steel, R. G. D., and J. H. Torrie, 1960. Principles and Procedures of Statistics, ed. 1. McGraw-Hill Book Company, Inc., New York.

Valadez, S., W. R. Featherston and R. A. Pickett, 1965. Utilization of safflower meal by the chick and its effect upon plasma lysine and methionine concentrations. Poultry Sci. 44: 909-915.