AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY

Batch #21

1. SUBJECT CLASSIFICATION

A. PRIMARY
Serials Y-AF30-0170-0000

B. SECONDARY
Agriculture--Plant breeding--Cereals--Sorghum

2. TITLE AND SUBTITLE
Inheritance and improvement of protein quality and content in Sorghum b olor (L.) Moench; annual report,1972

3. AUTHOR(S)
(101) Purdue Univ. Dept.of Agronomy

DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1973	71p.	ARC 633.174.P985b

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Purdue

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)
(Adm.and research summaries)

9. ABSTRACT

10. CONTROL NUMBER
PN-RAR-401

11. PRICE OF DOCUMENT

12. DESCRIPTORS
Proteins
Sorghum

13. PROJECT NUMBER

14. CONTRACT NUMBER
CSD-1175 Res.

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

A N N U A L R E P O R T

ON

INHERITANCE AND IMPROVEMENT OF PROTEIN QUALITY AND CONTENT IN *SORGHUM BICOLOR* (L.) MOENCH

January 1, 1972 - December 31, 1972

Report no. 9

Prepared by:

J. D. Axtell, Project Leader
D. L. Oswalt, Assistant Project Leader
Department of Agronomy, Agricultural Experiment Station
Purdue University, Lafayette, Indiana

Contract csd/1175

Submitted to:

Agency for International Development
Department of State
Washington, D. C.

NOT FOR PUBLICATION

REPORT SUMMARY

A. 1. Project Title and Contract Number: "Inheritance and Improvement of Protein Quality and Content in Sorghum bicolor (L.) Moench". Contract No. AID/csd-1175.

2. Principal Investigator, Contractor and Mailing Address: John D. Axtell, Department of Agronomy, Purdue Research Foundation, Purdue University, W. Lafayette, Indiana 47907.

3. Contract Period (as amended): July 1, 1966 to March 31, 1975.

4. Period covered by report: January 1, 1972 to December 31, 1972.

5. Total AID funding of contract to date: $1,177,902.

6. Total expenditures and obligations through previous contract year: (7-1-66 to 3-31-72) $935,684.

7. Total expenditures and obligations for current year: (4-1-72 to 12-31-72) $139,687.

8. Estimated expenditures for next contract year: (4-1-73 to 3-31-74) $249,971.

B. Narrative Summary of Accomplishments and Utilization:

Grain sorghum is a major source of carbohydrate and protein for many millions of people in the developing world. It is generally recognized that the nutritional quality of many sorghums now being consumed is relatively poor when compared to the other major cereals. This project has identified many of the problems responsible for this poor nutritional quality through a closely coordinated interdisciplinary approach by animal nutritionists, biochemists and plant geneticists. Protein quality is limited by the low lysine content of the sorghum grain, which reflects the high prolamine content of the endosperm, and the relatively small embryo size as a proportion of the mature grain. The tannin compounds present in the grain of some cultivars substantially reduce protein availability, which indirectly has a major negative effect on the nutritional quality of grain sorghum.

Sorghum germplasm with superior nutritional quality has been obtained by screening over 10,000 lines in the world sorghum collection for protein, lysine and tannin content, and also from biological evaluations in small animal trials. Random mating populations have been developed from these selected superior lines for distribution and utilization in the LDCs. An International Protein Yield and Quality Trial nursery has been established at approximately 15 locations throughout the world to determine the adaptability of improved germplasm and to monitor progress made in the improvement of nutritional quality.

Data on the chemical composition and agronomic characteristics of over 800 lines has been summarized for distribution to sorghum workers throughout the world. Research information has been distributed through seminars, journal publications and annual reports. Graduate student and postdoctorate training programs continue to supply needed trained scientists for sorghum improvement programs in temperate and tropical areas of the world.

PERSONNEL

Department of Agronomy

Dr. J. D. Axtell (Associate Professor, Project Leader)

Mr. D. L. Oswalt (Graduate Student, Assistant Project Leader)

Dr. G. Srinivasan (Postdoctorate)

Dr. H. A. Ibrahim (FAO Postdoctorate Fellow)

Mr. R. E. Schaftert (Graduate Student)

Mrs. Ardith Spies (Administrative Assistant)

Mr. D. P. Mohan (Graduate Student)

Mr. Rameshwar Singh (Graduate Student)*

Mr. Samwiri Mukuru (Graduate Student)*

Mr. Rex de Leon (Technician)

Mr. John Wells (Technician)

Mrs. Joan Sparks (Technician)

Department of Biochemistry

Dr. E. T. Mertz (Professor)

Dr. R. Jambunathan (Postdoctorate)

Mrs. Lourdes Tanchoco (Technician)

Department of Animal Science (Cooperating Staff)

Dr. W. R. Featherston (Professor)

Dr. J. C. Rogler (Professor)

Mr. W. D. Armstrong (Graduate Student)*

* Graduate students that are conducting research pertinent to the objectives but not financially supported by this contract.

A. GENERAL BACKGROUND

Sorghum is the fourth most important cereal crop in the world, being surpassed only by rice, wheat and corn in world-wide importance. In Africa and much of Asia it is the princiapl source of energy for many millions of people and provides a major source of protein in the human diet. Though it is considered relatively high in carbohydrates and a fair source of total protein compared to most cereal crops, the nutritional quality is the poorest of the major cereals with regard to protein content, amino acid balance and total digestibility.

The purpose of this project is to develop and release for utilization in the LDC's superior varieties or lines of sorghum with genetically controlled higher protein content, improved amino acid balance and total digestibility. Thousands of lines from the world sorghum collection and the various breeding programs are being evaluated for levels of total protein and for quality by chemical and biological means. The more promising strains are recombined in various ways to improve further the amount and quality of protein in breeding populations. The parameters of inheritance of the high nutritional quality factors are in the process of being determined. Lines which do not produce seed at Purdue (about 50%) are sent to Puerto Rico for multiplication. There these lines are screened for improved yield for the tropics and seed returned to Purdue for screening of nutritional characteristics. Selected germplasm and supporting cultural practice

information are provided to established programs and interested cooperators to test, screen and to assist in the exchange of breeding materials. Graduate degree and non-degree training programs at Purdue and workshops in selected LDCs are developed and regularly conducted to increase the research capacity of developing nations with the desire of improving the nutritional quality of their sorghum.

B. STATEMENT OF PROJECT OBJECTIVES AS STATED IN THE CONTRACT.

Objective 1 - Identify sorghum lines with improved protein quality and quantity utilizing both chemical and biological methods.

Objective 2 - Identify the chemical nature and composition of the protein fractions of selected sorghum genotypes and correlate the grain fraction composition with nutritonal quality.

Objective 3 - Ascertain the role of various chemical components of sorghum grain such as polyphenols (tannins), protein quality and carbohydrate availability in monogastric animal nutrition.

Objective 4 - Determine the mechanism of inheritance of high nutritional quality and develop breeding methods and materials including populations with improved biological quality for potential utilization in developing countries.

Objective 5 - Disseminate research information and germplasm with superior nutritional quality for utilization in the LDCs.

C. CONTINUED RELEVANCE OF OBJECTIVES

Objective one should encompass the identification of high lysine endosperm mutants in sorghum from chemical mutagen treatments, in addition to screening of world collection germplasm. High lysine mutants in barley (5-6 percent lysine, expressed as a percent of protein) have resulted from mutation induction research recently reported by Danish workers (Ingversen, J., Andersen, A. J., Doll, H. and Koije, B. 1972. Selection and properties of high lysine barleys. - Proc. FAO/IAEA/GSF research coordination meeting on the use of nuclear techniques for improvement of seed protein. Neuberberg (Munich), 26-30 June 1972, IAEA, Vienna (in press).)

This lines of research should be pursued as part of an overall balanced approach to improving lysine content in sorghum. Since this is a new area of research not previously supported by contract funds, reprints of two journal articles are attached as Appendix C to illustrate the capability of project personnel for conducting research in mutagenesis.

D. ACCOMPLISHMENTS TO DATE

1. Findings.

The major research finding during 1972 has been the discovery and identification of factors responsible for the reduced protein availability or digestibility in grain sorghum. The presence of tannin compounds in some grain sorghum lines has been known for several years, but the negative effect of tannins on protein availability (and indirectly on nutritional quality) has only now been demonstrated by research conducted on this project. This was made possible by a closely coordinated interdisciplinary approach between biochemists, animal nutritionists, and plant geneticists. We believe our research on the effect of tannins on nutritional quality represents a major contribution toward the understanding of an important nutritional problem which may exist in many sorghum consuming areas of the world.

Our data suggests that the protein present in high tannin sorghum grain is unavailable for utilization by monogastric animals, which presumably includes human populations. In essence we are proposing that much of the protein being produced in some sorghum consuming areas of the world is currently being wasted, but could be salvaged if low tannin sorghum genotypes were substituted for the high tannin varieties now being grown. This, of course, is an oversimplified solution to the problem, since the tannins which cause nutritional problems also confer some very desirable agronomic characteristics to the grain such as bird resistance and the ability of the maturing grain to tolerate "weathering". An alternative solution is to develop grain milling or processing

methods to separate the tannins from the grain before consumption. The "Palyi" milling system now being tested experimentally in Nigeria (personal communication from Dr. Hugh Doggett) may represent a method of achieving the separation of tannins from mature grain with relatively simple, low cost equipment adaptable to developing countries.

These results (alluded to above and presented in more detail in the next section) represent both a difficult challenge and an important opportunity for improving the nutritional quality of sorghum for use in the LDCs.

2. Interpretation of Data and Supporting Evidence.

The nutritonal problems in sorghum parallel those in other major cereals in many respects, but also differ in some important respects. The major components of nutritional quality in sorghum are listed below:

I. Protein Quality
   - A. Lysine Content
     1. Prolamine Content
     2. Embryo Size

II. Protein Availability
   - A. Tannin Content

Protein quality is limited by the low lysine content of sorghum grain, which reflects the high prolamine content of the endosperm, and the relatively small embryo size as a proportion of the mature grain.

Protein availability is apparently limited in some sorghum genotypes by the presence of unidentified polyphenolic compounds located primarily in the testa layer of the grain. These pigmented compounds have not been well characterized chemically and are referred to generically as "tannins". The testa layer lies between the aleurone cells which comprise the outer layer of the endosperm and the pericarp or seed coat. We do not fully understand how these tannin compounds influence the nutritional quality of sorghum. Our hypothesis at present is that the seed proteins become complexed or bound with the tannin compounds of the whole grain, and that the complexed proteins are substantially less available for utilization by monogastric animals.

Amino Acid Composition. The average protein and amino acid composition of 522 lines from the world sorghum collection are presented in Table D-1. The average protein content of these lines is 12.6 percent and the average lysine content (expressed as a percent of protein) is 2.1 percent. A more meaningful assessment of amino acid content from a nutritional point of view is a comparison of essential amino acid content in sorghum with the rat requirement, as shown in Figure D-1. This illustrates the deficiency in lysine, and the excessive leucine content present in sorghum. The methionine content of sorghum is low, but if one considers the cystine content of 1.5 percent the overall sulfur amino acid content approaches that required by the rat. The

Table D-1. Protein and Amino Acid Composition of Sorghum Grain.*

Composition	Mean	Standard Deviation
Protein	12.61	1.89
Lysine	2.14	0.35
Histidine	2.01	0.20
Arginine	3.59	0.44
Aspartic Acid	7.83	0.77
Threonine	3.26	0.21
Serine	4.52	0.32
Glutamic Acid	23.22	1.99
Proline	8.16	0.89
Glycine	3.07	0.27
Alanine	9.89	0.71
Cystine**	1.50	-
Valine	5.35	0.31
Methionine**	1.80	-
Isoleucine	4.08	0.25
Leucine	14.27	1.21
Tyrosine	4.50	0.32
Phenylalanine	5.19	0.37
Tryptophan***	1.31	0.14

---

* Weighted average for 522 lines.
** Weighted average for 3 lines.
***Weighted average for 9 lines.

tryptophan content of sorghum based on our evidence at this time seems to be adequate which is in contrast to the low tryptophan content in normal corn.

Fractionation of Whole Grain and Endosperm Proteins. Dr. Mertz and Dr. Jambunathan at Purdue have recently completed the fractionation of sorghum proteins using the procedure of Landry and Moureaux (1970). This procedure solubilizes most of the nitrogen of sorghum and yields five different solubility fractions. Results of the fractionation of whole grain from two low tannin and two high tannin sorghum lines are shown in Table D-2. The average percent nitrogen in each

Figure D-1.
Essential Amino Acids.

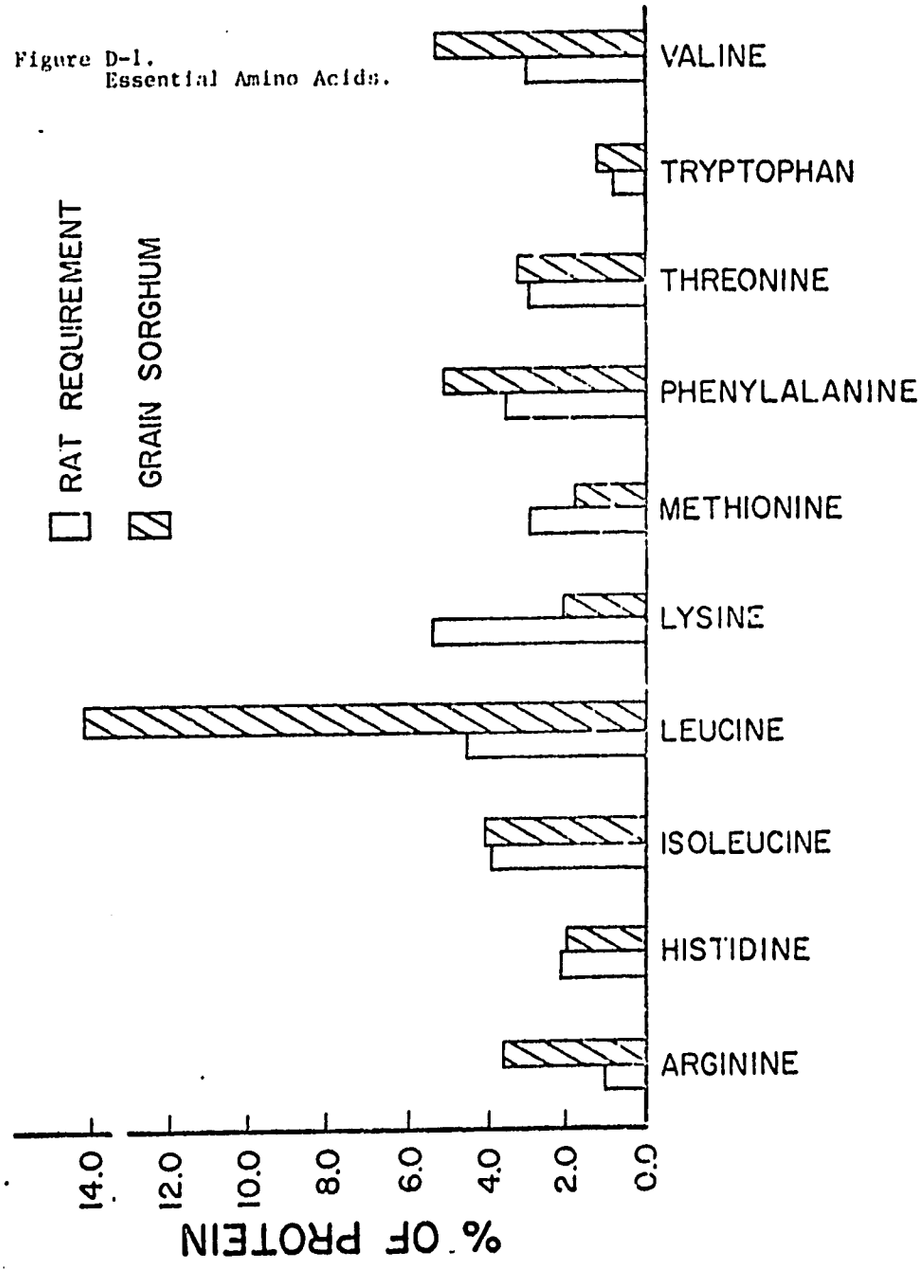


Table D-2. Nitrogen Distribution in Whole Grain.* (Lysine as Percent of Protein in Parentheses).

Fraction	Low Tannin	High Tannin
I (Saline)	16.1 (5.8)	4.9 (3.1)
II (Isopropanol)	14.5 (0.3)	4.2 (0.4)
III (Isopropanol + 2-Mercaptoethanol)	18.6 (0.1)	17.7 (0.2)
IV (Borate buffer + 2 Mercaptoethanol)	6.3 (2.3)	16.2 (2.9)
V (Borate buffer + 2 Mercaptoethanol + Sodium Dodecyl Sulfate)	32.1 (2.8)	52.6 (1.3)
Total Nitrogen Extracted	87.5	89.9

---

* Percent of Soluble Nitrogen.

fraction for the low and high tannin lines is shown in each column, with the average lysine content expressed as percent of protein for each fraction in parentheses. A number of observations could be made but two should be emphasized. First, the distribution of protein in various fractions is distinctly different between the high and low tannin lines. This suggests that the presence of tannins has altered the solubility of sorghum proteins, perhaps by binding or forming complexes with the proteins. This idea is supported by the observation that the first fraction in the high tannin samples is very low in protein content, although one would expect it to be reasonably high since Fraction I represents the albumins and globulins

which are indispensable for the germination and sustenance of the plant. Second, within the low tannin sorghum, the protein content of fractions II and III is high, but the lysine content of these proteins is very low. A summary illustration of Dr. Jambunathan's fractionation studies of proteins from low tannin sorghums is presented in Figure D-2. The bar on the right of each pair represents protein and lysine content of the endosperm fractions, with the bar on the left representing whole grain fractionations. This illustrates the preponderance of protein in Fraction II and Fraction III in endosperm and whole grain fractionations and also the low lysine content of proteins in these fractions.

Growth Response of Rats Relative to Lysine and Tannin Content. Since lysine is the first limiting amino acid in sorghum an experiment was designed to verify the growth response of rats when fed sorghum rations supplemented with adequate lysine hydrochloride to fulfill the rat requirement for lysine plus a 25 percent excess. The results of this experiment are shown in Figure D-3. Two low tannin lines (IS2319 and IS0129) and one high tannin line (IS6992) were included in this trial. As you can see the rat growth on low tannin sorghum rations supplemented with lysine, vitamins and minerals was substantially greater than growth on the ration supplemented only with vitamins and minerals. In contrast, rats fed the high tannin sorghum (IS6992) lost weight on the unsupplemented ration and gained only slightly on the ration supplemented with

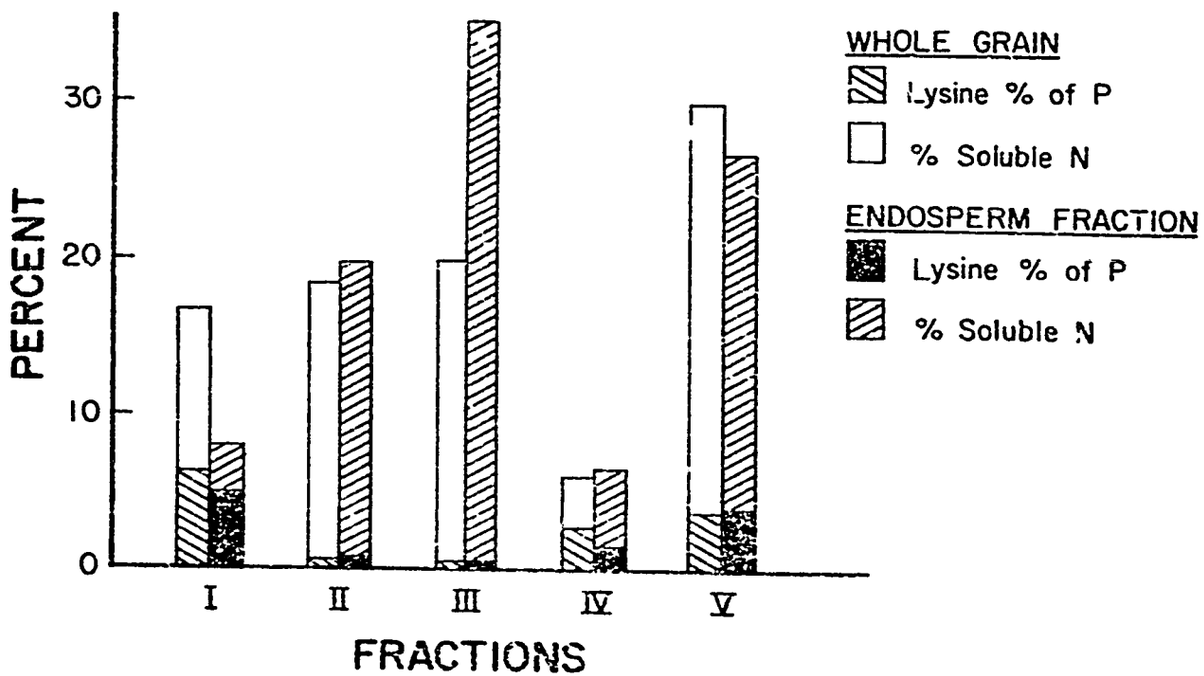
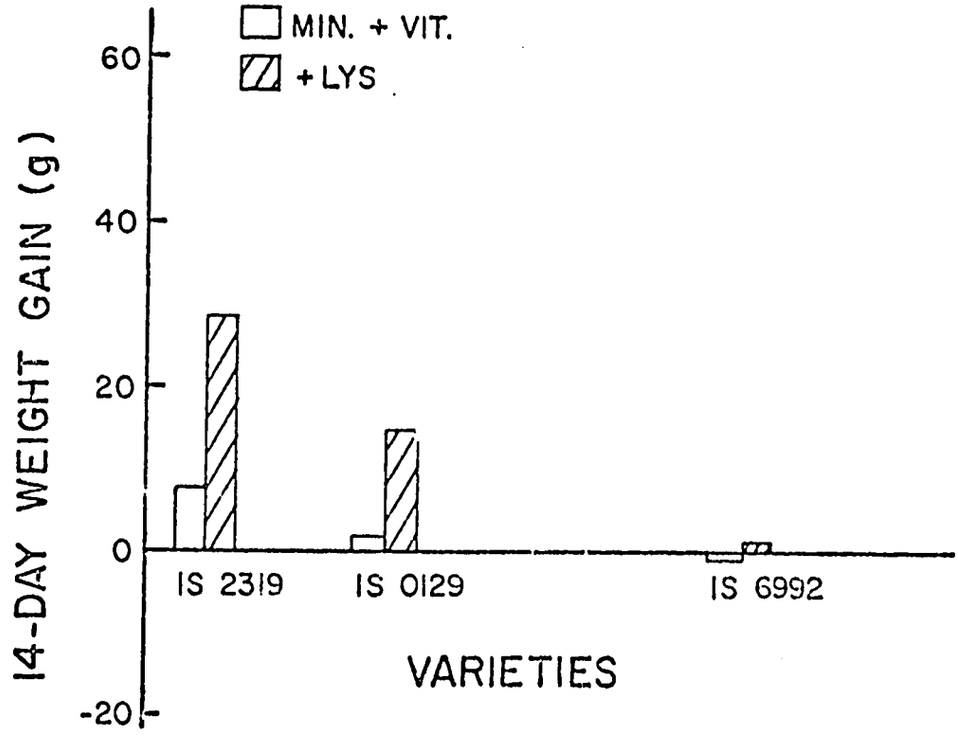

PERCENT
30
20
10
0
I
II
III
IV
V
FRACTIONS
WHOLE GRAIN
Lysine % of P
% Soluble N
ENDOSPERM FRACTION
Lysine % of P
% Soluble N

Figure D-2.

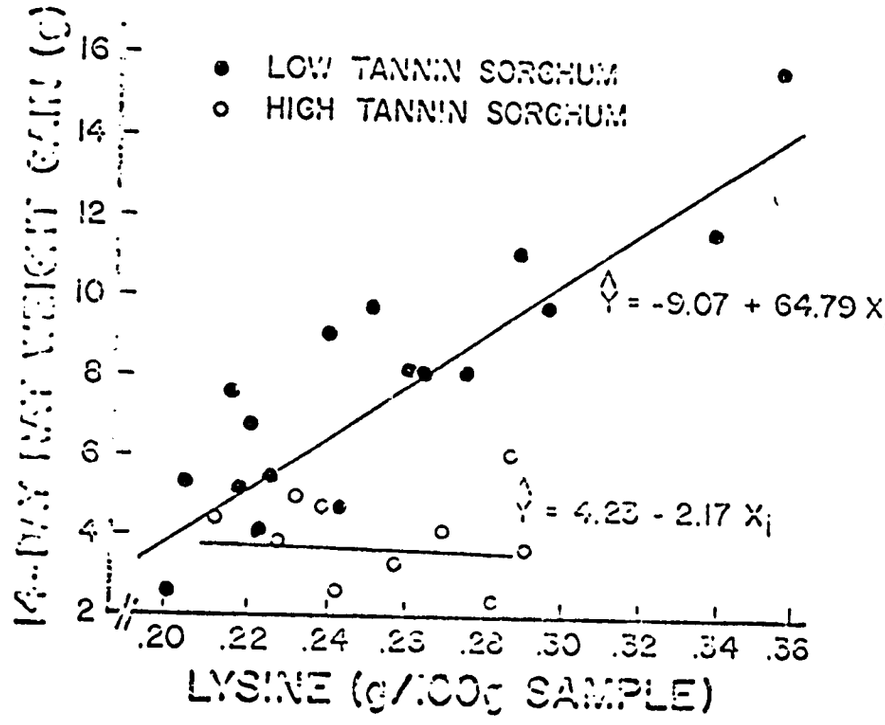
Figure D-3. Rat Weight Gains on Iso-Nitrogeneous Samples of Supplemented Grain Sorghum Lines.



lysine. This observation was first noted by Drs. Mertz and Jambunathan about a year ago using other high tannin sorghums, and has since been repeated with several high tannin lines. These results suggest that lysine is the first limiting amino acid in low tannin sorghum lines but that other factors are first limiting in high tannin lines.

The results obtained from lysine supplementation experiments are substantiated by data from rat growth trials conducted by Dallas Oswalt at Purdue. In this experiment we used 17 low tannin sorghum lines and 10 high tannin lines which represented a range in variation for protein and lysine content of sorghum lines available from our screening program of the world sorghum collection. The results of this experiment, illustrated in Figure D-4, demonstrate that rat weight gain is dependent on lysine content in the low tannin sorghum group, but not in the high tannin sorghum group. The regression of rat weight gain on lysine content for the high tannin group is nearly zero, whereas the regression coefficient for the low tannin groups is about 65. (From the historical point of view this difference in response to lysine content between high and low tannin sorghum lines caused considerable confusion before we were able to distinguish differences between these two groups. Perhaps you can imagine the problems which would be involved in interpreting this data if all the points on this graph were indistinguishable. One would certainly be tempted to conclude

Figure D-4.


LOW TANNIN SORGHUM
HIGH TANNIN SORGHUM
Ŷ = -9.07 + 64.79 X_i
Ŷ = 4.23 - 2.17 X_i
16
14
12
10
8
6
4
2
.20
.22
.24
.26
.28
.30
.32
.34
.36
LYSINE (g/100g SAMPLE)

that chemical analysis for lysine content was unrelated to the biological value of the grain.) We now have a simple, rapid chemical assay for tannin content which so far has been throughly reliable for separating sorghum lines into high and low tannin groups. We use the acidified vanillin method of tannin analysis described by Burns (1970) which estimates tannin content as catechin equivalents. It should be emphasized that the values obtained from this test are based on catechin equivalents, not actual tannin content. Rooney et al (1972) at Texas A & M have reported that catechin equivalent values for grain sorghum are correlated with tannin values obtained with other methods. In our experience the range of catechin equivalents for sorghum is from 0 to 10. We have classified sorghum lines as low tannin if the catechin equivalent value is below 1.00.

Frequency of High Tannin Sorghum Genotypes in the World Collection. We have only limited evidence at this time on the frequency of high tannin sorghum genotypes in the world collection. Among 472 lines which we have analyzed for complete amino acid content, shown in Table D-3, 300 were classified as low tannin and 172 were high tannin lines. The average catechin equivalent values for the low and high tannin lines were 0.38 and 3.40, respectively. There were no significant differences in protein or essential amino acid content between the two groups. We have just completed evaluating 288 lines collected recently in Cameroon, Africa. The data on tannin and protein content

Table D-3. Protein and Amino Acid Composition of High and Low Tannin Grain Sorghum. (Amino Acid Content Expressed as % of Protein.)

Essential Amino Acids	300 Low Tannin	172 High Tannin
Catechin Equivalents	0.38 ± 0.24+	3.40 ± 2.35+
Protein	12.71 ± 1.86	12.42 ± 1.95
Lysine	2.11 ± 0.33	2.15 ± 0.35
Histidine	2.02 ± 0.19	1.99 ± 0.21
Arginine	3.56 ± 0.42	3.60 ± 0.43
Threonine	3.26 ± 0.20	3.24 ± 0.18
Cystine*	0.94 ± 0.22	0.89 ± 0.22
Valine	5.33 ± 0.29	5.37 ± 0.31
Methionine*	1.02 ± 0.53	1.01 ± 0.36
Isoleucine	4.08 ± 0.25	4.07 ± 0.22
Leucine	14.33 ± 1.20	14.17 ± 1.10
Phenylalanine	5.21 ± 0.36	5.12 ± 0.34

+ Standard Deviation.
* Values may be low due to excessive oxidation during hydrolysis.

Table D-4. Frequency of High and Low Tannin Sorghum Genotypes Among 288 Lines Collected in Cameroon, Africa.

	High Tannin	Low Tannin
Number of Lines	229	59
Average Catechin Equivalent Value	4.07	0.49
Average Percent Crude Protein	10.61	10.93

of these lines is reported in Table D-4. Roughly 80 percent of these lines were classified as high tannin genotypes with an average catechin equivalent value of 4.07. There was no difference in protein content between high and low tannin groups, although both were lower than the overall average of 12.6 percent reported in Table D-1. This can probably be accounted for by the observation that the Cameroon lines represent an unusually large seeded collection. In general, it can be concluded that high tannin sorghum genotypes may comprise a significant

proportion of the sorghum germplasm in some areas of the world.

Alkali Dehulling of High and Low Tannin Sorghum Grain. Since the tannin in sorghum grain is contained primarily in the testa layer beneath the pericarp, we have tried with some success to remove the tannin with an alkali dehulling technique described by Dr. Blessin (1971) at the USDA Laboratory in Peoria, Illinois. This method involves hot sodium hydroxide treatment of the whole grain for six to eight minutes followed by repeated washing with distilled water. The data in Table D-5 shows the effect of dehulling on tannin content, protein content, rat gain and feed consumption for one low tannin Texas hybrid (RS610) and two high tannin, high lysine lines (IS6992 and IS8260) from the world sorghum collection.

Table D-5. Alkali Dehulling of High and Low Tannin Grain Sorghum.

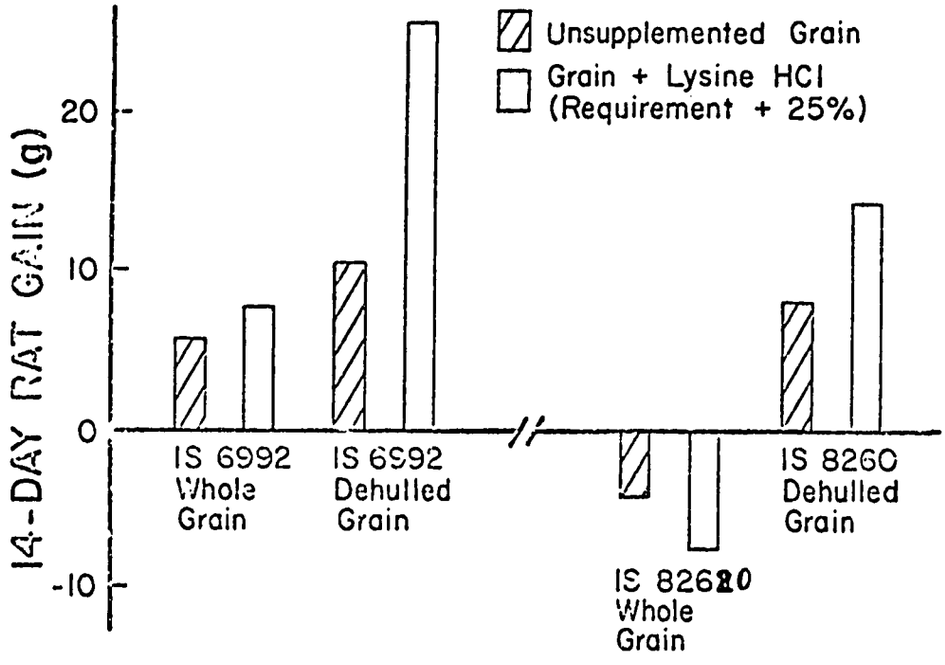
Entry	Catechin Equiv.	Percent Protein	14-Day Rat Weight Gain (g)	Feed Consumed (g)
RS610	.48	9.9	5.26	112
RS610 (dehulled)	.10	9.9	6.72	132
IS6992	1.74	9.4	5.73	99
IS6992 (dehulled)	.07	9.8	10.20	101
IS8260	3.71	8.1	-4.12	95
IS8260 (dehulled)	.10	8.4	7.98	97

Catechin equivalent values were reduced without substantial change in protein content in all cases. Rat weight gain was not significantly

improved by dehulling the low tannin RS610 hybrid, but was substantially increased by dehulling of both high tannin lines. There was no large difference in the amount of feed consumed between hulled and dehulled samples which indicates that the poor weight gain for whole grain samples of IS6992 and IS8260 was not caused by reduced intake.

All of our previous tests on the difference in response of lysine supplementation between high and low tannin sorghum lines have been made by comparing lines from the world collection which differ in tannin content but are not isogenic for other characteristics. A more direct test can be made by utilizing the alkali dehulling technique to obtain "low tannin" control lines which can then be compared with whole grain with the same genetic background but with a high tannin content. The results of an experiment comparing the biological value of whole grain samples from two high tannin lines, and dehulled counterparts of each line, with and without lines supplementation are shown in Figure D-5. In both cases the rats gained little or no weight on the whole grain (high tannin) rations supplemented with lysine, but responded to lysine supplementation of the dehulled (low tannin) counterpart rations. The evidence from this and other studies discussed demonstrates that lysine content is the major factor limiting the biological value of low tannin sorghum grain, but is not <u>first</u> limiting for high tannin sorghum.

Figure D-5. Lysine Supplementation of Whole Grain and Dehulled High Tannin Sorghum Lines.



Supplementation with Soybean Meal. One possible explanation for lack of rat growth response in lysine supplemented high tannin sorghum rations is that the tannin compounds may produce a toxic effect which counteracts the expected growth response from lysine supplementation. The data in Figure D-6 suggest that this is not the case since the addition of only five percent soybean oil meal to high tannin rations produced a very significant increase in rat growth. In this experiment, conducted by Schaffert (1972) at Purdue, rations containing two low tannin and two high tannin lines were supplemented with 0, 5, 10 or 15 percent soybean oil meal, and rat growth response measured in a 13-day trial. It seems unlikely that the addition of small quantities of soybean meal would dilute any toxic effect to the extent required to account for the substantial rat gain illustrated in Figure D-6. We would expect the low tannin lines to respond to soybean supplementation because of the relatively high lysine content supplied. It is quite apparent that something is added with the soybean oil meal which can correct a nutritional deficiency or imbalance in the high tannin rations. The effect of soybean meal supplementation on feed efficiency ratios is illustrated in Figure D-7. This again shows the striking reduction in amount of feed consumed per gram of gain when high tannin rations are supplemented with five percent or more soybean oil meal. The most viable possibility at this time is that the soybean oil meal supplies available protein which is deficient

Figure D-6.

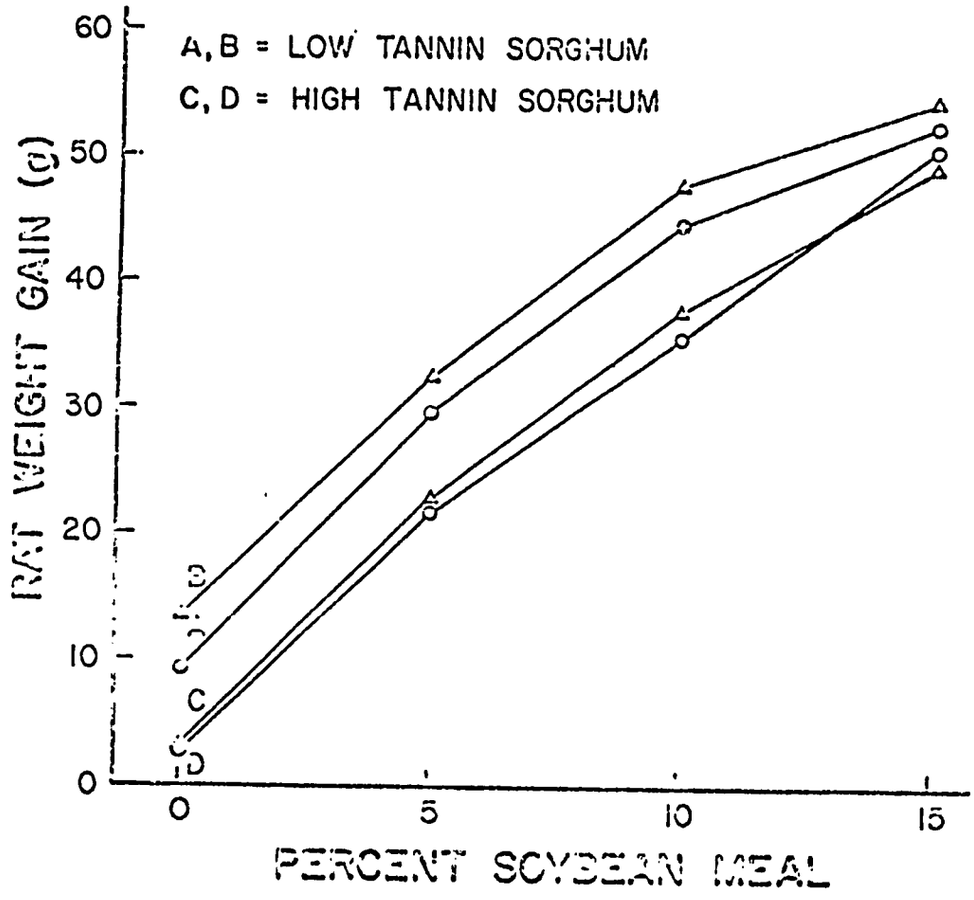
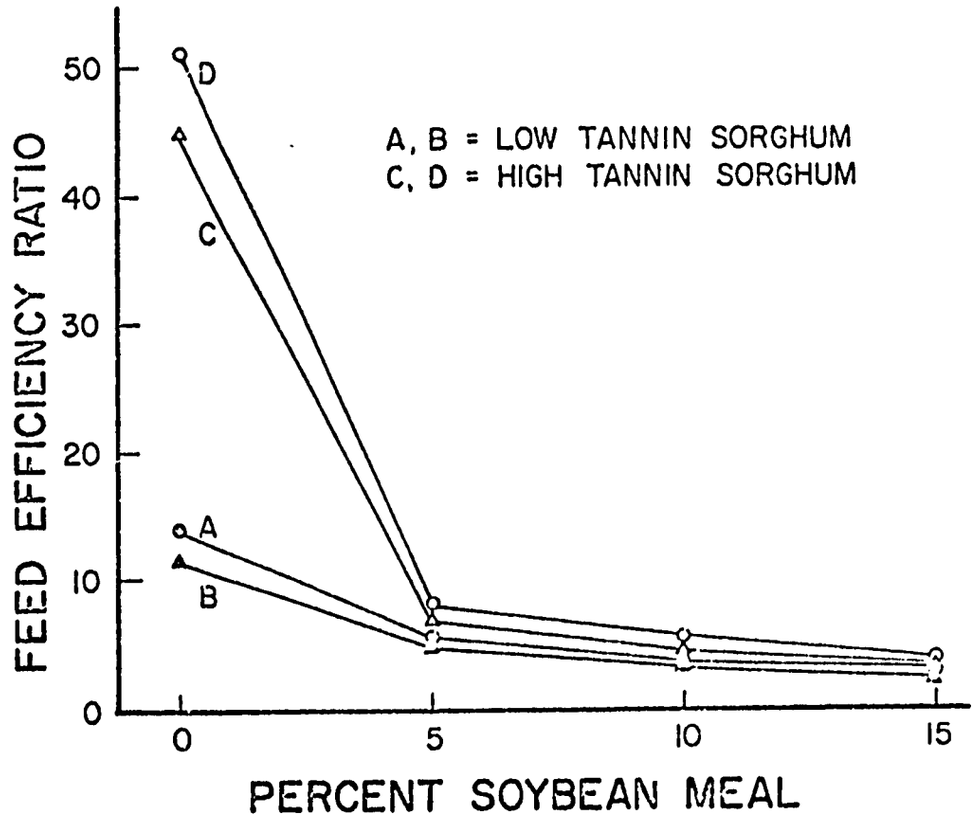

A, B = LOW TANNIN SORGHUM
C, D = HIGH TANNIN SORGHUM
RAT WEIGHT GAIN (g)
60
50
40
30
20
10
0
0
5
10
15
PERCENT SOYBEAN MEAL

Figure D-7.


FEED EFFICIENCY RATIO
50
40
30
20
10
0
D
C
A
B
A, B = LOW TANNIN SORGHUM
C, D = HIGH TANNIN SORGHUM
0
5
10
15
PERCENT SOYBEAN MEAL

in high tannin lines because the sorghum protein is complexed or by some other mechanism made unavailable for monogastric animals. The evidence obtained by Drs. Jambunathan and Mertz on protein fractionation supports this explanation, since the presence of tannin compounds apparently alters the solubility of major protein components in high tannin sorghum lines. Dr. Jambunathan is currently determining the molecular weight and other characteristics of the proteins in each high tannin sorghum fraction, which should provide direct biochemical evidence on whether these proteins are complexed with tannins or not. There are other possible explanations which need to be tested, including the following:

a) Soybean oil meal may provide some essential amino acid other than lysine which is selectively unavailable in high tannin rations.

b) There may be a deficiency of available inorganic nitrogen, needed for biosynthesis of non-essential amino acids and/or other nitrogenous compounds vital for normal growth and development in high tannin sorghum rations, perhaps because of the unavailability of the nitrogen from the sorghum protein.

c) There may be compounds in soybean oil meal which can bind more competitively with tannins, and thereby replace the protein bound to tannin making it more available.

Each of these possibilities is currently under test.

In summary, the protein quality in most grain sorghum is marginal with regard to lysine content, and it would appear that among the high tannin lines only a part of this protein is available for utilization by monogastric animals.

What is the status of our efforts in improving the nutritional quality in sorghum? The tannin problem has already been discussed. If we are correct in our assumption that tannins complex with seed proteins, and that these proteins are then less available to monogastric animals, there are several alternatives:

1) Use only low tannin sorghums for consumption by human and other monogastric animals and find other methods for controlling birds, which is one major reason for using high tannin sorghum germplasm. Since tannin content is simply inherited and controlled by only one or two major genes this is an easy task for the breeder.
2) Use high tannin sorgham lines for their desirable agronomic characteristics, and plan to supplement with additional protein to meet the nutritional requirement. If this approach is adopted one should bear in mind the likelihood that you are essentially wasting some of the protein in the sorghum grain. I do not believe that this is economically feasible in most areas of the world where sorghum is a major component of the human diet.

3) There may be dehulling procedures or methods of dry milling that could be used to remove the pericarp and testa cells which contain the tannin compounds.

4) There may be additives that will preferentially bind with the tannins and allow the protein to be utilized.

With regard to improvement of lysine content there are excellent opportunities for increasing germ size. Grain sorghum germ size ranges from 7.8 to 12 percent of the whole grain. This is smaller than the germ size in corn. In my estimation this difference explains part of the difference in lysine content between normal corn and sorghum. Normal corn contains approximately 2.5 to 2.8 percent lysine (expressed as percent of protein) whereas normal sorghum contains approximately 1.9 to 2.2 percent lysine. The difference in average oil content between corn (4 to 5 percent) and sorghum (2 to 3 percent) also suggests difference in germ sizes between these species since most of the oil is contained in the germ. We have identified several sorghum lines with 2.5 to 2.6 percent lysine which have a relatively large germ size. We should be able to make quite rapid progress in selections from random mating populations derived from selected large germ lines without reduction in yield potential. This should lead to improved nutritional quality.

Another possibility for improving lysine content is through the use of endosperm "mutants" which effect carbohydrate synthesis.

Misra et al (1972) have reported recently that these mutants in corn also effect lysine content in the endosperm. Mr. Rameshwar Singh working in our laboratory has identified five such "mutant" lines in the world sorghum collection this past year. The protein and lysine content of all five lines are shown in Table D-6. These are preliminary results, and are very interesting from a theoretical point of view, but it is too early to speculate on the practical value of these carbohydrate mutants for improving the nutritional quality of sorghum.

Table D-6. "Sugary" or "Brittle" Endosperm Lines.

IS Number	% Protein	Lysine % of Protein	Lysine % of Sample
Sorghum Average	12.61	2.14	.269
5376	16.3	2.27	.370
5614	14.8	2.65	.392
5623	15.1	2.73	.412
4526	16.2	2.71	.439
4668	14.9	2.18	.325

The prolamine content of sorghum endosperm is high, as we have seen, and the lysine content of the prolamine fraction is very low in sorghum as it is in corn. The situation in sorghum parallels that in normal corn in many respects. There is every reason to believe that mutants which reduce or block prolamine synthesis also occur in sorghum.

We have now completed examining sectioned grains of about 9,000 lines in the world sorghum collection and identified possible opaque grain phenotypes. Some have been grown in Lafayette in 1972 and others (light-sensitive lines) are being grown in Puerto Rico this winter. Protein and lysine analysis of these putative opaque lines will reveal whether any low prolamine lines have been identified. Preliminary results of two lines from Ethiopia identified by Mr. Rameshwar Singh are encouraging. The protein content of these lines is 12 and 15 percent, with lysine contents of 3.0 and 2.9 percent (expressed as percent of protein), respectively. Dr. Jambunathan has just completed fractionation of the endosperm proteins of these two lines and the results are presented in Table D-7.

Table D-7. Nitrogen Distribution in Sorghum Endosperm.

Fraction	Sorghum Average	Ethiopia 204-1	Ethiopia 204-2
I	7.3	20.97	15.71
II	16.8	13.70	12.19
III	32.4	21.49	25.45
IV	7.8	8.43	5.98
V	25.3	24.23	31.84
Total Nitrogen Extracted	89.5	88.8	91.17

Note the reduction in percent protein in the prolamine fractions (II and III) and the increase in percent protein in fraction I, which is the lysine rich fraction in sorghum. Data from a preliminary rat feeding trial of one of these lines compared with our best check line (IS2319) is presented in Table D-8.

Table D-8. Results of 7-Day Rat Feeding Trial.

Entry	Rat Weight Gain (g)
Ethiopia 204-2	10.2*
IS2319 (check)	4.3**

* Average of four rats
** Average of three rats

This verifies that the biological value of Ethiopia 204-2 is indeed superior to our best check line. We do not believe, at this time, that these lines from Ethiopia represent the equivalent in sorghum of the opaque-2 high lysine mutants in corn. Much more information is needed, but it is fair to conclude that Ethiopia 204-2 and 204-2 represent a step in the right direction, i.e., toward better nutritional quality in grain sorghum.

In summary, it will be necessary to consider each of these parameters (prolamine content, germ size and tannin content) in the nutritional quality in sorghum. It is unlikely that any lines in

the world sorghum collection will have all three necessary characteristics. It is concluded we will have to identify lines with each component of nutritional quality and then recombine them to obtain genotypes with the desired combination of characteristics.

REFERENCES CITED

Blessin, C. W., R. A. Anderson, W. L. Deatherope and G. E. Inglett. Effect of Alkali Dehulling on Composition and Wet Milling Characteristics of Sorghum Grain. Cereal Chemistry 48: 528-532. 1971.

Burns, R. E. Method for Estimation of Tannin in Grain Sorghum. Agron. Jour. 63:511-512. 1971.

Jambunathan, R. and E. T. Mertz. Fractionation of Whole Kernel and Endosperm Proteins of Sorghums Having Different Tannin Contents. Jour. Agric. Food Chem. (In Press - 1973)

Landry, J. T. and T. Moureaux. Heterogeneite des Glutelines du Grain de Mais: Extraction Selective et Composition en Acides Amines des Trois Fractions Isolees. Bull. Soc. Chim. Biol. 52:1021. 1970.

Maxson, E. D. and L. W. Rooney. Two Methods of Tannin Analysis for Sorghum bicolor (L.) Moench Grain. Crop Science. 12:253-254. 1972.

Misra, P.S., R. Jambunathan, E. T. Mertz, D. V. Glover, H. M. Barbosa and K. S. McWhirter. Endosperm Protein Synthesis in Maize Mutants with Increased Lysine Content. Science. 176:1425-1427. 1972.

Schaffert, Robert. Protein Quantity, Quality, and Availability in Sorghum bicolor (L.) Moench Grain. Ph.D. Thesis. Purdue University. 1972.

3. Research Design.

Several methods for lysine analysis have been evaluated during the past year (a complete report is appended with research results). Results from dye-binding estimates of basic amino acid content were highly correlated with the biological value of grain sorghum within the low tannin group. This technique will be adopted as a rapid screening method for low catechin equivalent samples. Short column chromatography will continue to be used for lysine estimation in high tannin samples.

The NEOTEC grain quality analyzer is currently being evaluated for rapid determinations of protein, oil and moisture content. Preliminary results suggest that correlations with micro Kjeldahl nitrogen are good (r = 0.96).

E. DISSEMINATION AND UTILIZATION OF RESEARCH RESULTS.

1. Dissemination of Results.

Publication of research data in journals with the distribution of the annual report data resulted in widespread utilization of findings. Several requests for additional copies of the 1971 report were received from AID missions. Staff participation in seminars at Miami, Caracas, Mexico City and Washington and a one-week workshop for South American workers in Brasilia gave direct contact with research and INCAP workers.

Visits to disease and research field days in Texas with visits by U.S. and other country workers to the Purdue University campus with their collecting ideas, data and genetic materials resulted in sharing project findings. Training of graduate students from the U.S. and other countries stimulated and directed interest to the potentials for protein quality studies and developments in grain sorghum and the progress being accomplished. A bibliographic list of publications and short abstracts of each is attached as appendix E-1 (a). A list of short statements that identify each known use of materials produced by this project is attached as appendix E-2 (b).

2. Evidence and Cases Where Findings are Being Used in LDC's and U.S.

   a) Lines have been selected from the 20 entries in the First Purdue-AID International Protein Yield and Quality Trials and entered into extensive yield trials for possible increase and release in Brazil, and data from over 20 locations are being collected from plantings being harvested now.

   b) A special study by Dr. Lynn Bates at Kansas State University with three selections of each of two levels of lysine and tannin has been established from our data and inventory at one level of protein. Several high tannin sorghum lines were sent to the University of Kentucky Biochemistry Department for chemical analysis of the tannin compounds present.

c) Feeding trials to compare rats, mice, chicks, voles and crickets were entered by selections from our data and inventory in connection with CIMMYT evaluation of other crops.

d) Requests for protein quality selections and specific phenotypes have been filled from Mexico, Brazil, Puerto Rico, India, Uganda and the U.S.

e) Sets of slides showing equipment, phenotypes and disease and insect damage were sent to Argentina, University of Brasilia, Campinas, Sao Paulo, Sete Lagoas and Fortaleza in Brazil as requested by participants in the workshop.

f) USDA workers at Peoria, Illinois were sent at their request representative genotype samples of known levels of tannin, protein and lysine.

g) Visitors from Malawi, W. Pakistan, Brazil, Uganda, Kenya, Nigeria and the U.S. and international centers discussed and received data and procedures relevant to adaptation in LDC programs of their involvement.

h) Requests for computer programs developed for handling field and protein data have been answered by sending the programs to Brazil and Texas workers.

i) A simplified general procedures handbook for nursery development is in a rough draft stage in response to Brazilian requests for a nursery procedure guide. This effort is to be completed in the near future.

j) High altitude high protein types have been requested for use in Mexico and the cooler areas of Brazil. Our best line selections have been sent with relevant data.

k) High protein ms_3 populations requested for use in Brazil and India with A and B line selections requested by Argentina, Colombia and Brazil were provided.

l) Entries with known disease and insect resistances having protein estimates have been requested by Indonesia. Others are also requesting this information. Some have been referred to the Texas program.

m) Hybrids, populations, selections and data from this project are forming a basis for the Sorghum Division of the Brazilian National Special Agricultural Research Program.

n) Samples for standardization and evaluation of NEOTEC's Grain Quality Analyzer were selected from inventory samples with known data. This may be a valuable tool for rapid estimations of moisture, protein and oil in LDCs and other countries.

o) Samples representing a high protein potential, but also potential forage varieties based on our field data were selected for requested experimental use in Haiti, Puerto Rico and Brazil.

p) Data being returned to us indicates use of the number coding system for note-taking and management suggestions distributed with requested seed sets.

3. Ways to Use Research Data More Effectively.

   a) Continue full cooperation with ICRISAT and with work being done in Puerto Rico, Texas and Nebraska to avoid duplications and collect and summarize known data for more efficient utilization and distribution of collection items. The establishment of staff to coordinate and produce data summaries to pull all sorghum work together is needed. This should be an additional contract attached to one of the present research programs.

   b) A simplified nursery handbook outlining field layout systems, note-taking systems, data handling procedures and sources and type of equipment is needed to help coordinate data recording and stimulate workers in LDCs to investigate sites and systems when establishing new test sites and for renewal of older programs.

   c) Continue the development and conduction of workshops related to production and management factors contributing to protein and other nutritional factors in Africa and Asia in cooperation with ICRISAT.

4. Involvement of LDC Personnel and Institutions.

   a) The workshop at Brasilia was organized and locally supported by the Ministry of Agriculture, University of Brasilia and USAID personnel in Brasilia. Dr. R. C. Pickett met with the planning committees and they developed the program

and made local arrangements. Their invitation to our project personnel to present papers at the symposium was very effective in further development of the current interest in sorghum in Brazil.

b) The First Purdue-AID International Protein Yield and Quality Trials involved selecting entries on the basis of previously distributed germplasm data and Purdue research data and correspondence with workers in areas where the trials were placed in previous years as well as concerning these specific trials. Their return of field books and samples for analysis and data summarization is leading to the selection of entries for a broad based widely adapted random mating population with above average protein quality and yield potential to further LDC use in their breeding programs.

c) Dr. Helmi Ibrahim from Egypt is here for a one-year study program sponsored by FAO, and Mr. Raimundo de Pontes Nunes from Fortaleza, Ceara, Brazil arrived recently for a Ph.D program sponsored jointly by Ford Foundation and USAID. Both are scheduled for future sorghum research programs when they return to their countries. One student from India, one from Uganda and two from the U.S. will be completing Ph.D. programs in 1973.

d) Cooperation with Texas, Arizona and Georgia in disease and insect evaluation of selected materials and the testing for

protein quality of the converted lines from Texas has continued to identify genotypes more suitable for breeding programs.

e) Cooperation with USDA in Puerto Rico in completing their inventory of the IS collection and for selection of other potentially high quality entries now in the world sorghum collection has continued. They are also helping advance our random mating populations.

f) Extensive correspondence involving germplasm, management factors and nutritional quality resulted from the continued wide distribution of research reports resulting in visitors from LDCs and others to our laboratories and fields for direct contact with this program.

F. STATEMENT OF EXPENDITURES AND OBLIGATIONS AND CONTRACTOR RESOURCES.

Category	Total Budget Amount 4/1/72-3/31/73	To Date 4/1/72-12/31/72	Estimated 1/1/73-3/31/73	Total Actual and Estimated
Salaries & Wages	$101,850	$ 73,997	$23,890	$ 97,887
Overhead	63,962	46,470	15,003	61,473
Salary Related Cost	8,183	3,767	1,220	4,987
Non-Expendable Equipment	4,000	516	3,484	4,000
Expendable Equipment & Supplies	10,800	9,083	2,000	11,083
Winter Nurseries	8,000	-0-	11,700	11,700
Travel & Subsistence	4,000	4,637	-0-	4,637
Computer Service, Publications, Workshops and Seminars	13,000	1,217	4,185	5,402
Subcontract Analysis	28,423	-0-	36,825	36,825
Grand Total	$242,218	$139,687	$98,307	$237,994

G. WORK PLAN AND BUDGET FORECAST FOR 1973-74.

Objective 1 - Identify sorghum lines with improved protein quality and quantity utilizing both chemical and biological methods.

a) A major effort will be made to complete chemical analysis of the world collection of sorghum lines in our inventory for tannin content, lysine content and protein content.

   1) Tannin content will be estimated as catechin equivalents which has been a reliable assay that is consistently negatively correlated with rat response.

   2) The high tannin sorghum lines will be analyzed for lysine content using short column ion-exchange chromatography on the Beckman Amino Acid Analyzer. High lysine lines will be crossed with low tannin genotypes to extract genes conditioning high lysine content in low tannin genotypes.

   3) The low tannin sorghum lines will be analyzed for lysine content using the dye-binding technique, followed by rat feeding trials on the best entries.

b) Evaluate F_2 and F_3 progeny from low tannin sorghum genotypes treated with chemical mutagens in 1972 for isolation of low prolamine (high lysine) endosperm mutants.

c) Make chemical evaluation of sorghum lines which produce grain with a non-vitreous endosperm phenotype selected by examination

of sectioned grains of lines in the world collection.

d) Evaluation of 124 sorghum lines released by the USDA Texas Conversion Program for protein, lysine and tannin content. Nutritional quality will be verified with rat feeding trials on the most promising lines.

e) Evaluation of a technique for total sulfur determination of sorghum grain as a means of estimating sulfur-bearing amino acid content of sorghum lines.

f) Continue protein yield trials with 12-15 cooperators in the U.S. and overseas using 20 sorghum lines selected for the initial release of 500 lines and other quality selections.

g) Continue sampling from F_2 to F_5 progeny of crosses between high protein quality lines. Begin evaluation of lines from ms_3 high protein and high lysine populations.

Objective 2 - Identify the chemical nature and composition of the protein fractions of selected sorghum genotypes and correlate the grain fraction composition with nutritional quality.

a) Fractionate sorghum types showing major differences in nutritional value based on rat feeding tests into five soluble fractions (Landry-Moureaux method). The five fractions will be examined by chromatography and disc gel electrophoresis to identify individual proteins and protein-polyphenol complexes which may enhance or reduce the feeding value of the whole sorghum grain.

b) Determine lysine content of a wide spectrum of sorghum genotypes in low tannin and dehulled high tannin samples using the pyridine method (E. Villegas and E. T. Mertz, CIMMYT Res. Bull. No. 20, 1971) and correlate the lysine content with rat performance and with lysine content of individual protein fractions.

c) Isolate protein-polyphenol complexes and determine their nutritive value in the rat.

Objective 3 - Ascertain the role of various chemical components of sorghum grain such as polyphenols (tannins), protein quality and carbohydrate availability in monogastric animal nutrition.

a) To study the influence of dietary supplementation of methyl group donors, specifically methionine and choline, on the chick's utilization of sorghum grain containing high levels of tannic acid.

b) To compare the nutritive quality of low and high tannin sorghum grain from which the tannin containing testa layer has been chemically removed.

c) To study the feasibility of using an *in vitro* enzyme digestion assay as a measure of the amino acid availability of sorghum grain containing varying amounts of tannins which have shown by growth studies to support widely differing rates of growth and feed efficiency.

d) Evaluate carbohydrate digestibility and rat performance of 30 waxy endosperm lines selected from the world sorghum collection.

Objective 4 - Determine the mechanism of inheritance of high nutritional quality and develop breeding methods and materials including populations with improved biological quality for potential utilization in developing countries.

a) Continue development of high protein and high lysine male sterile ms_3 populations at Purdue and Puerto Rico.

   1) Third random mating generation for high lysine B and R populations (release seed).

   2) Second random mating generation for high protein B and R populations.

   3) Second random mating generation for high yield with above average protein B and R populations.

   4) First random mating generation for populations developed from 20 outstanding lines with superior protein yield.

   5) First random mating generation for population developed from lines selected on superior rat weight gains.

   6) Continue backcrossing elite lines (high lysine such as IS8260 and others) on ms_3 stock to develop pure lines for future inheritance studies.

   7) Continue developing exotic cytoplasmic male sterile A and B lines (about 20 new backcrosses initiated each year).

b) Use A lines after backcross six to set up a diallel to study the inheritance of the traits affecting biological value.

c) Continue to evaluate families in the F_3, F_4, F_5, F_6 and F_7

generation made by crossing various combinations of protein level, and nutritive value as determined by rat feeding.

d) Study inheritance of genes controlling tannin content in sorghum using F_2 progeny from high tannin x low tannin crosses.

e) Continue to study the environmental effects on protein yield and nutritional quality. All selections grown at multiple locations will be analyzed for genotype x environment interactions.

f) The inheritance of the ability of plants to take up nitrogen differentially under various nutrient levels and balances will be investigated as related to grain protein quantity and quality.

Objective 5 - Information and germplasm utilization and dissemination.

a) Make available and distribute collected and developed information for improved nutritional quality of sorghums, distribute selected germplasm to established programs and interested cooperators, and develop cooperative programs to test, screen and exchange breeding materials.

1) Breeding and evaluation material will be distributed to cooperators as follows:

- Twenty selected diverse lines for breeding sources will be sent to cooperators requesting seed. Instructions for management, data collection and return of select grain samples useful for our study will accompany the seed shipment. Seed of selected lines and all data will be returned for analysis.

- Populations and segregating materials will be made available.
- All lines going to advanced trials will be sent for resistance studies, e.g., anthracnose (Georgia), Shoot fly (India and Africa) etc., as such trials can be arranged in cooperation with ICRISAT.

2) Print and distribute catalogs or suitable materials to enable adequate utilization of data related to origin, composition, inheritance and nutritional quality of populations and collection items.

3) Ph.D. degree programs with thesis on the work related to this project will be continued at about the level of four candidates at a time.

4) Non-degree programs (number determined largely by cooperators) with response by this project to the following:
   - Continuation of visitors from many countries.
   - Short-term AID-supported individuals and groups.
   - Longer term (six months to one year) visiting professors and others.
   - Commercial company and other trainees.
   - Special research problems by superior Purdue undergraduate students.
   - Post-doctorates (threepositions funded by this project).

5) Workshops.
   - Continue to implement a Latin American Workshop for sorghum

workers to be conducted in Puerto Rico in January 1974.

- Initiate and develop plans for a workshop to be held in South-east Asia as soon as feasible to be followed by one in Africa (possibly Ethiopia) in cooperation with ICRISAT.

6) Initiation of opportunities to share findings and problems with ICRISAT and co-workers will be promoted by visits to the Texas sorghum program, Nebraska sorghum program, attendance at relevant seminars and conferences, inviting co-workers to visit the project's nursery and laboratories, Purdue Agronomy Farm Field Day participation and continued cooperation with the Indiana Agricultural Extension Service.

Budget:

Line item 1 - Salary and Wages	$116,469
Line item 2 - Indirect Costs (62.8%)	73,143
Line item 3 - Salary Related Costs	8,659
Line item 4 - Permanent Equipment	4,000
Line item 5,6 - Expendable Supplies	8,000
Line item 7 - Winter Nursery	6,500
Line item 8 - Travel	4,000
Line item 9 - Computer Services	2,000
Line item 10- Sub-Contract Services	21,200
Line item 11- Publications	2,000
Line item 12- Workshops, Seminars	4,000
Total	$249,971

APPENDIX:

D. Current Research Report Topics.

1. Components of Nutritional Quality in Grain Sorghum. J. D. Axtell, R. C. Pickett, D. L. Oswalt, R. Jambunathan and G. Srinivasan.

2. Genotype by Environment Interactions for Yield, Protein, Lysine, Oil and Seed Weight in Sorghum bicolor (L.) Moench. R. E. Schaffert, R. C. Pickett, D. L. Oswalt and J. D. Axtell.

3. Amino Acid Composition of Whole Kernel and Endosperm Protein Fractions of Sorghum. R. Jambunathan and E. T. Mertz.

4. Comparison of Chemical Evaluation Techniques with Biological Values of High and Low Tannin Grain Sorghum. R. Jambunathan, J. D. Axtell, E. T. Mertz, D. L. Oswalt, and G. Srinivasan.

5. Amino Acid Composition of Sorghum Grain and Relationships Between Amino Acids and Protein. G. Srinivasan, J. D. Axtell, R. Jambunathan and D. L. Oswalt.

6. Influence of Supplemental Nitrogen on the Relationship Between Tannin Content and In Vitro Dry Matter and Nitrogen Disappearance in Sorghum Bicolor (L.) Moench Grain. R. E. Schaffert, D. L. Oswalt and V. L. Lechtenberg.

7. Comparative Studies of the Utilization of Bird Resistant and Non-Resistant Sorghum Grain by Chicks. W. D. Armstrong, J. C. Rogler and W. R. Featherston.

8. Effect of Supplemental Protein on the Nutritive Value of High and Low Tannin Sorghum Bicolor (L.) Moench Grain for the Growing Rat. R. E. Schaffert, D. L. Oswalt, and J. D. Axtell.

9. A Comparison of Three-Row and One-Row Plots for the Evaluation and Selection of Lines for Protein Content. D. L. Oswalt.

10. Preliminary Results of the First Purdue-AID International Protein Yield and Quality Trial. D. L. Oswalt, R. C. Pickett, and J. D. Axtell.

APPENDIX:

E-1a. Bibliographic List and Short Abstracts of Research Reports for 1972 Representing Efforts to Disseminate the Results of the Research Project.

1. Axtell, J. D. Purdue University International Sorghum Program. Paper Presented at the AAAS Symposium entitled "Organizing for International Research" December 28, 1972, Washington, D. C.

2. Axtell, J. D., R. C. Pickett, D. L. Oswalt, R. Jambunathan and G. Srinivasan. Components of Nutritional Quality in Grain Sorghum. Paper Presented at the CIMMYT-Purdue International Symposium on Protein Quality in Maize, December 4-8, 1972 at El Batan, Mexico.

3. Armstrong, W. D., W. R. Featherston and J. C. Rogler. Influence of Methionine and Other Dietary Additions on the Performance of Chicks Fed Bird Resistant Sorghum Grain Diets. Poultry Science (In Press - 1973).

4. Collins, F. C. and R. C. Pickett. Combining Ability for Grain Yield, Percent Protein, and g Lysine/100g Protein in a Nine-Parent Diallel of Sorghum Bicolor (L.) Moench. Crop Science 12:423-425. 1972.

5. Collins, F. C. and R. C. Pickett. Combining Ability for Yield, Protein, and Lysine in an Incomplete Diallel of Sorghum Bicolor (L.) Moench. Crop Science 12:5-6. 1972.

6. Jambunathan, R., J. S. Misra and E. T. Mertz. Nutritive Value and Protein Solubility Characteristics of Normal and Pigmented Sorghums. Federation Proceedings. (In Press - 1973)

7. Oswalt, D. L., R. E. Schaffert, R. C. Pickett and J. D. Axtell. Relationships of Chemical Compositions to Biological Values of Sorghum bicolor (L.) Moench. Agronomy Abstracts. 1972. p. 70.

8. Oswalt, D. L. First Interamerican Sorghum Symposium. Papers Presented at the First Interamerican Sorghum Symposium, August 28-31, 1972. Brasilia, Brazil.

9. Rostagno, H. S., W. R. Featherston and J. C. Rogler. Studies on the Nutritional Value of Sorghum Grains with Varying Tannin Content for Chicks. Growth Studies. Poultry Science. (In Press - 1973).

10. Rostagno, H. S., J. C. Rogler, and W. R. Featherston. Studies on the Nutritional Value of Bird Resistant Sorghum Grain for Chicks. Amino Acid Digestibility Studies. Poultry Science. (In Press - 1973).

11. Schaffert, R. E., D. L. Oswalt and R. C. Pickett. Genotype by Environment Interaction Effects for Grain Yield, Protein, Lysine, Oil and Seed Weight of Sorghum bicolor (L.) Moench Agronomy Abstracts. 1972. p. 19.

12. Schaffert, R. E. Protein Quantity, Quality and Availability in Sorghum bicolor (L.) Moench Grain. Ph.D. Thesis, Purdue University. 1972.

13. Srinivasan, G. and D. L. Oswalt. Rat Growth Response Related to Grain Sorghum. Jour. An. Sc. 35:1110. 1972.

E-1b. Uses of Materials Produced by This Project.

a) Correspondence with individual workers (indicated in brackets) from each of the following countries was answered by sending data, information and/or germplasm as specifically requested; often more than one round of correspondence evolved with a given worker; Argentina (2), Australia (1), Botswana (1), Brazil (7), Chile (3), Colombia (2), Congo (1), Costa Rica (1), Ethiopia (1), Hawaii (2), India (9), Israel (1), Jordan (1), Kenya (1), Korea (3), Lebanon (2), Malawi (2), Mexico (4), New Zealand (1), Nicaragua (1), Nigeria (2), Paraguay (1), Peru (4), Philippines (1), Senegal (1), Tonga (1), Uganda (2), Upper Volta (1), Uruguay (1), Venezueal (2), and West Pakistan (1). In addition requests from workers in California (1), Colorado (1), Georgia (3),

Illinois (2), Kansas (2), Nebraska (6), Puerto Rico (1) and Texas (6) have been answered. This represents contact with over 80 individuals, 33 countries and 50 separate programs working on sorghum quality control and improvement.

b) The First Interamerican Sorghum Symposium was held August 28-31, 1972 in Brasilia, Brazil with our staff presenting six sections and conferring personally with the workers, students and university staff in attendance. Over 134 registered for the four-day workshop representing Brasilia (65), Brazil other than Brasilia (54), Mexico (3), Honduras (1), Argentina (4), Venezuela (3), Puerto Rico (1), Costa Rica (1) and Purdue (2). Requests for data, slides of nursery procedures and disease and specific information were provided to the University staff at Brasilia and other key trainers of workers. The need for a nursery handbook to enable the use of uniform procedures in planning and data collection was expressed.

c) Annual report numbers 7 and 8 were sent to those requesting current data. Demands for report no. 8 were great enough to require reprinting of an additional 125 copies making a total distribution of approximately 695 copies.

d) The project director presented papers at the CIMMYT-Purdue Internationul Symposium on Protein Quality in Maize held at El Batan, Mexico, December 4-8, 1972 and at the AAAS Symposium on "Organizing for International Research" in Washington D. C. December 27 and 28, 1972.

e) Two papers were presented in November at the American Society of Agronomy meetings, Miami, Florida; one paper was given in November at the Midwestern Section of the American Society of Animal Science meetings in Chicago and one paper was given at the Federation meetings, Atlantic City in April of 1972.

f) Local seminars at Purdue University were presented at the request of the Animal Science Department (2 seminars) and two were presented in the Plant Breeding Seminar.

g) Requests for computerized listings of the complete list of all IS origin information have been requested and sent to seven people.

h) The mailing list kept current for all known sorghum workers has been sent to all requesting its use (4 or 5).

i) The computer system used for data handling, plot randomization, field book printing and pedigree listing has been requested and sent to Texas and Brazil.

j) Sorghum germplasm is being utilized in Brazil extensively by the Ford Foundation sorghum project at Fortaleza and the Brazilian National Special Agricultural Research Program at Sete Lagoas. Nine lines were selected from our First Purdue-AID International Protein Yield and Quality Trial sent to Fortaleza and have now been planted in more than 20 yield trials throughout Brazil.

k) Requests regarding the 20 selected lines in the First Purdue-AID International Protein Yield and Quality Trials and their general widespread adaptation is prompting requests for additional selected sets before the original set can be completely finished.

ABSTRACTS

PURDUE INTERNATIONAL SORGHUM PROGRAM. J. D. Axtell, Department of Agronomy, Purdue University, Lafayette, Indiana.

(An invited paper presented at the AAAS Symposium on Organizing for International Research, Washington, D. C., December 27, 1972.)

Sorghum is the fourth most important cereal crop in the world, being surpassed only by wheat, rice and corn in world-wide importance. In Africa and much of Asia, grain sorghum is the principal source of energy for many millions of people, and provides a major source of protein in the human diet. There is an urgent need for improving the nutritional quality of the grain sorghums which are used in the human diet in these areas of the world. This need was recognized in 1966 by the United States Agency for International Development with the establishment of our program at Purdue University with the primary purpose of developing and releasing sorghum germplasm with higher protein content, improved amino acid balance, and better total digestibility for utilization in the lesser developed countries of the world. Our project has major objectives in three areas: research, application and utilization of the research findings, and training. This paper discusses each of these areas to illustrate the interdependence of these functions in meeting the overall objectives of the project.

This research supported by the United States Agency for International Development Contract AID/csd-1175 entitled "Inheritance and Improvemen of Protein Quality and Content in Sorghum bicolor (L.) Moench".

ABSTRACTS

COMPONENTS OF NUTRITIONAL QUALITY IN GRAIN SORGHUM. J. D. Axtell, R. C. Pickett, D. L. Oswalt, R. Jambunathan and G. Srinivasan. Department of Agronomy, Purdue University, Lafayette, Indiana 47907.

(This paper presented at the CIMMYT-Purdue International Symposium on Protein Quality in Maize, El Batan, Mexico, December 4-8, 1972.)

There are several factors which effect nutritional quality in cereal crops. The nutritional problems in sorghum parallel those in other major cereals in many respects, but also differ in some important respects. Protein quality is limited by the low lysine content of sorghum grain, which reflects the high prolamine content of the endosperm and the relatively small embryo size as a proportion of the mature grain. Protein availability is apprently limited in some sorghum genotypes by the presence of unidentified polyphenolic compounds located primarily in the testa layer of the grain. These pigmented compounds have not been well characterized chemically and are referred to generically as "tannins". We do not fully understand how these tannin compounds influence the nutritional quality of sorghum. Our hypothesis at present is that the seed proteins become complexed or bound with the tannin compounds of the whole grain, and that the complexed proteins are substantially less available for utilization by monogastric animals. This report presents the data and experimental evidence which supports these general observations, and briefly describe the status of our efforts toward improving the nutritional quality of sorghum.

This research supported by United States Agency for International Development Contract AID/csd-1175 entitled "Inheritance and Improvement of Protein Quality and Content in Sorghum bicolor (L.) Moench."

ABSTRACTS

INFLUENCE OF METHIONINE AND OTHER DIETARY ADDITIONS ON THE PERFORMANCE OF CHICKS FED BIRD RESISTANT SORGHUM GRAIN DIETS. W. D. Armstrong, W. R. Featherston and J. C. Rogler, Department of Animal Science, Purdue University, Lafayette, Indiana 47907.

Studies were conducted on the performance of chicks fed diets containing the bird resistant sorghums BR64 and IS8260 as compared to chicks fed diets containing the non-resistant sorghums RS610 and RS671 and to observe the effects on chick performance and leg scores of various deitary supplements. Feeding bird resistant sorghum grains BR64 and IS8260 resulted in significantly poorer growth and feed efficiency as compared to that noted when non-resistant sorghum grains RS610 and RS617 were fed. Supplementation of bird resistant sorghums BR64 and IS8260 with methionine resulted in a marked improvement in chick growth and feed efficiency to levels comparable to those noted with the non-resistant sorghums. Supplementation of the bird resistant sorghums with choline did not result in an improvement in chick growth or feed efficiency. Methionine supplementation did not overcome the growth depressing effects noted when 1.0% commercial tannic acid was added to the sorghum RS671 diet. Additions of 1.0% polyvinylpyrrolidone overcame the depressing effects of commercial tannic acid additions to sorghum RS617 diets as well as the tannin provided by the bird resistant sorghum BR64.

An increased incidence and severity of a leg abnormality was

noted in the more rapidly growing chicks fed the bird resistant sorghum BR64 and IS8260 diets supplemented with methionine. Supplementation of the non-resistant sorghum diets with methionine did not result in an increased incidence or severity of the leg abnormality. Dietary supplementations of lysine, carnitine or a mineral mix containing calcium, manganese and zinc failed to alleviate the problem.

Poultry Science
(In Press - 1973)

Animal Science Department project 01568 entitled "Nutrition and Bone Formation in Young Chicks". Partial support was provided by the United States Agency for International Development Contract AID/csd-1175 entitled "Inheritance and Improvement of Protein Quality and Content in *Sorghum bicolor* (L.) Moench."

ABSTRACTS

COMBINING ABILITY FOR GRAIN YIELD, PERCENT PROTEIN, AND g LYSINE/100g PROTEIN IN A NINE-PARENT DIALLEL OF SORGHUM BICOLOR (L.) MOENCH".

F. C. Collins and R. C. Pickett. Department of Agronomy, Purdue University, Lafayette, Indiana 47907.

Parents and one set of F_1 hybrids from a nine line diallel of Sorghum bicolor (L.) Moench were evaluated for combining ability for grain yield, percentage protein, and g L/100g P using the Griffing analysis. The ranges in performance were 31 to 159 q/ha for yield, 9.2 to 18.2% for protein and 1.74 to 2.74% for lysine in the protein. General (GCA) and specific (SCA) combining ability were found to be important for all three characters. The GCA:SCA ratio of mean squares indicated that additive gene action was more important for protein and less important for yield and g L/100g P. One parent had large GCA effects for all three characters. Several hybrids exhibited heterosis for percentage protein while no positive heterosis was observed for g L/100g P. Protein was negatively correlated with g L/100g P and yield. Yield and g L/100g P were positively associated.

Crop Science 12:423-425
1972.

This research was supported by the United States Agency for International Devel pment through Contract AID/csd-1175 entitled "Inheritance and Improvement of Protein Quality and Content in Sorghum bicolor (L.) Moench".

ABSTRACTS

COMBINING ABILITY FOR YIELD, PROTEIN, AND LYSINE IN AN INCOMPLETE DIALLEL OF SORGHUM BICOLOR (L.) MOENCH. F. C. Collins and R. C. Pickett. Department of Agronomy, Purdue University, Lafayette, Indiana 47907.

Estimates of general and specific combining ability for grain yield and protein and lysine levels in the grain were obtained by evaluating the performance of 48 F_1 sorghum hybrids which were derived from crossing 12 restorer lines onto 4 male sterile testers. Significant differences among restorer lines were found in general combining ability for yield, protein, and lysine while significant differences among the male sterile testers existed for yield and protein. The variation due to specific combining ability was not significant for any of the characters.

Heterosis for yield was exhibited by most of the hybrids while only four hybrids demonstrated heterosis for percentage protein and no hybrids were superior to either parent for percentage lysine.

Percentage protein was negatively correlated with yield and percentage lysine and levels of lysine was not significantly related to yield. However, the degree of these associations was not strong enough to prevent incorporating high levels of protein and lysine into high yielding lines if simultaneous selection was performed for all three characters.

Crop Science 12:5-6. 1972.

This research was supported by the United States Agency for International Development through Contract AID/csd-1175 entitled "Inheritance and Improvement of Protein Quality and Content in *Sorghum bicolor* (L.) Moench".

ABSTRACTS

FIRST INTERAMERICAN SORGHUM SYMPOSIUM. D. L. Oswalt, Department of Agronomy, Purdue University, Lafayette, Indiana 47907.

The full four-day workshop-type meeting in Brasilia, Brazil was well attended by 134 participants representing Brazil, Mexico, Honduras, Argentina, Venezuela, Puerto Rico, Costa Rica and this project in the U.S. The participants represented all but four major sorghum research centers in South America. Over 40 papers were formally presented. Six presentations were made representing the Purdue-AID work. They were summarized as three papers which are attached to the trip report. The attendance and discussion evolving from presentations demonstrated the immediate interest in sorghum improvement and production especially in Brazil. The requests for visual aids, germplasm and systems of uniform evaluations of the total sorghum plant performance and quality in a handbook form demonstrate the timeliness of this workshop and values of much of the information regarding techniques which were presented. The Brazilian establishment of an annual Brazilian Sorghum Workers Conference and the establishment at this conference of a committe for another such symposium in three years further demonstrates the continuing initiative of the symposium. Visitation at two locations of our first Purdue-AID International Protein Yield and Quality Trials showed good performance of the lines under well managed systems and a relatively high degree of selection being made for in-country follow-up by wide spread yield trials within Brazil of nine lines selected from the First Purdue-AID International Protein Yield and Quality Trial containing 24 entries.

This research was supported by the United States Agency for International Development through Contract AID/csd-1175 entitled "Inheritance and Improvement of Protein Quality and Content in Sorghum bicolor (L.) Moench".

ABSTRACTS

STUDIES ON THE NUTRITIONAL VALUE OF SORGHUM GRAINS WITH VARYING TANNIN CONTENT FOR CHICKS. GROWTH STUDIES. H. S. Fostagno, W. R. Featherston and J. C. Rogler, Department of Animal Science, Purdue University, Lafayette, Indiana 47907.

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.

Poultry Science
(In Press - 1973)

---- ------

Animal Science Department project 01568 entitled "Nutrition and Bone Formation in Young Chicks". Partial support was provided by the United States Agency for International Development Contract AID/csd-1175 entitled "Inheritance and Improvement of Protein Quality and Content in Sorghum bicolor (L.) Moench".

ABSTRACT

GENOTYPE BY ENVIRONMENT INTERACTION EFFECTS FOR GRAIN YIELD, PROTEIN, LYSINE, OIL AND SEED WEIGHT OF SORGHUM BICOLOR (L.) MOENCH.
R. E. Schaffert, D. L. Oswalt and R. C. Pickett, Department of Agronomy, Purdue University, Lafayette, Indiana 47907.

Ten sorghum genotypes from the World Collection and their hybrids with two male steriles were grown for two years in Indiana, Texas and Nebraska. Grain yield, percent protein, protein yield, lysine (% protein and % sample), lysine yield, seed weight, protein per seed, percent oil, plant height, and days to median flower were measured. The genotype-year-location interaction was significant for all variables except lsyine (% protein). The genotype-location interaction was significant for all variables except grain yield, protein yield, lysine yield, lysine (% sample), and oil. The genotype-year interaction was significant for all variables except percent protein, lysine (% sample), and plant height. Genotypes were different for all variables. Days to flower were negatively correlated with percent protein (-0.56) and positively correlated with lysine (% protein) (0.61). Percent protein was negatively correlated with lysine (% protein) (-0.66) and positively correlated with lysine (% sample) (0.68), percent oil (0.48), and seed weight (0.51). These data indicated that for most variables the substitution of years for locations or locations for years in a testing program would have little effect.

Agronomy Abstracts. 1972 p.19

This research was supported by the United States Agency for International Development through Contract AID/csd-1175 entitled "Inheritance and Improvement of Protein Quality and Content in *Sorghum bicolor* (L.) Moench".

ABSTRACTS

PROTEIN QUANTITY, QUALITY, AND AVAILABILITY IN SORGHUM BICOLOR (L.) MOENCH GRAIN. R. E. Schaffert.

Thirty-five genotypes were planted in six location including Indiana, Nebraska, and Texas in each of two years for the purpose of estimating genotype-environment interactions for yield, protein, lysine, oil, and seed size. Significant genotype-year-location interactions existed for grain yield, percent protein, protein yield, percent lysine of sample, lysine yield, percent oil, seed weight, protein per seed, height and days to median flower. The relative small genotype-year and genotype-location interactions of nearly equal magnitude indicated that years and locations could be interchanged for percent protein, lysine as a percent of protein, lysine as a percent of the sample, percent oil, seed weight, and protein per seed without increasing the variance of a genotype mean. Correlations between genotypes averaged across environments indicated that percent protein could be increased by selecting for increased oil or protein per seed. Protein per seed was not correlated with yield but percent oil was negatively correlated with yield. The positive correlation between days to flower and percent lysine of protein and the negative correlation between days to flower and percent protein indicated that selection for these traits should be done within maturity groups.

The *in vitro* dry matter disappearance (IVDMD) and *in vitro* nitrogen loss (IVNL) techniques were used to study the effect of tannin on the nutritive

---

This research was supported by the United States Agency for International Development through Contract AID/csd-1175 entitled "Inheritance and Improvement of Protein Quality and Content in *Sorghum bicolor* (L.) Moench".

value of sorghum grain. The IVDMD technique detected differences within high tannin varieties, within low tannin varieties and between high and low tannin varieties. The addition of small amounts of urea to the system decreased the experimental error nearly 75%. Significantly lower values for IVDMD and IVNL were observed for the high tannin varieties. The average difference of IVDMD between high and low tannin varieties with urea and one incubation was 14.1%, without urea and two incubations was 8.3%, and with urea and two incubations was 7.8%. Approximately 50% of the difference in IVDMD between high and low tannin varieties was accounted for by differences in tannin content and insoluble protein. It was assumed that the tannin bound to the protein to form an insoluble complex. The IVDMD technique can be an important tool of the plant breeder for selecting genotypes with superior nutritive value.

Four levels of protein supplementation, with low and high tannin sorghum grain each with a low and high level of protein in the grain were fed to weanling rats. Thirteen-day weight gain, feed efficiency ratio, protein efficiency ratio, and feed consumed were highly significant for tannin levels and levels of protein supplementation. Protein efficiency ratio and feed consumed were highly significantly different for levels of grain protein. The high tannin grain had poorer weight gains, reduced feed efficiency and lower protein efficiency. Feed consumption of the high tannin diets was greater or equal to the low tannin diets. Significant differences between high and low tannin genotypes for weight gain were observed at intermediate levels of protein supplementation (5 and 10% soybean meal) but not at the high level (15%) of supplementation. The

lack of antagonistic interactions with supplemental protein for weight gain, feed efficiency, protein efficiency and feed consumption indicated that protein from soybean meal can be supplemented without changing the relative performance of different sorghum genotypes.

Ph.D. Thesis. 1972.
Purdue University

ABSTRACTS

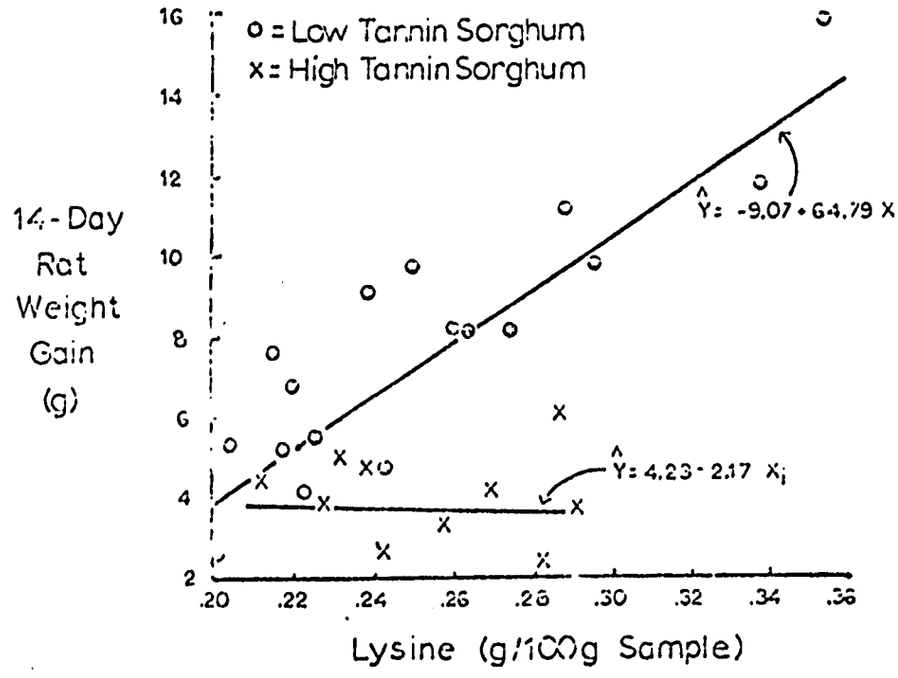
RELATIONSHIPS OF CHEMICAL COMPOSITIONS TO BIOLOGICAL VALUES OF SORGHUM BICOLOR (LINN.) MOENCH GRAIN. D. L. Oswalt, R. E. Schaffert, R. C. Pickett and J. D. Axtell, Department of Agronomy, Purdue University, Lafayette, Indiana 47907.

Ninety three low tannin and thirty four high tannin grain sorghum samples were supplemented with minerals and vitamins and fed to weanling rats for fourteen days. Weight gains were expressed as a percent of the check sample (PCS). PCS values were negatively correlated with catechin equivalents (tannins). In the low tannin samples the PCS values were positively correlated with in vitro dry matter disappearance (IVDMD), protein, and lysine percents of sample, while leucine and phenylalanine percents of protein were negatively correlated with PCS values. The range of PCS values was from -48 to 216 with IVDMD being the best single estimator of rat performance. In the high tannin samples PCS values ranged from -57 to 73 and were positively correlated with percent oil and methionine plus cystine (relative estimates), tyrosine, and phenylalanine percents of protein. High tannin sample PCS values indicated protein unavailability and available amino acid imbalances.

Agronomy Abstracts. 1972. p. 70

This research was supported by the United States Agency for International Development through Contract AID/csd-1175 entitled "Inheritance and Improvement of Protein Quality and Content in Sorghum bicolor (L.) Moench".

RELATION OF RAT GROWTH TO HIGH AND LOW TANNIN GRAIN SORGHUM AND LYSINE CONTENT.



This research was supported by the United States Agency for International Development through Contract AID/csd-1175 entitled "Inheritance and Improvement of Protein Quality and Content in Sorghum bicolor (L.) Moench".

ABSTRACT

RAT GROWTH RESPONSE RELATED TO GRAIN SORGHUM. G. Srinivasan and D. L. Oswalt. Department of Agronomy, Purdue University, Lafayette, Indiana 47907.

Feeding trials of 125 grain sorghum samples selected from the world collection were conducted to study the effect of amino acid content and polyphenols on weight gain in rats as a part of a grain sorghum protein quality improvement project. The 14-day feeding trials revealed that the weight gain in rats was significantly influenced by polyphenol content in grain sorghum. Slow growth or even weight loss was found when the high polyphenol grain sorghum samples were fed with vitamin and mineral supplementation. The influence of the polyphenols masked the differences in protein level and other amino acid quality factors in the feed. Supplementation of grain samples high in polyphenols with soybean oil meal (0, 5, 10 and 15 percent soybean oil meal) greatly increased the amount of weight gain, but did not alter the comparative weight gain responses of individual samples in the high or low polyphenol groups. Correlations of amino acid, protein with weight gain in high and low polyphenol sorghum lines and removal of polyphenols by chemical dehulling and supplementation with individual amino acids were also studied.

Jour. An.Sc. 35:1110. 1972.

This research was supported by the United States Agency for International Development through Contract AID/csd-1173 entitled "Inheritance and Improvement of Protein Quality and Content in Sorghum bicolor (L.) Moench".

ABSTRACTS

STUDIES ON THE NUTRITIONAL VALUE OF BIRD RESISTANT SORGHUM GRAIN FOR CHICKS. AMINO ACID DIGESTIBILITY STUDIES. H. S. Rostagno, J. C. Rogler and W. R. Featherston. Department of Animal Science, Purdue University, Lafayette, Indiana 47907.

Studies were conducted to determine apparent and corrected amino acid digestibility of sorghums varying in tannin content. The effects of adding tannic acid to low tannin sorghum and a protein-free diet were also investigated. Supplementation of a protein-free diet with 1.41% tannic acid resulted in a four-fold increase in endogenous amino acid excretion. The addition of tannic acid to a low tannin sorghum to provide 1.41% tannin produced a relatively small decrease in apparent amino acid digestibility which could be accounted for by the increase in endogenous amino acid excretion. Apparent and corrected amino acid digestibilties of sorghums of intermediate and high tannin content were greatly lower than the low tannin sorghum or the low tannin sorghum plus tannic acid equivalent to the high tannin sorghums. Apparent digestibility of all of the amino acids for the low, intermediate and high tannin varieties was 73, 41 and 22%, respectively, whereas the corresponding value for the low tannin sorghum plus tannic acid was 63%.

Poultry Science
(In Press - 1973)

Animal Science Department project 01568 entitled "Nutrition and Bone Formation in Young Chicks". Partial support was provided by the United States Agency for International Development Contract AID/csd-1175 entitled "Inheritance and Improvement of Protein Quality and Content in *Sorghum bicolor* (L.) Moench".

ABSTRACT

NUTRITIVE VALUE AND PROTEIN SOLUBILITY CHARACTERISTICS OF NORMAL AND PIGMENTED SORGHUMS. R. Jambunathan, P.S. Misra and E. T. Mertz. Department of Biochemistry, Purdue University, Lafayette, Indiana 47907.

Low pigment sorghum variety A (IS 0062) and pigmented sorghum variety B (IS 2283) were each fed to six weanling rats for a period of four weeks (95% ground sorghum, 4% minerals, 1% vitamin mix). Rats on variety A gained an average of 8.7g per week, those on variety B lost 0.2g per week. Protein fractionation of powdered defatted kernels was carried out with the following solvents successively (sequence D - J. Landry and T. Moureaux, Bull. Soc. Chim. Biol. 52:1021 (1970). Fraction: I-0.5M NaCl, II-70% isopropanol (v/v), III-70% isopropanol with 0.6% 2-mercaptoethanol (2-ME), IV-borate buffer (u0.5, pH 10) with 0.6% 2-ME, V-borate buffer with 0.6% 2-ME and 0.5% sodium lauryl sulfate (w/v). More than 87% of the total nitrogen was solubilized. The percent of total nitrogen in the five fractions of sorghums A and B was respectively I:16.8, 3.7; II: 18.4, 1.9; III: 21.6,21.1; IV: 4.9, 13.6; V: 26, 47. The percent distribution of soluble lysine in sorghums A and B was respectively I: 46.8, 0.8; II: 0.8, 0.1; III:0.5, 1.1; IV: 4.2, 22.7; V: 47.7, 75.3. Similar growth response and nitrogen and lysine distribution were obtained with a second low pigment (IS 3982) and pigmented sorghum (IS 6992). It is suggested that the pigments in sorghum bind to the major proteins, reducing their nutritive value and changing their solubility characteristics.

Federation Proceedings 1973 (in press)

This research was supported by the United States Agency for International Development through Contract AID/csd-1175 entitled "Inheritance and Improvement of Protein Quality and Content in Sorghum bicolor (L.) Moench".