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AN EVALUATION OF PEELING BIRD RESISTANT SORGHUM GRAINS

by

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INTRODUCTION

Sorghum has been a staple food in India while in the United States it is mostly used in livestock feeds. Hybridization and the latest agricultural practices have helped improve and develop varieties of sorghum adaptable to different areas of the world. In the United States alone sorghum production was 24.2 million tons during the year 1971 (1). Apart from its use as a food and in feeds, it is used in industries for various purposes.

With increases in human population and their needs for food and animal protein, concerted efforts have to be made to develop high yielding varieties of sorghum. Needs are also evident for development of processing techniques to improve its use in foods and livestock feeds.

Geneticists have evolved higher yielding varieties which will increase quantities available. Some hybrids have been developed to be resistant to bird depredation. Material such as these have been reported to be of lower biological value.

Grain sorghum has, however, been getting considerable attention as a replacement for corn in livestock rations. It has been studied comparatively with corn as well as barley. Due to differences in varieties, location, irrigation and other cultural practices, values obtained are difficult to compare. In general the range in protein content is fairly wide, and variations in limiting amino acids are found in different samples of sorghum. This probably accounts for the conflicting claims found in the literature.

Once grain forms little can be done to change the proportions of its various components. Still, the best use of the available nutrients might be achieved with the help of newer processing devices.

Among the different types of sorghum grains, bird resistant types are comparatively dark seeded. Their utilization by livestock and poultry has been reported to be lower than other sorghums.

The objective of the present study was to determine if the oft suggested factor, "TANNINS" is located primarily in the pericarp, and if so, its affects on in vitro enzymatic degradation of proteins and starches. Biological evaluations using Japanese quail (Coturnix coturnix japonica) were used to assess the affect of using a brush machine to remove bran and reduce or eliminate the factor involved in poor performance.

REVIEW OF LITERATURE

Sorghum Grain in Cattle, Lambs, Swine and Poultry

Grain sorghum from the world collection has been studied to evaluate factors such as: genetic control and environmental interactions of amino acid composition and levels of protein (2). On a whole grain basis it was reported that protein had a range of 7-26%. Low yielding varieties had higher protein values and variation in composition was found to be related to size, composition of the embryo and to endosperm composition. While environmental interactions were significant in relation to protein levels it was not a major factor in amino acid composition. Size of embryo was found to vary from 9.7-14.1% of the dry matter, and embryo protein content ranged between 19-25.9%; while endosperm showed a range of 9-13%.

Deyoe (3) reported protein values of 5.9-12.1% for 231 samples of sorghum grown in 1962. Another set of 300 samples in 1963 had protein values ranging between 7.2-13.5%. Corn samples studied had a smaller range of 6.4-10.0%. Six commercial hybrid varieties grown during two crop years were found to be similar in protein content and amino acid composition (4). It was also reported that significant differences existed in grain when comparing that from nonirrigated and irrigated land. Interactions of irrigation and fertilization were not consistent from year to year, or between hybrids.

Utilization of sorghum in feed for livestock and poultry has received much attention. Different varieties of sorghum have been

found to vary in their feeding values. It has been indicated that this could be due to factors such as: soil, fertilizers, irrigation and stage of maturity at harvesting.

McGinty (5) in studies with eight varieties grown in the same area with similar cultural practices found protein to range between 12.08 and 15.03%. Dry matter (in vitro) digestibility did not differ significantly amongst the five varieties, but digestibility was slightly lower for Kaoling and Darset grains. Significantly lower values were also observed for the digestibility of protein in Darset and Kaoling when compared to other varieties tested.

Beckwith and Jones (6) reported that four hybrids of grain sorghum had almost identical composition. They suggested however, that breaking of disulfide bonds and partial hydrolysis of primary amides and peptide chains might make components of protein more available for utilization.

Nutritive values of sorghum grain have been studied in comparison to corn and barley. Many workers (7, 8, 9, 10) have reported feeding values of sorghum equal to corn and possibly better than barley. Some recent investigators however have found sorghum not as efficient as corn or barley in terms of cattle gains, thus contradicting earlier reports (11, 12, 13).

Gordon et al. (14) compared corn and sorghum grain digestibility, energy value, nitrogen retention and metabolizable energy at three levels of intake. Digestibilities of dry matter, organic matter, crude protein, ether extract, crude fiber and nitrogen free extract of the two grains were not significantly different. Corn and sorghum did not differ in nitrogen retention values at any level of intake.

Significantly higher values for nitrogen retention were seen for intermediate and higher intake levels than for the maintenance level. Neither level nor type of grain had significant effects on digestible energy or metabolizable energy. Digestion trials for barley and milo by Saba et al. (15) showed that digestibility of protein and nitrogen free extract was significantly lower for milo. They attributed lower nitrogen free extract digestibility to a lower digestibility of milo starch. In studies on net energy of barley and milo, Garrett et al. (16) found no significant differences in net energy values for 50:50 mixtures. Differences between 70% barley or milo or 50:50 mixtures were not significant in terms of daily gains or percent body fat.

When comparing corn with milo Hall et al. (17) found no significant differences due to grain source on carcass constituents. Keating et al. (18) reported that the digestion coefficients were equal for milo and barley when using a 50% roughage ration for steers, but total digestible nutrients were higher for milo. This they thought to be due to a slower rate of passage of milo, which allowed more time for rumen fermentation. The nitrogen free extract and gross energy values were significantly higher for milo in all-grain rations for lambs. This was not in agreement with the results obtained with cattle.

Digestibilities of four hybrids studied by McCollough and Drake (19) showed no significant differences among hybrids for protein, crude fiber, ether extract, nitrogen free extract, total digestible nutrients or gross energy. These workers (20) also found no significant differences in feeding values of the four hybrids.

Utilization of milo, corn, opaque-2 corn and wheat in swine rations

was studied by Jensen et al. (21). They found that milo supplemented with lysine supported satisfactory gains but was less efficient in its utilization than opaque-2 corn plus soybean meal and opaque-2 plus lysine. This was in agreement with an earlier report (22) in which milo plus lysine was equal to a 12% corn-soybean meal diet for gains, gain per feed ratio and carcass development in finishing swine.

Waggle et al. (23) working on the relationship of protein level of grain sorghum to its nutritive value and amino acid composition found that distribution of sorghum amino acids was not influenced significantly by protein level. Based on the performance of chicks they observed that gain in weight remained uninfluenced by protein levels when grain was used in diets at equal protein levels. High protein grain was found to result in significantly more gain in weight than low protein grain when diets were formulated to equal quantities of grain sorghum and soybean meal.

Shoup et al. (24) using six varieties of sorghum grain found only small differences in amino acid composition and protein quality. Chick studies confirmed that neither location nor hybrid had a significant effect on performance. Availability of amino acids from these sorghum hybrids did not appear to be a problem since a 20% replacement of amino acids with pure amino acid mixture resulted in no improvement in growth.

Grain sorghum for layers was compared to corn by Chavez et al. (25). Significant differences were not observed due to source of grain, and no differences were found in feed conversion and egg weights. Significant increases in egg size and production was found when safflower oil was incorporated in diets containing these grains. This increase was

attributed to the inclusion of fatty acids supplied by safflower oil.

Using different proportions of corn and sorghum at protein levels of 15 and 18% Malik and Quisenberry (26) found egg production to be significantly higher in all corn and 50:50 corn-milo diets than in all other combinations. Contrary to these findings Berry (27) found no significant differences when all corn, 50:50 corn-milo and all milo rations were given to layers. When corn based rations having 17.43% and 18.03% protein and diets predominantly of milo were fed for a period of six weeks by Adolph and Grau (28), no significant differences in performance were noticed.

Studies of the interactions of protein level and grain source on performance of layers in relation to egg-size, production and body weight were reported by Deaton and Quisenberry (29). Average body weight was better at 16% protein level than 14% regardless of protein source. Egg production was higher in birds receiving 16% protein. Dietary treatments did not significantly affect mortality.

Deaton and Quisenberry (30) studied the effects of amino acids in low protein corn and sorghum diets and concluded that factors other than amino acid patterns influenced the performance of birds on low protein sorghum diets.

Adrian (31) reported that all African cereals including sorghum were lysine deficient and protein digestibility of sorghum was 90% that of corn. Lysine and threonine were found to be deficient in sorghum grain by Pond et al. (32). Findings of Vavich et al. (33) indicated lysine to be the limiting factor in sorghum which had high protein content. They further suggested that lysine proved a limiting amino

acid for growing chicks.

Ozmet et al. (34) stated that corn and milo were of equal nutritive values in broiler diets when used on an equal basis. Comparisons of varieties of grain sorghum with each other and against corn as the major component in practical chick diets were made by Kemmerer and Heywang (35). Hegari, 7078-milo and DD 38 milo gave significantly lower growth rates than corn, but Martin milo equalled the corn diet. They observed that efficiency of sorghum grains fed during hot weather was as good as that of corn; this was not so in cooler months. Supplementation with 0.5% lysine hydrochloride did not consistently improve the nutritive value.

Processing Methods Used for Improving Sorghum Utilization

Improvement in the utilization of sorghum grain can be accomplished to some extent by different methods of processing. These methods include: reconstitution, dry and moist rolling, steaming, flaking, cooking and popping. All these are aimed at achieving better utilization of the available energy. The results have varied and some methods have proved to be more efficient than others. Much of the work reported has been based on cattle performance and in vitro evaluation.

Riggs and McGinty (36) working on early harvested and reconstituted grain reported that all components had better digestibility in reconstituted grain than dry grain. In an earlier report McGinty et al. (37) reported digestibility coefficients in cattle for dry matter, organic matter, nonprotein organic matter and crude protein. The values for these were found to be significantly better in reconstituted sorghum

grain than values obtained with coarsely ground grain. Similar improvements were observed by Parrett and Riggs (38) as cattle on reconstituted grain gained 0.06 kg. more per day on 15% less dry matter per unit of gain than those fed other grains.

Conclusions of Buchanan et al. (39) were that digestibility of dry matter, organic matter, nonprotein organic matter and energy in reconstituted grains were better than finely or coarsely ground sorghum grain. A greater digestibility of nonprotein organic matter was observed in diets containing a steam-processed product than ground products. No apparent differences in digestibility were reported when processing methods were compared on lambs. While nitrogen was not affected, a decreased nitrogen digestibility ($P < .01$) was observed in a steam-processed product.

Mehen et al. (40) using 77% milo reported that digestion coefficients for dry matter, gross energy and crude protein were not significantly different when comparing dry rolled vs. fine grinding or steam processed with pressure cooked grain. Comparing dry and moist heat processing they found significant differences in dry matter and gross energy digestibilities due to processing.

Keating et al. (41) reported a significant increase in digestibility of nitrogen free extract due to cooking. Comparisons of flaked, popped and cracked milo by Ralph et al. (42) revealed no differences in feed conversion, but consumption of flaked milo was significantly less than other treatments. Average daily gains for the three treatments (91% cracked, 81% flaked and 81% popped milo) were 1.27, 1.12 and 1.23 kg./day, respectively.

Husted et al. (43) determined digestibility of rations containing 77% milo processed as follows: dry rolled, steam processed flaked, steam processed cut, and water soaked cut. Digestibility of the nitrogen free extract fraction of the rations with steam processed flaked milo was significantly ($P < .05$) greater than other rations. The three treatments did not differ significantly in the performance of steers. Total digestible nutrients were significantly higher for steam processed flaked milo ($P < .05$). Another trial revealed increased digestibility of nitrogen free extract ($P < .05$) for rations containing either steam processed or pressure cooked and flaked milo when compared to dry rolled or fine ground milo. Grain receiving moist heat treatments had significant increases in total digestible nutrients. These observations were suggestive that improvements can be achieved in digestibility with either steam processing and flaking or pressure cooking and flaking.

Lofgreen and Hull (44) found a consistent decrease in intake of rations containing milo which was steam pressure processed. Utilization was better for pressure cooked grain when compared to steam processing done at atmospheric pressure. Holmes et al. (45) found that grain which received steam treatment at 3.5 kg. per square centimeter pressure before rolling had a rapid and more nearly complete fermentation compared to steaming at atmospheric pressure.

The effect of rolling on sorghum grain has proved beneficial (46). Improvements in feeding value was also observed by Fox et al. (47) when bird resistant sorghum grain silage was rolled and fed to steers. Significantly higher daily gains ($P < .01$) were obtained with rolled bird resistant sorghum grain silage. Similar improved daily gain and

feed efficiency has been reported by Newland et al. (48). Their figures for daily gains and feed efficiency, comparing rolled vs. unrolled were: 1.11 kg. vs. 0.80 kg. daily and 4.30 kg. vs. 5.28 kg. gain respectively.

Ellis and Carpenter (49) studied popped milo, and reported a slower rate of weight gain, but feed requirement was 16.6% less for a kg. of gain. Riggs et al. (50) made similar observations of reduced intake and increased feed efficiency. Heat treated grains had significantly higher digestibilities of dry matter, organic matter, nonprotein organic matter and nitrogen free extract, but not for ether extract or protein. They concluded the changes were due to heat treatment rather than popping.

Influences of grain processing on digestion by rumen microorganisms was studied by Trei et al. (51) by measuring gas production. They suggested that milo must be satisfactorily flaked after moist heat treatment. Such treatment may cause either alterations in the starch granule or may result in the disorganization of the protein matrix surrounding the starch granules. An earlier finding of Trei (52) was that as the flakes become thinner gelatinization was increased. This was in agreement with the report of Osman et al. (53), who found an increased amylolytic digestion of milo with increased flake flatness.

Inhibitors in Sorghum Grains

As early as 1936 Vinall et al. (54) mentioned in their description of brown seeded varieties, the presence of bitter flavor. Pigments are found in epicarp and nucellar layers and those in the latter were suggested to influence the degree of bird resistant characteristics.

MacMasters and Hilbert (55) also reported the existence of pigments in the same location of sorghum grain.

Blessin et al. (56) indicated the presence of Leucoanthocyanins in the water soluble pigments of domestic varieties of sorghum grain. Later Blessin et al. (57) suggested that anthocyanogens present in brown seeded sorghums imparted astringent flavors. These were located in the pericarp and essentially absent in the endosperm.

Roux (58) and Roux and Evelyn (59) have suggested that anthocyanogens are the precursors of condensed tannins. Bate-Smith and Rasper (60) concluded the principle tannin in sorghum was a Leucoanthocyanin yielding Letolinidin(3',4',5',7-tetrahydroxyflavylium) when heated with mineral acid.

In an extensive study of waxy and nonwaxy sorghum varieties Miller and Kneen (61) showed that various fractions of germ and bran contained a potent amylase inhibitor.

This inhibitor was later shown to be a general protein denaturant (Strmeyer and Malin, 62) capable of inactivating a variety of enzymes. These properties are said to be due to a series of oligomeric condensed tannins of the leucocyanidin group varying in the degree of polymerization rather than to any individual specific enzyme antagonist. A complete inhibition of amylase activity was approached as the ratio of inhibitor to enzyme was increased.

Similar inhibitory effects were observed on rumen cellulase by tannin extracts from serica forage (63). The reduction in the activity of cellulase was proportional to the concentration of the inhibitor present.

Bird Resistance and Utilization

Bird resistance as described by Harris (64) is, "that mechanism or characteristic of a variety that, when given a choice of feeding material, birds will not normally depredate." Apart from this he suggested that other factors such as bird population, choice in feeding and other factors contribute to bird resistance in varying degrees.

McClymont (65) in his experiments with sorghum grain replacing wheat found no bad effects for laying birds, but in chicks he found a 50% depression in growth rate at 28-63% levels. Harms et al. (66) also noted a depression and poor feed conversions. Basing selection on seed color of grain Thayer et al. (67) compared sorghum grain with corn and concluded that the seed color in improved varieties was not a dependable measure.

It has been shown that palatability is not necessarily associated with livestock gains provided the product is consumed in quantities large enough to promote growth.

West (68) suggested that tannins in the pericarp were not the factor involved in palatability of sorghum grain. Sang and Fuller (69) working with six varieties of sorghum grain observed some correlation in growth between tannin and fiber found predominantly in the pericarp. When using levels of 0.2, 0.4 and 1.6% tannin in grain growth rates were significantly improved by the inclusion of choline and methionine (as hydroxy analog MHA). In some diets a partial benefit was seen from the inclusion of sources of a labile methyl group. Their main observation was, that, tannins of grain sorghum differ chemically from the tannic acid used in the trial.

Fuller et al. (70) reported that while grain with 1.65% tannin content caused retarded growth in chicks, use of sorghum grain containing 1.28% tannin resulted in growth equivalent to that obtained with corn or non-brown sorghum grains. This indicates that tannin contents above certain levels can cause changes in growth rate, whereas up to those levels they are tolerated by poultry.

Fox et al. (46) working with bird resistant sorghum grain suggested that decreased nutritive value could be due to low digestibility of plant tissue and unbroken grain in silage. Their trials however were inconclusive as to whether tannins inhibited digestibility by rumen microorganisms.

McGinty and Riggs (71) and McGinty (72) removed the pericarp of three varieties of sorghum grain and observed that, in vitro digestibility of the endosperms did not differ. When the pericarps were added to endosperms in all possible combinations, digestibility was affected in those combinations in which pericarps of Darset and Kaoliang were added. Combinations of pericarps with their respective endosperms resulted in values similar to that of intact grains. Their work indicated that the "factor or factors" which have an influence on digestibility or utilization, were evidently in the pericarp.

MATERIALS AND METHODS

Grains Used

Three bird resistant varieties: F-65, B.R.64 and K.A.S.-614 were obtained from Dekalb in 1969 and stored in the original bags at room temperature. Moisture content of the grains ranged between 10.8-12.2. These varieties were brown seeded and grain size was smaller compared to commercial sorghum grain. The grain used as a control was a hybrid commercial grain, obtained in 1971. This was light brown in color with a moisture content of 11.9%.

Tempering and Peeling

The present study involved the use of an effective peeling of the grain for an eventual separation of the bran and grain with the germ intact. Before tempering the grains were screened to remove foreign material. The control grain was tempered for a long temper of 16 hours at 14% moisture and a short temper of 40 minutes at 18% moisture. Bird resistant grains were given a long temper of 16 hours at 20% moisture followed by a short temper of an hour bringing the moisture content to 28% just before processing.

A brush machine developed at Kansas State University (4) was used with certain modifications to attain the desired product. The bottom perforated half was replaced with a solid plate on which strips of emery-paper were fixed at a 45° angle to the axis of the plate. A nylon cylinderical brush was used instead of a wire brush and was run

at approximately 1400 r.p.m. Processed grain fed at a rate of 1.1 kg. per minute controlled by a vibratory feeder was collected at the other end where a funnel-shaped outlet was provided at the bottom.

The processed grain as it came from the brush machine was spread on plastic sheets for air drying. Bran was separated using an aspirator. Grain was separately collected and then the bran was once again aspirated to collect particles of broken endosperm and germs. The latter were found in small amount when compared to endosperm. This fraction was added to the grain thus only two products were produced:

a. Peeled grain + Broken parts of endosperm and germs.

b. Pericarp i.e. Peelings.

In the preliminary trials various treatments were used for tempering and peeling. These involved a series of trials with variations of time and moisture to give the temper an interval to attain good peeling. Efficiency of pericarp separation was evaluated by percent yield, the extent of breakage of grain and visual inspection of the peeled grains.

Proximate Analysis

Proximate analyses of samples obtained from the four sorghum grains after peeling (Product a and b) were determined by A.O.A.C. 1965 (73) for moisture, protein, ash, fat and fiber.

Amino Acid Analysis

Amino acids were determined by ion exchange chromatography using a Beckmann Amino Acid Autoanalyser Model 120-B, after acid hydrolysis

of samples. Hydrolysates were prepared following the procedure of Waggle et al. (74) and analyzed by the methods of Spackman et al. (75) and Moore et al. (76).

Tannins In Peeled Grains and Peelings

The method for determining tannins in cloves and allspice (73) was used with some modifications. A 1% tannic acid solution was prepared, different aliquots of this were taken with 20.0 ml of indigo solution and 750.0 ml of water. These were titrated using a potassium permanganate solution. A standard cure was obtained by plotting the values for milligrams of tannic acid against the volume of permanganate solution used.

Two gram samples were extracted with anhydrous ether for 20 hours and the residue was boiled in 300 ml water for two hours. It was then allowed to cool and the volume made to 500 ml. The mixture was mixed well by shaking and then it was centrifuged at 30,000 x G. for 30 minutes. The supernatants in 25 ml aliquots plus 20.0 ml indigo solution and 750.0 ml water were titrated against potassium permanganate solution. A blank was obtained excluding the supernatant. The difference between readings was read from the standard curve and expressed as percent tannins in sample.

Activity of Amylases

A modified method of Sung (77) was utilized to study enzymatic hydrolysis with α- and β-amylases. The samples were digested for one hour at 40° instead of two hours at 30°. Values obtained were

expressed as milligrams of maltose per gram of sample. This study was made to determine if tannins in the peeled grains and the pericarps had any influence on the activity of the amylases.

Pepsin-Pancreatin Digestion

Studies involving proteolytic enzymes were undertaken to evaluate effects of peeling on the availability of protein to enzymatic hydrolysis, and to find if the tannins or other factors influenced protein hydrolysis.

Digests were prepared by the method of Walter and Mark (78). Finely ground 1.0 gram samples in duplicate were digested at 37° for three hours in 15.0 ml hydrochloric acid (0.1N) containing 3.0 mg of pepsin. These were placed in a constant temperature water bath and occasionally shaken. After neutralization with 7.5 ml sodium hydroxide (0.2N) 7.5 ml of pH 8.0 phosphate buffer containing 8.0 mg of pancreatin were added to the digestion mixture. Fifty parts per million of merthiolate were added to prevent growth of microorganisms. Digestion was continued for 24 hours at 37° with occasional shaking. Removal of digestion mixtures from the water bath was followed by the addition of 7.0 ml 60% trichloroacetic acid and then 5.0 ml glacial acetic acid. The solution was then allowed to stand for one hour.

Samples were filtered under mild vacuum through Whatman #2 filter paper, which had been weighed previously. The filtrate was collected in clean erlenmeyer flasks. Residues collected on the filter paper were washed twice with distilled water and allowed to air dry before being dried in an air oven.

α-amino nitrogen was determined by the method of Mikelsen et al. (79) after modifications. From the filtrate a 1.0 ml aliquot was diluted with 50.0 ml of double distilled water and 1.0 ml of this was transferred to a matched tube containing 1.0 ml of ninhydrin solution. The tubes were placed in actively boiling water for 15 minutes and then cooled in running cold water for 5 minutes. 5.0 ml of ninhydrin diluent was added to the tube and mixed. A blank was obtained by using 1.0 ml distilled water in place of the diluted filtrate. Percent transmittance was recorded on both tubes at 570 nm using a Bausch and Lomb Spectronic-20.

A standard curve was prepared by recording percent transmittance against increasing concentrations of glycine. Using the glycine curve, free α-amino nitrogen was computed and expressed as milligrams of glycine equivalents.

Samples of dried residue plus filter paper were weighed and weight of residue calculated. Each was then digested and nitrogen was determined (73) by micro-kjeldahl and percent protein was calculated. The method outlined by Gehrt (80) was followed with minor modifications to calculate the indigestible protein of the respective sample. The percent digestibility was then calculated.

Nutritional Studies

Studies with Japanese quail (Coturnix coturnix japonica) were conducted to determine the effects of peeling on varieties of sorghum grain using peeled grain with and without respective peelings and effects of including peelings of bird resistant grains to the peeled

commercial sorghum grain. Composition of basal diet is shown in Table 1 and details of experimental diets (1-11) are given in Table 2. Protein content of the diets ranged between 26.2-28.2% on an as is basis. Amino acids of all diets were determined using the methods described.

One day old quail chicks were randomly distributed in groups of 13-14 chicks with two replications per treatment. A completely randomized experimental design was used. Chicks were housed in wire floor metal batteries.

For the first week all groups were maintained on control diet, then the chicks were leg banded and weighed individually and supplied experimental diets. The duration of the experiment was three weeks with feed and water supplied ad-libitum during the trial. Weekly weight gains were recorded for individual chicks and feed consumed was computed for each group.

TABLE 1. COMPOSITION OF BASAL MIX USED IN QUAIL GROWTH STUDIES

Ingredients	Percent
Sorghum Grain[1]	38.73
Soybean Meal	39.90
Wheat Middlings	6.37
Dehydrated Alfalfa Meal	2.45
Fish Meal	1.96
Meat Scrap	4.90
Distillers Dried Solubles	1.96
Dried Whey	1.96
Dicalcium Phosphate	1.23
Salt	0.49
Trace Mineral Mixture[2]	0.05
Vitamin Premix[3]	0.025

[1] Sorghum grain used was peeled, or peeled plus peelings.

[2] CCC Trace Mineral Mixture, Calcium Carbonate Company, Quincy, Illinois. Supplies (g/kg of diet) Mn 0.05; Fe 0.05; Cu 0.005; Zn 0.025; Co 0.0005; I 0.0015; Ca 0.058.

[3] Supplies per kilogram of diet: 2,700 I.U. Vitamin A; 1,850 ICU Vitamin D_3; 10.6 mg. riboflavin; 20.6 mg. pantothenic acid; 32.5 mg. niacin; 320 mg. choline chloride; 12.2 mcg. Vitamin B_{12}.

TABLE 2. IDENTIFICATION, COMPOSITION AND ANALYSES OF EXPERIMENTAL DIETS USED IN QUAIL GROWTH STUDIES

Diets	Sorghum Varieties	Basal Mix[1]	Processed Grain		Moisture	Protein[2]*	Fiber*
			Peeled Grain	Peelings			
		%	%	%	%	%	%
1	Commercial Grain Peeled + Peelings	61.27	35.21	3.52	7.4	26.7	5.5
2	Commercial Grain Peeled	61.27	38.73	-	6.9	27.1	4.7
3	F-65 Peeled Grain + Peelings	61.27	33.51	5.22	6.8	27.6	5.0
4	F-65 Peeled Grain	61.27	38.73	-	6.7	28.2	4.7
5	BR-64 Peeled Grain + Peelings	61.27	34.16	4.57	6.2	27.8	5.3
6	BR-64 Peeled Grain	61.27	38.73	-	7.2	26.6	5.0
7	AKS-614 Peeled Grain + Peelings	61.27	33.43	5.30	6.4	27.1	4.7
8	AKS-614 Peeled Grain	61.27	38.73	-	6.3	27.1	4.7
9	Comm. Grain Peeled + F-65 Peelings	61.27	35.21	3.52	6.5	26.2	4.7
10	Comm. Grain Peeled + BR-64 Peelings	61.27	35.21	3.52	6.3	26.7	5.2
11	Comm. Grain Peeled + AKS-614 Peelings	61.27	35.21	3.52	6.3	26.6	5.0

[1]Basal mix composition given in Table 1.

[2]Percent protein (N x 6.25).

*Reported on an "as is basis."

RESULTS AND DISCUSSION

Tempering and Peeling

The yields of products are given in Table 3. Compared to the commercial grain the other three hybrids had smaller grain size and adhesion of pericarp to the grain was firmer. This necessitated a longer tempering at 20% moisture and an increased short temper of 60 minutes bringing the moisture content to 28% for the three varieties prior to peeling. Optimal conditions for peeling were attained after preliminary trials in which different conditions of moisture and time were studied. The products were evaluated for color of peeled grain, breakage and the yield of the peelings. A long temper was found to be more beneficial in avoiding breakage as it toughened the grain and loosened the pericarp. Tests were also made in early stages with 1.0% acetic acid and 1.0% sulfuric acid with no advantage.

As the fines contained germ and endosperm grits, these were separated and added back to the peeled grain. Product yield of peeled grain was between 88.2-91.9%, while bran ranged between 9.1-13.7%. These results for product yields are similar to those reported by Shoup (4) who used a wire-brush peeler. Similar results were also reported by Hubbard *et al.* (81) who separated endosperm, germ and bran by hand.

TABLE 3. PERCENT YIELD OF PEELED GRAIN AND PEELINGS AFTER TEMPERING, PEELING AND AIR-SEPARATION

Sorghum Varieties	Peeled Grain		Peelings
	Intact Grain	Fines	
	%	%	%
Commercial Grain[1]	79.8	12.1	9.1
Sorghum F-65[2]	74.3	12.2	13.5
Sorghum BR-64[2]	69.0	19.2	11.8
Sorghum AKS-614[2]	67.9	18.4	13.7

[1] Long temper - 16 hours to 14% moisture.
Short temper - 40 minutes to 18% moisture.

[2] Long temper - 16 hours to 20% moisture.
Short temper - 1 hour to 28% moisture.

Proximate Analyses of Peeled Grains and Pericarps

The data obtained by proximate analyses of the peeled grains and pericarps is given in Table 4. The data shows bran fractions had higher values for ash, fat and fiber. The shift in fat level could have been due to fine particles of germ and also to aleurone material included in the fraction. Peelings also contained some endosperm particles. The values of fiber were found to be higher in peelings than the peeled grain and ash content of peelings was found to be higher than the respective grain. The calculated values reported for nitrogen free extract were lower for peelings and so were moisture contents. The shifts observed in ash, fiber, fat and N.F.E. would be expected since the bran of grains would be expected to follow these trends. The data are also similar to those reported by Shoup (4).

Among peeled grains, protein was higher in F-65 and AKS-614 while variations in ash were small. Fat levels in peeled grains were high in F-65 and AKS-614. Nitrogen free extract, determined by difference, was lower in F-65 and AKS-614.

Amino Acids in Peeled Grains and Peelings

Table 5 shows the data of amino acid composition for peeled grains and the pericarps. In the peeled grains commercial sorghum had higher values for essential amino acids except methionine, isoleucine, leucine and phenylalanine. Among the three bird resistant varieties amino acid composition varied little but F-65 had highest values for phenylalanine. The differences in amino acids were found to be smaller in the four pericarps analyzed.

TABLE 4. PROXIMATE ANALYSES OF PEELED GRAINS AND PEELINGS[1]

Sample	Moisture	Protein[2]	Ash	Ether Extract	Fiber	Nitrogen Free Extract[3]
	%	%	%	%	%	%
Peeled Commercial Sorghum Grain	9.0	7.7	1.3	2.0	1.4	78.6
Peeled F-65	9.1	9.4	1.2	2.5	0.9	76.9
Peeled BR-64	9.0	7.9	1.1	1.9	1.5	78.6
Peeled AKS-614	8.9	9.6	1.0	2.2	1.3	77.0
Peelings of Com. Sor. Grain	7.4	8.9	3.7	4.6	4.9	71.5
Peelings of F-65	6.8	8.8	2.6	4.7	6.6	70.5
Peelings of BR-64	7.8	9.3	4.0	6.4	4.3	68.2
Peelings of AKS-614	7.6	9.6	3.3	5.3	4.6	69.6

[1] Values reported on an "as is basis."

[2] Percent protein (N x 6.25).

[3] Calculated values of nitrogen free extract.

TABLE 5. SUMMARY OF PROTEIN[1] LEVEL AND AMINO ACID[2] DISTRIBUTION IN PEELED GRAINS AND PEELINGS

	Peeled Grain				Peelings			
	Comm. Grain	F-65	BR-64	AKS-614	Comm. Grain	F-65	BR-64	AKS-614
Protein, %	7.7	9.4	7.9	9.6	8.9	8.8	9.3	9.6
AMINO ACID								
Lysine	2.34	1.83	1.80	1.63	3.96	3.71	4.19	2.97
Histidine	2.28	2.09	2.04	2.04	2.53	2.41	2.71	2.01
Arginine	3.96	3.47	3.20	3.06	5.87	6.17	6.14	4.39
Aspartic Acid	6.84	6.92	6.45	6.57	8.25	9.10	8.66	7.11
Threonine	3.51	3.34	3.47	3.24	4.19	4.33	4.46	3.55
Serine	4.72	4.90	4.86	4.75	5.26	5.38	5.71	4.81
Glutamic Acid	21.08	23.32	21.85	23.49	17.71	16.69	19.36	18.16
Proline	8.45	8.28	8.48	8.73	7.18	6.77	7.01	6.32
Glycine	3.88	2.97	3.13	2.76	5.00	5.25	5.17	4.09
Alanine	7.68	10.44	9.63	10.28	8.48	8.71	9.07	8.61
Half Cystine	2.44	2.60	3.25	2.71	2.24	1.52	1.52	2.00
Valine	4.96	4.87	4.66	5.32	5.62	5.80	6.00	5.04
Methionine	1.13	1.21	1.12	1.36	1.62	1.44	1.67	1.48
Isoleucine	3.93	4.17	3.97	4.08	3.84	4.05	4.23	3.50
Leucine	13.11	15.19	13.87	15.21	10.84	11.56	11.99	11.17
Tyrosine	4.18	4.47	3.97	4.32	3.63	3.97	3.68	3.47
Phenylalanine	5.37	6.03	5.34	5.63	4.89	5.07	5.17	4.73

[1] Percent protein (N x 6.25).

[2] 2 g. amino acid/16 g. N.

Leucine was comparatively higher in bird resistant sorghum pericarp than in the pericarp of commercial grain. The same trend was noted in the peeled grain for the four varieties.

Tannins

Data shown in Table 6 gives the tannin levels in the peeled grains and peelings of the four types of sorghum grains. In peeled grains the tannin content ranged between 0.35 and 1.55%, whereas in peelings it was 0.52-2.26%. The presence of tannins in the peeled grains was associated with:

1. Difficulty of separating the pericarp from the grain.
2. The inclusion of endosperm grit and germ fraction (with their bran portion intact) in the peeled product.

The presence of higher quantities of tannins in the pericarps of sorghum is in agreement with the earlier reports (54, 57, 61, 71, 72).

The method used gave a quantitative estimate of tannins, but the types of tannins were not studied.

Activity of Amylases on Peeled Grains and Peelings

Studies conducted to determine the activity of amylases on grains and peelings are summarized in Table 7. As the total starch content of the samples was not determined, the figures for nitrogen free extract were used as an estimate of enzymatically available carbohydrate. Peeled grains had 76.9-78.6% nitrogen free extract while the range was 68.2-71.5% in the peelings.

The effects of amylases were determined and expressed in terms of

TABLE 6. PERCENT TANNINS IN PEELED GRAINS AND PEELINGS

Sorghum Varieities	Percent Tannins	
	Peeled Grain	Peelings
Commercial Sorghum Grain	0.35	0.525
Sorghum Grain F-65	0.60	1.475
Sorghum Grain BR-64	1.55	2.25
Sorghum Grain AKS-614	1.45	2.26

TABLE 7. STUDIES OF β- AND α-AMYLASE ACTIVITY ON PEELED GRAINS AND PEELINGS

Sample Identification	N.F.E.	Tannins	Milligrams Maltose/ Gram of Sample	
			β-amylase	α-amylase
	%	%		
Peeled, Comm. Sorghum Grain	78.6	0.35	28.75	56.00
Peeled, F-65 Grain	76.9	0.60	40.50	67.25
Peeled, BR-64 Grain	78.6	1.55	13.00	19.25
Peeled, AKS-614 Grain	77.0	1.45	17.75	41.12
Peeling, Commercial Grain	71.5	0.525	40.50	106.50
Peeling, F-65 Grain	70.5	1.475	60.00	142.12
Peeling, BR-64 Grain	68.2	2.25	33.37	46.50
Peeling, AKS-614 Grain	69.6	2.26	37.00	44.50

Peeled Grains β-amylase $r = -0.8367$

Peelings β-amylase $r = -0.5039$

Peeled Grains α-amylase $r = -0.8519$

Peelings α-amylase $r = -0.6960$

milligrams of maltose per gram of sample. From the values of maltose and the percent of tannins in the sample the relationship of tannin and amylase activity was examined. Regression lines obtained from the relationships are shown in Figure 1. In the samples examined grains with higher tannin contents gave lower maltose values, thus indicating a negative correlation.

The peelings of all four grains had a similar trend. The values for maltose on the separated bran were higher when compared to their respective peeled grains. In view of the lower nitrogen free extract contents, and higher tannin values of the four peelings the plausible reasons might be:

1. Pericarps were exposed to water while grain was being tempered bringing about some chemical change including increased enzyme activity.
2. The slight rise in temperature of the grain in peeling might have contributed to starch damage or other chemical or physical changes.
3. Presence of endosperm fractions from the broken grains, or the effect of excessive peeling of some grains causing the removal of some endosperm along with the pericarp resulting in readily available carbohydrate for action of the enzyme.

The maltose values reflect to a certain extent the varying degrees to which the tannins may affect amylases. With α-amylase the yields of maltose were higher than obtained with β-amylase. The comparative efficiency of α-amylase would be expected since α-amylase will act on both 1,6 and 1,4 glucose linkages and thus would be expected to act more rapidly.

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

THIS IS AS RECEIVED FROM CUSTOMER.

a	Peeled grains with β-amylase	Y = 41.80 - 17.02X	r = -0.84
b	Peelings with β-amylase	Y = 54.57 - 7.28X	r = -0.50
c	Peeled grains with α-amylase	Y = 74.90 - 29.36X	r = -0.85
d	Peelings with α-amylase	Y = 150.75 - 40.45X	r = -0.69

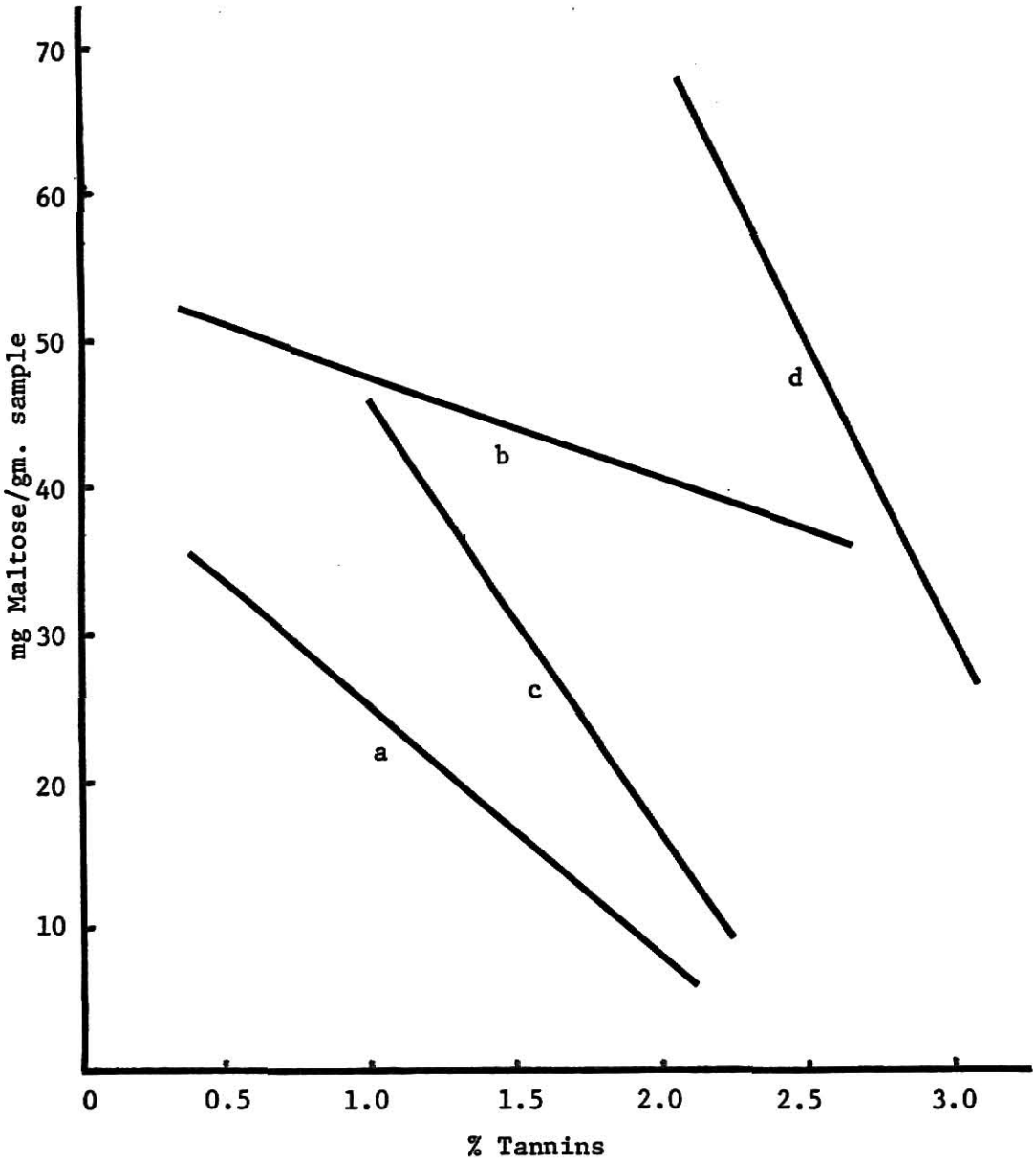

Fig. 1. Effects of tannin content on the activities of β- and α-amylases on peeled grains and peelings.

The influence of tannins on the enzymes observed in the present study was similar to the findings of Miller and Kneen (61) who reported the presence of a potent inhibitor of amylases in the germ and bran of sorghum varieties. Similar inactivation of a variety of enzymes by condensed tannins were recently reported by Strumeyer and Malin (62).

The values of maltose were higher in F-65 when compared to commercial grain. It was noted that tannin content of this variety was higher. The high values for maltose for the two fractions in spite of the higher levels of tannin indicates that, apart from quantity, the inhibitory influences may depend on the type of tannin or other associated factors.

Pepsin-Pancreatin Digestions

Data on yield of mg glycine equivalent produced, percent protein in residue and apparent digestibility of proteins is given in Table 8. The protein percentages varied in grains as well as in pericarps. These values were used in calculating glycine equivalents, percent protein in residue and percent digestibility of protein in the respective sample.

The proteolytic activities of pepsin and pancreatin were measured and expressed in terms of milligrams of glycine equivalents. These values had a negative correlation with increasing concentrations of tannins in the samples studied. The correlation coefficients between percent tannins and glycine equivalents were -0.60 and -0.97, for peeled grains and pericarps respectively. Regression lines are shown in Figure 2.

TABLE 8. YIELD OF MG. GLYCINE EQUIVALENTS FOLLOWING PEPSIN-PANCREATIN DIGESTION, PROTEIN IN RESIDUE AND APPARENT DIGESTIBILITY OF PROTEINS

Sample	Protein[1] Dry Basis	Tannins	mg. Glycine Equivalents	Protein in Residue	Protein Digest-ibility
	%	%		%	%
Peeled Grains					
Comm. Sorghum Grain	8.46	0.35	24.01	2.08	75.41
Sorghum Grain F-65	10.34	0.60	29.89	2.49	75.91
Sorghum Grain BR-64	8.68	1.55	16.67	4.69	45.96
Sorghum Grain AKS-614	10.53	1.45	25.03	4.11	60.96
Peelings					
Comm. Sorghum Grain	9.61	0.52	22.78	3.13	67.42
Sorghum Grain F-65	9.44	1.47	16.72	4.12	56.35
Sorghum Grain BR-64	10.08	2.25	7.18	7.53	25.29
Sorghum Grain AKS-614	10.38	2.26	7.24	7.94	23.50

[1] Percent protein (N x 6.25)

Tannin Vs. mg. Glycine Equivalents
Peeled Grains r = -0.60
Peelings r = -0.97

Tannin Vs. % Protein in Residue
Peeled Grains r = +0.99
Peelings r = +0.94

a Peeled grains Y = -0.60 + 0.47X r = 0.99

b Peelings Y = -0.20 + 0.32X r = 0.94

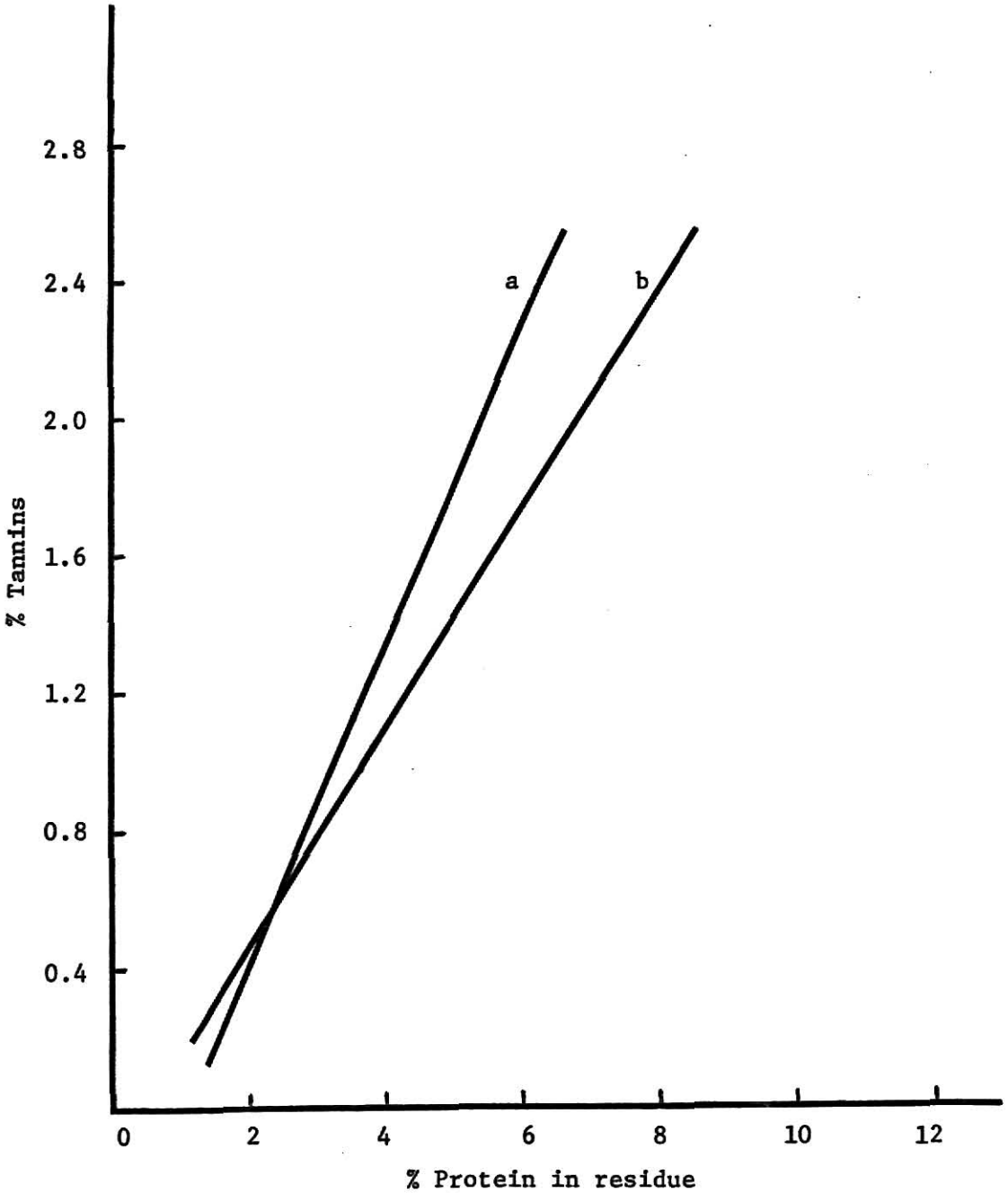

Fig. 3. Effects of tannin content on residual protein after pepsin-pancreatin digestion of peeled grains and peelings.

Protein values in the residue also reflect the influence of tannin levels. Samples with lower percentages of tannins had less residual proteins and conversely higher residual protein values were observed in samples which had higher percentages of tannin ($r = 0.99$ and 0.94 respectively, Figure 3). This inhibitory activity of tannins was also evident in the values computed for percent digestibility of proteins in the sample. In this study the proteolytic activity of pepsin and pancreatin was not studied individually. However inhibition of combined activities were positively related to the levels of tannin in the samples. Driedger and Hatfield (82) have reported a 90% decrease in deamination of soybean meal when treated with 10% tannin. They found tannins affected pancreatin digestion significantly but not that of pepsin.

The modified methods were found to be efficient in comparing the proteolytic activity of enzyme-substrate mixtures, as the substrates were digested under identical conditions.

Nutritional Studies

Weight gains, feed consumption and feed conversion for the three week growth trials are given in Table 9. At the end of the trial an analysis of variance (A.O.V.) (83) was conducted. The differences in weight gains and feed conversions were nonsignificant between treatments. The amount of protein supplied by the varieties of sorghum grain in the eleven diets ranged between 2.98-3.71%, and the estimated value of tannins in the diets ranged between 0.13-0.63%. This value was lower than those reported as causing depression in weight gains.

a Peeled grains $Y = 2.57 - 0.06X$, $r = -0.60$

b Peelings $Y = 3.03 - 0.14X$, $r = -0.98$

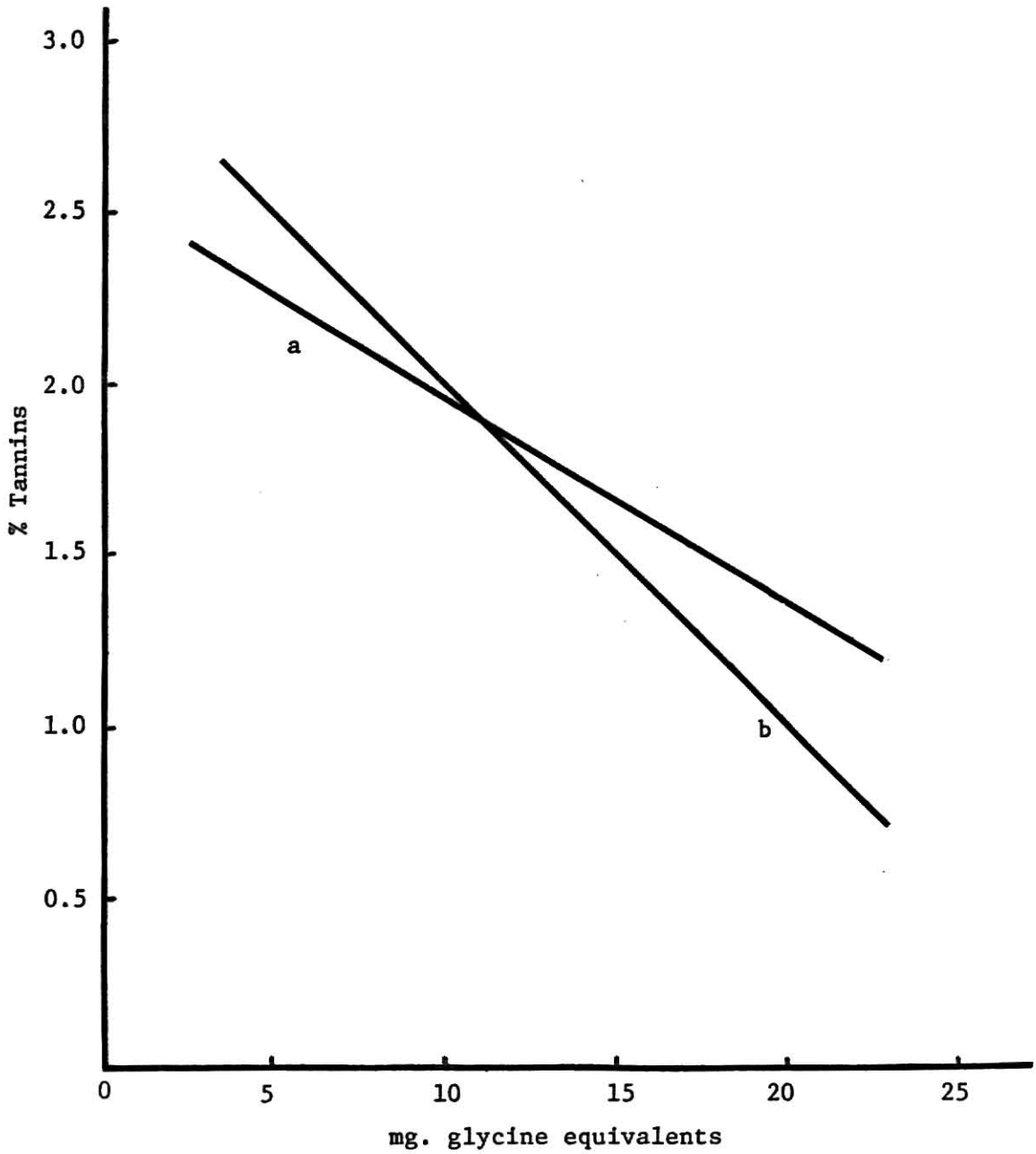

Fig. 2. Effects of tannin content on pepsin-pancreatin digestion of peeled grains and peelings.

TABLE 9. WEIGHT GAINS, FEED CONSUMPTION AND FEED CONVERSION OF JAPANESE QUAIL (COTURNIX COTURNIX JAPONICA) ON EXPERIMENTAL DIETS

Diets	Treatments	No. of Chicks per Group	Total Weight Gained per Group grams	Total Feed Consumed per Group grams	Feed Conversion gms. Feed/ gms. Gain
1	Commercial Grain Peeled + Peelings	13	807.50[a]	2040.5[b]	2.52[c]
2	Commercial Grain Peeled	13	800.50	1977.5	2.47
3	F-65 Peeled Grain + Peelings	13	806.85	2041.0	2.52
4	F-65 Peeled Grain	13	807.35	1973.0	2.44
5	BR-64 Peeled Grain + Peelings	13	805.70	1991.0	2.47
6	BR-64 Peeled Grain	13	807.85	1977.0	2.44
7	AKS-614 Peeled Grain + Peelings	13	844.25	2148.5	2.54
8	AKS-614 Peeled Grain	13	839.25	2039.0	2.42
9	Comm. Grain Peeled + F-65 Peelings	14	871.15	2171.5	2.49
10	Comm. Grain Peeled + BR-64 Peelings	14	879.35	2156.0	2.45
11	Comm. Grain Peeled + AKS-614 Peelings	14	851.10	2361.0	2.77

[a,b,c] Average of duplicate treatment.

There appears to be agreement between the results of this study and the reported data (70) where equivalent weight gains were observed in chicks receiving up to 1.28% tannin in diets, while weight gains were affected at 1.65% level.

The nonsignificant differences in gains and feed conversions may also indicate that these were not influenced because growth rates of quail may not be affected in the same manner by bird resistant sorghums. In the report of Fuller (69) tannic acid even at a 0.2% level had affected growth rate in chicks and inclusion of choline and methionine alleviated the effects. The control diet contained 0.19% tannins, which could have influenced growth rate if affects were on a comparative basis. Differences found in this study were not significant. This was also evident in feed consumption data. Birds on diet 2 consumed less feed and had slightly better feed conversions.

The availability of proteins in the diet from sources other than sorghum could have compensated any inhibitory effect on protein digestion since sorghum protein in the diets made up only 3.34% of the total protein. The protein levels in the diet ranged between 26.2-28.2% which may have been too high to show inhibitory effects on protein utilization.

Average weight gains of males and females are given in Table 10. Analysis of variance for the differences in weight gains of males and females was computed. The weight gains were significantly higher for females ($P < 0.01$), however no significant differences were detected between treatments.

TABLE 10. AVERAGE WEIGHT GAINS OF MALES AND FEMALES ON EXPERIMENTAL DIETS

Diets	Treatments	Average Weight Gains per Bird, g.	
		Male	Female
1	Commercial Grain Peeled + Peelings	61.41	62.83
2	Commercial Grain Peeled	61.57	61.58
3	F-65 Peeled Grain + Peelings	60.26	63.05
4	F-65 Peeled Grain	59.11	62.97
5	BR-64 Peeled Grain + Peelings	60.26	65.13
6	BR-64 Peeled Grain	59.05	64.51
7	AKS-614 Peeled Grain + Peelings	63.92	66.24
8	AKS-614 Peeled Grain	62.15	66.30
9	Comm. Grain Peeled + F-65 Peelings	60.83	62.53
10	Comm. Grain Peeled + BR-64 Peelings	60.60	65.67
11	Comm. Grain Peeled + AKS-614 Peelings	58.67	62.96

Average weight gains of females significantly higher ($P < 0.01$) within treatment.

The amino acid composition of the diets (Table 11) did not show any marked differences between diets. No mortality, or apparent sickness was noted due to any of the dietary treatments.

TABLE 11. MOISTURE, PROTEIN CONTENT AND AMINO ACID COMPOSITION OF EXPERIMENTAL DIETS

	Diets										
	1	2	3	4	5	6	7	8	9	10	11
Moisture, %	7.40	6.90	6.80	6.70	6.20	7.20	6.40	6.30	6.50	6.30	6.30
Protein, %[1]	26.70	27.10	27.60	28.20	27.80	26.60	27.10	27.10	26.20	26.70	26.60
AMINO ACIDS[2]											
Lysine	6.57	6.65	6.35	6.48	6.65	6.69	6.53	6.29	6.61	6.68	6.85
Histidine	2.88	2.92	2.82	2.89	2.94	2.91	2.96	2.81	2.86	3.00	3.17
Arginine	7.75	7.88	7.61	7.75	7.76	7.92	7.80	7.61	7.85	8.18	8.29
Aspartic Acid	12.69	13.07	12.61	12.73	13.06	13.28	12.99	12.96	12.98	13.29	13.41
Threonine	4.65	4.74	4.66	4.69	4.70	4.89	4.78	4.82	4.73	4.86	4.87
Serine	6.02	6.19	6.07	6.10	6.20	6.40	6.21	6.38	6.26	6.40	6.37
Glutamic Acid	21.60	22.30	21.91	22.20	22.00	23.15	22.82	22.84	22.36	22.56	22.78
Proline	6.93	6.53	7.01	7.19	7.23	7.38	7.21	7.23	6.93	7.12	7.29
Glycine	6.40	6.45	6.27	6.24	6.54	6.64	6.61	6.42	7.04	6.62	6.63
Alanine	6.37	6.59	6.65	6.66	6.64	6.89	7.06	7.14	6.74	6.82	6.80
Half Cystine	2.18	2.05	1.72	1.94	1.31	2.06	2.18	2.36	1.37	1.84	2.53
Valine	5.60	5.94	5.68	5.82	5.93	5.89	6.05	5.41	5.89	5.73	5.65
Methionine	1.61	1.64	1.57	1.60	1.59	1.64	1.65	1.68	1.59	1.61	1.74
Isoleucine	4.89	5.10	4.96	4.98	5.03	5.11	5.09	5.05	5.03	5.07	5.26
Leucine	9.96	10.41	10.34	10.39	10.26	10.51	10.78	11.00	10.17	10.31	10.54
Tyrosine	4.13	4.24	4.21	4.28	4.24	4.19	4.22	4.05	4.11	4.23	4.31
Phenylalanine	5.7	5.75	5.70	5.71	5.93	5.92	5.97	5.49	5.80	5.92	6.01

[1] Percent protein (N x 6.25).

[2] g. amino acid/16 g. N.

SUMMARY

The present study was undertaken to determine, if the factor generally considered to affect utilization of sorghum grains was predominantly present in the pericarp.

Bird resistant sorghum hybrids F-65, BR-64, and AKS-614 were obtained from Dekalb in 1969. A commercial sorghum variety obtained in 1971 was used as a control. After preliminary studies tempering conditions were developed to process the grains based on a long temper followed by a short temper. Tempering conditions depended on time and moisture levels.

A nylon-brush peeler was used for the peeling process. After peeling the product was air dried and aspirated to give: peeled grain and peelings (pericarp). Proximate analyses of the two fractions of the four hybrids were conducted. Pericarps of the four hybrids had higher values for fat, probably due to the inclusion of germ aluerone material and endosperm fractions. Fiber content of the pericarp material was higher when compared to the peeled products. Ash content of peeled grains were similar, but the values were higher in pericarp material ranging between 2.6-4.0%.

Peeled commercial grain had higher values for essential amino acids except methionine, isoleucine, leucine, and phenylalanine. Variation in the other hybrid was small. Leucine was higher in pericarp material and peeled grain of the hybrids when compared to commercial grain.

Tannin content of the peeled grain and pericarp material showed that peelings had higher quantities of tannins. Peeled grains

contained 0.35-1.55% tannins and pericarp material ranged between 0.52-2.26%.

Enzymatic activity of α- and β-amylase enzymes indicated that tannins had an inhibitory effect on these enzymes. Negative correlation coefficients were found between tannin level and enzymatic activity.

Similar negative correlations existed for pepsin-pancreatin digestion of proteins. The yield of mg. glycine equivalents was lower for samples in which tannin content was high. Determination of residual proteins indicated a positive correlation between tannin and non-digested residual protein. Increased tannins resulted in lower digestibility of proteins.

Nutritional studies with quail did not show significant differences in weight gains or feed conversion. Sorghum grains provided between 2.98-3.71% of the protein, while the diets had a range of 26.2-28.2%. Tannin content of the diets was between 0.13-0.63% and were lower than values reported by others to affect chick growth.

Average weight gain of females were significantly higher ($P < 0.01$) than weight gains observed for males. There were no significant differences between treatments, however.

Amino acid analyses of the different diets showed little differences between diets.

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AN EVALUATION OF PEELING BIRD RESISTANT SORGHUM GRAIN

by

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This study was conducted to determine, whether factor often considered as affecting the utilization of sorghum grains was primarily located in the pericarp of the grain. The study also evaluated the effect of peeling grains on its utilization.

Three bird-resistant hybrids, F-65, BR-64, and AKS-614, were obtained in 1969 from Dekalb and were compared to a commercial sorghum grain obtained in 1971.

Grains were tempered before peeling. A long temper followed by a short temper was given to give effective peeling with as little breakage as possible. Tempering time and moisture levels varied according to grains.

Peeling was conducted using a modified nylon-brush peeler developed at Kansas State University. Air-dried materials were aspirated, yielding 88.2-91.9% peeled grain and 9.1-13.7% peelings. Proximate analyses for the grains and their peelings showed a higher percentage of fat, ash, and fiber in the latter. Peeled commercial grains had better values for all amino acids except methionine, isoleucine, leucine, and phenylalanine.

Determination of tannins in the samples showed pericarp material of all grains contained higher percentages of tannins. Presence of tannins in the peeled grains could be attributed to the inclusion of endosperm-grit and germ fractions (with the bran portion still adhering) in the peeled grain, and this could not be separated.

Production of maltose by α- and β-amylases was decreased with increasing levels of tannins present in the peeled grain and pericarp material. Hence negative correlation was found between maltose

produced and percent tannins in the samples.

Effects on pepsin-pancreatin digestion were determined and expressed as mg. of glycine equivalents. These values were low in samples with high tannin content. Residual undigested protein in the samples following pepsin-pancreatin digestion was high in those samples which contained more tannins. This gave a positive correlation of 0.99 for grain and 0.94 for pericarp material. Percent digestibility of the protein was low in samples having higher levels of tannins.

Studies with Coturnix quail did not show significant differences for weight gains or feed conversion between treatments using the different processed grain and combinations with the separated pericarp material. While the protein in the diets (1-11) ranged between 26.2-28.2% the amount of protein supplied by various grains was only 2.98-3.71%.

Range of tannins in the diets was 0.13-0.63% and were below levels reported to slow growth of chicks. Data on amino acids showed little difference between diets. Females grew significantly ($P < 0.01$) faster than males.