Improvement of the Nutritive Value of High Tannin Sorghums for Broiler Chickens by High Moisture Storage (Reconstitution)

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ABSTRACT Grains from three high and one low tannin sorghum cultivars were treated as follows: 1) untreated, no water was added, the dry grain had an average moisture content of 8% and 2) the moisture content of the grain was raised by adding 25% (w/w) distilled water to the grain. The treated grain was then stored for 10 or 20 days with a 2% level of acetic-propionic acid mixture (60/40, v/v) added to deter fungal growth. This treated grain was used in diets during a 3-week feeding trial with broiler chickens. High moisture storage (reconstitution) of high tannin sorghums decreased their extractable tannin content. Chickens fed diets containing these treated sorghums had improved weight gains (23 to 83 g) and feed efficiencies compared to birds fed diets containing the untreated grain. Treatment of low tannin sorghum did not improve weight gains. Reconstitution of high but not low tannin sorghums improved protein digestibility (6 to 16%) and dietary metabolizable energy (.1 to .3 kcal/g) for broiler chickens. There was a highly significant cultivar effect on leg scores, but the correlation between dietary tannin content and leg scores was low (r = .10), suggesting that tannin content was not a major factor in leg abnormality incidences shown. The improvement in weight gains, feed efficiencies, and protein digestibilities at 10 and 20 days storage periods was not different (P>.05), indicating that the benefits of high moisture storage were already obtained by 10 days.

(*Key words:* tannins, sorghum, high moisture storage, nutritive value, chickens)

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INTRODUCTION

The presence of tannins in some cultivars of sorghum has been associated with depression of growth rate, feed intake, protein digestibility, metabolizable energy, and also with leg abnormalities in chickens (Chang and Fuller, 1964; Connor *et al.*, 1969; Rostagno *et al.*, 1973, 1977; Armstrong *et al.*, 1974; Nelson *et al.*, 1975; Herstad, 1979; Elkin *et al.*, 1978). However, the tannins in these cultivars have also been associated with reduced depredation of grain by birds (McMillian *et al.*, 1972), reduced preharvest germination (Harris and Burns, 1970), and improved weathering characteristics (Harris and Burns, 1973). To retain the advantages of tannin in the bird resistant sorghums and at the same time to improve the nutritive value of the grain for nonruminants, detoxification methods including mechanical abrasion of the seed coat (Chibber *et al.*, 1978), supplementation with methionine, or addition of polyvinylpyrrolidone to the diets (Armstrong *et al.*, 1973), and use of chemicals (Price *et al.*, 1978a, 1979; Chavan *et al.*, 1979; Daiber, 1975; Ford and Hewitt, 1979; Muindi *et al.*, 1980; Muindi and Thomke, 1981) have been reported. Recently, Reichert *et al.* (1980) showed that anaerobic storage of moist grain deactivated tannins and improved the nutritional quality of the high tannin sorghums for rats. The process of adding sufficient moisture back to grain and sealing the moist grain from the environment so that fermentation can occur has been termed "reconstitution" (Lichtenwalner *et al.*, 1979). This study was conducted to investigate the effect of high moisture storage (reconstitution) of three high and one low tannin sorghums on their nutritive value for broiler chickens.

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MATERIALS AND METHODS

Treatment of Grain. Sorghum grains from three high (P570, AKS614, AR3003 x TX430) and one low (Yellow No. 2) tannin sorghum cultivars were used in the experiment. The cultivar P570 was obtained from King Grain Ltd., Chatham, Ontario while AKS614 and AR3003 x TX430 were obtained from the University of Arkansas, Fayetteville, AR. The Yellow No. 2 was obtained from U.S.A. The chemical composition of these sorghums is shown in Table 1.

The grains were divided into 25-kg batches and treated as follows: 1) Untreated, no water was added (the average moisture content of the grain was 8%). 2) Moisture content of the grain was raised by adding 25% (w/w) distilled water. An acetic and propionic acid mixture (60/40, v/v) was also added at 2% w/w. The ingredients were mixed in a cement mixer, which was closed to reduce loss of moisture through evaporation. The mixing was continued until the sorghum grain imbibed all the water, which was indicated by lack of lump formation by the grain. The mixing took an average of 2.5 hr per batch, although the cultivar P570 was observed to imbibe water faster than the other three cultivars. The grain was then stored in sealed plastic buckets for 10 days at 25 C. Subsequently the grain was dried in an oven at 38 C for 24 hr before being ground for inclusion in chicken diets. 3) The treatment was as in (2) but stored for 20 days.

Samples of both control and reconstituted grain were taken for tannin content analysis.

Formulation of Diets. The grain treated as described was ground in a hammer mill (1.6-mm screen) and incorporated into broiler starter diets (Table 2) at a level of 75%. Soybean meal (47% crude protein) was added at 14 or 15% to obtain about 15% crude protein in the diets. This protein level is suboptimal for the starting broiler chick but was chosen deliberately to exacerbate the effects of tannin (Rostagno *et al.*, 1973; Glick and Joslyn, 1970). The diets were supplemented with lysine and methionine to meet requirements (Scott *et al.*, 1976). Minerals and vitamins were included in the diets to meet the requirements of broiler chickens (National Research Council, 1977). Chromic oxide was included at a level of .5% for determination of digestibility of protein (DP) and apparent metabolizable energy (AME).

Experimental Design. A growth study was conducted, using 288 1-day-old chicks in a 3-week feeding trial, with 48 cages of six chicks per cage and 4 cages per treatment arranged as a 3 x 4 factorial in a completely randomized design. Feed and water were provided to the birds *ad libitum*. Feed consumption and individual bird weights were recorded weekly. In the last week of the trial, excreta samples from each cage were collected, dried at 65 C, as described by Shannon and Brown (1969), ground through 1-mm screen, and stored for chemical analysis.

Chemical Analysis. Feed and excreta samples were analyzed for moisture, energy and crude protein using standard methods (Association of Official Analytical Chemists, 1980). Chromic oxide, in both diets and excreta, was analyzed by the method of Fenton and Fenton (1979). Tannin analysis was conducted using the

TABLE 1. *Chemical composition of sorghum grains*

Component	Cultivar			
	P570	AKS614	AR3003 X TX430	Yellow No. 2
Dry matter (DM), %	92.4	92.9	92.5	92.0
Gross energy, kcal/g DM	4.6	4.6	4.6	4.6
Percentage of DM				
Crude protein	11.4	13.1	10.3	11.8
Ether extract	3.2	3.7	3.4	3.5
Crude fiber	2.6	2.6	2.5	2.4
Ash	1.4	1.5	1.3	1.5
Tannin	3.7	3.0	2.2	.1

[1] Vanillin-HCl determination.

TABLE 2. *Composition of diets (as fed basis)*

	Diets											
	P570			AKS 614			AR3003 X TX430			Yellow No. 2		
	Days of storage			Days of storage			Days of storage			Days of storage		
Ingredients[1,2]	0	10	20	0	10	20	0	10	20	0	10	20
	(%)											
Sorghums	75	75	75	75	75	75	75	75	75	75	75	75
Dextrose (glucose)	1.2	1.2	1.2	1.2	1.2	1.2	.3	.3	.3	1.2	1.2	1.2
Soybean meal (47% crude protein)	14	14	14	14	14	14	15	15	15	14	14	14
Lysine[3]	.2	.2	.2	.2	.2	.2	.1	.1	.1	.2	.2	.2

[1] In addition, all diets contained: corn oil, 5%; monodicalcium phosphate, 1.8%; calcium carbonate, 1.35%; salt (iodized), .25%; vitamin mixture, .5%; mineral mixture, .1%; chromic oxide, .5%, and methionine, .1%.

[2] Vitamin and mineral mixtures supplied the following per kilogram of diet: vitamin A, 12,000 IU; vitamin D_3, 1,000 IU; vitamin E, 10 IU; vitamin K, 2 mg; riboflavin, 4 mg; d-calcium pantothenate, 10 mg; niacin, 25 mg; choline chloride, 500 mg; folic acid, 1 mg; vitamin B_{12}, 10 μg; pyridoxine hydrochloride, 3 mg; biotin, 200 μg; thiamin hydrochloride, 2 mg; ethoxyquin, 125 mg; manganese, 80 mg; zinc, 60 mg; iodine, .4 mg; selenium, .1 mg; copper, 4 mg.

[3] Added as lysine hydrochloride.

vanillin-HCl method (Burns, 1971) with reagent blanks as suggested by Price *et al.* (1978b).

Determination of Digestibility of Protein, Metabolizable Energy, and Tannin Content of the Diets. Because the chicken urinary and fecal nitrogen are present together in the excreta, urinary nitrogen was separated from the fecal by the method of Ekman *et al.* (1949). This method takes advantage of the fact that non-protein nitrogen substances are soluble in water and that soluble proteins are precipitated as uranium compounds. The DP and AME of the diets were calculated using the standard equations (Lloyd *et al.*, 1978). Tannin contents of the diets were calculated from the values of the whole grains.

Leg Scores. Broiler chickens fed high tannin sorghum diets have been reported to show a higher incidence of a leg abnormality, which includes bowing of the legs or a perosis-like condition (Rostagno *et al.*, 1973; Armstrong *et al.*, 1973). To investigate whether reconstitution reduced the incidence of leg abnormality, leg scoring was done using the subjective score method of Armstrong *et al.* (1973). On the last day of the feeding trial the birds' legs were examined and the following scores given: 1, normal; 2, slightly abnormal; 3, severely abnormal; 4, unable to stand.

Statistical Analysis. Weight gain, feed consumption, and feed efficiency (FE) values were calculated and with DP, AME, and leg scores data were subjected to analysis of variance and the means compared according to the Students-Newman-Keuls' (SNK) multiple range test (Steel and Torrie, 1960). Regression and correlation analyses were also done so as to describe various relationships.

RESULTS

Tannin Deactivation. High moisture storage (reconstitution) decreased the extractable tannin content of the high tannin sorghums to a level similar to that of low tannin sorghum (Fig. 1). The greatest reduction of extractable tannin content in each of the high tannin sorghums occurred in the first 10 days of storage and then gradually fell to lower values at 20 days.

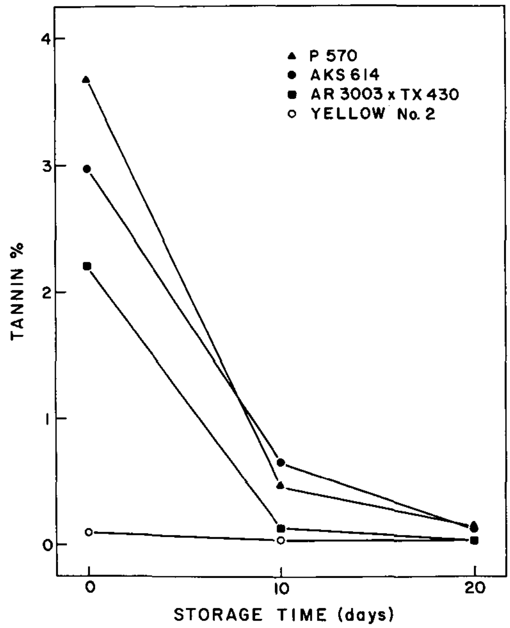

FIG. 1. Effect of reconstitution on tannin deactivation in three high and one low tannin sorghums.

Performance Improvement. The initial weight of the birds showed a correlation (P<.01) with weight gains. To remove variation due to initial weight, covariance analysis was done. The effects of cultivars and treatments were highly significant (P<.01) and their interaction was also significant (P<.05). The adjusted weight gain means are shown in Table 3. Comparison of untreated sorghum diets showed that P570 gave the lowest weight gain (275.5 g) while the Yellow No. 2 sorghum supported the highest gains (420.8 g). The AKS614 and AR3003 × TX430 cultivars had similar and intermediate weight gain values and were not significantly higher (P<.05) than the P570 value. Reconstitution significantly improved (P<.05) the weight gains with high tannin sorghums (P570 and AKS614) but did not improve weight gains with low tannin sorghum. For all the high tannin sorghums, the improvement of weight gains at 10 days storage was similar to that at 20 days of storage. Comparison of the sorghums showed that the low tannin sorghum diets supported the highest weight gains. Reconstitution of the high tannin sorghums did not improve the weight gains to the level achieved with low tannin sorghum except in the case of AKS614 where the weight gains on reconstituted sorghum diets were similar to those of the low tannin sorghum. Reconstitution of AR3003 × TX430 did not improve the weight gain significantly (P>.05) as compared to the untreated AR3003 × TX430.

Feed consumption and feed efficiency values

TABLE 3. *Mean effect of reconstitution of high and low tannin sorghums on weight gains, feed consumption, feed efficiency, protein digestibility, and metabolizable energy in broiler chickens from 0 to 3 weeks of age*

Sorghums	Treatment[1]	Weight gain[2]	Feed consumption	Feed efficiency	Protein digestibility	Metabolizable energy
		(g)	(g)	(g gain/g feed)	(%)	(kcal/g)
P570	0	275.5^{a}	544.6^{a}	$.51^{a}$	67.7^{a}	3.4^{a}
	10	344.9^{bc}	586.4^{ab}	$.59^{cde}$	79.9^{c}	3.5^{ab}
	20	350.9^{bc}	616.0^{ab}	$.57^{bcd}$	80.6^{c}	3.6^{bc}
AKS614	0	306.3^{ab}	576.2^{ab}	$.54^{ab}$	71.2^{b}	3.6^{bc}
	10	382.9^{cd}	633.7^{ab}	$.62^{def}$	81.5^{cd}	3.7^{bcd}
	20	388.6^{cd}	661.3^{ab}	$.59^{cde}$	87.1^{e}	3.9^{de}
AR3003 × TX430	0	321.1^{ab}	581.8^{ab}	$.54^{abc}$	81.5^{cd}	3.7^{cde}
	10	344.3^{bc}	576.8^{ab}	$.60^{de}$	87.5^{e}	3.8^{cde}
	20	328.9^{b}	368.1^{ab}	$.58^{bcde}$	88.4^{e}	3.7^{cde}
Yellow No. 2	0	420.8^{d}	675.4^{b}	$.62^{ef}$	84.5^{de}	3.7^{cde}
	10	436.8^{d}	676.9^{b}	$.65^{f}$	84.8^{de}	3.9^{e}
	20	430.6^{d}	666.7^{ab}	$.65^{f}$	84.7^{de}	3.8^{cde}
	SE[3]	14.0	26.6	.01	.83	.04

a,b,c,d,e,f Means that do not share a common superscript in a column are significantly different ($P<.05$).

[1] 0, 10, 20 represent untreated, 10 days storage, and 20 days storage, respectively.

[2] Adjusted for initial weights of birds.

[3] Standard error of the mean.

are shown in Table 3. Chickens on the untreated P570 diet consumed significantly less (P<.05) feed than those on untreated and 10-day-storage Yellow No. 2 diets, but consumption was similar to those with AKS614, AR3003 × TX430, and 20-day-storage Yellow No. 2 diets. The untreated high tannin sorghum diets produced lower (P<.05) FE values than the untreated low tannin sorghum diet (Table 3). Reconstitution significantly improved (P<.05) FE values for the high tannin sorghums, P570, and AKS614 but not for the low tannin sorghum. The improvement in feed efficiency was similar for 10 and 20-day storage treatments of high tannin sorghums. The untreated AR3003 × TX430 diet produced an FE value similar to that of the 20-day storage diet but lower (P<.05) than that of the 10-day-storage diet.

Tannin content of the diets showed highly significant correlations with weight gains (r = −.57) and feed efficiency (r = −.78). There was no significant (P>.05) correlation between tannin content of the diets and feed consumption by birds.

Protein and Energy Utilization. Analysis of variance results showed highly significant (P<.01) effects of cultivars, reconstitution, and cultivar × reconstitution interaction on protein digestibility. Both cultivars and treatments contributed equal percentages (39%) of total variance and both of these factors and their interaction term accounted for 79.9% of the variance in protein digestibility. Comparison of cultivar × treatment means (Table 3) showed that reconstitution improved (P<.05) protein digestibility of high tannin sorghums but had no effect on protein digestibility of low tannin sorghum. The results also showed that protein digestibility was lowest for untreated P570 followed by untreated AKS614 and then untreated AR3003 × TX430 and Yellow No. 2 diets. This follows the tannin content pattern in these cultivars. A highly significant (P<.01) negative correlation (r = −.89) between protein digestibility and tannin content was obtained.

The metabolizable energy data analysis showed that cultivar, treatment, and cultivar × treatment interaction had highly significant effects. Cultivar effect was shown to be the most important factor, contributing 53.29% of the total variance; treatment contributed only 21.16%. Comparison of the cultivar × treatment means (Table 3) showed that the untreated P570 diet had the lowest (P<.05) AME value as compared to the other untreated sorghum diets. Diets containing P570 and AKS614 stored for 20 days showed higher (P<.05) AME values as compared to their respective untreated sorghum diets. Reconstitution did not increase AME values for AR3003 × TX430 and Yellow No. 2 sorghums (P>.05). Highly significant correlations between AME and tannin content of the diet (r = −.66) and protein digestibility (r = .79), respectively, were obtained.

Leg Scores. Analysis of variance indicated a highly significant effect (P<.01) of cultivars but treatment effect was not significant (P>.05) (Table 4). The cultivar and treatment effects accounted for 7.8 and .6% of the total leg-score variance, respectively. The mean leg-score of birds on P570 diets was the highest (Table 4). The birds on AKS614 and Yellow No. 2 diets had similar mean leg scores, while AR3003 × TX430 had the lowest value, although it was not significantly lower (P>.05) than the value

TABLE 4. *Mean effect of reconstitution of high and low tannin sorghums on leg scores*[1] *of chickens*

	Sorghums				
Treatment[2]	P570	AKS614	AR3003 × TX430	Yellow No. 2	Mean
			(Mean leg score)		
0	2.21	1.67	1.25	1.39	1.63[a]
10	1.91	1.96	1.43	1.78	1.78[a]
20	1.96	1.52	1.35	1.50	1.58[a]
Mean	2.03[a]	1.72[b]	1.34[c]	1.56[bc]	

[a,b,c]Means that do not share a common superscript in a row or in a column are different (P<.05).

[1] Values assigned for leg condition: 1, normal; 2, slightly abnormal; 3, severely abnormal; 4, unable to stand.

[2] 0, 10, and 20 represent untreated, 10 days storage, and 20 days storage, respectively.

for Yellow No. 2 diets. The correlation coefficient between the tannin content and the leg-scores was low (r = .10).

DISCUSSION

The mechanism of tannin deactivation during reconstitution of high tannin sorghums is not known. The process is probably similar to the polymerization of tannins during the ripening of the sorghum seed, which ceases when the moisture content drops. If this polymerization process is assumed, then the increase of moisture only provides the medium in which the natural process of polymerization continues. The improvement of the feeding value of reconstituted high tannin sorghums suggests that in the deactivation process, tannins are polymerized to an extent that they lose their ability to bind proteins. Goldstein and Swain (1963) have shown that tannin polymers of above 10 flavan monomers are too insoluble and have too few reactive sites or are too large to fit the protein orientation for crosslinking.

The improvements in weight gain and feed efficiency with reconstitution are probably due to the improvement in protein and energy utilizaton. The lack of significant correlation between tannin content and feed consumption may be indicative of a lack of astringency in the mature and dry sorghum grains. Astringency in fruits has been reported to decrease during ripening (Goldstein and Swain, 1963).

The significant improvement of dietary AME with reconstitution of high tannin sorghums and also the presence of a highly significant ($P<.01$) correlation between AME and tannin percentage are indicative of a direct effect of tannins on metabolizable energy. Other studies have also shown that tannins affect the digestibility of energy in rats (Featherston and Rogler, 1975; Muindi and Thomke, 1981). A significant ($P<.01$) correlation between AME and DP indicates that the increase in DP contributed significantly to the increase in AME during reconstitution. These results suggest that the tannin content of the diets has both direct and indirect effects on the dietary AME.

The leg abnormality observed in the birds was similar to that reported by Rostagno *et al.* (1973) and Armstrong *et al.* (1973) and that was described as distortion of the long bone by Riddel (1981). The results of leg score data showed that P570 was associated with the highest leg abnormality incidences followed by AKS614, Yellow No. 2, and AR3003 × TX430. The lack of significant difference ($P<.05$) between the mean leg score values for the low tannin sorghum (Yellow No. 2) and the high tannin sorghums, AKS614 and AR3003 × TX430, respectively, casts a doubt on whether the leg abnormality incidences were related exclusively to the tannin content of the sorghums. In addition, the total leg score variance accounted for by cultivar and treatment effects (8.4%) and the correlation between dietary tannin content and the leg scores (r = .10) were low. This indicates high error variance. It appears that dietary tannin content was not a major factor in leg abnormality incidences.

In this study we have shown that reconstitution of high tannin sorghums improves their feeding value for broiler chickens. The result showing that the benefits of reconstitution after 10 days of storage are similar to those obtained after 20 days of storage has economic implications. In addition, the method is inexpensive and practical for use under farm conditions.

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