Traditional Processing of High-Tannin Sorghum Grain in Uganda and Its Effect on Tannin, Protein Digestibility, and Rat Growth

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In the southern highlands of Uganda and neighboring areas, where high-tannin sorghum [*Sorghum bicolor* (L.) Moench] types with soft endosperm grains are extensively grown, a unique traditional technology was evolved to process high-tannin grains before they are consumed. This technology, which is simple and uses locally available material, involves mixing high-tannin grains with wood-ash slurry, followed by soaking the grains in water overnight. The grains are then germinated for 3–4 days, dried in the sun, cleaned, and ground into flour. This wood ash treatment is shown to effectively detoxify the grain and improve the nutritional quality up to the level of low-tannin grains. The traditional technology to process high-tannin sorghum is described, and its simplicity and effectiveness in detoxification and nutritional quality improvement are demonstrated.

INTRODUCTION

In some parts of Africa, low-tannin sorghums cannot be grown because of excessive bird damage prior to harvest. As a result, bird-resistant high-tannin cultivars are grown and consumed. The high-tannin sorghums have also been reported to be resistant to weathering in the field and preharvest germination (Harris and Burns, 1970, 1973). Unfortunately, high-tannin sorghums produce various toxic effects when included in the diets of most animals (Price et al., 1980; Hahn et al., 1984). In chicks, rats, mice, hamsters, and Japanese quail, the effects of high-tannin grain are manifested as reduction in growth rate, feed efficiency, and protein digestibility (Butler, 1989). In addition, tannins have been reported to reduce egg production in laying hens, produce leg abnormalities in chicks, increase the activity of UDP-glucuronyltransferase in chick livers, and cause hypertrophy and increased production of proline-rich proteins in the parotid glands of rats (Armstrong et al., 1974; Butler, 1989). The effects on leg anomalies and UDP-glucuronyltransferase activity would suggest that tannins and/or other polyphenolic compounds are absorbed from the digestive tract. Increased production of proline-rich proteins in the parotid glands is thought to involve a protective mechanism to detoxify tannins, since their proteins bind readily to tannins.

Several mechanical and chemical methods have been reported to overcome the toxic effects of high-tannin grain (Chibber et al., 1978; Price and Butler, 1978; Price et al., 1979; Reichert et al., 1980; Muindi et al., 1981; Mitaru et al., 1983), but none have been used by traditional sorghum consumers in Africa because they are either too expensive or not practical. In southern Uganda, Rwanda, and Burundi where large quantities of high-tannin sorghums are grown, the grain is processed by a traditional method before consumption. This method involves treatment with wood ash, soaking in water overnight, and germination. This popular method is believed to improve the nutritional quality and palatability of high-tannin sorghum grain. Therefore, we studied the effect of the traditional processing method on tannin and in vitro protein digestibility of high-tannin grains of a local cultivar from Kabale, Uganda. We also compared the performance of rats fed diets containing wood-ash-treated and untreated RS 610 (low-tannin) and DeKalb BR 64 (high-tannin) sorghum hybrid grains.

MATERIALS AND METHODS

Sorghum Grain and Traditional Beverages. Traditionally processed and unprocessed sorghum grains (0.45 kg each) of a local sorghum cultivar from Kabale, Uganda, were air freighted to West Lafayette, IN, in July 1985. The grains were refrigerated until analysis was initiated in January 1986. Samples of native nonalcoholic (Obushara) and alcoholic (Omuramba) beverages prepared from processed grain were brought from Kabale by the first author in August 1986. In general, Obushara is prepared by mixing whole grain flour and water and heating to the boiling point. After cooling, additional water is added to produce a nonalcoholic thin porridge. Omuramba is prepared by mixing whole grain flour with water and heating to form a thin porridge that is allowed to ferment in a pot for a week. Natural yeasts on the grain ferment the flour. Using a series of boiling steps followed by fermentation, Omuramba is produced. The entire process of preparing Omuramba takes about 4 weeks. The freshly prepared finished products were transported in a cooler to the United States. Unfortunately, specific descriptions of how they were prepared are not available.

Grain Processing with Wood Ash. RS 610 and DeKalb BR 64 were grown in the field at the Purdue University Agronomy Research Center in 1986. Grain of each cultivar was treated as follows:

1. *RS 610-1 and BR 64-1* are untreated controls of low- and high-tannin cultivars, respectively.
2. *RS 610-2 and BR 64-2.* Six kilograms of each whole grain was wrapped in cheesecloth, soaked in water for 15 h, drained, placed in a covered cardboard box, and allowed to germinate at room temperature for 4 days. The germinated grain was dried at room temperature for 48 h followed by 48 h in a dryer at 60 °C.
3. *RS 610-3 and BR 64-3.* Six kilograms of each whole grain was thoroughly mixed with 750 mL of wood-ash slurry (1.0 g of clean hardwood ash/mL of water). The ash-treated grain was

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Table I. Composition of Experimental Diets

ingredients	experimental diet 1	2	3	4	5	6	7	8
RS 610-1 (8.8)[a]	84.08							
RS 610-2 (9.0)		84.08						
RS 610-3 (8.9)			84.08					
RS 610-4 (9.3)				84.08				
BR 64-1 (8.0)					92.49			
BR 64-2 (8.4)						92.49		
BR 64-3 (8.3)							92.49	
BR 64-4 (8.7)								92.49
cornstarch	8.41	8.41	8.41	8.41				
common[b]	7.51	7.51	7.51	7.51	7.51	7.51	7.51	7.51
crude protein, %	7.40	7.57	7.48	7.81	7.40	7.77	7.68	8.05

[a] Percent protein of the grain. [b] Common ingredients as percent of the diet: mineral mix (AIN-76), 3.5; vitamin mix (AIN-76), 1.0; corn oil, 2.0; lysine hydrochloride, 0.75; choline chloride (50%), 0.25; BHT (100%) 0.01.

Table II. Effect of Wood-Ash Treatment on Grain Color and Tannin Content of Ugandan and U.S. High-Tannin Sorghum Grains

cultivar	phenotypic grain color	treatment	total extractable tannin (catechin equivalent)
Kabale local (Ugandan)	brown	none	6.88
Kabale local (Ugandan)	black	wood ash + germination	0.04
P 954063 (U.S.)	white	none	0.04
DeKalb BR 64 (U.S.)	brown	none	7.35

then wrapped in cheesecloth, soaked in water for 15 h, and drained. The grain was then dried as described for RS 610-2 and BR 64-2.

4. RS 610-4/BR 64-4. The same treatment as for RS 610-3/BR 64-3 was used except that the grain was germinated and dried as for the RS 610-2/BR 64-2 treatment.

Diets. The eight diets for rats used in the experiment are presented in Table I. Diets 1–4 contained ground RS 610 low-tannin sorghum (LTS) that had been processed as described for the corresponding treatments. Diets 5–8 contained ground BR 64 high-tannin sorghum (HTS) that had been treated similarly as RS 610 grain. An attempt was made to make the LTS and HTS diets isonitrogenous based on the protein analyses of the untreated grains. However, all treatments with wood ash and/or germination increased the protein content slightly, and therefore only the control diets (1 and 5) were actually isonitrogenous.

Rats. Male weanling rats of the Sprague-Dawley strain (Harlan Laboratories, Indianapolis, IN) were placed in individual wire-floored cages. They were fed a commercial laboratory animal diet for an adjustment period of 3 days. The rats were then weighed and allotted to each diet treatment on the basis of body weight so that the initial weight for each group was essentially the same. Each treatment consisted of 10 rats. Feed and water were provided ad libitum throughout the 20-day period.

Chemical Analyses. The processed and unprocessed sorghum grain from Kabale and the U.S. control cultivars (P 954063 and DeKalb BR 64) as well as treated DeKalb BR 64 and RS 610 grains were analyzed for tannin content using the modified vanillin assay (Price et al., 1978); the results are expressed as catechin equivalents. The crude protein content was determined according to the AOAC (1980) procedure. The method of Axtell et al. (1981) as modified by Mertz et al. (1984) was used to estimate in vitro protein digestibility of the grains and beverages.

RESULTS AND DISCUSSION

Tannin Content of Grain. Data in Table II show the tannin content of the processed and unprocessed grain from Kabale, Uganda, and the grain of U.S. control cultivars. The unprocessed grain from Kabale had a tannin content (6.88%) in the range of that for DeKalb BR 64 (7.35%), while the traditionally processed grain had a tannin content (0.04%) similar to that found for P 954063.

The tannin content (catechin equivalent) of RS 610, untreated and treated (RS 610-1–4), was essentially zero in all cases. In contrast, the catechin equivalent of untreated HTS (BR 64-1) was 7.35%. This was reduced to 2.4% by soaking in water followed by germination (BR 64-2) and reduced further to the zero level of RS 610 by both treatments using wood-ash slurry (BR 64-3 and BR 64-4).

Protein Digestibility. In vitro protein digestibility values of the processed and unprocessed grain from Kabale and that of Obushara and Omuramba are shown in Table III. The digestibility values of uncooked and cooked flour of processed grain are 66.6 and 42.1%, respectively, which are similar to digestibility values of uncooked and cooked P 954063. Previous studies have shown that low-tannin sorghums, unlike millet (*Pennisetum glaucum* L.) or maize (*Zea mays* L.), undergo a sharp decrease (about 30%) in in vitro pepsin digestibility on cooking in water (Mertz et al., 1984; Ejeta et al., 1987). The digestibility of uncooked (15.9%) and cooked (8.5%) flour of unprocessed grain is unacceptably low. The traditional wood-ash processing of the high-tannin grain significantly improved its digestibility to the level found in the white-seeded low-tannin cultivar P 954063.

The digestibility value of cooked Obushara is 46.2%, while that of cooked Omuramba is 73.2%. The digestibility of Omuramba is significantly higher than that of Obushara, which is probably due to the effect of fermentation. The alcohol content of Omuramba was about 2.8%, which is almost half that of clear beer. Other fermented products, i.e., Kisra (a fermented Sudanese bread made from sorghum flour), Abrey (a fermented Sudanese drink) (Axtell et al., 1981), and Nasha (a fermented Sudanese baby food) (Graham et al., 1986), also show an improvement in digestibility over that of unfermented cooked sorghum flour. Fermentation appears to protect the proteins from becoming resistant to digestion by pepsin on cooking (Hamaker et al., 1987).

In vitro protein digestibility of the four different treatments for RS 610 and DeKalb BR 64 is shown in Table IV. Digestibility of untreated RS 610 was relatively high (84.2%), and treatment with wood ash alone had little effect (81.2%). In contrast, protein digestibility of untreated BR 64 was very low (13.3%) and was improved by all treatments. Protein digestibility was lower for BR 64 as compared with that for RS 610 for all treatments except the wood-ash treatment followed by germination (treatment 4). This reduction was most dramatic for the controls followed by the water and germination treatment (treatment 2). While both germination treatments of RS 610 (treatments 2 and 4) reduced digestibility, similar treatment of BR 64 improved digestibility, particularly treatment 4 for which the value was equivalent to that of RS 610 similarly treated. The largest improvement was

Table III. In Vitro Protein Digestibility of Sorghum Grain and Beverages from Kabale, Uganda

cultivar	treatment	grain/beverage	protein, % (N × 6.25)	digestibility,[a] % uncooked	digestibility,[a] % cooked
local	none	grain	9	16	9
local	wood ash + germination	grain	11	67	42
local	wood ash + germination + cooked (no fermentation, nonalcoholic)	beverage (Obushara)	N/D[b]	N/D	46.2
local	wood ash + germination + cooked (fermentation, alcoholic)	beverage (Omuramba)	N/D	N/D	73
P 954063	none	grain	11	65	44

[a] Values are means of triplicate determinations. [b] N/D, not determined.

Table IV. Effect of Sorghum Grain Treatments on in Vitro Protein Digestibility, Rat Weight Gain, and Gain/Feed Ratios

sorghum cultivar	treatment	in vitro protein digestibility, %	diet	20-day wt gain,[a] g	gain/feed
RS 610	RS 610-1	84	1	45.5[b]	0.20
RS 610	RS 610-2	57	2	27.9[d]	0.15
RS 610	RS 610-3	81	3	36.5[c]	0.18
RS 610	RS 610-4	52	4	14.3[e]	0.09
BR 64	BR 64-1	13	5	7.2[f]	0.05
BR 64	BR 64-2	27	6	1.5[f]	0.01
BR 64	BR 64-3	75	7	52.5[a]	0.21
BR 64	BR 64-4	54	8	30.4[c,d]	0.15

[a] Means with different superscripts are significantly different ($P < 0.05$) as determined by the Newman–Keuls multiple range test (Steel and Torrie, 1980).

achieved by treatment with wood-ash slurry alone (75.4%), which approached the value of RS 610 similarly treated. Germination of BR 64 following wood-ash treatment reduced digestibility (53.7%) compared to wood ash alone.

Rat Feeding Trials. Feeding a diet containing untreated DeKalb BR 64 (diet 5) reduced the growth rate dramatically compared with feeding untreated low-tannin RS 610 (diet 1) (Table IV). Treatment with water followed by germination reduced growth rate in rats fed either RS 610 or BR 64 diet (diets 2 and 6 vs 1 and 5). The lack of growth improvement in rats fed BR 64 treated in this manner occurred even though the assayable tannin was reduced considerably by this procedure (from 7.5 to 2.4 catechin equivalents).

Treatment of RS 610 with wood ash alone reduced growth in rats compared with rats fed diets containing untreated RS 610 control diet (diet 3 vs 1). However, treatment of BR 64 with wood ash completely overcame the growth depression of BR 64 (diet 7). Growth rate was significantly greater in rats fed diets containing BR 64 grain treated in this manner compared with those fed any of the RS 610 diets, including the untreated control (diet 7 vs 1–4). Germination following wood-ash treatment depressed growth rate with both sorghum grains compared with wood ash alone (diets 4 and 8 vs 3 and 7), with the greatest reduction noted with RS 610. A possible explanation for the poorer growth of rats fed germinated sorghum may involve mold production during the germination process. The grains had a definite moldy odor after germination, which was particularly noticeable in those treated with water followed by germination.

Although growth rate followed in vitro protein digestibility in several cases, there were noticeable exceptions. For example, although wood-ash treatment of RS 610 had little effect on in vitro digestibility (treatment 1 vs 3), growth rate was significantly reduced (diet 1 vs 3). Similarly, both germination treatments of RS 610 (treatments 2 and 4) showed similar in vitro digestibility values, but growth rate was poorer in rats fed grain treated with wood ash compared with water (diet 4 vs 2). With BR 64, treatment with water followed by germination improved in vitro digestibility but depressed growth rate compared with the control. Feeding rats BR 64 treated with or without germination paralleled the in vitro digestibility values (diets 7 and 8). Feed efficiency values (Table II) were similar to the growth data, with the poorest efficiency noted in rats exhibiting low weight gains.

Conclusions. Our results indicated that treatment of high-tannin sorghum grain with a wood-ash slurry reduced the assayable tannin content, increased in vitro protein digestibility, and overcame the growth depression of dietary tannins. The action of wood ash is probably due to its alkali content, simulating other alkaline treatments that detoxify tannins (ammonium hydroxide, potassium carbonate, etc.). Germination of the grains is not necessary to achieve these results and may actually reduce the benefits of wood-ash treatment if not properly processed.

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