CP 681 1454

Traditional Technologies in Small Grain Processing

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Abstract

Traditional small grain (mainly sorghum and millets) producers in the semi-arid tropics of Africa and India have developed simple but effective technologies to process their grains. These technologies are variable, depending on the types of grains produced. In general, traditional grain-processing technologies are used for cleaning, dehulling, and grinding grain into flour. Farmers in the southern highlands of Uganda and neighboring areas, where high-tannin sorghum types with soft endosperm grains are extensively grown, have developed a unique traditional technology of processing high-tannin grains before they are consumed. This technology involves mixing high-tannin grains with wood-ash slurry, followed by soaking the grains in water overnight. The grains are then germinated for 3 to 4 days, followed by drying in the sun, cleaning, and grinding into flour. This treatment effectively detoxifies the grain and improves its nutritional quality to the level of low-tannin grains. In this paper, traditional cleaning, dehulling, and grinding into flour of small grains are reviewed briefly; the traditional technology of processing high-tannin sorghum grains is described; and its effectiveness in improving nutritive quality is reported. The applicability of the technology to a range of sorghum grains is also discussed.

Introduction

Sorghum and millets are the most important small grains for millions of resource-poor farmers in the semi-arid tropics of Africa and India. These farmers have developed simple grain-processing technologies that significantly improve the acceptability and quality of these grains. Traditional technologies are used to clean, dehull, and grind small grains into flour. In the southern highlands of Uganda and neighboring countries, a unique traditional processing technology was developed for the high-tannin sorghum produced exclusively in these areas. The technology, which involves treating the grain with wood ash, soaking in water, and germinating the grain is very popular and is believed to improve the nutritional quality of brown-seeded high-tannin sorghum grains. In this chapter, traditional technologies for dehulling, grinding, and processing high-tannin sorghum grains are reviewed. The effectiveness of these technologies in detoxification and improving nutritional quality are investigated.

Traditional Small Grain Dehulling and Grinding

Traditional small grains (sorghum, pearl millet, and finger millet) are hand harvested, dried, and stored in traditional storage structures. Small quantities are regularly hand threshed, cleaned, winnowed, and sometimes pounded to remove tight glumes. Sorghum grain may be dehulled before grinding, depending on the types of grains produced and the foods prepared.

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ICRISAT Conference Paper no. CP 681.

Mukuru, S.Z. 1992. Traditional technologies in small grain processing. Pages 47–56 *in* Utilization of sorghum and millets (Gomez, M.I., House, L.R., Rooney, L.W., and Dendy, D.A.V., eds.). Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Although sorghum is not dehulled to produce *towo* in certain localities in Nigeria, dehulling the grain for *ogi* preparation is usually carried out because it is generally accepted that dehulling improves the *injera* quality (Gebrekidan and Gebrehiwot 1987). The highly corneous grains are much easier to dehull and give higher grain recovery rates. In general, white-seeded high-tannin types that also have a soft endosperm are not dehulled (Mukuru et al. 1982).

Traditional dehulling generally involves pounding the soaked or damp grain in a wooden mortar with a wooden pestle and winnowing to separate the dehulled grain from bran (Eggum et al. 1983, Mitaru et al. 1983, Mukuru 1986). In Mali and Burkina Faso, the grain is dehulled before it is made into *to* (Boling and Eisener 1982). In India, on the other hand, sorghum is dehulled in a stone mortar with a wooden pestle after moistening (Murty et al. 1982).

Cleaned whole or dehulled grain is ground into flour on traditional grinding stones—a small flat stone on a larger rectangular one. The grain must be clean and sufficiently dry to produce flour of acceptable quality. The grains are crushed into flour by the constant friction of the two stones. In Nigeria (Obilana 1982) and Botswana (Boling and Eisener 1982), dehulled grains are pounded in a wooden mortar with a pestle and sieved at intervals to produce flour. For many people in rural areas where mechanical grinders are unavailable and where prices charged for grinding are prohibitive, the traditional method is still used.

Traditional Processing of High-Tannin Sorghum Grain

Brown-seeded, high-tannin sorghums are grown both for food and drink in various parts of Africa where the bird (*quelea*) problem is severe because these types are least preferred by birds. High-tannin sorghums also have an agronomic advantage over low-tannin types because they are resistant to grain molds and preharvest germination (Harris and Burns 1970a, Harris and Burns 1970b). The disadvantage of brown-seeded sorghum grains is their antinutritional character. When used as food, the tannins in the grain bind up enzymes and proteins in the digestive tract causing low digestibility (Hahn et al. 1984).

Mechanical and chemical methods have been developed to overcome the antinutritional effects of high-tannin grain (Chibber et al. 1978, Mitaru et al. 1983, Price et al. 1979, and Scheuring et al. 1982), but these are expensive and impractical for resource-poor farmers. In the southern highlands of Uganda where high-tannin sorghums are consumed, a popular processing technology has been developed.

Processing Technology

First, brown-seeded, high-tannin sorghum grains are cleaned and winnowed to remove loose dirt, glumes, and other particles. The cleaned grain is then thoroughly mixed with wood ash slurry, which is obtained by dissolving one part wood ash (weight) to one part water (volume). Approximately 150 mL of wood ash slurry is sufficient for 1 kg of grain. The treated grain is transferred into a grass basket and soaked in water overnight (12-15 h). After soaking, the grains are well drained and covered in grass for 3-4 days until germination when the radicle is about 2 cm long. Germinated grain is then spread in the sun to dry. After drying, it is cleaned by pounding in a wooden mortar with a pestle to shake off loose wood ash dust and to break the dried radicles off the grain. After winnowing, the grain is ready to be ground into flour on traditional grinding stones. The flour is generally used to prepare traditional beverages called *obushara* (nonalcoholic) and *omuramba* (approximately 2.8% alcohol).

Effect of Traditional Processing on Nutritional Quality

Traditionally processed and unprocessed grains of a brown-seeded, high-tannin local sorghum cultivar were obtained from southern Uganda in 1986 and analyzed at Purdue University for tannin content, percent protein, and in vitro protein digestibility. Grains of 954 063 (low tannin) and BR 64 (high tannin) were also analyzed as controls. The results, shown in Table 1, clearly demonstrate the effectiveness of the traditional processing technology in improving nutritional quality of high-tannin grain. Traditional processing significantly reduced tannin content from 6.88% to 0.04%, which is not significantly different from that of 954 063 (a white-seeded low-tannin sorghum), and significantly improved protein content and in vitro protein digestibility to the level of that of the low-tannin 954 063 control.

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Table 1. Tannin content, percent protein, and in vitro protein digestibility of traditionally processed and unprocessed grains of a high-tannin local sorghum from Uganda compared with controls 954 063 (low tannin) and BR 64 (high tannin).

					In vitro protein digestibility – uncooked (%)		
						Traditional beverages	
Sorghum	Treatment	Grain color	Tannin (CE)	Protein (%)	Grain	*Obushara* (nonalcoholic)	*Omuramba* (alcoholic)
Local sorghum	Unprocessed	Brown	6.88	9.12	15.9	-	-
	Processed	Black	0.04	10.47	66.6	46.2	73.2
954 063	Unprocessed	White	11.41	64.9	-	-	-
BR 64	Unprocessed	Brown	-	-	-	-	-

CE = Catechin equivalent.

Table 2. The effect of 0.01 NaOH and three wood ash treatments on grain color, percentage of dry matter loss, and tannin contents (CE) of grains of a high-tannin local sorghum from Uganda.

Treatment	Grain color	Dry matter loss (%)	Tannin content	Reduction in assayable tannins (%)
1. Unprocessed grain	Brown	0	9.284	0
2. Water	Brown	3	3.628	61
3. 0.01 NaOH	Black	4	0.224	98
4. Ash filtrate	Black	4	0.360	96
5. Ash residue + water	Black	4	0.247	97
6. Ash slurry + water	Black	4	0.336	96
7. Water + germination	Brown	16	2.640	72
8. 0.01 NaOH + germination	Black	17	0.072	99
9. Ash filtrate + germination	Black	12	0.128	99
10. Ash residue + water + germination	Black	16	0.080	99
11. Ash slurry + water + germination	Black	16	0.048	100
12. Traditionally processed	Black	18	0.052	99

Treatments as follows:
1 = Unprocessed grain.
2 = Grain soaked in water for 12 h.
3 = Grain soaked in 0.01 NaOH for 12 h.
4 = Grain soaked in wood ash slurry filtrate for 12 h.
5 = Grain mixed with wood ash slurry residue and soaked in water for 12 h.
6 = Grain mixed with wood ash slurry and soaked in water for 12 h.
7 = Same as (2) and germinated for 2 days in an oven at 30°C.
8 = Same as (3) and germinated for 2 days in an oven at 30°C.
9 = Same as (4) and germinated for 2 days in an oven at 30°C.
10 = Same as (5) and germinated for 2 days in an oven at 30°C.
11 = Same as (6) and germinated for 2 days in an oven at 30°C.
12 = Traditionally processed grain from Uganda.

vitro protein digestibility at Purdue. Percent protein digestibility of *obushara* was lower than that of the processed grain, while that of *omuramba* was much higher. It has been reported that sorghum, unlike other cereal grains, drastically loses its in vitro protein digestibility when cooked (Axtell et al. 1981, Axtell et al. 1982, Mertz et al. 1984). However, percent digestibility of fermented sheet-baked sorghum products (*kisra* and *abrey*) from the Sudan was found to be similar to or higher than that of the uncooked grain, indicating that fermentation improved digestibility (Axtell et al. 1982, Eggum et al. 1983).

Standardizing the Technology for Laboratory Use

Small quantities (60 g) of unprocessed grain from Uganda were processed using wood ash and 0.01 NaOH. Treatments and results are presented in Table 2. In all cases (except where the grains were soaked in water) processed grains changed color from brown to black, similar to the traditionally processed grain. The percentage of dry matter loss was low (3-4%) for treatments where the grains were not germinated, but higher (16-17%) for treatments where the grains were germinated. There was reduction in assayable tannins of up to 61% for the treatment where the untreated grains were soaked in water and an additional 11% when germination followed. However, the percentage of reduction of assayable tannins was very high (96-97%) when the grains were mixed with wood ash slurry, wood ash slurry filtrate, or residue. An additional small reduction (2-4%) resulted when these treatments were followed by germination. The percentage of reduction in assayable tannins caused by 0.01 NaOH did not differ significantly from the percentage of reduction following wood ash treatments. It appears from these studies that any amount of wood ash is effective in reducing assayable tannins without germinating the grain. Calcium and potassium were found to be the major chemical components in sample wood ashes from both Uganda and USA. The pH of both wood ashes was the same (11.5).

Applying Standardized Processing Technology to Different Grain Types

The effect of ash treatment on sorghum grains differing in color, testa layer (absent or present), tannin content, endosperm texture and type, seed size, and seed shape was determined by mixing 100 g grains of each cultivar with 15 mL wood ash slurry, soaking in water for 12 h, and drying at room temperature. Wood ash slurry was obtained dissolving 100 g wood ash in 100 mL water. The objective of processing these grains was to find out whether sorghum grains differing in physical and chemical grain characteristics behave differently when treated with wood ash.

Color changes after the wood-ash treatments varied among the 40 cultivars tested. Grains of only 13 cultivars changed from brown to black, as did grains of the local cultivar from Uganda. Grains of the other cultivars changed only slightly. Cultivars with grains that did not change from brown to black after processing were unacceptable. The tannin content of unprocessed grains of the 40 cultivars ranged from 0.00 to 15.31 catechin equivalent (CE) (methanol extracted) and from 0.00 to 1.65 CE (acidified methanol). We separated the 40 cultivars into four groups. The treatment with wood ash was effective in reducing tannin (methanol) in the high-tannin groups but not as effective for tannin extracted in acidified methanol. Because tannin content in the low-tannin groups was very low, treatment with wood ash made no significant difference (Table 3).

The effect of wood ash slurry concentrations on the tannin content of grains of six high-tannin cultivars was determined by mixing 100 g of each with 15 mL of six different concentrations of wood ash slurry and then soaking in water for 12-15 h. The six slurry concentrations were obtained by dissolving 100 g wood ash in 50, 100, 200, 300, 400, and 500 mL water. Grains of cultivars that did not receive the ash treatment did not change color after soaking in water. Grains of IS 12591, IS 21045, and IS 21003 changed grain color slightly with the lower wood ash slurry concentration treatments (400-500 mL), but became much darker with intermediate concentrations (200-300 mL), and turned black with the highest concentrations (50-100 mL). Grains of IS 9215 changed color slightly when treated with low and intermediate slurry concentrations (500 mL, 400 mL, 300 mL, 200 mL). At higher concentrations (50 mL, 100 mL), the grains of IS 9215 changed from brown to dark brown. Grains of IS 7177 changed from brown to black at even the lowest wood ash slurry concentration (500 mL) while grains of IS 8182 did not change color at low and intermediate slurry concentrations, but changed slightly at the highest concentrations.

Reduction in assayable tannins extracted in methanol was low and insignificant for all grains of the six cultivars when they were soaked only in water (with-

Table 3. Mean and range of tannin content (CE) of untreated and treated sorghum grains grouped on the basis of tannin content and tannin types.

Tannin classification		Untreated		Wood ash treatment plus soaking[1]	
		Methanol	Acidified methanol	Methanol	Acdified methanol
Low tannin Group I	Mean	0.01	0.05	0.02	0.02
	Range	0.00-0.2	0.00-0.10	0.00-0.06	0.01-0.03
Low tannin Group II	Mean	0.05	0.30	0.06	0.01
	Range	0.00-0.22	0.10-0.58	0.00-0.19	0.00-0.02
High tannin Group III	Mean	2.65	0.61	0.02	0.11
	Range	1.38-3.84	0.26-1.12	0.00-0.05	0.00-0.38
High tannin Group IV	Mean	7.37	0.98	0.06	0.16
	Range	5.19-15.31	0.55-1.65	0.00-0.47	0.00-0.77

SE untreated = ±0.031 methanol and ±0.010 acidified methanol
SE treated = ±0.003 methanol and ±0.112 acidified methanol

1. Grains (100 g) mixed with 15 mL of wood ash slurry (100 g dissolved in 100 mL of water and soaked in water for 12 h).

out the wood ash treatment). At the lowest wood ash slurry concentration (500 mL), tannin content (methanol) of grains of IS 9215 was reduced significantly from 5.40 to 0.01, while that of IS 7177 was reduced from 6.49 to 0.14. Grains of the remaining four cultivars required higher wood ash slurry concentration treatments to significantly reduce their tannin contents to below 0.2 CE. The grains of IS 8182 required the highest wood ash slurry concentration (100 mL) treatment to reduce their tannin content to below 0.1 CE (Fig. 1). Significant reduction in assayable tannin extracted in acidified methanol required higher wood ash slurry concentrations (Fig. 2). At 200 mL wood ash slurry concentration grains of IS 9215 were

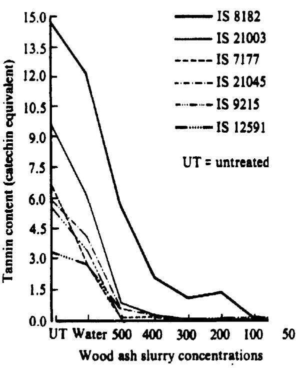

Figure 1. The effect of six wood ash slurry concentrations on tannin content (extracted in methanol) of grains of six high-tannin sorghums.

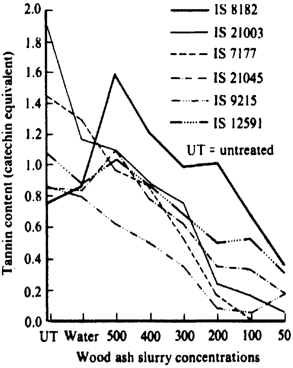

Figure 2. The effect of six wood ash slurry concentrations on tannin content (extracted in acidified methanol) of grains of six high-tannin sorghums.

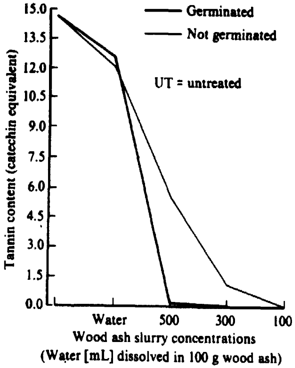

Figure 3. Tannin content (methanol) of IS 8182 grains treated with different concentrations of wood ash slurry and soaked in water for 12 h or soaked in water for 12 h and germinated.

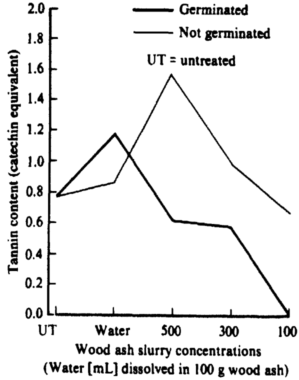

Figure 4. Tannin content (acidified methanol) of IS 8182 grains treated with different concentrations of wood ash slurry and soaked in water for 12 h or soaked in water for 12 h and germinated.

reduced to 0.08 CE and those of IS 7177 to 0.16 CE, while those of IS 21003 required 100 mL, and grains of IS 21045 required 50 mL wood ash slurry concentrations. Even at the highest concentration (50 mL) treatment, tannin content (acidified methanol) of the grains of IS 8182 could not be reduced to below 0.20 CE. However, a combination of the lowest wood ash slurry concentration (500 mL) and germination significantly reduced tannin content (methanol) of IS 8182 to below 0.2 (Fig. 3). Tannin content (acidified methanol) of grains of IS 8182 required a combination of higher wood ash slurry concentration (100 mL) and germination to reduce tannin content to below 0.1 CE (Fig. 4).

Experiments were also carried out to determine the length of time required to soak the high-tannin grains in water after wood ash treatment to reduce assayable tannins to acceptable levels. Grains of four cultivars (IS 8182, IS 21003, IS 7177, and IS 9215) were mixed with wood ash slurry and then soaked in water for 1, 3, 6, 9, 12, and 15 h (Fig. 5). Wood ash slurry was obtained by dissolving 100 g wood ash in 100 mL water. Grain of IS 7177 and IS 21003 changed from brown to dark brown only after 6 h of soaking and did not change subsequently. Grains of IS 8182, on the other hand, did not change color after 3 h of soaking. After 6 h of soaking, however, the grains

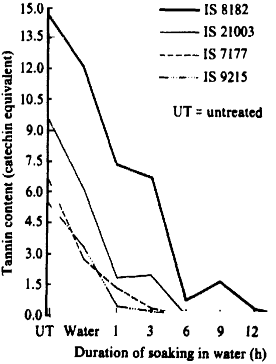

Figure 5. The effect of soaking grains of four high-tannin sorghums in water after wood ash treatment on tannin content (extracted in methanol).

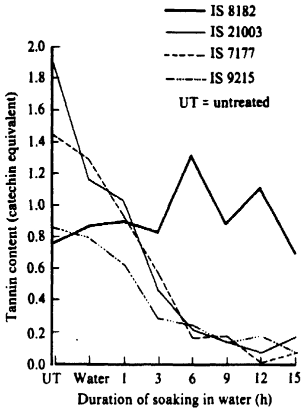

Figure 6. The effect of soaking grains of four high-tannin sorghums in water after wood ash treatment on tannin content (extracted in acidified methanol).

changed slightly from light brown to brown. Assayable tannin (methanol) of grains of IS 9215 was reduced from 5.40 to 0.43 CE after 1 h soaking, from 6.49 to 0.35 CE for IS 7177 after 3 h soaking, from 9.46 to 0.03 CE for IS 21003 after 6 h of soaking, and from 14.60 to 0.40 CE for IS 8182 after 12 h soaking (Fig. 6). After 9 h of soaking, assayable tannin (acidified methanol) for IS 9215 was reduced to 0.13 CE, for IS 21003 to 0.14 CE, and for IS 7177 to 0.17 CE. Grains of IS 8182 were only slightly reduced (from 0.76 to 0.69 CE) even after 15 h soaking. In fact, assayable tannin (acidified methanol) for grains of IS 8182 appeared to increase after 6 and 9 h of soaking.

Effect of Wood Ash-Treated Grains on Rat Growth

In 1986, rat feeding trials were conducted with the grains of two sorghum hybrids, BR 64 (high tannin) and RS 610 (low tannin) at Purdue to determine the effect of wood ash treatment on the growth of weaning rats.

Diets containing four treatments each of BR 64 and RS 610 were fed to weaning rats for 20 days.

Treatments and results are presented in Table 4. Wood ash Treatment 3 reduced assayable tannin content for BR 64 grains by 96%, and Treatment 4 by

Table 4. The effect of four different treatments on grains of two sorghum hybrids - RS 610 (low tannin) and BR 64 (high tannin) - on their protein and tannin content, in vitro protein digestibility, and rat weight gain after 20 days' feeding.

Sorghum variety	Treatments	Protein (%)	Tannin content (CE)	In vitro protein digestibility (uncooked)	Rat weight gain (g)
RS 610	1	8.8	0.00	84.2	45.5
	2	9.0	0.14	56.6	27.9
	3	8.9	0.07	81.2	36.5
	4	9.3	0.02	52.3	14.3
SR 64	1	8.0	10.04	13.3	7.2
	2	8.4	6.38	27.4	1.5
	3	8.3	0.39	75.4	52.5
	4	8.7	0.03	53.7	30.4
SE			±0.046	±0.53	±2.30

Treatments as follows:

1 = Control (untreated).

2 = Grains soaked in water for 12 h and germinated for 4 days at room temperature.

3 = Grains mixed with wood ash slurry and soaked in water for 12 h and germinated for 4 days at room temperature.

4 = Grains germinated for 4 days at room temperature.

CE = Catechin equivalent.

99%. Simultaneously, in vitro protein digestibility was increased by five times in Treatment 1 and by four times in Treatment 4. On the other hand, wood ash Treatment 3 for RS 610 decreased in vitro protein digestibility from 84.2% to 81.2%, while Treatment 4 decreased it from 84.2% to 52.3%. Soaking the grain in water and then germinating it increased in vitro protein digestibility of grains of BR 64 only slightly (from 13.3% to 27.4%), but decreased in vitro protein digestibility of grains of RS 610 (from 84.2% to 56.6%). Weaning rats fed BR 64 subjected to Treatment 3 gained 52.5 g after 20 days, significantly more than those fed diets containing treated and untreated grains of BR 64 or RS 610. Weaning rats fed diets containing BR 64 subjected to Treatment 2 gained significantly less weight than those fed diets containing untreated BR 64 (control). Weaning rats fed diets containing RS 610 subjected to Treatments 2, 3, and 4 gained less weight than those fed diets containing untreated RS 610. Grains of BR 64 and RS 610 developed mold during germination, partly explaining the poor performance of rats fed diets containing germinated grains.

Discussions and Conclusions

Effective traditional dehulling and grinding technologies for small grain developed by resource-poor farmers in the semi-arid tropics of Africa and India are still commonly used. These technologies utilize locally available equipment such as wooden mortars and pestles for dehulling and grinding stones. Traditional grain dehulling, which involves pounding damp grain in a mortar with a pestle, winnowing, and grinding dehulled grain, is a tedious and time-consuming job. In India, the dehulling process has generally been discarded and is only used occasionally. Increased urbanization and the availability of electrically powered flour mills have prompted consumers to use grit from whole grains (Mukuru et al. 1982). In many African countries, small-scale mechanical grinders have been introduced for maize and sorghum (Mitaru et al.). In Botswana, small versions of IDRC/PRL batch dehullers are now being operated successfully in several villages by Rural Industries Promotion of Botswana (Boling and Eisener 1982). In Nigeria, where diesel or electric grinders and mills are available, dried dehulled grain is dry milled (Mukuru 1986). However, for many people in rural areas in Africa where mechanical grinders are unavailable or expensive, traditional dehulling is still practised. Research and development in the 1990s should give top priority to developing simple but effective technologies for resource-poor farmers for threshing, cleaning, dehulling, and grinding their small grains.

The traditional processing technology for high-tannin grain detoxifies the grains and significantly improves its nutritional quality to the level of low-tannin sorghum grains.

Germinated sorghum grain contains appreciable amounts of cyanogenic glycoside, which yields hydrocyanic acid (HCN) through hydrolysis and is potentially poisonous (Panasink and Butler 1978). However, Dada and Dendy (1987) reported that the removal of shoots and roots on germinated grain lowered the HCN content by more than 90%, and boiling the slurry or steaming the paste eliminated the HCN completely. Since the traditional method of preparating *obushara* or *omuramba* involves boiling the slurry, the HCN should be completely eliminated.

Traditional processing technology could be modified and transferred to resource-poor farmers in areas where high-tannin sorghums are produced because of the severity of the bird (*quelea*) constraint.

Acknowledgments

The summary of results reported in this paper were obtained from studies conducted at Purdue University in 1986 by S.Z. Mukuru in collaboration with the following Purdue professors: J.D. Axtell, G. Ejeta, L.G. Butler, A.W. Kirleis, and J.C. Rogler.

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Discussion

J.E. Cecil: If you fed the animals sprouted sorghum without cooking it, how did you know how much of the lower weight gain was because of a different level of cyanide?

S. Z. Mukuru: It is true that the sprouted grains were fed to rats without cooking. It is possible cyanide may be responsible for lower weights. This requires further investigation.

J.D. Axtell: What proportion of the sorghum grain in your village in Uganda is used for fermented and unfermented porridges versus that used for traditional *ugali*? Also, how widespread is ash treatment and traditional sprouting processing used? Are they practiced anywhere other than southern Uganda?

S.Z. Mukuru: In the past about 50% of the grains were used untreated for traditional *ugali* and the other 50% traditionally processed and used for beverages. At present very little grain is used for *ugali*. Approximately 80% of the grain produced is traditionally processed and used for beverages. Traditional processing of high-tannin grain appears to be restricted to the southern highlands of Uganda and in neighboring areas in eastern Burundi and Rwanda, and probably Zaire. I do not know of any other area in East Africa where high-tannin grain is traditionally processed using wood ash. There are reports that high-tannin sorghum grain is treated with *magadi* soda in Tanzania.

J.N. Mushonga: Is there any color difference between treated and untreated sorghum?

S.Z. Mukuru: Yes. There are color differences in products from processed and unprocessed grains. Beverages made from unprocessed grains are brown while beverages made from processed grains are off-white with black specks. Unprocessed grains are not used to prepare alcoholic beverages.

J.M. Mwale: Did you measure the pH of the ash solution?

S.Z. Mukuru: Yes, it was 11.5.

O. Olatunji: Are there health hazards associated with the local method of processing sorghum?

S.Z. Mukuru: As far as I know no health hazards at all are associated with the local processing method. It has been reported that germinated grains contain high amounts of cyanide but subsequent studies have shown that traditional food preparation eliminates hydrocyanic acid (HCN) completely.

M.I. Gomez: Do you have any explanation of the difference in the pattern of protein digestibility between BR 64 and the low-tannin sorghum using the wood ash treatment?

S.Z. Mukuru: In vitro protein digestibility of RS 610 untreated grain and that of grains treated with wood ash and soaked in water are not significantly different. The low in vitro digestibility of germinated grains of RS 610 may be due to molds that develop on the grains during germination.

A.B. Obilana: D.A.V. Dendy of ODNRI reports that cyanide in germinated seeds or young seedling sprouts is removed by indigenous processing or use of ash is significant. This confirms the long-time use of such grains in weaning foods and lactating mothers' foods (thin porridge) in Africa. It nullifies the fear of health hazards associated with foods from such grains.

A.O. Koleoso: Did you determine the concentration of the alkali in the wood ash—possibly as potash?

S.Z. Mukuru: Wood ash from Uganda and West Lafayette, USA, were analyzed for their chemical components. Calcium was found to be the major mineral component, followed by potassium. A broad range of other elements including aluminum, iron, magnesium, phosphorus, sulfur, etc, were found to be present in lower concentrations.

J.M. Mwale: Would there be any difference in terms of type of equipment to use at village level compared to modern equipment?

S.Z. Mukuru: No, no difference at all. We have obtained similar results with various types of equipment in the laboratory.