

Alkali Debranning of Sorghum and Millet

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ABSTRACT

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Aqueous solutions of sodium hydroxide were used to debran whole sorghum and millet grains. The alkali solution was effective in dissolving the pericarp, leaving the kernel free of pericarp. Various combinations of concentration of sodium hydroxide (3, 6, and 10%, w/w) and soaking duration (5, 8, and 10 min) were investigated. Two cultivars of sorghum (Dionje and Jumbo) and one cultivar of pearl millet (IM) were used in

the study. A 10% aqueous solution of sodium hydroxide at 60°C was most effective in dissolving the pericarp of both sorghum and millet after 10 min of soaking, resulting in ≈90% yield of clean endosperm for all grain types. The debranning process reduced the fiber content (measured as crude fiber) of sorghum cultivars Dionje and Jumbo by 37.6 and 41.8%, respectively; and pearl millet by 32%.

Sorghum and millet are ranked fifth and sixth, respectively, in world cereal crop production and utilization (Dogget 1988). They are well adapted to a wide range of ecological conditions and are able to produce good yields under dry conditions unfavorable to most other cereals. They are widely grown in the semiarid tropics of Africa and Asia, and constitute a major source of carbohydrates and proteins for people living in these regions. Although the use of sorghum and millet as human food is widespread, the technology for processing these grains into consumable products is still far from adequate compared with other major cereal grains such as maize, wheat, and rice.

Brown-seeded, high-tannin sorghum cultivars are very important in areas of the semiarid tropics where predation by birds is severe. Birds avoid these sorghums because of the high tannin content in the pericarp. These sorghums also have a number of agronomic advantages over low-tannin sorghums, including resistance to insect pests, grain molds, and preharvest germination (Harris and Burns 1970, Waniska et al 1989). However, these agronomic advantages are accompanied by nutritional disadvantages and reduced food quality. According to Hagerman and Butler (1981), tannins bind strongly and specifically to certain proteins, inhibiting their digestion. They also interfere with iron absorption by complex formation with iron in the gastrointestinal lumen, inhibiting its absorption. The fiber content and color of the grain also plays an important role in consumer acceptance of products prepared from these grains. Because these undesirable compounds are concentrated in the grain pericarp, removal of the pericarp significantly decreases their concentration, with a corresponding increase in nutritional quality and acceptance of food products made from these grains.

The principal method of pericarp removal in sorghum and millet is debranning, using either the traditional manual system of pestle and mortar or mechanical systems such as abrasive or attrition dehullers. However, most of these high-tannin sorghum cultivars have soft endosperms, and the present levels of recovery (% of debranned grain recovered after debranning) are low (<70%) for both methods, and the quality is poor due to excessive breakage of the grain and mixing of pericarp fragments with the flour. Percentage recovery is particularly low for the soft endosperm cultivars that are highly prone to shattering during the debranning process,

with mechanical systems giving the worst results (Mwasaru et al 1988, Reichert et al 1988). As a result, most of these soft endosperm sorghum cultivars are either being phased out or are used for making alcoholic and nonalcoholic drinks or used as animal feeds. Given the precarious food supply in the areas in which these grains are major food crops, and the agronomic advantages offered by the high-tannin sorghum over other cultivars, there is a need for application of innovative technology in processing these grains.

Several approaches for detoxifying brown sorghum are practiced by the local people in areas where these sorghum cultivars are extensively grown. The most common is malting and treatment with alkaline materials. Farmers in the southern highlands of Uganda and neighboring areas employ a unique method for reducing the effect of tannin that entails mixing the grain with a wood ash slurry followed by soaking the grain in water overnight. This treatment effectively detoxifies the grain and improves its nutritional quality to the level of low-tannin grains (Mukuru 1992). A specific soil mineral found in Northern Tanzania known locally as *magadi* is also effective in reducing the antinutritional effects of high-tannin sorghum cultivars and improving the nutritional value of high-tannin sorghums (Monyo et al 1992). However, although these treatments are able to reduce the levels of tannin in the grain, they are unable to solve the problem of high fiber content and color imparted to the products made from the brown sorghums, factors which are very important in acceptance of products made from these grains.

Alkali debranning has been used for other cereal grains including corn, barley, rye, and oats to improve yield and provide new attractive ready-to-eat products (Barta et al 1966). Alkali treatment of corn under controlled conditions of temperature, alkali concentration, and soaking duration loosens and separates the pericarp to produce pericarp-free corn (Blessin et al 1970, Mistry and Eckhoff 1992) and pericarp-free sorghum in wet milling for starch production purposes (Blessin et al 1971). The use of alkali debranning could therefore be a potential method for the production of high-quality debranned grain from sorghum and millet, especially from those cultivars that are not suitable for conventional processing due to soft endosperm. This work applies the concept of alkali debranning for the production of pericarp-free sorghum and millet grain for human consumption as opposed to its use in starch production, with the objective of determining the optimum conditions for alkali debranning of sorghum and millet. The possibility of producing high-quality products from this otherwise rejected grain could lead to technological advantages, such as use of sorghum flour composited with wheat for making bread and biscuits, use of pearled sorghum grain as a rice substitute, and for production of snacks and other convenient foods that are in high demand in both rural and urban areas.

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TABLE I
Recovery Levels at Different Alkali Concentrations and Soaking Durations

| Grain Cultivar | Soaking (min) | Alkali Concentration ^a | |
|----------------|---------------|-----------------------------------|------------|
| | | 6% | 10% |
| Dionje | 5 | 91.8 ± 0.1 | 91.0 ± 0.2 |
| | 8 | 91.2 ± 0.1 | 90.4 ± 0.2 |
| | 10 | 90.8 ± 0.2 | 90.0 ± 0.1 |
| Jumbo | 5 | 90.0 ± 0.2 | 90.3 ± 0.1 |
| | 8 | 90.1 ± 0.1 | 89.7 ± 0.1 |
| | 10 | 89.6 ± 0.2 | 89.2 ± 0.1 |
| IM | 5 | 93.1 ± 0.1 | 91.3 ± 0.1 |
| | 8 | 91.7 ± 0.1 | 90.7 ± 0.1 |
| | 10 | 91.1 ± 0.1 | 90.2 ± 0.2 |

^a Each data point is an average of 5 replicates ± standard deviation. All values expressed in dry weight basis.

MATERIALS AND METHODS

Materials

Two cultivars of sorghum Dionje (a white pericarp and hard endosperm cultivar from Ilonga Research Institute, Tanzania) and Jumbo (a red pericarp and soft endosperm cultivar from Australia) and one pearl millet cultivar (IM) from ICRISAT-India, were used in this study. None of these grains had a pigmented testa. A solution of sodium hydroxide in water was used as the debranning agent (Blessin et al 1971, Mistry and Eckhoff 1992).

Determination of Pericarp Content

The pericarp content of the sorghum and millet was determined by manually peeling the pericarp from the grain kernel after soaking in distilled water for 15 min. The peeled grain and pericarp were air-dried to constant weight and their proportion determined. Three samples (2 g each) for each grain type were used for the determination of the pericarp content. This equates to ≈60, 66, and 140 grain kernels for Jumbo, Dionje, and IM, respectively.

Debranning Tests

The debranning process used in this study was a modified form of a process developed by Blessin et al (1970) for debranning yellow dent corn. Preliminary exploratory experiments were conducted using different combinations of alkali concentrations and soaking durations to determine the optimum conditions for sorghum and millet debranning. Dry, clean grain (5 g) was soaked in 20 mL of aqueous solution of sodium hydroxide at three different concentrations (3, 6, and 10%, w/w) for three different soaking durations (6, 8, and 10 min) and placed in a constant water bath at 60°C, the mean optimum temperature obtained in previous investigations by Blessin et al (1971), Mistry and Eckhoff, (1992), and Singh et al (1997) for debranning sorghum and corn for starch production purposes. The grain was stirred frequently during debranning. After each preset duration, the grain was removed from the water bath and thoroughly washed with hot water to prevent further action of the alkali. The residual alkali was neutralized by soaking the grain in glacial acetic acid for 5 min followed by further washing with water to remove excess acid and the detached pericarp. The debranned grain was air-dried to 12% mc, db (original moisture content before debranning) and weighed to determine the weight loss.

Proximate Composition of Debranned Grain

Knowledge of the proximate composition (protein, oil, ash, and crude fiber content) of the debranned grain was important in determining the effect of the alkali debranning on the composition of the final product. The proximate composition of the alkali debranned grain was determined according to Approved Methods (AACC 2000) and was compared with the chemical composition of undebranned and hand-peeled grain.

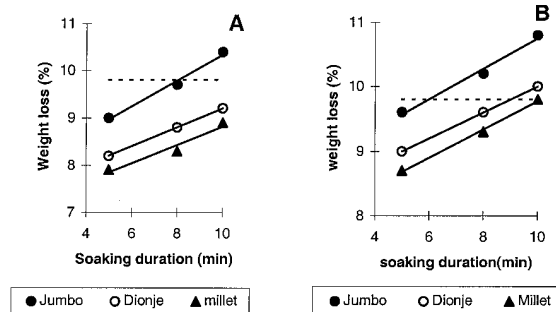


Fig. 1. Effect of soaking duration on weight loss at 6% (A) and 10% (B) alkali concentration. Dashed line is weight loss due to pericarp removal by hand-peeling.

Determination of Debranning Efficiency of Alkali Debranning

Debranning efficiency (D_{eff}) is the extent to which the pericarp has been removed from the endosperm. This was approximated by determining the crude fiber content of untreated, alkali-treated, and manually debranned grain. Crude fiber was used as a measure of debranning efficiency because it is a grain component that is more concentrated in the pericarp than in the endosperm. Therefore, its reduction reflects the extent of removal of the pericarp from the grain kernel. The debranning efficiency was then calculated as a ratio of the crude fiber in the chemically and manually (hand-peeled) debranned grain as:

$$D_{eff} = \left(\frac{\text{crude fiber reduction after alkali processing}}{\text{reduction after hand-peeling}} \right) \times 100 \quad (1)$$

RESULTS AND DISCUSSION

Pericarp Content of Sorghum and Millet Grain

The pericarp and endosperm contents determined by hand-peeling the grain were 11.4 ± 0.4% for Jumbo, 8.3 ± 0.3% for Dionje, and 9.9 ± 0.3% for IM. These values fall within the range of pericarp content of sorghum and millet reported in literature, which for sorghum was 4.8–11.6% and for millet was 7.2–10.7% (Serna-Saldivar and Rooney 1995).

Optimum Debranning Conditions for Alkali Debranning

The weight of material removed from the grain under different combinations of alkali concentration and soaking duration were used to select the most suitable combination for debranning of sorghum and millet. The % weight loss for the grains during soaking in 6 and 10% alkali concentration are shown in Fig. 1. A loss in weight equivalent to the average pericarp content of all three grains from hand-dissection (9.9%) was used as a guide to select the optimum conditions for the debranning process. The combination of alkali concentration and soaking duration that result in removal of material from the grain closest to the average pericarp content was selected as the optimum combination for the debranning process.

On the basis of the preliminary results, 10% alkali concentration and 10 min of soaking at 60°C were selected as the optimum debranning conditions for Dionje and IM, while 6% alkali concentration and 8 min of soaking at 60°C were the optimum conditions for Jumbo. The average yield of debranned grain obtained under these conditions was 89.2% for Jumbo, 90% for Dionje, and 90.2% for IM. Larger samples (50 g) were prepared and debranned under optimum conditions as determined from the initial exploratory tests. The percentage recovery after debranning is summarized in Table I. IM had the highest recovery level while Jumbo had the lowest. The proportion of the pericarp and the hardness of the grain might have influenced the amount of material removed. Because Jumbo had the thickest pericarp and softest endosperm, it

TABLE II
Proximate Composition (%) of Alkali Debranned and Untreated Sorghum and Millet

| Grain Cultivar | Crude Protein | Ash | Ether Extracts | Crude Fiber |
|------------------|-------------------------|--------------------------|----------------|-------------|
| Sorghum | (7.3–15.6) ^a | (1.1–4.5) | (0.5–5.2) | (1.2–6.6) |
| Dionje | | | | |
| Unprocessed | 9.06 | 1.95 ± 0.01 ^b | 2.85 ± 0.06 | 4.81 ± 0.05 |
| Alkali debranned | 9.37 | 1.85 ± 0.05 | 2.96 ± 0.02 | 3.09 ± 0.07 |
| Hand-peeled | 10.9 | 1.39 ± 0.01 | 2.13 ± 0.03 | 2.75 ± 0.09 |
| Jumbo | | | | |
| Unprocessed | 13.06 | 1.66 ± 0.07 | 4.19 ± 0.1 | 6.12 ± 0.03 |
| Alkali debranned | 13.44 | 1.58 ± 0.06 | 4.33 ± 0.2 | 3.56 ± 0.14 |
| Hand-peeled | 13.9 | 1.32 ± 0.02 | 3.34 ± 0.06 | 3.31 ± 0.09 |
| Millet | (8.6–19.4) | (1.6–3.6) | (1.5–6.8) | (1.4–7.3) |
| IM | | | | |
| Unprocessed | 10.18 | 1.98 ± 0.01 | 5.47 ± 0.06 | 7.17 ± 0.02 |
| Alkali debranned | 10.31 | 1.69 ± 0.01 | 5.94 ± 0.05 | 4.89 ± 0.09 |
| Hand-peeled | 11.87 | 1.63 ± 0.01 | 3.14 ± 0.06 | 3.64 ± 0.06 |

^a Ranges of proximate composition values of whole grain (Serna-Saldivar and Rooney 1995).

^b Each data point is an average of 5 replicates ± standard deviation. All values expressed in dry weight basis.

had more materials removed during the debranning process than the other grain cultivars, which had thin pericarp and harder endosperm.

Effect of Alkali Debranning on Proximate Composition of Debranned Grain

After debranning, the grain samples were air-dried, ground into flour, and chemically analyzed for protein, ash, crude fiber, and ether extracts by Approved Methods (AACC 2000). The results of the proximate analysis for both alkali-treated and untreated grain are summarized in Table II.

Alkali debranning significantly reduced the fiber content of both sorghum and millet. The crude fiber content reductions were 37.6% for Dionje, 41.8% for Jumbo, and 32% for IM. The ash content decreased slightly for all the debranned grain, while protein content and ether extracts of the debranned grain were slightly higher than that of untreated grain. This was probably because there was a relative increase in the proportion of the grain endosperm components as a result of the removal of the pericarp, which is high in fiber. The pH of the debranned grain was 6.0–6.7, indicating that the final product was slightly acidic. This may have been caused by the acetic acid used to neutralize the alkali after debranning was completed.

Debranning Efficiency of the Alkali Debranning Process

Visual inspection of the debranned grain indicated that the removal of the pericarp by alkali debranning was mainly due to dissolution of the pericarp rather than loosening and removal by mechanical action. No breakage of the grain kernels was caused by the debranning process, although stress cracks were evident in much of the endosperm of the debranned kernels. For Jumbo, removal of the pericarp from the kernel was readily apparent by visual inspection of the treated grain because its pericarp is highly pigmented compared with the rest of the kernel. This was more difficult for Dionje, where both the pericarp and the endosperm were white in color, and for IM, where both pericarp and endosperm are gray in color. More quantitative data on the degree of removal of pericarp and aleurone layer were acquired by staining the debranned kernels with iodine solution. Under these conditions, the endosperm stained blue-black, while the pericarp did not stain or was stained yellow. Results obtained from the iodine staining showed that the alkali dissolved the pericarp from all parts of the grain kernels except at the tip cap. The color of the debranned materials was white for Dionje and Jumbo and gray for IM. The debranning efficiencies based on crude fiber reduction (calculated using Eq. 1) were 83.5% for Dionje, 91.1% for Jumbo, and 74.4% for IM. The debranning efficiencies for the sorghums are close to the values for yield determined by drying and weighing the whole grains as shown in Table I.

SUMMARY AND CONCLUSIONS

Sodium hydroxide solution was very effective in debranning of sorghum and millet grain to give clean high-quality grain. The debranning action was due to desolution of the pericarp rather than loosening followed by mechanical abrasion. Optimum conditions for alkali debranning of sorghum and millet were 10% aqueous solution of sodium hydroxide (w/w) and 10 min of soaking for Dionje and IM at 60°C, while 6% aqueous solution of sodium hydroxide, 8 min of soaking at 60°C was the best combination for Jumbo.

The alkali debranning process was able to achieve high levels of recovery (91%) of pericarp-free endosperm from soft and pigmented grain which is impossible to achieve using conventional debranning methods. Crude fiber content in the debranned grain was also reduced by ≈45%, indicating that the process was highly effective in removing the pericarp from the grain kernels, which was confirmed by the high debranning efficiencies obtained for Jumbo (91.1%) and Dionje (83.5%). Other chemical constituents within the grain kernel were not significantly affected by the debranning process.

Although the alkali debranning process described here may not seem technologically suitable or economically feasible for traditional or other small-scale processing of sorghum and millet due to the nature of chemicals involved, it might be appropriate for an industrial-scale process in urban or semiurban areas for production of the high-quality sorghum and millet flour and other convenient food products such as rice substitute for a fast growing urban population. The consumption of sorghum and millet as whole grain offers several advantages including easy preparation and lower cost than rice or products prepared from flour because they do not require further milling. The recovery levels from this process are significantly higher than can be obtained using any of the current debranning systems. This improves the cost effectiveness of utilizing sorghum and millet as wheat flour substitutes for the production of high-quality products such as composite flour bread, biscuits, and snacks.

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