4. CHAPTER III

Effect of Chemical Conditioning on the Milling of High-Tannin Sorghum

ABSTRACT

Suitable methods are required for milling tannin-containing sorghums. Sorghum varieties, SV2 (tannin-free), Chirimaugute (medium-tannin) and DC-75 (high-tannin) were milled using a simple roller mill and a tangential abrasive decortication device. Grain was conditioned up to 20 % moisture prior to milling using HCl (0.9 %, v/v), formaldehyde (HCHO) (0.05 %, v/v), NaOH (0.3 %, v/v) and water as control. Abrasive decortication and roller milling reduced levels of the polyphenols. Polyphenol reduction was affected significantly by variety, chemical treatment and conditioning moisture ($P < 0.001$). NaOH and HCHO treatments gave lower polyphenol content in the meal after roller milling, but not after abrasive decortication. Enzyme inhibition (EI) by polyphenols was reduced by 52 % after decortication or roller milling. Chemical treatment did not significantly affect EI levels after decortication. EI was lowest at 12 % and 20% moisture conditioning prior to decortication and roller milling, respectively. NaOH and HCHO treatments gave the lowest EI when Chirimaugute was roller milled at 20 % moisture. Product yield was higher at 12 % moisture for SV2 and Chirimaugute, and at 16 % for DC-75, after decortication. Conditioning to 20 % moisture prior to milling did not improve product yield. Roller milling and decortication resulted in products that were lighter in colour than the grain. Conditioning using NaOH could be advantageous in roller milling but not abrasive decortication of tannin-containing sorghums.

INTRODUCTION

Sorghum industrial milling technology is still evolving, unlike those for wheat, rice and maize, where specialized milling technologies have been developed to give finished products of high acceptance. Roller mills with two pairs of rolls are gaining wide acceptance for small-scale maize milling in southern Africa. Conditioning sorghum using the same moisture levels applied to wheat results in a less clean fractionation as the sorghum bran is much more brittle (Perten 1977). Other researchers have revealed that roller milling results may be improved by steeping at high moisture contents under semi-wet conditions (Gomez 1993). An alternative approach to that of roller milling, is decortication. The decortication principle applied to rice and barley dehullers, decorticators and polishers has been used for sorghum (Hulse et al 1980; Reichert 1982). Abrasive decortication operates on the principle of progressively rubbing off the outer layers of the kernel (Oomah et al 1981). Traditionally, this is a dry technique requiring no conditioning so as to avoid clogging of the mill by use of high moisture grains. Decortication, followed by hammer milling, is the most common industrial sorghum milling process in southern Africa.

High-tannin sorghum challenges the miller to remove the testa layer and extract or transform the polyphenols. Mwasaru et al (1988) advocated development of harder, rounder grain with minimum polyphenol content before commercial milling of high-tannin sorghum can become economically feasible. However, it was concluded that widely cultivated Zimbabwean high-tannin sorghums lack ideal characteristics for processing (Chapter I), that is, a thin, white pericarp and corneous endosperm (Rooney and Walker 1978). Chemical treatments have been used to detoxify tannin-containing sorghums (Daiber 1975; Reichert et al 1980; Chapter II). The objective of this study was to investigate the effect of chemical conditioning on the milling of high-tannin sorghums.

MATERIALS AND METHODS

Grains

Sorghum (Sorghum *bicolor* (L.) Moench) grain of varieties, SV2 and Chirimaugute, and a hybrid, DC-75, were used. DC-75 (high-tannin) and SV2 (tannin-free) have relatively corneous endosperms while Chirimaugute (medium-tannin) has a floury endosperm (Chapter I). Pericarp thickness is thick in DC-75, medium in Chirimaugute and thin in SV2 kernels (Chapter I). The sorghums were grown in the 1996/97 season at Matopos, Zimbabwe in field conditions under normal agronomic practices.

Abrasive Decortication

A multi-sample tangential abrasive dehulling device (TADD Model 4E-230, Venables Machine Work Ltd., Saskatoon, Canada), consisting of 8-cup dehulling plate, was used for removing successive layers from sorghum grains abrasively at 1,750 rpm, following the technique developed by Oomah et al (1981) and Reichert et al (1986). Grain (20 g) was conditioned, in plastic containers, to 12, 16 or 20 % moisture using solutions of HCl (0.9 %, v/v), HCHO (0.05 %, v/v), NaOH (0.3 %, w/v) and water as control. Grains and the solution were thoroughly mixed twice. The samples were left to equilibrate overnight in the cold store at 4°C. The conditioned grains were milled for 2 min in the TADD and the yield (calculated at 16 % moisture basis) of decorticated grain was recorded.

Roller Milling

A double roll, roller mill with 1.5-mm vibrating screen, single pass (Maximill Model, Kroonstad, South Africa) was used to mill conditioned grain. The roll gaps on the mill were set at 0.15 mm for the top and 0.10 mm for the bottom roll. The top and bottom rolls were corrugated to 7 and 22 flutes/inch, respectively. Roll speeds were set at a differential of 1.25:1. Conditioning was carried out prior to milling using solutions of HCl (0.9 %, v/v), formaldehyde (HCHO) (0.05 %, v/v), NaOH (0.3 %, w/v) and water as the control. Grain (5 kg) was weighed into plastic bags. The moisture content (MC) of the grain was determined. The grain was conditioned by adding the solution to 16 or 20% moisture, the amount of which was determined by using the formula: {[(100-MC)/(100-desired moisture content)] - 1} x sample weight in g (AACC Method 26-95 1983). The grain was mixed thoroughly with the solution and the bag was sealed. The sample was left to equilibrate at 4°C overnight. The grain was thoroughly mixed twice during the conditioning period. The yield (calculated at 16 % moisture basis) of meal and offals obtained after roller milling was recorded.

Chemical analyses

The products obtained after roller and abrasive milling were ground to pass through an 800-µm sieve prior to analyses.

Polyphenol Analysis. The polyphenols in milled sorghum products were measured using the butanol-HCl (Porter et al 1986) and the vanillin-HCl (Burns 1971) methods. By using a blank subtraction with the vanillin-HCl assay, flavonoid components of the grain were eliminated and the reaction became more specific for condensed tannins (Price et al 1978). Sample extracts for the assays were obtained by shaking ground grain (0.2 g) in methanol (10 ml) for 20 min at 5 min intervals on a vortex mixer at room temperature. The supernatant was obtained by centrifuging for 10 min at 1200 x g. For the anthocyanidin production assay, 5 % HCl in n-butanol (6 ml) was added to the sample extract (1 ml) in a test tube. Iron chloride was omitted. The test tubes were placed in a forced-air oven at 100°C for 50 min. Absorbance was read at 550 nm against a reagent blank and no standard was used. The results were reported as absorbance units (A/g, dry basis). Catechin (Sigma Chemicals) was used as a standard in the vanillin assay and sample blanks were included. The results were expressed in catechin equivalents (g/100 g, dry basis).

Enzyme Inhibition. Enzyme inhibition in sorghum flour was determined following the method of Daiber (1975b). An enzyme extract was obtained by milling malt (5 g) in distilled water (100 ml) in an Ultra Turrax model T25 (Janke and Kunkel IKA-Labortechnik, Staufeni, Br., Germany) for 5 min and centrifuging the sample for 5 min. The extract (12 ml) was added to sorghum flour (120 mg) and the sample incubated for 30 min at 30°C. A blank sample containing no sorghum flour was included. After incubation, samples were centrifuged for 5 min and the supernatant was used for diastasis. Diastatic power (DP) was determined and percentage enzyme inhibition calculated as 100 x (original – residual activity)/(original activity).

Colour Values. Hunter L, a, and b values were obtained using a Hunter Colour Quest 45/0 LAV (Hunter Associates Laboratory, Inc. Reston, Virginia). An average of three readings per sample was taken.

Statistical analyses

The general linear model procedure of SAS version 6.12 (SAS Institute, Cary, NC) was used. Analysis of variance was used to determine the effect of variety, treatment, and moisture level prior to milling on polyphenol content, yield and quality of product. Means were separated using the least squares difference (LSD) at $P < 0.05$.

RESULTS AND DISCUSSION

The choice of chemical treatments for milling was based on previous reports using alkali (Chavan et al 1979, Reichert et al 1980), HCl (Reichert et al 1980), HCHO (Daiber 1975a), high-moisture reconstitution (Reichert et al 1980; Mitaru et al 1983) to improve the nutritional value of high tannin-sorghums. The selected concentrations were based on findings by Daiber (1975a) on HCHO and by Dewar et al (1997) on NaOH. The information obtained from preliminary experiments on steep water uptake using various concentrations of HCl was used as the basis for selecting the concentration of the acid. Conditioning moisture for roller milling was selected following findings by Gomez (1993). Conditioning during decortication is practised in the traditional mortar and pestle method up to about 20 % (Eggum et al 1982) but machine decortication in an abrasive mill is a relatively dry milling technique.

Product Yield

Yield of decorticated grain (87 to 96 %) was highest in SV2, a tannin-free variety (Table III-1). Oomah et al (1983) found extraction rates ranging from 71 to 98 % for 23 white sorghum varieties. DC-75 gave slightly higher yields than Chirimaugute (84 and 81 %, respectively) at 12 % moisture. Video image analysis of the endosperm texture of these grains indicated an increasing floury endosperm from SV2, DC-75 and Chirimaugute (Chapter I). Thus yield was more related to the floury nature of the grains as previously reported by Chibber et al (1978) and Reichert (1982) than their polyphenol content. The importance of a relatively corneous endosperm was emphasized by Munck et al (1982) when he noted that the introduced Tanzanian sorghum with 31 % soft endosperm was giving lower yields of 50 % compared to the local hard cultivars (3.9 to 13.6 % soft endosperm) that gave recoveries of 72 to 86 %.

Conditioning to 20 % resulted in lower yields for all varieties. Highest yields were achieved at 12 % with SV2 and Chirimaugute. Thus conditioning prior to decortication was not an advantage for the purpose of increasing product yield. However, yields were slightly improved at 16 % for DC-75. Meal yield was decreased by up to 8, 6, or 7 % on average when SV2, DC-75 and Chiri, respectively, were conditioned to 20 % moisture. High-tannin sorghum lines that could be abrasively decorticated and yield at least 70 % of product were also identified elsewhere (Reichert et al 1988). Subramanian et al (1988) found a correlation coefficient of +0.89 ($P<0.01$) when the traditional mortar and pestle method and the TADD abrasion equipment were used for sorghum milling. However, the reported yields could be slightly lowered under commercial operations as in most laboratory decorticators such as the modified Udy Cyclone mill by Shepherd (1979) and the TADD abrasion mill, the frictional forces between the grains are minimized, and the grains are decorticated in a gentler way compared to commercial decorticators (Munck 1995).

Treatment did not significantly affect yield of roller-milled product (Table III-1). SV2 and DC-75 gave higher product yield than Chirimaugute. The latter has a floury endosperm (Chapter I) and loss of endosperm fractions into the offal (bran) resulted in lower yield. However, yield of product was relatively higher than values previously reported for brown sorghums (Chibber et al 1978). The findings on product yield confirm the report by Gomez (1993) that roller milling of sorghum under semi-wet conditions (16 % moisture) is superior to dry milling (12 % moisture). Eggum et al (1982) demonstrated that only 59 % (compared to 79 % in wheat) of lysine remain in hand-dissected sorghum endosperm, and hence, in milling sorghum, a high extraction rate of 85 % is desirable. Extraction rates were reasonably high at the 16 % conditioning moisture with all the three varieties. There was no advantage in conditioning to 20 % moisture as yield of offal increased (Table III-1). Yield of offal, a by-product of sorghum milling, should be minimal as offal has less economic value as an animal feed than meal.

Polyphenol Content (Butanol-HCl Assay)

The polyphenol content of the meal was significantly affected ($P < 0.001$) by variety, chemical treatment and conditioning moisture prior to abrasive decortication or roller milling (Table III-2). Reduction in polyphenols, after milling, was due to loss of grain pericarp and testa layers as offal. Polyphenol content was markedly lower when abrasive decortication was used. Roller milled flour apparently had more offal contamination. Conditioning to 12 % moisture followed by decortication, a technique equivalent to the traditional dry abrasion practice, reduced polyphenol levels by 71 to 81 % in DC-75 and Chirimaugute, respectively. Polyphenol reduction was greatest at 12 % moisture and no further advantage was obtained by conditioning to higher moisture prior to decortication. It was presumed that polyphenol reduction was largely due to the abrading action. At 16 and 20 %, DC-75 flour had higher polyphenol content than at 12 % (Table III-2). Polyphenol content was 29 to 36 % less when DC-75 grain was conditioned to 16 % moisture and roller milled. Higher conditioning treatment resulted in better separation of offal from endosperm as polyphenol content was lower when Chirimaugute was conditioned to 20 than 16 % moisture. NaOH and HCHO generally gave lower polyphenols than water and HCl for both varieties as previously observed in steeping for malting (Chapter II). NaOH and HCHO treatments of high-tannin sorghums for feed have also been found to improve the weight gain of birds (Schutte and Smith 1991).

Polyphenol Content (Vanillin-HCl Assay)

Polyphenol reduction (range 12 - 53 %) was less pronounced in decorticated samples with the vanillin than with the butanol-HCl assay (Table III-3). The vanillin method tends to underestimate the weight of condensed tannins due to their reduced reactivity (Goldstein and Swain 1963). Polyphenol content was reduced by 41 % for DC-75 and 49 % for Chirimaugute after decortication at 12 % moisture. Reduction in polyphenol content was due to loss of the grain outer layers by abrasion. Chibber et al (1978) and Mwasaru et al (1988) reduced polyphenol content by up to 91 % using a similar dry abrasion technique, but at lower extraction rates. Polyphenol reduction exceeding 55 % was not achieved as yield of product was kept relatively high. Higher conditioning moisture during decortication resulted in less polyphenol extraction for both varieties presumably due to reduced abrasion of the outer layers of moist grain. Roller milling DC-75 after conditioning to 16 % moisture gave flour products that had higher polyphenol content than dry abrasive decortication at 12 %, giving further evidence that polyphenols were largely removed by the abrading action. However, polyphenol content was markedly reduced by 56 to 71 % after roller milling Chirimaugute at 20 % moisture. Polyphenol content was lower at 20 than 16 % in Chirimaugute roller milled meal. At 20 % moisture, HCHO and NaOH gave lower polyphenol content in Chirimaugute roller meal. Polyphenol reduction possibly involved formation of high molecular weight polymers (Porter 1992) that were cross-linked and insoluble.

Polyphenol Content (Vanillin-HCl with Blank Subtraction)

Tannin values differed significantly ($P < 0.001$) among treatments. Decortication resulted in lowest tannin levels at 12 % than at 16 and 20 % (Table III-4). The abrasive action of the TADD was mostly responsible for tannin removal in Chirimaugute and DC-75 grains. The tannin content of roller milled meal was reduced by 15 to 20 % and 18 to 44 % when DC-75 and Chirimaugute respectively, were conditioned to 16 % (Table III-4). Tannin reduction was higher for Chirimaugute than DC-75 when the vanillin method with blank extraction was used. The findings confirm the work of Reichert et al (1980) where tannins were reduced by 97, 83, 39 % when sorghum grains imbibed 0.8 M NaOH, 0.8 M HCl and water, respectively at 25 % by weight at 25°C with an equilibration period of 2 d. The differences in tannin reduction could be due to higher solution concentrations used in their experiments. Tannin reduction levels of 24-52 % were also reported when 10 % by weight of sorghum grain of 0.5 or 0.2 M NaOH was used for treatment of high-tannin sorghum that were then stored for 3 and 11 days (Price et al 1979). At 16 and 20 % moisture HCHO and NaOH generally gave lower tannin content in Chirimaugute meal.

Tannin Content of Offal (Modified Vanillin Assay)

Tannin levels differed significantly ($P < 0.001$) among treatments (Table III-4). The tannin content of the offal from the roller mill was higher than that of the whole grain, as the offal contained most of the pericarp and testa layers. Tannin content of offal was 72 - 126 % greater than in DC-75 grain at 16 % conditioning moisture. However, Chirimaugute had 0 - 30 % more tannin in its offal at the same moisture presumably due to higher endosperm contamination. Tannin content in the offal increased by 49 to 133 % when Chirimaugute was conditioned to 20 % moisture prior to roller milling. Thus conditioning Chirimaugute grains to higher moisture resulted in more tannins being extracted into the offal or less endosperm contamination of the offal. Tannin content of the offal was lower with NaOH and HCHO treatment at 16 % moisture. The findings are very important if offal is used for feeding purposes. At 20 % moisture, the tannin levels of Chirimaugute offal were markedly high with HCl. This confirms the findings in Chapter II that NaOH and HCHO are more effective than HCl in tannin deactivation.

Enzyme Inhibition by Polyphenols in the Meal

Enzyme inhibition (EI) assays indicated significant differences between the two varieties (Table III-5). The mean EI for Chirimaugute and DC-75 flour was 16 and 41 %, respectively. This was presumed to be due to the higher tannin content in DC-75 grains (Chapter I) that could not be completely removed. Chemical treatment had no effect on EI after abrasive decortication confirming the findings that abrasion was mostly responsible for polyphenol reduction. EI was similar at 16 and 20 % (mean 30 % EI) but differed significantly from the 12 % (mean 25 % EI) conditioning moisture. Thus conditioning to higher moisture was not important in abrasive decortication for the purpose of reducing the enzyme inhibitory power of polyphenols.

The control (water) gave higher inhibition that differed significantly from HCl, HCHO and NaOH treatment in roller milling. EI in Chirimaugute meal was higher at 16 than 20 % moisture (31 and 24 %, respectively). NaOH and HCHO gave the lowest enzyme inhibition when Chirimaugute was conditioned to 20 % moisture prior to roller milling. Thus roller milling at higher moisture showed the effectiveness of NaOH and HCHO on polyphenol reduction as previously reported in steeping experiments (Chapter II).

Product Colour

In sorghum milling, colour improvement is of primary importance for consumer acceptance. Variety, conditioning treatment and moisture significantly affected ($P < 0.001$) product colour (Table III-6). There was no advantage in conditioning up to 20 % moisture prior to abrasive decortication for the purpose of improving flour colour as L values were highest at 12 % (Table III-6). Chirimaugute produced the darkest flour although its polyphenol content was significantly less than that of DC-75. Factors other than polyphenol content alone, are involved in determining the colour of sorghum products (Rooney and Miller 1982). Hunter L values differed significantly among treatments with HCl giving a slight improvement in flour colour.

SV2 had higher L values than DC-75 and Chirimaugute after roller milling. SV2 is tannin-free variety, unlike the latter (Chapter I). Flour colour was improved more at 20 % than 16 % moisture for SV2 and Chirimaugute. HCl gave slightly higher L values than other treatments after roller milling SV2 and DC-75 as found in abrasive milling. The mean increase in L values was 7, 8 and 15 % after roller milling SV2, Chirimaugute and DC-75, respectively.

CONCLUSIONS

Conditioning treatment and moisture prior to roller milling of high-tannin sorghums improved product yield and reduced polyphenol content of the meal. Conditioning grains prior to abrasive decortication neither gave significant reduction in polyphenol content nor improved colour and yield of decorticated flour. Enzyme inhibition was higher in products obtained from the high-tannin than the medium-tannin variety. Polyphenol content was not related to yield and colour of the product after milling. The findings that abrasive and roller milling plus HCHO and NaOH reduced tannin content of offal could be important if offal is used for animal feed. Additional chemical work is needed on sorghum tannin so as to understand its chemical fate during processing.

LITERATURE [illegible]

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B[illegible] Method for estimation [illegible]

C[illegible] P. S. [illegible]

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[illegible] Sorghum Grain Quality [illegible]

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Table III-1. Effect of conditioning sorghum varieties, DC-75 and Chiri, to 16 and 20%, using water, HCl (0.9%, v/v), HCHO (0.05%, v/v), and NaOH (0.3%, w/v), prior to abrasive decortication and roller milling, on the meal and offal yield (% extraction at 16 % moisture).

Variety				SV2			
% Conditioning moisture content	12 AD[1]	16 AD	20 AD	16 RM	20 RM	16 RM-offal	20 RM-offal
Water (control)	95.0b[2]	94.7ab	87.8a	90.9	79.8	6.9	13.1
HCl	95.3ab	94.9a	87.8a	90.5	85.2	6.4	9.1
HCHO	95.3ab	94.6bc	86.7b	91.8	84.7	6.6	9.2
NaOH	95.6a	94.1c	87.8a	89.5	83.9	7.4	9.8
Mean	95.3	94.6	87.5	90.7	83.4	6.8	10.3

Variety				DC-75	
% Conditioning moisture content	12 AD[1]	16 AD	20 AD	16 RM	16 RM-offal
Water (control)	83.6c[2]	86.8ab	84.6ab	88.5	7.4
HCl	84.1bc	87.0a	84.4ab	87.5	8.0
HCHO	84.4ab	86.9ab	84.8a	88.1	7.0
NaOH	85.0a	86.3b	84.3b	89.9	6.7
Mean	84.3	86.8	84.5	88.5	7.3

Variety				Chiri			
Conditioning moisture content	12 AD[1]	16 AD	20 AD	16 RM	20 RM	16 RM-offal	20 RM-offal
Water (control)	81.2a[2]	80.3bc	74.6b	91.0	82.2	6.4	10.6
HCl	81.3a	80.0c	75.0b	90.3	82.0	6.3	11.3
HCHO	80.8ab	81.1a	75.9a	89.9	81.8	5.8	10.4
NaOH	80.5b	80.4ab	75.7a	89.4	82.9	6.2	10.9
Mean	81.0	80.5	75.3	90.2	82.2	6.2	10.8

[1]AD = abrasive decortication, RM = roller milling.

[2]Values with similar letters in the same column are not statistically different ($P < 0.05$).

Table III-2. Effect of conditioning sorghum varieties, DC-75 and Chiri, to 16 and 20%, using water, HCl (0.9%, v/v), HCHO (0.05%, v/v), and NaOH (0.3%, w/v), prior to abrasive decortication or roller milling, on the tannin content of the meal as measured by the butanol-HCl assay (A/g, dry basis).

Variety	DC-75				Chiri				
% Conditioning moisture content	12 AD[1]	16 AD	20 AD	16 RM	12 AD	16 AD	20 AD	16 RM	20 RM
Tannin content of raw grain	45.9	45.9	45.9	45.9	29.3	29.3	29.3	29.3	29.3
Treatment									
Water (control)	10.6b[2]	18.3b	20.8a	32.3a	6.5a	8.2a	8.0a	22.1a	6.3b
HCl	13.2a	15.7c	17.5bc	32.6b	6.2a	7.9a	7.9a	17.6b	9.3a
HCHO	13.1a	18.0b	15.2c	30.2c	5.4b	6.8b	5.3b	14.2c	5.0c
NaOH	13.4a	22.9a	17.9b	29.6c	6.3a	7.7a	4.8b	15.3c	5.8bc

[1]AD = abrasive decortication, RM = roller milling.
[2]Values with similar letters in the same column are not statistically different ($P < 0.05$).

Table III-3. Effect of conditioning sorghum varieties, DC-75 and Chiri, to 16 and 20%, using water, HCl (0.9%, v/v), HCHO (0.05%, v/v), and NaOH (0.3%, w/v), prior to abrasive decortication or roller milling, on the polyphenol content of the meal or offal as measured by the vanillin-HCl assay in catechin equivalents (g/100 g, dry basis).

Variety	DC-75					Chiri						
% Conditioning moisture content	12 AD[1]	16 AD	20 AD	16 RM	16 RM	12 AD	16 AD	20 AD	16 RM	20 RM	16 RM	20 RM
Polyphenol content of raw grain	6.3	6.3	6.3	6.3	(Offal)	3.8	3.8	3.8	3.8	3.8	(Offal)	(Offal)
Treatment												
Water (control)	3.8a[2]	4.7b	4.8c	5.0a	12.9b	1.8c	2.3b	2.3b	2.4d	1.3b	5.1b	7.4c
HCl	3.6b	4.6c	5.6a	4.6c	13.7a	1.9b	2.4a	2.6a	3.0a	1.7a	5.7a	9.6a
HCHO	3.6b	4.5d	4.8c	4.7b	11.0c	1.9b	2.1c	2.0d	2.5c	1.1d	4.8c	6.1d
NaOH	3.8a	4.9a	5.0b	4.7b	10.7d	2.1a	2.3b	2.1c	2.6b	1.2c	4.6d	8.0b

[1]AD = abrasive decortication, RM = roller milling.
[2]Values with similar letters in the same column are not statistically different ($P < 0.05$)

Table III-4. Effect of conditioning sorghum varieties, DC-75 and Chiri, to 16 and 20%, using water, HCl (0.9%, v/v), HCHO (0.05%, v/v), and NaOH (0.3%, w/v), prior to abrasive decortication or roller milling, on the tannin content of the meal as measured by the vanillin-HCl assay with blank subtraction in catechin equivalents (g/100 g, dry basis).

Variety	DC-75					Chiri						
% Conditioning moisture content	12 AD[1]	16 AD	20 AD	16 RM	16 RM	12 AD	16 AD	20 AD	16 RM	20 RM	16 RM	20 RM
Tannin content of raw grain	5.5	5.5	5.5	5.5	(Offal)	3.1	3.1	3.1	3.1	3.1	(Offal)	(Offal)
Treatment												
Water (control)	3.4b[2]	4.3b	4.3c	4.7a	11.6b	1.2c	1.6b	1.6b	1.7d	0.8b	3.4b	5.6c
HCl	3.2d	4.3b	5.1a	4.4b	12.4a	1.3b	1.7a	1.8a	2.5a	1.2a	4.0a	7.2a
HCHO	3.3c	4.1c	4.3c	4.4b	9.8c	1.2c	1.4c	1.3d	2.1b	0.7c	3.0d	4.6d
NaOH	3.5a	4.5a	4.5b	4.4b	9.4d	1.4a	1.6b	1.5c	2.0c	0.7c	3.1c	6.2b

[1]AD = abrasive decortication, RM = roller milling.
[2]Values with similar letters in the same column are not statistically different ($P < 0.05$).

Table III-5. Effect of conditioning sorghum varieties, DC-75 and Chiri, to 16 and 20%, using water, HCl (0.9%, v/v), HCHO (0.05%, v/v), and NaOH (0.3%, w/v), prior to abrasive decortication or roller milling, on enzyme inhibition (%) by the polyphenols in the meal.

Variety	DC-75				Chiri				
% Conditioning moisture content	12 AD[1]	16 AD	20 AD	16 RM	12 AD	16 AD	20 AD	16 RM	20 RM
% Enzyme inhibition of raw grain	80	80	80	80	33	33	33	33	33
Treatment									
Water (control)	36b[2]	46a	42c	54a	17a	12c	23a	19a	13a
HCl	24c	40b	51a	41b	12c	14bc	18b	17b	13a
HCHO	38b	41b	38d	38c	14b	17a	19b	14c	9b
NaOH	40a	46a	45b	43b	17a	16ab	11c	19a	9b
Mean (% reduction in inhibition)	58	46	45	46	55	56	46	48	67

[1]AD = abrasive decortication, RM = roller milling.
[2]Values with similar letters in the same column are not statistically different ($P < 0.05$).

Table III-6. Effect of conditioning sorghum varieties, DC-75 and Chiri, to 16 and 20%, using water, HCl (0.9%, v/v), HCHO (0.05%, v/v), and NaOH (0.3%, w/v), prior to abrasive decortication and roller milling, on meal lightness as measured by the Hunter Lab (L values).

Variety		SV2			DC-75			Chiri	
Conditioning moisture content	12% AD[1]	16% AD	20% AD	12% AD	16% AD	20% AD	12% AD	16% AD	20% AD
L value of whole grain flour	74.35	74.35	74.35	60.68	60.68	60.68	59.52	59.52	59.52
Water (control)	76.7c[2]	76.1b	76.0b	68.5d	66.5c	66.8b	66.3a	65.6a	65.1d
HCl	75.0a	76.3a	76.5a	68.8b	67.6a	67.2a	66.2ab	65.4b	65.6a
HCHO	76.9b	75.9c	75.8c	69.0a	67.0b	66.2c	66.2b	65.6a	65.4b
NaOH	76.5d	76.2a	75.7c	68.7c	66.3c	66.1c	66.2ab	65.3b	65.2c
Mean (% increase in L value)	3	2	2	10	10	10	11	10	10

Variety	SV2		DC-75	Chiri	
Conditioning moisture content	16% RM	20% RM	16% RM	16% RM	20% RM
L value of whole grain flour	74.35	74.35	60.68	59.52	59.52
Water (control)	79.7a[2]	80.4b	67.1d	65.6a	68.2b
HCl	79.8a	80.5a	69.0a	63.8b	67.7c
HCHO	78.8b	80.4b	68.7b	64.4d	68.5a
NaOH	79.7a	80.1c	67.7c	63.7c	67.6d
Mean (% increase in L value)	7	8	11	8	14

[1]AD = abrasive decortication, RM = roller milling.
[2]Values with similar letters in the same column are not statistically different ($P < 0.05$).

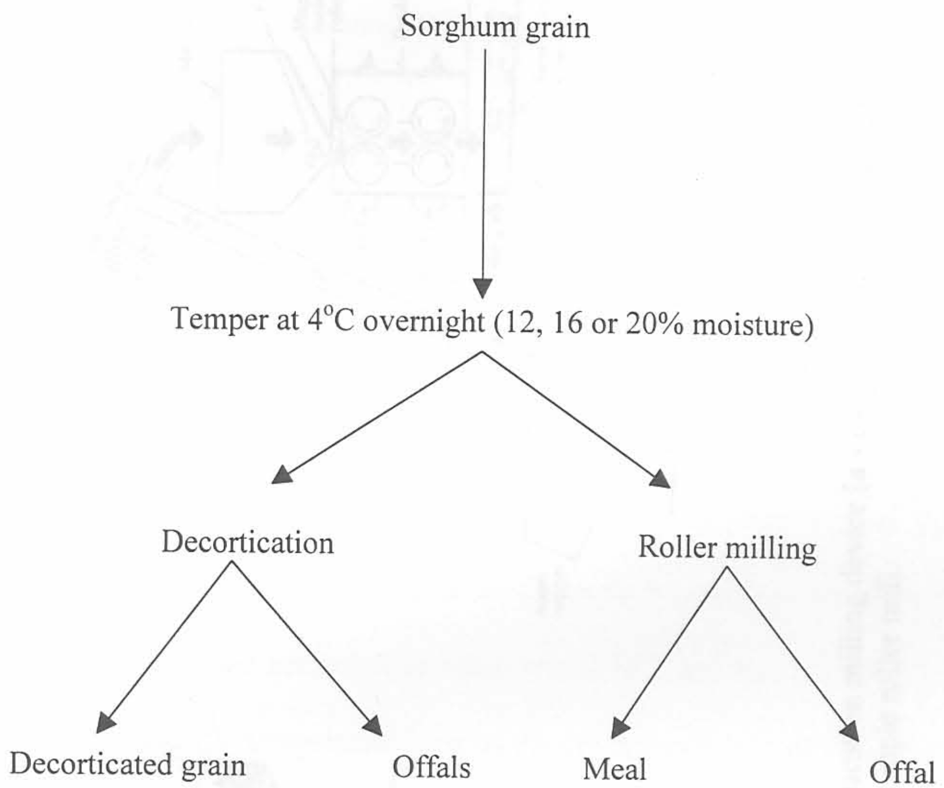
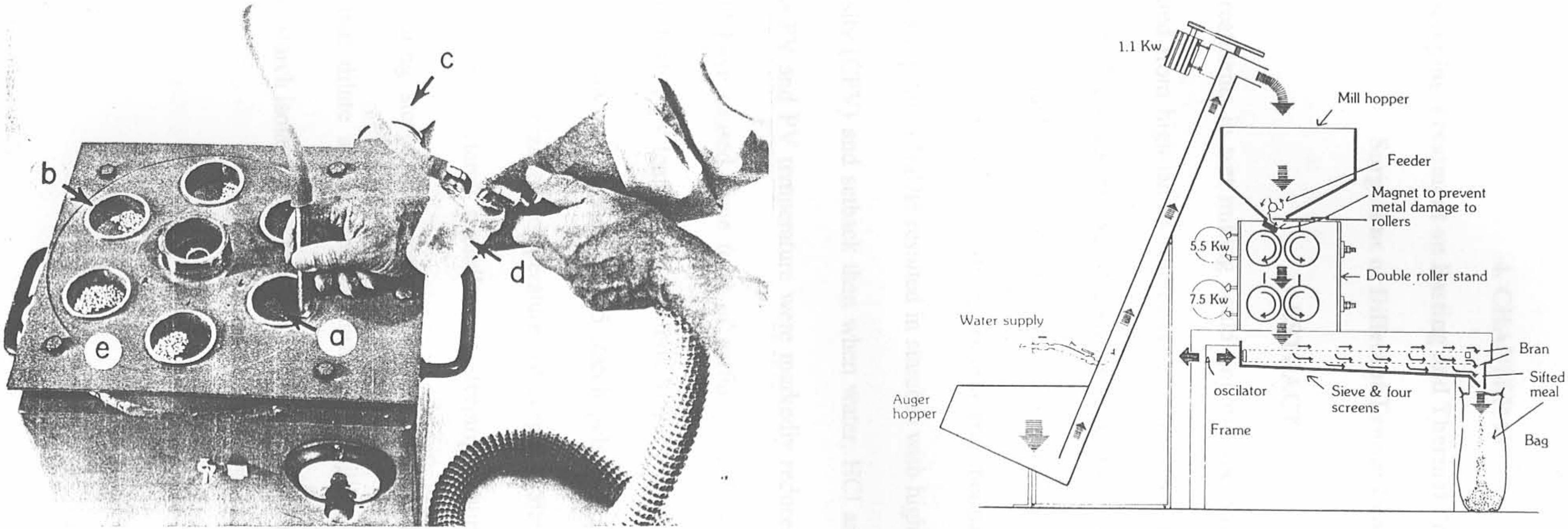


Figure III-1. Procedures used for abrasive decortication and roller milling of sorghum.



(a) (b)

Figure III-2. Diagrams illustrating the (a) abrasive decortication milling device [**a** - carborundum stone, **b** - sample cups, **c** - internal fan, **d** - vacuum device, **e** - dehulling headplate]; and (b) simple roller mill.