

Effect of chemical conditioning on the milling of high-tannin sorghum

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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 multi-sample 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%, w/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 and offal after roller milling. Enzyme inhibition (EI) by polyphenols was reduced by 52% after decortication or roller milling. Chemical treatment did not significantly affect EI levels after decortication. NaOH and HCHO treatments gave the lowest EI when Chirimaugute was roller milled at 20% moisture. The yield of product obtained after decortication was high at 12% moisture for SV2 and Chirimaugute and at 16% conditioning moisture for DC-75. 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. Both abrasive decortication and roller milling plus NaOH and HCHO reduced tannin content of offal. It is concluded that conditioning using NaOH could be advantageous in roller milling but not in abrasive decortication of tannin-containing sorghums.

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Keywords: sorghum; tannins; chemical treatments; milling

INTRODUCTION

Sorghum industrial milling technology is still evolving, unlike those for wheat, rice and maize, where specialised milling technologies have been developed to give finished products of high acceptance. Simple roller mills with two pairs of rolls are gaining wide acceptance for small-scale maize milling in southern Africa.¹ Conditioning sorghum using the same moisture levels applied to wheat results in a less clean fractionation, as the sorghum bran is much more brittle.² Other researchers have revealed that roller milling results may be improved by steeping at high moisture contents under semi-wet conditions.^{1,3} 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.^{4,5} Abrasive decortication operates on the principle of progressively rubbing off the outer layers of the kernel.⁶ Traditionally, this is a dry technique. Decortication followed by hammer milling is the most common industrial sorghum milling process in southern Africa.⁷

Milling high-tannin sorghums is particularly chal-

lenging, as antinutritional tannins contained in the testa layer have to be removed or the tannins extracted or transformed. Tannin-containing sorghums tend to be soft,⁸ making high endosperm recovery difficult. Mwasaru *et al*⁹ advocated development of harder, rounder grain before commercial milling of tannin-containing sorghum can become economically feasible. However, the available sorghum varieties, for example in Zimbabwe,¹⁰ lack ideal characteristics for processing; that is, a thin, white pericarp and corneous endosperm.¹¹ Chemical treatments have been used to detoxify tannin-containing sorghums.^{12,13} The objective of this study was to determine the effect of combining chemical treatment with conditioning on the milling of high-tannin sorghums.

MATERIALS AND METHODS

Grains

Sorghum (*Sorghum bicolor* (L) Moench) grain of varieties SV2 and Chirimaugute (Chiri) and hybrid variety DC-75 were used. DC-75 (high-tannin) and

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Contract/grant sponsor: McKnight Foundation Collaborative

Contract/grant sponsor: Crop Research Programme

(Received 4 February 2000; revised version received 13 June 2000; accepted 11 August 2000)

SV2 (tannin-free) have relatively corneous endosperms, as determined visually according to the method of Rooney and Miller,¹⁴ while Chirimaugute (medium-tannin) has a floury endosperm.¹⁰ The pericarp is thick in DC-75, medium in Chirimaugute and thin in SV2 kernels.¹⁰ 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 an eight-cup dehulling plate was used for removing successive layers from sorghum grains abrasively at 1750 rpm following the technique developed by Oomah *et al*⁶ and Reichert *et al*.¹⁵ The moisture content of the grain was determined. The amount of solution required to condition the grain was calculated according to AACC method 26-95.¹⁶ 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 a cold store at 4 °C according to the semi-wet milling procedure described by Gomez¹ and Cecil.³ The conditioned grains were milled for 2 min in the TADD, and the yield of decorticated grain was recorded and calculated on a uniform moisture basis.

Roller milling

A double-roll roller mill with a single-pass 1.5 mm vibrating screen (Maximill, Kroonstaad, South Africa) was used to mill conditioned grain. The roll gaps on the mill were set at 0.15 and 0.10 mm for the top and bottom rolls respectively. The top and bottom rolls were corrugated to 7 and 22 flutes per inch respectively. Roll speeds were set at a differential of 1.25:1. Grain (5 kg) was weighed into plastic bags. Conditioning was carried out prior to milling using solutions of HCl (0.9%, v/v), HCHO (0.05%, v/v), NaOH (0.3%, w/v) and water as control. The bag was sealed and the contents were mixed thoroughly. The sample was left to equilibrate at 4 °C overnight according to the semi-wet milling procedure.^{1,3} The yield of meal and offal obtained after roller milling was recorded and calculated on a uniform moisture basis.

Analyses

For the analyses the products obtained after roller and abrasive milling were ground to pass through an 800 µm sieve.

Polyphenol analysis

The polyphenols in milled sorghum products were measured using the butanol-HCl¹⁷ and vanillin-HCl¹⁸ 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.¹⁹ 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 × *g*. For the anthocyanin production assay, 6 ml of acid butanol (50 ml HCl (32%) dm⁻³) was added to 1 ml of sample extract in a test tube. 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 at 550 nm g⁻¹. Catechin (Sigma Chemicals) was used as a standard in the vanillin assay, and sample blanks were included. The results were expressed in catechin equivalents (mg CE per 100 mg sample).

Enzyme inhibition

Enzyme inhibition in sorghum flour was determined following the method of Daiber.²⁰ 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, Staufen, Br, Germany) for 5 min and centrifuging the sample for 5 min. To determine residual activity after enzyme inhibition, the extract (12 ml) was added to sorghum flour (120 mg). The mixture was shaken while incubating for 30 min at 30 °C. A sample containing no sorghum flour was included to determine original activity. After incubation, samples were centrifuged for 5 min and the supernatants were used for diastasis. Diastatic power (amylase activity) was determined and percentage enzyme inhibition calculated as 100 × (original activity – residual activity)/(original activity).

Colour values

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

Statistical analyses

The general linear model procedure of SAS version 6.12 (SAS Institute, Cary, NC, USA) 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,^{13,21} HCl,¹³ HCHO¹² and high-moisture reconstitution^{13,22} to improve the nutritional value of high-tannin sorghums. The selected concentrations of HCHO and NaOH were based on findings by Daiber¹² and Dewar *et al*²³ respectively. We used the information from our preliminary experiments on steep water uptake using

various concentrations of HCl as the basis for selecting the concentration of the acid. Conditioning moisture for roller milling was selected following findings by Gomez.¹ Conditioning during decortication is practised in the traditional mortar and pestle method up to about 20%,²⁴ but machine decortication in an abrasive mill is normally a dry milling technique.

Product yield

Yield of decorticated grain (87–96%) was highest for SV2, the tannin-free variety (Table 1). The yield falls within the range of extraction rates (71–98%) previously reported for 23 white sorghum varieties.²⁵ DC-75 gave slightly better 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.¹⁰ From visual observation it was clear that the lower yields were due to loss of endosperm fractions into the offal. Thus yield was more related to the floury nature of the grains, as previously reported by Chibber *et al*⁸ and Reichert,⁵ than their polyphenol content. The importance of a relatively corneous endosperm was emphasised by Munck *et al*²⁶ when they observed that introduced Tanzanian sorghum with 31% soft endosperm was giving lower yields of 50% compared to local hard cultivars (3.9–13.6% soft endosperm) that gave recoveries of 72–86%. However, yield of product was relatively higher than values previously reported for brown sorghums.^{3,8} The findings confirm the report by Gomez¹ that roller milling of sorghum under semi-wet conditions (16% moisture) is superior to dry milling.

Chemical treatment did not significantly affect yield of roller-milled product (Table 1). Conditioning to

20% moisture resulted in lower yields for all varieties. Thus conditioning prior to decortication was not an advantage for the purpose of increasing product yield. Eggum *et al*²⁴ demonstrated that only 59% (compared to 79% in wheat) of lysine remains 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 three varieties. However, yields were slightly better at 16% moisture for DC-75. Meal yield was decreased by up to 8, 6 and 7% on average when SV2, DC-75 and Chirimaugute respectively were conditioned to 20% moisture. High-tannin sorghum lines that could be abrasively decorticated and yield at least 70% of product have previously been identified.²⁷ Subramanian *et al*²⁸ 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 Shepherd²⁹ and the TADD abrasion mill, the frictional forces between the grains are minimised so that grains are decorticated in a gentler way compared to commercial decorticators.³⁰

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 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 con-

Table 1. Effect of conditioning sorghum varieties SV2, DC-75 and Chiri to 12, 16 and 20% moisture content using water (control), HCl (0.9%, v/v), HCHO (0.05%, v/v) and NaOH (0.3%, w/v), prior to abrasive decortication (AD) or roller milling (RM), on the meal and offal (O) yield

Treatment	12/AD	16/AD	20/AD	16/RM	20/RM	16/RM(O)	20/RM(O)
<i>SV2</i>							
Water	95.0b	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
<i>DC-75</i>							
Water	83.6c	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	
<i>Chiri</i>							
Water	81.2a	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

Values with same letter in same column for each variety are not statistically different ($P < 0.05$).

Table 2. Effect of conditioning sorghum varieties DC-75 and Chiri to 12, 16 and 20% moisture content using water (control), HCl (0.9%, v/v), HCHO (0.05%, v/v) and NaOH (0.3%, w/v), prior to abrasive decortication (AD) or roller milling (RM), on the tannin content of the meal as measured by the butanol–HCl assay (absorbance units at 550nm g⁻¹, dry basis)

Treatment	DC-75				Chiri				
	12/AD	16/AD	20/AD	16/RM	12/AD	16/AD	20/AD	16/RM	20/RM
Water	10.6b	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

Tannin content of raw grain: DC-75, 45.9; Chiri, 29.3.

Values with same letter in same column are not statistically different ($P < 0.05$).

tamination. Conditioning to 12% moisture followed by decortication, a technique equivalent to the traditional dry abrasion practice, reduced polyphenol levels by 71 and 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% moisture, DC-75 flour had higher polyphenol content than at 12% (Table 2). Polyphenol content was 29–36% less when DC-75 grain was conditioned to 16% moisture and roller milled.

With roller milling, NaOH and HCHO gave relatively lower polyphenols than water and HCl for both varieties, as we have observed in steeping experiments for malting (Beta *et al*, unpublished). NaOH and HCHO treatments of high-tannin sorghums for feed have also been found to improve the weight gain of birds.³¹

Polyphenol content (vanillin–HCl assay)

Polyphenol reduction (range 12–53%) was less pronounced in decorticated samples with the vanillin (Table 3) than with the butanol–HCl assay. The vanillin method tends to underestimate the weight of condensed tannins owing to their reduced reactivity.³² 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*⁸ and Mwasaru *et al*⁹ reduced polyphenol content by up to 91% using a similar dry abrasion technique, but at lower extraction rates. Polyphenol reduction exceed-

ing 55% was not achieved, as yield of product was kept relatively high.

Roller milling DC-75 after conditioning to 16% moisture gave flour products that had higher polyphenol content than those obtained by abrasive decortication at 12%, giving further evidence that polyphenols were largely removed by the abrading action. However, polyphenol content was markedly reduced by 56–71% after roller milling Chirimaugute at 20% moisture. Polyphenol content was lower at 20 than 16% moisture in Chirimaugute roller-milled meal.

At 20% moisture, HCHO and NaOH gave low polyphenol content in Chirimaugute roller-milled meal. Polyphenol reduction possibly involved formation of high-molecular-weight polymers³³ that were cross-linked and insoluble. The findings confirm the work of Reichert *et al*¹³ where tannins were reduced by 97, 83 and 39% when sorghum grains imbibed 0.8M NaOH, 0.8M HCl and water respectively at 25% by weight at 25°C with an equilibration period of 2 days. 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 0.2M NaOH was used for treatment of high-tannin sorghum that was then stored for 3 and 11 days.³⁴

The results of the vanillin–HCl assay with blank subtraction (Table 4) were essentially the same as above, only the magnitude was different. Thus the tannin content of roller-milled meal was reduced by 15–20 and 18–44% when DC-75 and Chirimaugute respectively were conditioned to 16% moisture (Table 4).

Table 3. Effect of conditioning sorghum varieties DC-75 and Chiri to 12, 16 and 20% moisture content using water (control), HCl (0.9%, v/v), HCHO (0.05%, v/v) and NaOH (0.3%, w/v), prior to abrasive decortication (AD) or roller milling (RM), on the polyphenol content of the meal and offal(O) as measured by the vanillin–HCl assay in catechin equivalents (mg CE per 100mg sample, dry basis)

Treatment	DC-75					Chiri						
	12/AD	16/AD	20/AD	16/RM	16/RM(O)	12/AD	16/AD	20/AD	16/RM	20/RM	16/RM(O)	20/RM(O)
Water	3.8a	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

Polyphenol content of raw grain: DC-75, 6.3; Chiri, 3.8.

Values with same letter in same column are not statistically different ($P < 0.05$).

Table 4. Effect of conditioning sorghum varieties DC-75 and Chiri to 12, 16 and 20% moisture content using water (control), HCl (0.9%, v/v), HCHO (0.05%, v/v) and NaOH (0.3%, w/v), prior to abrasive decortication (AD) or roller milling (RM), on the tannin content of the meal and offal(O) as measured by the vanillin-HCl assay with blank subtraction in catechin equivalents (mg CE per 100mg sample, dry basis)

Treatment	DC-75					Chiri						
	12/AD	16/AD	20/AD	16/RM	16/RM(O)	12/AD	16/AD	20/AD	16/RM	20/RM	16/RM(O)	20/RM(O)
Water	3.4b	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

Tannin content of raw grain: DC-75, 5.5; Chiri, 3.1.

Values with same letter in same column are not statistically different ($P < 0.05$).

The tannin content of offal differed significantly ($P < 0.001$) among treatments (Table 4). Offal polyphenol content was much higher than that of meal, because offal contained most of the pericarp and testa layers. Tannin content of offal was 72–126% greater than in DC-75 grain at 16% moisture. However, Chirimaugute had up to 30% more tannin in its offal at the same moisture, presumably owing to higher endosperm contamination. Tannin content in the offal increased by 49–133% 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 offal or less endosperm contamination of offal. Offal tannin content was low with NaOH and HCHO treatment at 16% moisture. At 20% moisture the tannin levels of Chirimaugute offal were markedly high with HCl.

Enzyme inhibition by polyphenols in the meal

Enzyme inhibition (EI) assays indicated significant differences between the two varieties (Table 5). The mean EI for Chirimaugute and DC-75 flour was 16 and 41% respectively. This was presumed to be due to the high tannin content in DC-75 grains¹⁰ that could not be completely removed. Chemical treatment had no effect on EI after abrasive decortication, confirming the finding 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 high moisture showed the effectiveness of NaOH and HCHO on polyphenol reduction.

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 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%. 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.³⁴ Hunter *L* values differed significantly among treatments, with HCl giving a slight improvement in flour colour, possibly owing to destruction of xanthophylls.

SV2 had higher *L* values than DC-75 and Chirimaugute after roller milling. SV2 is a tannin-free variety, unlike the latter.¹⁰ Flour colour was improved more at 20% moisture than at 16% moisture for SV2 and Chirimaugute. HCl gave slightly higher *L* values

Table 5. Effect of conditioning sorghum varieties DC-75 and Chiri to 12, 16 and 20% moisture content using water (control), HCl (0.9%, v/v), HCHO (0.05%, v/v) and NaOH (0.3%, w/v), prior to abrasive decortication (AD) or roller milling (RM), on enzyme inhibition (%) by the polyphenols in the meal

Treatment	DC-75				Chiri				
	12/AD	16/AD	20/AD	16/RM	12/AD	16/AD	20/AD	16/RM	20/RM
Water	36b	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 ^a	58	46	45	46	55	56	46	48	67

Enzyme inhibition of raw grain: DC-75, 80; Chiri, 33.

^a Percentage reduction in inhibition.

Values with same letter in same column are not statistically different ($P < 0.05$).

Table 6. Effect of conditioning sorghum varieties SV2, DC-75 and Chiri to 12, 16 and 20% moisture content using water (control), HCl (0.9%, v/v), HCHO (0.05%, v/v) and NaOH (0.3%, w/v), prior to abrasive decortication (AD) or roller milling (RM), on meal colour as measured by the Hunter L value

Treatment	SV2					DC-75				Chiri				
	12/AD	16/AD	20/AD	16/RM	20/RM	12/AD	16/AD	20/AD	16/RM	12/AD	16/AD	20/AD	16/RM	20/RM
Water	76.7c	76.1b	76.0b	79.7a	80.4b	68.5d	66.5c	66.8b	67.1d	66.3a	65.6a	65.1d	65.6a	68.2b
HCl	75.0a	76.3a	76.5a	79.8a	80.5a	68.8b	67.6a	67.2a	69.0a	66.2b	65.4b	65.6a	63.8b	67.7c
HCHO	76.9b	75.9c	75.8c	78.8b	80.4b	69.0a	67.0b	66.2c	68.7b	66.2b	65.6a	65.4b	64.4d	68.5a
NaOH	76.5d	76.2a	75.7c	79.7a	80.1c	68.7c	66.3c	66.1c	67.7c	66.2b	65.3b	65.2c	63.7c	67.6d
Mean ^a	3	2	2	7	8	10	10	10	11	11	10	10	8	14

L value of whole grain flour: SV2, 74.35; DC-75, 60.68; Chiri, 59.52.

^a Percentage increase in L value.

Values with same letter in same column are not statistically different ($P < 0.05$).

than other treatments after roller milling SV2 and DC-75 as found in abrasive milling. The mean increase in L value 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.

ACKNOWLEDGEMENTS

The authors are greatly indebted to the McKnight Foundation Collaborative Crop Research Programme for sponsoring this study carried under the project entitled 'Ecological biochemistry of proanthocyanidins and related flavonoids in the Zimbabwean small-scale farming system'.

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