Roller Milling – An Alternative Dry Milling Process for Sorghum

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Summary

The lack of an efficient milling technology has been identified as a constraint for expansion of the sorghum food industry. To identify efficient processes, a simple two-stage roller mill (RM) was compared with PRL-type abrasive decortication and hammer-milling (ADHM), using 12 different sorghum types. RM gave far better extraction rates (11% more) and throughput than ADHM. However, the meals obtained with RM were slightly darker with slightly higher ash and oil contents, and had fine particles than those produced with ADHM. Grain hardness affected extraction rate with ADHM, but not with RM. Overall, RM appears to hold great potential as a dry-milling process for large-scale industrial milling of sorghum.

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is an important cereal crop in the developing countries of Africa and Asia [1]. In Africa, it ranks second in production, after maize. Despite its importance, the sorghum food industry is non vibrant, constrained partly by the lack of efficient milling technology [2]. Today, sorghum milling is commonly done using abrasive decorticators and hammer mills, in small- and medium-scale commercial mills [3, 4]. However, the abrasive decorticators used are limited in terms of production throughput and control of meal quality, and are also associated with high milling losses [5, 6].

A recent development in Southern Africa has been the introduction of simple roller mills with two to three pairs of rolls and vibrating sieving screens [6]. These roller mills have attracted attention as a potential alternative for sorghum milling [5, 7]. However, information is scanty on their sorghum milling performance. This paper therefore draws comparisons between existing commercial abrasive milling technology and the newly introduced simplified roller mill, focusing on the quality of the meals produced.

Experimental

Twelve sorghum types with varied kernel characteristics were used (Table 1).

Abrasive decortication and hammer milling

A commercial mill that used Rural Industries Innovation Centre (RIIC, Kanye, Botswana) PRL type dehuller and hammer mill (ADHM) (Fig. 1) was engaged to produce the meals. Ten kg batches of sorghum were used. Using the dehuller, the bran was progressively abraded off and removed by means of a cyclone fan. Decortication was done to the operator's satisfaction. The grain was then milled using a hammer mill fitted with a 2.0 mm opening screen. Bran and meal were weighed to determine extraction rates.

Roller milling

A commercial roller mill (RM) (Maximill, Kroonstad, South Africa) (Fig. 2) with two pairs of fluted rolls and rated throughput of 500 kg/hr was used. The top rolls (coarse break rolls) had 8 flutes per 25 mm and the bottom rolls (fine break rolls) had 22 flutes per 25 mm. All roll pairs operated at differentials of 1.5:1. Five kg batches of clean grain were tempered to 16% moisture for 15 min in sealed plastic buckets at ambient conditions, stirring at intervals of 5 min to uniformly distribute added water. The tempered grain was roller milled immediately using top and bottom roller gaps of 0.80 mm and 0.30 mm, respectively. The milled stock was separated on vibrating sieves of mesh sizes 1.00 mm, 0.850 mm, 0.710 mm and 0.710 mm arranged in descending order. The first two sieves retained the bran, while the last two separated the meal.

Meal quality was evaluated on the basis of colour, ash and oil content, and particle size.

Table 1. Physical Characteristics of Kernels of 12 Sorghum Types used to Compare Abrasive Decortication & Hammer-Milling and Roller Milling

Sorghum type	Grain Size (mm)[1]	Pericarp	V H S[2]	TADD Yield at 4 min (g /100 g)	Grain colour[4]
	3.35 <%>2.80				
BSH1	50.0c	Medium	1.7b C	87.5f	White
Kanye std	30.5b	Thick	3.7h I	79.3b	White, mottled
LARSVYT	86.1ij	Thin	2.1c C	85.4d	White
Lekgeberwa	82.9hi	Thick	1.3a C	86.4de	White
Buster	55.1d	Thick	3.2fg I	87.5f	Red
Marupantsi	59.9e	Thick	2.9ef I	81.3c	Reddish-white
Mmabaitse	79.4fg	Thick	3.7h I	73.2a	White, mottled
Phofu	82.6gh	Medium	2.3c C	86.4de	White
Sefofu	21.4 a	Medium	2.2c C	87.3ef	White
Segaolane	89.3 j	Thin	2.5cd I	88.1f	white, mottled
SNK	78.8 f	Thick	3.4gh I	82.0c	Red
Town	82.9hi	Thin	2.7de I	86.4de	Red

Figures in columns with different letter notations are significantly different at P <0.05; [1]All classified as medium-size [2]Visual hardness score - scale 1-5, with 1 denoting corneous (hard) and 5 representing floury (soft) endosperm; C – corneous endosperm and I – intermediate

Fig. 1 PRL-type Abrasive decorticator (a) and hammer mill (b) similar to those used to produce abrasive decortication-hammer mill meal samples.

Fig. 2 Two roll roller mill used to produce roller milled meal samples.

Results and Discussion

Extraction rate

RM performed substantially better, giving an 11% (7.8 g/100 g) yield advantage over ADHM (Table 2). Interestingly, RM extraction rates did not correlate significantly with grain hardness, indicating that grain hardness is not important for achievement of good extraction rates with RM. In contrast to RM, there were significant correlations between ADHM extraction rate and grain hardness. The highest extraction rates were achieved with the relatively harder sorghum types, while the softer types gave the lowest extraction rates. This confirmed earlier reports that with abrasive decortication, hard endosperm grains give higher flour yields than those with softer endosperms [3].

Table 2.Effects of Abrasive Decortication & Hammer Milling (ADHM) and Roller Milling (RM) on the Extraction Rate of Sorghum Meal

Sorghum type	Meal extraction (g /100 g)	
	ADHM	**RM**
BSH1	83.1cd	81.6ab
Kanye Std	70.9ab	85.6gh
LARSVYT	79.6bcd	82.2bc
Lekgeberwa	80.0bcd	85.5gh
Buster	74.4abc	84.3efg
Marupantsi	73.2abc	83.9def
Mmabaitse	67.9a	83.2cde
Phofu	81.4cd	80.7a
Sefofu	77.2a-d	84.8fg
Segaolane	84.8d	86.8h
SNK	67.5a	83.2cde
Town	68.5a	82.6bcd
Mean	**75.7a**	**83.7b**

Table 3. Effects of Abrasive Decortication & Hammer Milling (ADHM) and Roller Milling (RM) on the Colour Properties (L, C^*_{ab} and H^*_{ab}) of Sorghum Meal*

Sorghum type	ADHM			RM		
	L*	C^*_{ab}	h^*_{ab}	L*	C^*_{ab}	h^*_{a}
BSH1	87.6gh	11.6g	80.2g	87.2i	12.4ef	81.8i
Kanye Std	82.7b	9.2a	58.4b	79.6c	10.0a	57.0b
LARSVYT	87.4g	11.2f	81.6h	85.8g	11.8d	81.4i
Lekgeberwa	87.7h	10.7e	80.0g	86.4h	11.8d	78.9h
Buster	86.7f	11.7g	75.0f	82.7f	12.5f	67.3e
Marupantsi	83.2c	9.7b	63.2c	78.5b	10.7b	59.2c
Mmabaitse	74.4a	10.1c	44.1a	71.4a	11.3c	44.3a
Phofu	86.4e	11.7g	81.0h	85.7g	12.4ef	81.2i
Sefofu	86.2e	11.4fg	75.6f	85.6g	12.1de	74.5g
Segaolane	84.6d	10.3cd	70.0e	82.4e	11.2c	68.5f
SNK	84.5d	10.6de	68.6d	81.5d	11.4c	64.9d
Town	84.6d	10.7e	68.3d	81.7d	11.4c	64.6d
Mean	84.6c	10.8b	70.5b	82.4a	11.6c	68.6a

L* - lightness, C^*_{ab} - chroma, and h^*_{ab} - hue

Meal colour

ADHM producing the lightest meals, while RM produced slightly darker meals (Table 3). The dark colour was presumably caused by the dark coloured pigments of bran, indicating higher bran contamination of meals obtained with RM. Higher bran levels in the latter were presumably caused by the friable sorghum pericarp, even after tempering [7,8].

Ash and oil content

Ash content is an indicator of the level of bran contamination in milled products [9]. ADHM produced meals with the lowest ash content, retaining 46-79% of the whole grain ash, while RM gave the highest ash content, with 70-84% of the whole grain ash retained in the meals (Table 4). Meal ash content correlated significantly and negatively with grain hardness with ADHM, indicating that the softer the grain, the more contaminated with bran the meal would be.

Table 4. Effects of Abrasive Decortication & Hammer Milling (ADHM) and Roller Milling (RM) on the Ash Content of Sorghum Meal

Sorghum type	Ash content of the meal (g /100 g)		
	Whole grain	**ADHM**	**RM**
BSH1	1.64g	1.38f [70.1]	1.49f [74.3]
Kanye Std	1.14a	1.00a [62.2]	1.04a [78.2]
LARSVYT	1.43d	1.31e [72.8]	1.42e [81.5]
Lekgeberwa	1.38cd	1.11b [64.4]	1.25b [77.5]
Buster	1.42cd	1.23d [64.3]	1.33cd[78.8]
Marupantsi	1.16a	1.01a [63.8]	1.04a [75.3]
Mmabaitse	1.58fg	1.10b [45.5]	1.33cd[69.9]
Phofu	1.36bc	1.21d [72.1]	1.27bc[75.1]
Sefofu	1.50e	1.24d [62.7]	1.38de[77.8]
Segaolane	1.32b	1.22d [78.7]	1.28bc[84.5]
SNK	1.43d	1.12b [52.9]	1.23b [71.7]
Town	1.55ef	1.16c [51.4]	1.41e [75.2]
Mean	1.41	**1.18a [63.4]**	**1.29b [76.6]**

Figures in square brackets are amounts (%) of whole grain ash retained in the meal

Table 5. Effects of Abrasive Decortication & Hammer Milling (ADHM) and Roller Milling (RM) on the Oil Content of Sorghum Meal

Sorghum type	Oil content of the meal (g /100 g)		
	Whole grain	**ADHM**	**RM**
BSH1	3.63e	2.53g [57.9]	2.56d [57.5]
Kanye Std	3.34c	2.14cd [45.4]	2.22b [56.9]
LARSVYT	3.31c	2.04bc [49.0]	2.31bc[57.4]
Lekgeberwa	4.67i	3.44i [58.9]	3.62h [66.3]
Buster	3.47d	2.36f [50.6]	2.68e [65.1]
Marupantsi	3.38c	2.28ef [49.4]	2.38c [59.1]
Mmabaitse	2.82a	1.67a [38.8]	2.06a [60.7]
Phofu	3.03b	1.99b [53.5]	2.37c [63.1]
Sefofu	4.20h	3.17h [57.4]	3.40g [68.6]
Segaolane	3.87g	3.19h [69.9]	3.03f [67.9]
SNK	3.65e	2.56g [47.4]	2.57d [58.6]
Town	3.79f	2.18de [39.4]	2.53d [55.1]
Mean	3.98	**2.46a [51.5]**	**2.64b [61.4]**

Figures in square brackets are amounts (%) of whole grain ash retained in the meal;

RM generally produced meals with significantly higher oil content than ADHM (Table 5). Overall, 55-69% of the oil originally present in the whole grain was retained in the meal with RM, while ADHM retained 39-70%, indicating that with ADHM high meal purity was achieved at the expense of extraction rate.

Particles size of the meals

RM produced finer meals, with all the particles passing through a 710 µm sieve size opening, whereas ADHM produced relatively coarser meals.

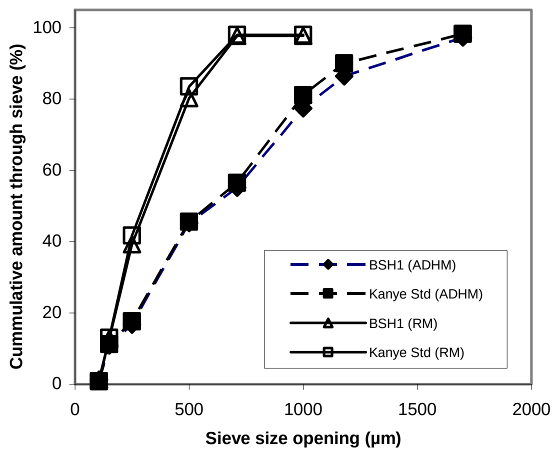

Fig 3. Particle size distributions of sorghum meals produced from corneous (BSH1) and intermediate (Kanye Std) endosperm grains with abrasive decortication & hammer milling (ADHM) and roller milling (RM).

Conclusions

RM produces meals with slightly darker colour and higher ash and oil contents than ADHM, but this slight loss in meal purity is offset by a substantial gain (11%) in extraction rate. Thus, RM holds great potential as a large-scale milling process for sorghum.

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