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Effect of germination and degree of grind (coarse/fine) on the extract and sugar contents of sorghum malts

O. O. Lasekan, M. A. Idowu & W. Lasekan

Department of Food Science and Technology, University of Agriculture, PMB 2240, Abeokuta - Ogun State, Nigeria

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Two sorghum cultivars, FDI and MDW, germinated for 2, 4 and 6 days, were micro-malted separately and milled into coarse (0·8–1·2 mm) and 'fine' (< 0·2 mm fraction) particle size. The extract, diastatic activity, residual starch and sugar production pattern of the differently ground malts were studied. The hot water extract, diastatic activity and sugar contents were increased by an extended period of germination and finer milling. While all studied parameters (hot water extract, diastatic activity, residual starch and sugar contents) were highly positively correlated for both coarse and 'fine' ground malts, only the hot water extract showed significant ($P < 0{\cdot}05$) differences in both types of grind (coarse and fine).

INTRODUCTION

Malting involves the germination of grain in such a way as to degrade or modify the endosperm, with a minimal loss in grain weight (Cook, 1962). Also, the process is designed to produce grain from which the maximum amount of carbohydrate can be extracted for fermentation in brewing and production of adequate levels of enzymes. The endosperm of malted sorghum retains starch compaction and is not as friable as the malted grain of barley (Palmer *et al.*, 1989). In malting barley, the combined actions of endo-β-glucanase and proteases render the hard endosperm friable, and optimal starch and protein extracts are released during mashing (Palmer, 1989). In mashing sorghum, endo-β-1, 3-glucanase tends to effect limited attack on the endosperm cell walls, causing some β-glucans to be released during mashing. Even in the presence of additional quantities of endo-β-1,3:1,4-glucanase and β-amylase enzymes, which are deficient in the malted sorghum, the malt will not give extracts comparable to barley malt (Palmer *et al.*, 1989; Okon, 1992).

To improve the extract development of sorghum malt, Palmer (1989) devised a decantation mashing procedure which converted sorghum malt more efficiently. Whilst the new sorghum malt mashing procedure produced worts which had starch extracts comparable with those of barley malt (Palmer *et al.*, 1989), the fermented extracts of the sorghum worts were still lower than those of barley malt. Recently, Blanchflower and Briggs (1991) reported a significant increase in the hot water extract values of triticales by an extended period of germination and finer milling. Okon (1988) has also suggested the possible dependence of sugar production in sorghum malt on the fineness of the grind.

In this study the effects of germination and of coarse/fine grind on the extract yield, and sugar production in two cultivars of sorghum malts were determined. The objective was to determine the desirable malt grist size range for increasing the level of fermentable sugars in the decantation malt mashing procedure of sorghum.

MATERIALS AND METHODS

Samples of sorghum varieties FDI and MDW were obtained from the International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Kano.

Thousand kernel weight was determined by the AOAC (1962) method. Endosperm texture and pericarp thickness were determined by the method of Rooney and Miller (1981).

Malt production

Sorghum was malted as described by Lasekan (1991, 1993). From each of the samples of FDI and MDW, 100 g were taken after germination for 2, 4 and 6 days

Table 1. Physical properties of sorghum cultivars FDI and MDW

Properties	Cultivars	
	FDI	MDW
One thousand kernel weight (g)	30·06[b]	42·20[a]
Endosperm texture	2·9[b]	3·1[a]
Pericarp thickness	Thin	Thick
Germination energy (%)	91[b]	96[a]
Germination capacity (%)	91[b]	97[a]
Malt yield %		
day '0'	95·1[b]	98·0[a]
day 2	70·6[b]	75·6[a]
day 4	52·1[b]	51·4[a]
day 6	39·7[b]	43·6[a]

Means of the same letter along the same row are not significantly different ($P > 0·05$).

and kilned separately before analysis. The malted grains were weighed and the weights used to calculate the malt yields. Malt yield was calculated as:

% Malt yield =
(Weight of dry malt/Weight of dry raw grain) × 100

Milling

A type-IV microhammer–cutter mill (Glen Mills Inc., Maywood, NJ) at settings of 0·7 mm and 0·2 mm was used in milling 100 g of each sorghum malt sample. Each sample of ground sorghum (100 g) was sifted on a stack of shaken sieves with apertures of 1·6, 1·2, 0·8, 0·7 and 0·2 mm. The grist retained on each sieve and that collected in the receiver pan (< 0·2 mm fraction) were weighed separately and each fraction was expressed as a percentage of the sum of sieved material to obtain the particle size distribution. The fraction <0·2 mm is referred to as the 'fine' flour fraction in this paper.

Chemical analysis

Total soluble sugars from coarse/fine ground sorghum meal were extracted with hot 80% aqueous ethanol. After evaporating the contents *in vacuo*, the residue was dissolved in water and made up to a known volume. Total soluble sugars were estimated by the phenol-sulphuric acid method (Dubois *et al.*, 1956). The extract was determined by the Institute of Brewing (1977) method. The sucrose content was determined by the Lane and Eynon method (Osborne & Voogt, 1978). The total fermentable sugars were estimated by adding up values obtained for the reducing sugars and sucrose contents. Diastatic activities of the malted samples were determined using a modified method of Henry (1984). One gramme of sample was extracted with 20 ml of NaCl (0·5% w/v) solution for 1 h at 25 °C. The extracts were filtered through Advantec No. 2 filter paper (Toyo Roshi Inc., Tokyo). The enzyme extracts were diluted 1 : 5 times and 1 ml aliquots were used to digest 20 ml of 2% acetate buffered (pH 4·5) starch solutions at 25 °C for 30 min. The reducing sugars were obtained by the method of Henry and Blakeney (1988). Diastatic power was calculated as milligrammes of reducing sugar produced per second per milligramme of malt.

Statistics

Analysis of variance (ANOVA) and correlation coefficients were calculated following the procedures in Blank (1980).

RESULTS AND DISCUSSION

The physical properties of grains and malts from FDI and MDW sorghum cultivars are shown in Table 1. The thousand kernel weight of sorghum cultivar MDW (42·20 g) was significantly ($P < 0·05$) higher than that of FDI (30·06 g). The endosperm texture of the sorghum cultivars had an intermediate texture between corneous and floury. The pericarp of MDW was thicker than that of the FDI. Similarly, the germination energy and germination capacity of MDW were also significantly ($P < 0·05$) higher than those of FDI. The malt yield of the sorghum cultivars decreases with germination time. However, the malt yield of MDW cultivar was significantly ($P < 0·05$) higher than that of the FDI cultivar.

The distributions of particle sizes in the sorghum cultivars (FDI and MDW) grists were determined (Table 2). Harvested sorghum does not have a husk, and visual inspection showed that, in the sorghum coarse grists, there were no large husk-like particles as seen in barley grists. Also, the flour particles were very granular in appearance. The distribution of particle sizes in coarsely ground sorghum malt cultivars showed that the MDW had fewer larger and fewer fine particles than the FDI cultivar. This is probably a reflection of

Table 2. The distributions of grist particle sizes of sorghum cultivars (FDI and MDW)

Grist	Malt type	Sieve fraction (% fresh weight)					
		1·6 mm	1·2 mm	0·8 mm	0·7 mm	0·2 mm	< 0·2 mm
Coarsely ground	MDW	6·2	29·1	34·0	12·0	16·0	2·7
	FDI	6·0	27·6	32·4	10·2	14·0	9·8
Finely ground	MDW	1·2	3·0	6·2	8·1	40·5	51·0
	FDI	0·1	0·9	4·5	7·7	37·0	59·8

The results are the means of duplicate determinations.

Table 3. The extract and sugar contents of two malted sorghum cultivars (FDI and MDW) of different grist sizes

Malt type	Grist size	Germination days	HWE[a] (L°/kg)	Sugars (mg/100 grains)				
				TSS	RS	S	TFS	NFS
		0	ND	33·6	12·0	10·0	22·0	11·6
FDI	(< 0·2 mm)	2	265	99·0	86·1	11·0	97·1	1·9
'fine'		4	272	104	106	17·4	123	7·5
		6	278	104	92·6	6·7	99·3	4·4
FDI	(0·8–1·2 mm)	0	ND	33·6	12·0	10·0	22·0	11·6
'coarse'		2	262	99·8	86·8	9·1	95·9	3·6
		4	269	125	104	16·6	121	4·1
		6	273	64·4	55·7	5·2	60·9	3·5
MDW	(< 0·2 mm)	0	ND	36·2	12·6	11·0	23·6	12·6
'fine'		2	268	118	101	11·3	113	4·9
		4	274	165	147	14·1	161	3·5
		6	280	143	138	2·9	141	1·9
MDW	(0·8–1·2 mm)	0	ND	36·2	12·6	11·0	23·6	12·6
'coarse'		2	263	106	89·8	11·3	101	4·9
		4	271	159	137	17·5	154	4·4
		6	275	122	120	1·4	121	1·0

[a] HWE (hot water extract 45 °C–80 °C–65 °C: TSS, total soluble sugar; RS, reducing sugar; S, sucrose; TFS, total fermentable sugar; NFS, non-fermentable sugar; ND, not determined.

the differences in their physical properties. Also, the FDI cultivar tended to have more fine particles than the MDW cultivar.

As with barley malts and triticale malts (Blanchflower & Briggs, 1991), hot water extract (HWE) values of the sorghum malts were increased by a more extended period of germination and finer milling (Table 3). In contrast to barley malt grists, wort separation from the sorghum malt grist was affected primarily by the degree of milling and only to a lesser extent by the malt germination period. The MDW sorghum cultivar produced more HWE in all types of grind than the FDI cultivar. Finely ground malt samples tended to produce more HWE than the coarse samples. Statistical analysis also showed that the HWE in coarse and finely ground malts were positively correlated for both FDI (r = 0·994) and MDW (r = 0·982) cultivars (Table 4). The F-values also indicated significant (P < 0·05) differences between the HWE of coarse and finely ground malts (Table 4).

The pattern of variation of the sugars during the malting stage showed that the sugars decreased in concentrations in 'one-day' malts (values not presented in table) but showed a rapid increase in concentration in 'two-day' malts and the 'four-day' malts (Table 3). After the fourth day of germination there was no further substantial increase in sugar concentration. This observation is similar to those reported by Faparusi (1970) and Vaidyanathan *et al.* (1992). The observed trend could be traced to the steeping stage when the metabolic activities of the grains which were previously

Table 4. Correlation and F-value matrix among grist's fermentable sugar, hot water extract, diastatic activity and residual starch of two cultivars of sorghum malts (FDI and MDW)

Malt type		Statistical analysis						
		Correlation (r)				F-values		
		Fine malt grist (< 0·2 mm)				Fine malt grist (<0·2 mm)		
Coarse	(0·8–1·2 mm)	TFS	HWE	DU	RES	TFS	HWE	DU
FDI	TFS	0·767				1·32*		
	HWE		0·994				29·17**	
	DU			0·998				2·71
	RES				0·996			
MDW	TFS	0·970				10·89*		
	HWE		0·982				40·77**	
	DU			0·999				4·06*
	RES				0·989			

TFS, Total fermentable sugar; HWE, hot water extract; DU, diastatic unit; RES, residual starch.
*Not significant (P > 0·05); ** significant (P < 0·05).

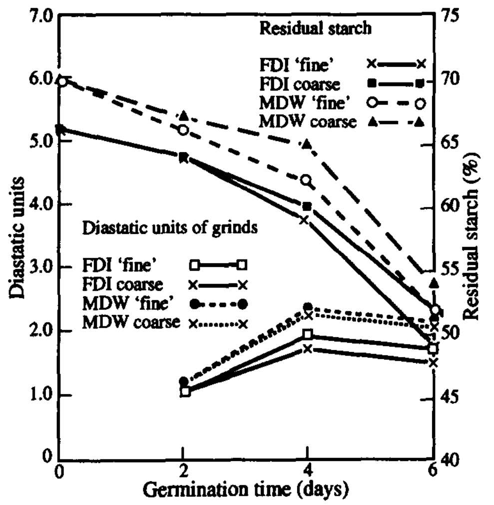

Fig. 1. The effect of germination time and particle sizes on the residual starch and diastatic activities (DU = mg glucose/mg of malt/sec from 2% soluble starch at 25°C) of two cultivars of sorghum.

dormant were resumed. Some of the sugars would be used in the metabolic processes.

Also, sorghum grains germinate rapidly and hence will require high energy-level compounds. This could be responsible for the initial fall in the concentrations of the sugars. However, when the amylase activity resumed, more sugars were produced than required for metabolism. This probably accounts for the increase in the concentration of the sugars between the second and the fourth day of germination.

In the present study, finer milling tended to increase the sugar content of the sorghum malts (Table 3), but the sugars produced, especially fermentable sugar (TFS), were still relatively lower than those of barley malt (Okon & Uwaifo, 1985). Whilst the total fermentable sugars (TFS) of the fine and coarsely ground malt samples (FDI and MDW) were positively correlated (Table 4), there was no significant ($P > 0{\cdot}05$) difference in the level of TFS produced by the different types of grind (coarse and fine) (Table 4).

Similar trends were noticed in the diastatic activities of the different malt samples (Fig. 1), but there have been conflicting views as to when the activity of these enzymes becomes manifested. In the present study, detectable activity started on the second day. The diastatic activity and the residual starch contents of coarse and finely ground malts were also positively correlated (Table 4) but there was no significant ($P > 0{\cdot}05$) difference between the diastatic activities of coarse and finely ground sorghum malts (FDI and MDW).

CONCLUSION

The hot water extract values of the sorghum malts were increased by a more extended period of germination and finer milling. High positive correlations and significant ($P < 0{\cdot}05$) differences were obtained for the HWE from both coarse and finely ground malts. The sugar production and diastatic activities of the sorghum malts followed a similar trend to the HWE. However, no significant ($P > 0{\cdot}05$) differences were noticed in the sugar contents and diastatic activities between coarse and finely ground malts.

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