963

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The Influence of Some Aspects of Grain Quality on Malting Potential in Sorghum

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ABSTRACT

Several grain and malt quality tests were applied to 22 sorghum cultivars, 17 with a white or yellow pericarp and five with brown grain. Significant differences between cultivars were found in all cases. The yellow- and white-grained sorghums showed a relationship between milling energy and both extract and grain nitrogen content, although significant correlations were not observed when all cultivars were analysed. The reduction in milling energy due to malting correlated significantly with the amount of nitrogen extracted, leading to a close relationship between soluble nitrogen ratio and malt milling energy, especially in white and yellow sorghums. All white- and yellow-grained cultivars, with high levels of extract, showed a higher grinding resistance for a given level of milling energy. This may derive from a greater degree of starch damage during milling, facilitating solubilisation of starch and partly overcoming problems associated with poor endosperm modification during malting and high gelatinisation temperature of unmodified starch granules.

INTRODUCTION

Sorghum has been traditionally malted in parts of Africa to produce an opaque beer[1]. Recently, interest has focused on the use of sorghum to replace barley, partially or completely, in the production of lager beer in Nigeria. This has resulted from the ban on barley imports, imposed by the government in 1988[2]. Considerable variation in quality characteristics exists in sorghum, and breeding of malting-quality cultivars should be possible[3]. In practice, with current genotypes, however, replacement of barley malt with malted sorghum in brewing is fraught with problems, which must be addressed by the breeder seeking to produce new cultivars. Enzyme levels, especially of amylases, are low[4], germination is frequently poor and uneven[5] and starch gelatinises at a relatively high temperature compared with that in barley[6]. Consequently, extract levels can be low, while malting losses, associated with the considerable rootlet and plumule growth observed, are unacceptably high[7].

Sorghum is unresponsive to exogenous gibberellic acid[8], so improved malting performance is highly dependent on the production of cultivars with better malting characteristics. This is, in turn, dependent on seeking genotypes with improved expression of the factors listed above and incorporating the desired genes into adapted genotypes. Within breeding programmes, however, selection for malting quality is complicated by the very large numbers of samples with small quantities of grain, so rapid, small-scale tests are necessary[9]. Unlike barley, it has not, so far, proved possible to assess malting potential from tests performed on unmalted sorghum grain[10], although some success has been achieved in adapting tests used for screening malted barley. Swanston *et al.*[10] suggested screening breeding lines by measuring the milling energy of sorghum malt, i.e. the mechanical energy required to grind a sample to flour, and the diastatic power, following extraction of the flour.

In barley, milling energy has been shown to relate to both cell-wall structure[11] and the ease of modification of the protein matrix around the starch granules[12]. During the malting of sorghum, cell walls appear to remain substantially intact[13],

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Table I Results of unmalted grain tests on 22 sorghum cultivars

Character	Milling energy (joules)	Grinding resistance (s)	Grain nitrogen (%)
Mean	275	7·0	1·46
Min	176	3·1	0·94
Max	369	10·9	1·97
Sig. of diff.			
Between cultivars	***	***	***
Between duplicates	ns	ns	ns

*** $0{\cdot}001 > P$.
ns, not significant at the 5% level.

so the reduction of milling energy during malting would be expected to result from degradation of other structural components in the grain. In this paper we consider whether the relationship between results from several grain tests can, in fact, give some indication of malting potential in sorghum. We also consider the effects, both of grain nitrogen content and the portion extracted during the malting process, on other aspects of quality. A rapid method for measuring extracted nitrogen is also assessed as a potential test for rapid screening of sorghum malt samples.

EXPERIMENTAL

Materials

Twenty-two sorghum cultivars covering a wide range in malting quality were used in the study. Of the 22 genotypes assessed, 17 had white or yellow pericarps, while the remaining five were of the red or brown type. As cultivars of the latter type gave low extracts in a previous study on malting quality[3], they may influence strongly the relationship between grain and malt results. In this paper, therefore, results are presented both for all samples and for white- and yellow-grained samples only.

Methods

The grain samples were assessed in duplicate for a number of grain quality attributes. These comprised grain milling energy[14] and grinding resistance, a measure of the time required to collect a given quantity of flour during the milling process[15]. The samples were also malted in duplicate by the method of Swanston *et al.*[16].

Malted samples were extracted as described by Jayatissa *et al.*[3], except that sample size was scaled down[16]. Extractable nitrogen content was determined by a Technicon auto-analyser technique[1] and, in addition, by a rapid spectrophotometric method[18]. This involved measuring the difference in absorption at two wavelengths in the UV spectrum of a dilute malt extract and calculating from a standard equation. Diastase activity was measured as described previously[16], including the portion remaining active after heat treatment[10]. In barley, this portion is regarded as *alpha*-amylase, but, as this was not confirmed in this experiment, it will be referred to here as heat-stable amylase. Milling energy of the malt samples was also assessed and the proportion (%) of milling energy lost during the malting process calculated.

RESULTS AND DISCUSSION

A wide range in values was obtained for all the grain quality characteristics measured (Table I). Agreement between duplicate measurements for grain nitrogen and milling energy values were of the order observed in populations assessed previously[16]. Similarly, characters measured after malting showed large differences between cultivars (Table II), although the effect of the malting process was to introduce larger differences between laboratory replicates. These probably arose from slight differences in the extent of modification as no problems or obvious differences in germination were observed during malting.

In a previous study, no relationship was found between hot-water extract and either grain nitrogen content or grain milling energy[16]. Here, a similar result was found when all cultivars were included (Table III). A significant negative correlation was observed between milling energy and extract for white- and yellow-grained cultivars,

Table II Results of tests on malted grain of 22 sorghum cultivars

Character	Extract (%)	Malt milling energy (joules)	Extractable nitrogen (g/litre)	Diastase (enzyme units)	Heat-stable amylase (enzyme units)
Mean	53·7	152	0·347	4·0	2·4
Min	29·6	112	0·151	1·3	0·8
Max	70·2	256	0·532	8·2	4·4
Sig. of diff.					
Between cultivars	***	***	***	***	***
Between duplicates	**	**	ns	ns	ns

*** $0{\cdot}001 > P$, ** $0{\cdot}01 > P > 0{\cdot}001$.
ns, not significant at the 5% level.

Table III Correlations between extract and results of grain tests of 22 sorghum cultivars

Character	Correlation coefficient
Extract per cent vs	
Grain nitrogen (%)	−0·185 ns (−0·212 ns)
Milling energy (joules)	−0·150 ns (−0·557*)
Grinding resistance (s)	−0·031 ns (−0·167 ns)

* $0{\cdot}05 > P > 0{\cdot}01$.
ns, not significant at the 5% level.
Figures in parenthesis exclude the five high-tannin brown-grained cultivars.

however. No correlation with extract was observed for grinding resistance. In barley, Camm *et al.*[12] suggested that milling energy did not correlate significantly across cultivars with grain nitrogen content, but significant correlations were observed between milling energy and both total extractable (soluble) nitrogen and soluble nitrogen ratio (SNR). This disagreed with a previous study[9], in which grain nitrogen content was shown to correlate significantly, though not highly, with both milling energy and grinding resistance. The relationship between parameters of grain hardness and nitrogen content of sorghum grain and wort were therefore considered here.

A highly significant correlation was found between extractable nitrogen as determined by the spectrophotometric and auto-analyser methods, respectively (Table IV). Consequently, the rapid method would appear to be extremely suitable as a screening procedure. The data obtained can also be used to calculate the soluble nitrogen ratio (SNR), i.e. the proportion (%) of nitrogen extracted during the malting process. Results presented in Table IV show that, for all samples, there was no significant correlation between grain nitrogen content and either grinding resistance or milling energy of grain or malt. For white- and yellow-grained cultivars, a significant correlation was observed between grain nitrogen content and grain milling energy, similar in magnitude to that previously observed between milling energy and extract (Table III). In all cultivars, however, both malt milling energy and especially milling energy loss during malting were significantly correlated with the quantity of nitrogen extracted during malting (Table IV). This led to a significant association between the milling energy of the malt, which is an indication both of the initial grain milling energy and the extent to which it is reduced by breakdown of the internal structure of the grain during malting, and SNR, which is dependent on both the initial nitrogen content and the proportion extracted. This was particularly evident in white- and yellow-grained cultivars, where a highly significant correlation was observed between malt milling energy and SNR.

In sorghum, a very close association has been found between endosperm texture, i.e. the proportion of vitreous endosperm, and the work required to grind a sample, as assessed by both the Brabender hardness test and in an Alpine universal mill[19]. As milling energy is a measure of the mechanical energy used in grinding, it is likely to be influenced by a similar aspect of the endosperm structure. It might also be assumed that an endosperm texture resistant to milling would take longer to reduce to flour, so a close association between grinding resistance and other grain hardness tests would be expected. Differences in the relationships of milling energy and grinding resistance to both the extract and nitrogen contents

Table IV Correlations between grain and extractable nitrogen contents and grain and malt hardness parameters in 22 sorghum cultivars

	Grain nitrogen	Extractable nitrogen (rapid method)	Soluble nitrogen ratio
Extractable nitrogen (auto-analyser)		0·900***	
Grinding resistance	0·416 ns	0·184 ns	−0·191 ns
	(0·478 ns)	(0·158 ns)	(−0·327 ns)
Grain milling energy	0·372 ns	−0·017 ns	−0·353 ns
	(0·573*)	(−0·102 ns)	(−0·680**)
Malt milling energy	0·154 ns	−0·446*	−0·635**
	(0·248 ns)	(−0·491*)	(−0·779***)
Milling energy loss during malting	0·240 ns	0·585**	0·436*
	(0·278 ns)	(0·645**)	(0·423 ns)

Levels of statistical significance as in Tables I–III.
Figures in parenthesis exclude brown-grained cultivars.

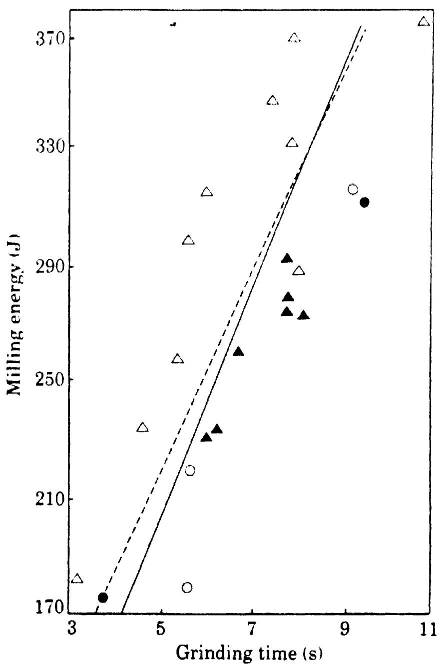

Figure 1 Relationship between milling energy and grinding resistance for 22 cultivars of sorghum. Correlation coefficient $r = 0{\cdot}81$, $0{\cdot}001 > P$. Regression equations are as follows: for all cultivars (continuous line) $y = -0{\cdot}301 + 0{\cdot}026x$; for white and yellow types only (broken line) $y = -0{\cdot}798 + 0{\cdot}027x$. △, white- or yellow-; ○, brown-grained. Shading of symbols denotes genotypes with extracts above 60%.

of yellow- and white-grained cultivars appeared to contradict this assumption, and suggested that comparison between results obtained by the two methods may be of interest.

A highly significant correlation was observed between these two aspects of grain hardness, and it was possible to draw regression lines both for all genotypes and for white- and yellow-grained cultivars only (Fig. 1). For the latter group, it was observed that the regression line divided the population into two distinct groups; all those having an extract in excess of 60% fell into the group with higher grinding resistance times for a given level of milling energy. These are listed in Table V, along with the two other white or yellow cultivars in the same group. Of these, genotype 14 gave a very low extract, but was also characterised by a low SNR, a low level of heat-stable amylase activity and a high malt milling energy. For the cultivars assessed here, therefore, it appears that the relationship between milling energy and grinding resistance offers a means of eliminating most of the genotypes without malting potential by means of tests performed on the unmalted grain, greatly reducing the number of samples on which malting and subsequent enzyme assays are necessary. If the remaining samples are then further selected, following malting, for either malt milling energy or heat-stable amylase, it would leave a population containing eight yellow or white genotypes, which includes the seven with the highest extracts of the 17 malted here. For the sorghum breeder, seeking a rapid means to select the most promising lines,

Table V Malting results for white- or yellow-grained sorghums with a low milling energy: grinding resistance ratio. Units of measurement are as in previous tables

Genotype number	Extract	Rank for extract[a]	Extractable nitrogen	SNR	Diastase	Heat-stable amylase	Malt milling energy
1	61·0	8	411·1	25·5	4·0	2·4	143·0
2	61·5	7	390·2	32·3	4·2	3·4	142·1
5	60·1	9	355·4	25·7	4·7	2·4	158·7
7	65·9	4	427·3	27·5	7·0	4·1	140·2
8	57·7	11	418·0	31·6	5·2	2·4	151·3
9	66·9	3	372·8	29·2	2·8	2·6	123·4
10	68·2	2	333·3	25·8	2·9	2·8	140·6
14	42·4	19	288·1	21·1	2·9	1·4	252·4
18	70·2	1	384·4	33·1	6·4	2·5	117·8

[a] Rank is based on performance of all cultivars tested. Those ranked 5 and 6 were brown-grained and are not included in the above table.

Table VI Correlations between extract, diastase activity and a range of malt tests on 22 sorghum genotypes

	Extract	Diastase	Heat-stable amylase
Diastase	0·281 ns (0·119 ns)		
Heat-stable amylase	0·621** (0·574*)	0·496* (0·455 ns)	
Malt milling energy	−0·387 ns (−0·592*)	−0·266 ns (−0·343 ns)	−0·511* (−0·556*)
Extractable nitrogen	0·240 ns (0·284 ns)	0·756*** (0·811***)	0·580** (0·617**)
SNR	0·475* (0·535*)	0·475* (0·379 ns)	0·514* (0·574*)

Levels of statistical significant as in Tables I–III.
SNR–soluble nitrogen ratio.
Figures in parenthesis exclude brown-grained types.

rather than necessarily measuring quality parameters to the highest degree of accuracy, this is therefore an approach with considerable potential.

Grinding resistance is defined as the time required to collect a given volume of flour, and is strongly influenced by the particle size distribution within the flour[15]. The manner in which the endosperm fractures is important, and, in particular, a strong association was observed in wheat[15] between grinding resistance and extent of starch damage. In sorghum, physical damage of starch granules facilitates extraction[20], and would, therefore, partially overcome problems associated with poor modification of the vitreous endosperm[7] and high gelatinisation temperature of the unmodified starch granules[6]. Sufficiently high levels of starch-degrading enzymes, with an adequate proportion of heat stability, would be necessary to obtain a high level of extract, following the procedure used here. It is possible, therefore, that those genotypes, which show higher levels both of extract and of grinding resistance, at given levels of milling energy, may also exhibit a higher degree of starch damage during milling.

In barley, all genotypes with the highest levels of extract have a low milling energy due to a mealy endosperm texture[21]. In this study, high levels of extract were associated with sorghum genotypes over a range of milling energy (Fig. 1).

Mould resistance is a particular problem in cultivars lacking tannins, and soft-grained types are particularly vulnerable[22]. By selecting genotypes with moderately high levels of milling energy and high levels of grinding resistance, it may be possible to combine improved mould resistance with malting potential.

Table V indicates that genotype 14 may have given poor extract because of poor modification or heat-stable amylase activity, rather than low diastase, although a previous study showed a highly significant correlation between diastase and extract[16]. A close association between diastase and heat-stable amylase was also observed, however[10]. In this population, the correlation between diastase and heat-stable amylase was much lower, especially in the white- and yellow-grained types, where it failed to reach significance (Table VI). Consequently, while the level of heat-stable diastase was significantly correlated with extract, the total diastase activity, which included a substantial heat-labile proportion in certain genotypes, was not. A significant correlation was observed between malt milling energy and extract, for white and yellow cultivars, but this was of a much lower magnitude than that observed for malted barley[23], where amylase levels are much less critical. Extract also correlated significantly with SNR, but at too low a level to enable SNR to be used as a predictor of extract.

The highly significant correlation between diastase activity and total extractable (soluble) nitrogen (Table VI) suggested an association between starch- and protein-degrading enzymes. In barley, a number of enzymes are synthesised and released under the control of gibberellic acid, but a similar mechanism has not been detected in sorghum[8]. Two proteolytic systems have been investigated in malting sorghum, however, and one, an exopeptidase associated with the embryo, showed a similar pattern in development to the amylase also associated with this tissue[8]. The possibility that the synthesis and release of several sorghum enzymes could be under some form of common control remains an area for further study.

In conclusion, it appears that, within the white- and yellow-grained sorghums assessed here, it is possible to predict malting potential from unmalted grain. In addition, measurement of malt milling energy, which correlates highly with SNR, may be a useful indicator of the extent of grain modification during malting.

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