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GRAIN AND MALT MILLING ENERGIES IN SORGHUM AND THEIR RELATIONSHIPS WITH EXTRACT AND DIASTATIC POWER

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Twenty three sorghum genotypes were shown to vary widely for a range of grain and malt quality characters. Grain milling energy did not give an indication of the likely malting performance of sorghum samples. There were, however, close relationships between malt milling energy and both % extract and diastatic power, if samples with unusually high or low grain nitrogen contents were excluded from the population under study. Rapid screening of very small malt samples for milling energy and diastatic power could form the basis for malting quality selection in early generations of sorghum breeding programmes.

Key Words: *Sorghum (Sorghum bicolor (L.) Moench), malting quality, extract, milling energy, diastatic power*

INTRODUCTION

The ban imposed by the Nigerian government, in 1988, on the import of barley malt, has necessitated the use of indigenous cereals such as sorghum (*Sorghum bicolor* (L.) Moench) in the brewing industry[4]. Sorghum malt has been utilised in the production of opaque, or kaffir beer, on an industrial scale, in southern Africa. Consequently, much of the research on malting quality in sorghum has been directed towards cultivars suitable for this purpose[8]. Aisien and Muts[5] suggested that the use of sorghum in the brewing of European type lager beers was adversely affected by slow saccharification and severe filtration problems. However, Jayatissa *et al.*[13] suggested that there was a wide range, within the sorghum germplasm, for a number of malting characters, with some cultivars producing malt extracts comparable with those of barley.

The breeding of sorghum genotypes suitable for malting appears to be feasible, but it will encounter the same problems found in barley. The very large numbers of small samples from the early generations of breeding programmes necessitate the use of rapid screening tests[9]. This paper reports a preliminary assessment of whether certain techniques developed for barley could be successfully adapted to enable screening for malting quality in sorghum.

MATERIALS AND METHODS

A range of sorghum samples was provided by the West African Sorghum Improvement Programme of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Of these samples, 24 were chosen for the present study, representing a wide range in both grain nitrogen contents and milling energies. These grain samples were harvested from an irrigated off season breeding nursery grown at Kadawa, Nigeria, during February–May, 1990. Most of the genotypes represent improved cultivars bred by ICRISAT, using parents of diverse origin. The grain was sun dried and fumigated with phostoxcin. Milling energies were assessed on 5 g samples of all genotypes by means of a Comparamill[1] and nitrogen contents were determined, using a Kjeltec 1030 auto analyser, after digestion of samples by the method of Starr and Smith[16].

Following surface sterilisation for 20 mins, in sodium hypochlorite solution (1% available chlorine)[3], 15 g samples were rinsed before steeping for 3 hr at 25–26°C. Following a 1 hr air rest, steeping was continued for a further 17 hr. For germination, samples were transferred to plastic containers lined with moist filter papers and placed in an incubator containing a tray of water to ensure a high level of humidity. At daily intervals samples were removed and carefully dematted and, every second day, the filter papers were replaced and 4 ml distilled water was added. The temperature was maintained throughout at 25–26°C and germination was allowed to continue for 6 days before kilning at 50°C for 24 hr[10].

Following malting, 5 g malt samples were assessed for milling energy as already described and the resultant flour was retained. From each sample, 1 g of flour was extracted for 3 hr in a 0.5% solution of sodium chloride containing 0.01% calcium chloride. After centrifugation at 6000 rpm for 5 min, diastatic power was measured by an automated method[14]. Results were expressed in enzyme units, where 1 unit will liberate 1.0 mg of maltose from starch in 3 min at pH 6.9 and at 20°C and were calculated from a standard curve prepared from a commercially obtained diastase. Automated analysis of amylase activity, following the above extraction procedure, has been related to a reference method by Smith[15].

Hot water extracts were carried out on 2 g malt samples based on the method of Swanston and Taylor[20] for barley, except that the extraction period and temperatures were as described by Jayatissa *et al.*[13], i.e. 1 hr at 45°C followed by 3 hr at 70°C.

Grain testing and malting were both carried out in duplicate, but during the germination period, both duplicates of sample number 22 became heavily infected with mould and were discarded. Consequently the results presented are confined to the remaining 23 samples.

RESULTS AND DISCUSSION

A wide range was observed within the sorghum population for all the characters measured (Table I). Very close agreement was observed between duplicate measurements on grain characters. In barley, Cowe *et al.*[7] reported standard deviations between duplicate samples for milling energy to be of the order of 2–10 joules. This was higher than for the inorganic standard due to variations in grain shape affecting the physical orientation of the samples falling into the mill. In the sorghum samples assessed, grain shape was more regular and spherical and standard deviations between milling energy estimates were in the region of 1.5–2 joules. Standard deviations between duplicate samples for grain nitrogen content were of the order of 0.01%. Parameters measured on malt showed significant differences between genotypes but not between duplicate malt

TABLE I Variation in grain and malt quality characters in a population of 23 sorghum cultivars

Character	Mean	Standard Deviation	Range Lowest	Range Highest
Grain Milling Energy (Joules)	358.5	56.66	224.5	491.9
Grain Nitrogen (%)	1.50	0.290	1.01	2.40
Extract (%)	58.0	5.96	49.0	69.0
Malt Milling Energy (Joules)	128.0	23.63	90.2	161.1
Diastatic Power (Enzyme Units)	7.5	0.73	4.6	10.2

TABLE II Analysis of variance for characters measured in malted samples of 23 sorghum cultivars

	df	% Extract M.S.	Diastatic Power M.S.	Malt Milling Energy M.S.
Between:				
Genotypes	22	70.97***	5.90***	1116.98***
Duplicates	1	2.93	0.25	1.57
Error	22	12.19	0.53	43.51
Total	45			

*** 0.001 > P.

TABLE III Correlation matrix for grain and malt milling energy, % extract, diastatic power and grain nitrogen content in 23 sorghum cultivars. Figures in parentheses indicate correlation coefficients calculated without samples 14 and 21

	% Extract	Grain Milling Energy	Malt Milling Energy	Diastatic Power
% Extract				
Grain Milling Energy	−0.28			
Malt Milling Energy	−0.45* (−0.75***)	0.67***		
Diastatic Power	0.78***	−0.11	−0.50* (−0.78***)	
Grain Nitrogen	0.15	0.15	0.24	0.44*

* 0.05 > P > 0.01, ** 0.01 > P > 0.001, *** 0.001 > P.

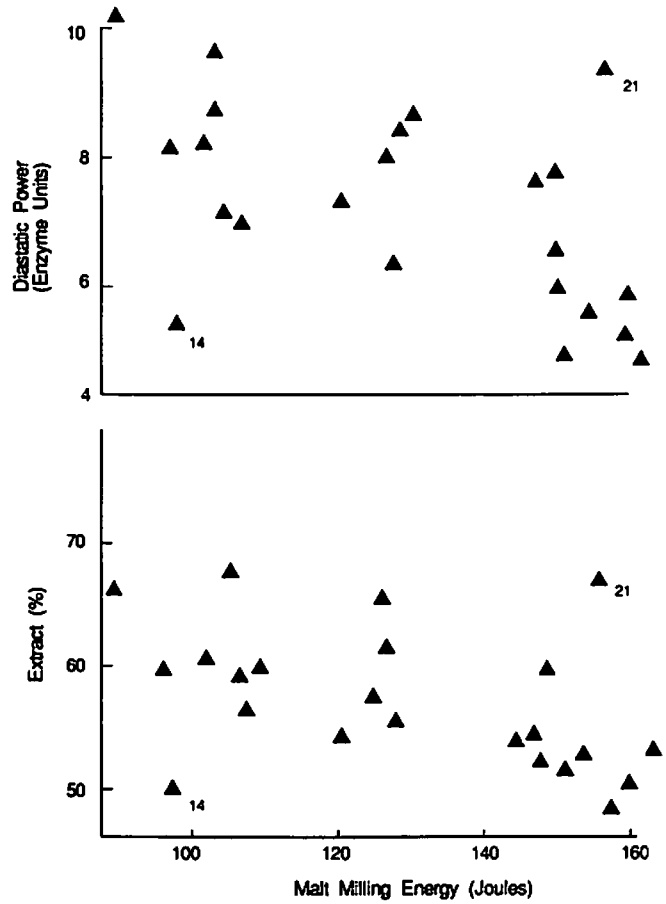

FIG. 1. Relationship between malt milling energy and both diastatic power and extract in 23 sorghum genotypes.

samples derived from the grain of a single genotype (Table II), indicating that the malting technique used should be suitable for screening breeding populations. The range of extract values obtained (approximately 50–70%) was not as wide as that observed by Jayatissa *et al.*[13], but this probably reflects the genotypes in the present study.

A highly significant correlation was observed between % extract and diastatic power (Table III). This confirms previous research which has implicated low levels of starch degrading enzymes as one of the major factors limiting malting quality in sorghum[5] and which necessitates the addition of exogenous enzymes during mashing[4]. There was a significant correlation between diastatic power and grain nitrogen content, but this was low with variation in nitrogen content only accounting for around 20% of the variation in diastatic power.

Correlations involving extract and milling energy in both grain and malt (Table III) differ somewhat from those reported for barley[18] and there was no significant correlation between grain milling energy and % extract in the sorghum samples. The endosperm of sorghum contains both vitreous and mealy regions with the percentage of vitreous endosperm highly correlated with grain hardness as measured in the Brabender hardness test[12]. Therefore, the vitreous part of the endosperm is likely to contribute substantially to the milling energy of the grain. As it remains largely unmodified during malting[5], it will also contribute the major part of malt milling energy. Consequently a strong, positive correlation between grain and malt milling energy, as observed in Table III, would be expected.

In barley, milling energy does not correlate significantly with nitrogen content between cultivars[6], although within cultivars there is an association[7]. A similar situation may exist in sorghum. Genotypes 14 and 21 had nitrogen contents which were very much lower (1.01%) and higher (2.40%) respectively than any of the other samples. They also differed greatly from the other 21 samples with regard to the relationship between malt milling energy and both diastatic power and % extract (Fig. 1). When these two samples are removed from the calculations, the correlations between malt milling energy and both extract and diastatic power are greatly increased. It is therefore suggested that the unusual nitrogen levels of these two samples had a large effect on the structure of the protein matrix within the unmodified part of the endosperm leading to estimations of milling energy which were not strictly comparable with those of the rest of the population. Malt milling energy is likely to be a more useful parameter in predicting samples producing good levels of extract than the correlation coefficient, for all 23 samples, presented in Table III suggests.

It is interesting to note that in genotypes 14 and 21, high extract was associated with the genotype demonstrating high nitrogen content. This is the reverse of what would be expected in barley, but is probably a further demonstration of the importance of diastatic power in determining extract in sorghum. Genotype 14 demonstrated particularly low diastase activity, while high activity was observed in genotype 21.

The highly significant correlation between diastatic power and malt milling energy may directly reflect the contribution of

starch granule modification to loss of milling energy during malting. Aisien[3] observed degradation of starch granules in the mealy endosperm after malting, although the cell wall structure appeared intact. Glennie *et al.*,[11] however, reported that pitting of the starch granules was preceded by removal of the protein matrix. Large amounts of protein were also found to be associated with cell walls isolated from the unmalted grain and these were greatly reduced during germination[10]. Those samples with higher diastase activity may also, therefore, have higher levels of proteases.

This could be predicted in barley, where production and secretion of a range of enzymes are under the control of gibberellic acid, but a similar situation has not been found in sorghum. Aisien[2] reported that the hormones GA1 and GA3, found in barley, are absent in sorghum and addition of exogenous gibberellic acid had no effect on sorghum amylase production. This remains an area where much research is required.

The results presented here suggest that it is possible to apply rapid screening tests, such as milling energy and an automated test for diastatic power on the retained flour to sorghum malt samples. This will constitute a useful screening system for malting potential although there may be some restriction to the range of grain nitrogen content within which it can be operated with optimum precision. While the limited quantities of malt required enable the method to be applied to small grain samples from breeding lines, selection for malting quality cannot, at present, be practised until malting is completed. This may still be too time-consuming to screen very large populations. In barley, changes in milling energy observed early in the malting cycle[19] enable accurate ranking of genotypes for malting potential[17,20]. Future research will be directed towards ascertaining whether sorghum can also be screened following an abbreviated malting regime, thereby enabling an increased throughput of samples.

References

1. Allison, M. J., Cowe, I. A., Borzucki, R., Bruce, F. M. & McHale, R. *Journal of the Institute of Brewing*, 1979, **85**, 262.
2. Aisien, A. O. *PhD Thesis*, Heriot-Watt University, Edinburgh, 1980.
3. Aisien, A. O. *Journal of the Science of Food and Agriculture*, 1982, **33**, 754.
4. Aisien, A. O. In: *Industrial Utilization of Sorghum, Summary Proceedings of a Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria*, ICRISAT, Patancheru, 502324, India, 1990, 29.
5. Aisien, A. O. & Muts, G. C. J. *Journal of the Institute of Brewing*, 1987, **93**, 328.
6. Camm, J-P., Ellis, R. P. & Morrison, W. R. *Aspects of Applied Biology 25, Cereal Quality II*, 1990, 121.
7. Cowe, I. A., Cuthbertson, D. C. & Swanston, J. S. *Journal of the Institute of Brewing*, 1989, **95**, 423.
8. Daiber, K. H., Malherbe, L. & Nouvellie, L. *Brauwissenschaft*, 1973, **26**, 220.
9. Ellis, R. P., Swanston, J. S. & Bruce, F. M. *Journal of the Institute of Brewing*, 1979, **85**, 282.
10. Glennie, C. W. *Cereal Chemistry*, 1984, **61**, 285.
11. Glennie, C. W., Harris, J. & Liebenberg, N. V. D. W. *Cereal Chemistry*, 1983, **60**, 27.
12. Hallgren, L. & Murty, D. S. *Journal of Cereal Science*, 1983, **1**, 265.
13. Jayatissa, P. M., Pathirana, R. A. & Sivayogasunderam, K. *Journal of the Institute of Brewing*, 1980, **86**, 18.
14. Salatan, L. T. & Scharoun, J. *Wallerstein Laboratory Communications*, 1965, **28**, 191.
15. Smith, D. B. *Technicon Colloquium on Automated Analyses*, London, 10 Nov., 1970.
16. Starr, C. & Smith, D. B. *Journal of Agricultural Science (Cambridge)*, 1978, **91**, 639.
17. Swanston, J. S. *Journal of the Institute of Brewing*, 1990, **96**, 209.
18. Swanston, J. S., Allison, M. J. & Taylor, K. *Proceedings of the Third Institute of Brewing Conference on Malting, Brewing and Distilling, Aviemore*, 1990, 338.
19. Swanston, J. S. & Taylor, K. *Journal of the Institute of Brewing*, 1988, **94**, 311.
20. Swanston, J. S. & Taylor, K. *Journal of the Institute of Brewing*, 1990, **96**, 3.