INFLUENCE OF MALTING ON SORGHUM PROTEIN QUALITY

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The cereal sorghum (*Sorghum bicolor*) (L.) Moench) is a critically important food crop in sub-Saharan Africa on account of its drought tolerance. The increased use of sorghum as a food in this region could alleviate the problem of chronic under nourishment, as sorghum is much better suited to cultivation in the semi-arid tropics than non-indigenous cereals such as wheat or maize. However, a problem with sorghum is that the quality of its protein, in terms of digestibility is inferior to that of other cereal foods, especially when sorghum foods are cooked. Research conducted within EC INCO-DC PROJECT "Improvement of the protein quality of sorghum and its introduction into staple food products for southern and eastern Africa" showed that malting, in addition to improving the malt quality characteristics (e.g. diastatic power and free amino nitrogen), improved the digestibility and quality of the protein, which generally increased with increasing malting time. In one of the sorghum varieties studied *in vitro* protein digestibility was improved by a staggering 110%. Malting similarly improved other protein quality characteristics, including percentage protein, the nitrogen solubility index and the content of the first limiting amino acid, lysine. Soaking sorghum grain for a relatively short period during the steeping process in a dilute solution of NaOH was found to significantly improve the beneficial effects of malting in terms of diastatic power and free amino nitrogen and to marginally enhance the beneficial effect of malting on the protein quality and digestibility. It would appear that the simply technology of malting may offer a means by which to improve the quality and digestibility of sorghum protein.

INTRODUCTION

The cereal sorghum (*Sorghum bic*olor) (L.) Moench) is indigenous to the semi-arid tropics (SAT) of Africa. The increased use of sorghum as a food in sub-Saharan Africa could alleviate the problem of chronic under-nourishment, as sorghum is much better suited to cultivation in the SAT than non-indigenous cereals such as wheat or maize. It can endure hot and dry conditions and also withstand heavy rainfall accompanied by some water logging. In fact, sorghum can consistently produce a crop under climatic conditions where other cereals fail.

However, a well-identified and important problem relating to the nutritional value of sorghum is that the protein of cooked sorghum is significantly less digestible than that of other cooked cereals[1-3]. Since cereals are invariably cooked prior to consumption, the lower digestibility of sorghum protein militates significantly against the use of this cereal.

Malting has been identified as a traditional processing technology that could possibly be used to improve the nutritional quality of the protein[4]. The process of malting comprises three unit operations, *viz*. steeping, germination and drying. A number of factors are known to have an effect on the development of enzymes synthesised during germination and thus on the quality of the malt produced. The moisture content of the grain at the end of steep (steep-out moisture) has been shown to be significantly correlated with the resulting malt quality[5]. Recent research has shown that steeping sorghum in a dilute solution of alkali increases the rate of water uptake into the grain during steeping (probably as a consequence of disrupting the molecular structure of the non-starch polysaccharides which make up the structure of the sorghum cell walls[6]) and also increases the quality of the malt produced at least in terms of brewing quality characteristics *viz*. diastatic power (amylase activity) and free amino nitrogen (free amino acids and short peptides)[6-8]. In this EC-funded research project it was decided to investigate the effect of malting and that of alkali steeping during malting on the digestibility of the sorghum protein.

EXPERIMENTAL

Grain

Condensed tannin-free sorghum grain from Kenya (Local White and KAT 369) and South Africa (NK 283 and PAN 8564) was used.

Malting

Samples of pre-washed, spin-dried (one min at 300 x g) sorghum grain (500 g) were steeped in continuously changing fresh 25°C tap water for 24 hours or in the alkali treatment study, in a still solution of NaOH (0 (control), 0.1, 0.2, 0.3, 0.4 and 0.5% w/v) during the first 8 hours of steep and, thereafter, in continuously changing fresh 25°C tap water for the remainder of the 24-hour steeping period. Following steeping, the grains were germinated for various different times in a conditioned cabinet set at 25°C and 100% relative humidity. Twice daily during the germination period, the grain was removed from the conditioned cabinet and steeped for a short time (10 min)

in tap water. The excess surface-held water was then removed and the grain returned to the conditioned cabinet. Germination was stopped after the pre-determined time by drying the malt in a force-draft oven set at 50°C for 24 hours.

Analyses

The quality of the malt was assessed in terms of diastatic power (DP; water extraction method) and free amino nitrogen (FAN) according to standard methods[9]. The *in vitro* protein digestibility of the malted samples was assessed according to a well-established method[10] except that filtration, using Whatman No. 4 filter paper, was substituted for the centrifugation step to prevent losses caused when the supernatant was discarded. The Nitrogen Solubility Index (NSI) was determined using the American Association of Cereal Chemists Method[11] and the total protein content (N x 6.25) was analysed using a Kjeldahl method[12]. Rapid analysis of lysine was determined using a Pre-column derivatisation using the PICO.TAG Reversed Phase HLPC Method[13].

RESULTS AND DISCUSSION

A major objective of malting is to promote the development of hydrolytic enzymes, which are not present in the non-germinated grain. Sorghum malt quality (at least for sorghum brewing) is assessed primarily in terms of DP and FAN. DP is a measure of the joint activity of α- and ß-amylase. In general, the DP of the malts increased with increasing germination time to about 6 days (Table I). In agreement with what has been reported by others[5, 14] when the malting time was extended to 8 days, the DP of the malt tended to decline. FAN is produced during malting by the action of endogenous proteinase and peptidase enzymes on the protein reserves of the grain[15] and the breakdown products are collectively referred to as FAN. For all the sorghum varieties tested malting improved malt FAN, which increased with increasing germination time over the 8-days malting (Table I). Variety Local white produced malt with the highest whole malt FAN (199 mg/100 g) followed by PAN 8564, NK 283 and KAT 369 (135, 117 and 113 mg/100 g, respectively). These findings support those of others[5, 16].

Malting also significantly ($p<0.05$) improved the *in vitro* digestibility and the quality of the sorghum protein, which increased with increasing malting time (Table II[17]). For the Kenyan Local white variety malting improved the digestibility of the protein by a staggering 110% and increased the percentage protein, the nitrogen solubility index and lysine content by as much as approximately 8.5, 251 and 32%, respectively. It should be noted that the improvement in lysine content is not simply a consequence of protein concentration but rather a true increase in lysine. The significant increase in the NSI supports the idea that the increase in *in vitro* protein digestibility is probably due to structural changes and the enzymic hydrolysis of proteins into more digestible forms such as amino acids and small peptides. The evidence would seem to support the suggestion that the simple technology of malting offers a means by which to improve the quality and digestibility of sorghum protein.

Sorghum grain	Malting time (days)			
	3	4	6	8
Diastatic power (SDU/g)				
NK 283	9	18	27	23
PAN 8564	13	21	32	27
KAT 369	7	13	12	9
Local white	13	26	25	6
Free amino nitrogen (mg/100 g)				
NK 283	50	78	110	117
PAN 8564	53	85	122	135
KAT 369	53	74	109	113
Local white	85	118	195	199

Table I Effect of malting time on the diastatic power and free amino nitrogen content of sorghum malts

In the alkali treatment study it was found that for varieties PAN 8564 and NK 283 (1998 harvest) steeping the grain for the first 8 hours of the steeping period in 0.2 or 0.3% NaOH improved the quality of the malt in terms of DP and FAN (Table III). A concentration of 0.4% NaOH did not significantly affect malt quality and 0.5% significantly reduced the malt DP and FAN. For variety NK 283, the greatest improvement in malt DP, arguably the most important indicator of malt quality occurred when NaOH was administered at a concentration of 0.2%. At this concentration the DP was improved by almost 45%. This finding supports those of others [6, 7] and has great relevance to the sorghum malting industry which has had to rely on manipulating malting conditions such as time, temperature, aeration and watering regimes in order to optimise the quality of the malt produced.
It should be cautioned, however, that the optimal NaOH concentration to positively affect sorghum malt quality may be variety specific and also seasonally dependant (although 0.3% NaOH treatment was found to be effective for the PAN 8564 grain tested in this investigation it was not found to improve the malt quality of a previous season's PAN 8564 grain (results not shown).

In terms of its effect on protein digestibility, steeping in dilute NaOH (0.1, 0.2 and 0.3%) produced small improvements, up to approximately 7 and 6% for NK 283 and PAN 8564, respectively (Table III). As was the case for DP and FAN, steeping the grain in higher concentrations of NaOH actually reduced the digestibility of the protein. Variety NK 283 appeared particularly sensitive to the higher concentrations (0.5% occasioned a reduction of approximately 22%).

	Malting time (days)		
	0	**5**	**7**
	Total protein (%)		
PAN 8564	7.1[1] (0.2)[2]	7.3[1] (0.2)[2] **2.8**[3]	7.3 (0.1) **2.8**
Local white	10.6 (0.2)	11.1 (0.2) **4.7**	11.5 (0.1) **8.5**
	***in vitro* Protein digestibility (%)**		
PAN 8564	36.0 (5.2)	54.9 (2.1) **52.5**	54.2 (1.5) **50.6**
Local white	31.0 (1.9)	61.0 (1.3) **96.8**	65.2 (2.6) **110.3**
	Nitrogen Solubility Index (%)		
PAN 8564	20.7 (1.0)	37.6 (0.9) **81.6**	45.5 (0.3) **119.8**
Local white	15.0 (1.3)	37.1 (1.5) **147.3**	52.7 (0) **251.3**
	Lysine content (%)		
PAN 8564	0.17[1]	0.18[1] **5.9**[3]	0.23 **35.3**[3]
Local white	0.22[1]	0.26 **18.2**[3]	0.29 **31.8**[3]

Source: Donaldson, 1999[17]

[1] average
[2] standard deviation (no standard deviation is given for lysine as all values were 0)
[3] % increase due to malting

Table II Effect of malting time on the protein quality (protein content, protein digestibility, Nitrogen solubility index and lysine content) of sorghum varieties PAN 8564 and Kenyan local white

CONCLUDING REMARKS

The technology of malting would seem to offer a simple means by which to improve the digestibility and quality of sorghum protein.

Alkali treatment, in conjunction with malting, can be used as a relatively cheap technology to significantly improve the malting quality of sorghum in terms of DP and FAN. The increase in protein digestibility occasioned by malting can be marginally increased by introducing an alkali steep during malting. The concentration of NaOH to be used to bring about the beneficial effects, however, may be variety related (may also be seasonally affected) and it must be carefully monitored so as to avoid toxic effects on the grain. This technology has significance for large industrial

maltings. Indeed, it has already been introduced commercially into Nigeria (S.M. Joustra, Brewing Consultant, South Africa, pers. comm.; L.I. Ezeogu, University of Nigeria, pers. comm.). It offers a relatively inexpensive means of significantly improving the malting quality of the sorghum and also improving the throughput of the malting plants. It may also have the added advantage of minimising microbial growth, which may well be one of the biggest issues inhibiting the use of sorghum malt. In optimising malt quality it should be cautioned that a balance needs to be found between producing the required quality and minimising the associated malting losses (loss of dry matter associated with malting)[5].

NaOH concentration (%)	NK 283			PAN 8564		
	DP (SDU/g)	FAN (mg/100 g)	Protein digestibility (%)	DP (SDU/g)	FAN (mg/100 g)	Protein digestibility (%)
0	24.5	126	34.2	30.0	139	36.7
0.1	29.0	142	35.5	36.5	165	37.3
0.2	35.5	152	36.6	40.0	169	38.8
0.3	34.0	153	36.7	36.5	160	38.5
0.4	26.5	128	34.1	26.5	131	34.4
0.5	14.0	81	26.7	15.0	93	30.5

Table III Effect of steeping (0-8 hours) in different concentrations of NaOH on the diastatic power, free amino nitrogen content and the *in vitro* protein digestibility of sorghum malt (varieties NK 283 and PAN 8564) (malting time of 7 days)

The technology of malting could also be applied to relatively poor rural communities where nutritional enhancement would appear to be most required. Malted sorghum, with improved protein quality and digestibility could be used in the formulation of weaning foods. In rural communities the first weaning foods are generally gruels made from cereals with low nutritional density and energy levels. Introducing a small amount of malted sorghum flour "power flour" to the thick porridge gruel will quickly liquefy it without reducing, perhaps even increasing the nutritional value and make it more acceptable and more easily digested by the infant. The reader is referred to an information handbook, produced as an output of this EC INCO-DC PROJECT, which gives a practical guide to producing sorghum malt of good and consistent quality at a small-scale and also its incorporation into weaning foods and wheat:sorghum composite breads[18].

In applying, particularly the alkali steeping technology to rural areas the challenge would be in adapting the technology so that small changes in the concentrations of NaOH to be used do not have such significant effects on the quality of the malt.

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