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Determination of Improved Steeping Conditions for Sorghum Malting

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ABSTRACT

The effect of various steeping conditions (time, temperature and aeration) on the quality of sorghum malt for brewing (in terms of diastatic power, free amino nitrogen and hot water extract) was examined. Steeping time and temperature had a highly significant effect on sorghum malt quality. In general, malt quality increased with steeping time (from 16–40 h). Malt diastatic power increased with steeping temperature (up to 30°C) and free amino nitrogen and extract content peaked at a steeping temperature of 25 °C. Aeration during steeping appeared to enhance the extract and free amino nitrogen content of the finished malt. Sorghum malt quality was found to be directly related to the steep-out moisture of the grain.

Keywords: sorghum, steeping, malting.

INTRODUCTION

In Africa, the cereal sorghum is malted widely to provide an important raw material in brewing. In southern Africa, approximately 200 000 tonnes per annum of malted sorghum are used in the production of traditional (opaque) sorghum beer[1]. Since a ban on the importation of barley malt by the Nigerian government in 1988, there has also been growing interest in the use of malted sorghum in the brewing of clear lager type beers[2].

Malting is the germination of cereal grain in moist air under controlled conditions, the primary objective being to promote the development of hydrolytic enzymes which are not present in the ungerminated grain. The malting process can be divided into three physically distinct operations, i.e. steeping, germination and drying.

Steeping (the soaking of grain in water) is widely acknowledged as the most critical stage of the malting process[3,4]. This is a consequence of the importance of initiating germination such that modification of the endosperm structure will progress at a rate producing malt of the desired quality. Factors that are important for the successful initiation of germination are adequate moisture, temperature and the presence of oxygen[3]. These factors can affect the extract yield, diastatic activity and other important malt quality characteristics[5].

Much emphasis has been placed on the effects of various germination conditions on the quality of sorghum malt[5–11]. However, despite the acknowledgement of the importance of the steeping process in malting, there have, until recently, been only limited studies on the effect of steeping conditions on sorghum malt quality[11–16]. Indeed, the work done has been limited in its scope, virtually

ABBREVIATIONS USED: AB = air-blast; AR = air-rest; NA = non-aerated; DP = diastatic power; FAN = free amino nitrogen; SDU = sorghum diastatic units.

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Table I Effect of steeping time, temperature and aeration on the diastatic power of sorghum malt (SDU/g)

Steeping time (h)	Temperature (°C)								
	20			25			30		
	Aeration								
	AR	AB	NA	AR	AB	NA	AR	AB	NA
16	29	24	26	27	33	33	35	31	33
24	32	30	28	31	29	36	38	36	38
40	35	35	31	35	37	37	43	40	39

AR = air-rest, AB = air-blast, NA = non-aerated.

Analysis of variance for malt diastatic power

Source of variation	Mean square	DF	F	P
Time	92·06	2	24·17	0·000
Temperature	111·27	2	29·22	0·000
Aeration	2·58	2	0·68	0·534
Time*Temperature	1·72	4	0·45	0·770
Time*Aeration	3·31	4	0·87	0·523
Temperature*Aeration	13·83	4	3·63	0·057
Residual	3·81	8		

DF = degree of freedom, F = F-test, P = significance level.

only being concerned with final warm water steeping[12–16]. This may relate to the assumption made in an earlier study that regarded steeping time as unimportant in determining sorghum malt quality[7]. This is reflected in commercial sorghum malting practice in South Africa where steeping times, of a maximum of 24 h, and sometimes as short as 6 h, are employed.

In view of this, a systematic investigation of the effect of steeping conditions on sorghum malt quality is needed. In this study the effect of steeping time, temperature and aeration on sorghum malt quality was investigated.

EXPERIMENTAL

Materials

Grain

Sorghum (*Sorghum bicolor* (L.) Moench) grain of cultivar Barnard Red was used.

Steeping equipment

The steeping apparatus consisted of three perspex vessels each of 2 kg capacity. Each vessel was fitted with a water-jacket in which attempered water was circulated to control the temperature of the water within the vessels. A pump connected to an air supply was used to aerate the steeping water (air-blast (AB)). The air-rest (AR) method of aeration was achieved by periodically draining the steeping water from the grain and allowing the grain to rest for a predetermined period of time in the air before refilling the vessel with fresh attempered water. Non-aerated (NA) steeping conditions were achieved by steeping the grain for the full steeping period in non-aerated water. The conditions of steep (duration and frequency of air-blast and air-rest periods) within each of the vessels were controlled and monitored by computer.

Methods

Steeping

Samples of grain (500 g), in nylon mesh bags (400 × 400 mm), were steeped at a pre-determined temperature (20, 25 or 30 °C). After the first hour, the steeping vessels were drained and refilled with fresh attempered tap water. Grain at each of the pre-determined temperatures was steeped for one of three different times (16, 24 or 40 h), under one of three conditions of aeration (AR, AB or NA conditions). Oxygen levels were not monitored during the different steeping treatments, as the aeration treatments attempted to reproduce the steeping conditions used in South African commercial sorghum maltings. At the end of steeping, the grain was centrifuged in a domestic spin drier (AEG type SD 452BN) for one min at 300 × ***g*** to remove the surface film of moisture.

Germination

The bag-held grain was germinated in a water-jacketed incubator (Forma Scientific, Marrietta, U.S.A.) set at 25 °C and 100% relative humidity. Twice daily, the bags were removed from the incubator, the grain turned (to avoid meshing of the roots and shoots) and steeped for 10 min in tap water. Following the short steep, the grain was spin-dried (1 min at 300 × ***g***) to remove the excess surface-held water and returned to the incubator.

Drying

After 6 d from the beginning of steeping, germination was arrested by drying the malt for 24 h in a forced draft oven set at 50 °C.

Analyses

Steep-out moisture. The mass of the spin-dried, steeped grain was determined and the steep-out moisture calculated as a percentage. The results were expressed on a wet weight basis.

Malting loss. The loss of dry grain material as a consequence of the malting processes was calculated as a percentage and expressed on a wet weight basis.

Diastatic Power (DP). Diastatic power (DP) was determined according to the South African Bureau of Standards method 235[17], except that water was used as the extractant, and 5 g of malt used and the extraction volume reduced accordingly. The results were expressed as sorghum diastatic units (SDU)/g dry weight.

Free amino nitrogen (FAN). The FAN content of the malt was determined according to the ninhydrin method described by Morrall *et al.*[5], except that 1 g of malt was used. The results were expressed as mg FAN/100 g dry weight.

Hot water (60 °C) extract. Samples of malt (7·78 g) were placed in 80 mL plastic tubes containing 62·22 g of distilled water. Extraction was conducted at 60 °C and the specific gravity of the extract determined as described by Morrall *et al.*[5]. The results were expressed as percentage dry weight.

RESULTS AND DISCUSSION

Effect of steeping conditions on malt quality

Sorghum malt quality for sorghum beer brewing is defined primarily in terms of DP and FAN[7,18]. DP is a measure of the joint *alpha*- and *beta*-amylase activity[19]. DP is especially important in the case of sorghum malt as the level of the *beta*-amylase enzyme in sorghum is intrinsically low[20,21]. FAN, the proteolytic breakdown products of endosperm proteins, composed of amino acids and small peptides, is important in brewing since it is the source of nitrogen for yeast during fermentation[22]. In sorghum beer brewing, it is particularly important as the FAN in the wort may be limiting due to the high proportion of unmalted cereal adjunct in the grist[18]. In conventional clear lager beer brewing, as opposed to opaque sorghum beer brewing, the most important malt quality criterion is extract[23]. Extract is a measure of how much malt will dissolve during the brewing process. This is a less important measure of malt quality in sorghum beer brewing as malt makes up only approximately 30% of the cereal grist[23].

In 1962 Novellie[7] reported that steeping time had little effect on the final DP of sorghum malt. Results of the present study, however, indicate that malt DP increased significantly with increasing steeping time (Table I; $P<0·001$). In addition to DP, other malt quality parameters important for brewing, FAN and extract content, were improved significantly by increasing the steeping time (Tables II and III, respectively). Sorghum, unlike barley, must be watered during germination. Novellie[7], possibly believing that the grain hydration requirements were met on the floor (i.e. during germination), did not regard steeping time as important in determining malt quality. The present study, however, indicates clearly that the steeping times of 16 h or less as currently practised in South African maltings (some as low as 6 h) are sub-optimal. It is important to note, however, that unless the oxygen requirements of the grain can be satisfied, long steeping times may lead to anoxic

Table II Effect of steeping time, temperature and aeration on the free amino nitrogen content of sorghum malt (mg/100 g)

Steeping time (h)	Temperature (°C)								
	20			25			30		
	Aeration								
	AR	AB	NA	AR	AB	NA	AR	AB	NA
16	68	69	66	99	104	94	92	97	85
24	72	67	69	108	107	103	94	97	94
40	95	95	90	120	117	105	117	111	107

AR = air-rest, AB = air-blast, NA = non-aerated.

Analysis of variance for malt free amino nitrogen

Source of variation	Mean square	DF	F	P
Time	1030·57	2	208·82	0·000
Temperature	2146·78	2	435·00	0·000
Aeration	104·67	2	21·21	0·001
Time*Temperature	49·38	4	10·01	0·003
Time*Aeration	18·71	4	3·79	0·051
Temperature*Aeration	10·75	4	2·18	0·162
Residual	4·94	8		

DF = degrees of freedom, F = F-test, P = significance level.

conditions which may be compounded by microbial proliferation.

Analysis of variance indicated that steeping temperature also had a significant effect on the malt quality (Tables I, II and III). Malt DP was enhanced not only by an increase in the steeping time but also by an increase in the temperature of the steeping water ($P<0{\cdot}001$). The maximum DP of 42·6 SDU/g was obtained in grains steeped for 40 h under AR, 30 °C conditions (Table I). With respect to malt FAN and extract content, it was apparent that 25 °C was optimum (Tables II and III). The highest values for malt FAN and extract (119·8 mg/100 g and 62·2%, respectively), were obtained from grain that had been steeped at 25 °C for 40 h under AR conditions for the former and for 24 h under aerated conditions for the latter. Steeping temperature has also been shown to be important in that, although cultivar related, steeping sorghum with a final warm water steep (40 °C for 6 h) improves the quality of the malt[12–16]. In South Africa, few commercial malting operations have temperature-controlled steeping vessels. In winter the temperature of the steeping water can be as low as ±12°C and in summer as high as ±34 °C (unpub. data). These results show clearly the need for temperature control during steeping.

It has been stated that adequate oxygen is necessary for the formation of *alpha*-amylase and peptidase and that excessive carbon dioxide inhibits the formation of these enzymes even in the presence of sufficient oxygen[24]. In terms of FAN and to a lesser extent extract content, this would appear to hold true in that aeration during steeping improved the quality of the malt ($P<0{\cdot}001$ and $P<0{\cdot}05$, respectively) (Tables II and III). Analysis of variance, however, suggested that aeration during steeping did not significantly affect the DP of the malt ($P>0{\cdot}05$; Table I). In other studies[13,15], however, even the length of the air rests employed during steeping were shown to significantly affect the quality of sorghum malt produced. The apparent discrepancy between these results may be explained by the fact that the FAN and extract assays measure the products of enzymic hydrolysis, whereas DP measures enzyme activity. During malting, DP has been shown to increase gradually and thereafter reach a plateau[5,25]. Therefore, it is probable that even if the enzyme activity of the

Table III Effect of steeping time, temperature and aeration on the extract content of sorghum malt (%)

Steeping time (h)	Temperature (°C)								
	20			25			30		
	Aeration								
	AR	AB	NA	AR	AB	NA	AR	AB	NA
16	48	49	47	58	59	56	57	54	54
24	53	51	48	62	62	58	57	58	55
40	56	56	52	61	61	59	54	61	58

AR = air-rest, AB = air-blast, NA = non-aerated.

Analysis of variance for malt extract

Source of variation	Mean square	DF	F	P
Time	33·00	2	12·02	0·004
Temperature	157·46	2	57·34	0·000
Aeration	19·12	2	6·96	0·018
Time*Temperature	5·75	4	2·10	0·173
Time*Aeration	2·27	4	0·83	0·544
Temperature*Aeration	1·79	4	0·65	0·641
Residual	2·75	8		

DF = degrees of freedom, F = F-test, P = significance level.

Table IV Effect of steeping time, temperature and aeration on malting losses (%)

Steeping time (h)	Temperature (°C)								
	20			25			30		
	Aeration								
	AR	AB	NA	AR	AB	NA	AR	AB	NA
16	16·2	16·5	16·1	17·7	17·3	17·2	18·0	17·5	17·4
24	16·2	16·1	16·4	17·5	18·2	17·4	17·4	17·5	17·4
40	16·5	16·6	15·8	17·1	17·4	15·5	18·3	17·7	16·3

AR = air-rest, AB = air-blast, NA = non-aerated.

Analysis of variance for malting losses

Source of variation	Mean square	DF	F	P
Time	0·29	2	4·14	0·058
Temperature	3·84	2	54·54	0·000
Aeration	1·06	2	15·07	0·002
Time*Temperature	0·30	4	4·26	0·039
Time*Aeration	0·54	4	7·61	0·008
Temperature*Aeration	0·15	4	2·18	0·161
Residual	0·07	8		

DF = degrees of freedom, F = F-test, P = significance level.

Table V Effect of steeping time, temperature and aeration on the steep-out moisture of sorghum grain (%)

Steeping time (h)	Temperature (°C)								
	20			25			30		
	Aeration								
	AR	AB	NA	AR	AB	NA	AR	AB	NA
16	30·5	30·9	30·6	31·6	31·9	31·8	33·2	32·8	34·1
24	nd[a]	31·1	30·4	31·8	33·5	32·5	34·6	34·2	34·4
40	33·5	32·9	32·6	34·4	35·0	33·6	35·9	36·5	35·2

[a] Not determined.
AR = air-rest, AB = air-blast, NA = non-aerated.

Analysis of variance for steep-out moisture

Source of variation	Mean square	DF	F	P
Time	14·54	2	66·60	0·000
Temperature	18·37	2	84·13	0·000
Aeration	0·38	2	1·75	0·242
Time*Temperature	0·16	4	0·74	0·592
Time*Aeration	0·43	4	1·96	0·206
Temperature*Aeration	0·24	4	1·08	0·434
Residual	0·22	7		

DF = degrees of freedom, F = F-test, P = significance level.

grains exposed to different levels of aeration had developed at different rates, this would not be reflected in the DP after 6 d germination.

Aeration and steeping temperature and the combined effect of time and aeration were found to have a significant effect on malting losses ($P<0{\cdot}01$, $P<0{\cdot}001$ and $P<0{\cdot}01$, respectively; Table IV). Malting losses were generally retarded by steeping the grain for increasing periods in non-aerated water but the higher the steeping temperature the higher the losses accrued. These results are not unexpected as malting losses are an outcome of respiratory metabolism and, therefore, any condition that affects respiration and consequently malt quality will also affect the losses accrued.

Effect of steeping conditions on steep-out moisture

The steep-out moisture content of the grain was significantly affected by both steeping time and temperature ($P<0{\cdot}001$). There was a general increase in steep-out moisture with increasing steeping time (16–40 h) and temperature (20–30 °C) (Table V). Analysis of variance indicated that aeration did not significantly affect the steep-out moisture of the grain ($P>0{\cdot}05$).

It has been reported[26] that the moisture content of barley at the end of steeping (as long as air-rests are employed) is an effective way of selecting the steeping regime giving the highest hot water extract. In this study, a significant correlation was obtained between the steep-out moisture and malt DP (R = 0·862; accounting for 74·2% of the variation) (Fig. 1). Significant correlations were also found between steep-out moisture and FAN, and extract content (R = 0·736 and R = 0·578, accounting for 54·2% and 33·5% of the variation, respectively) (Fig. 1). It would appear, therefore, that steep-out moisture may similarly provide the sorghum maltster with a rough tool with which to select the steeping procedure that will maximise the malting quality of the grain. Although the absolute steep-out moisture may vary depending upon the grain size and cultivar, generally the higher the steep-out moisture the better the quality of the malt produced.

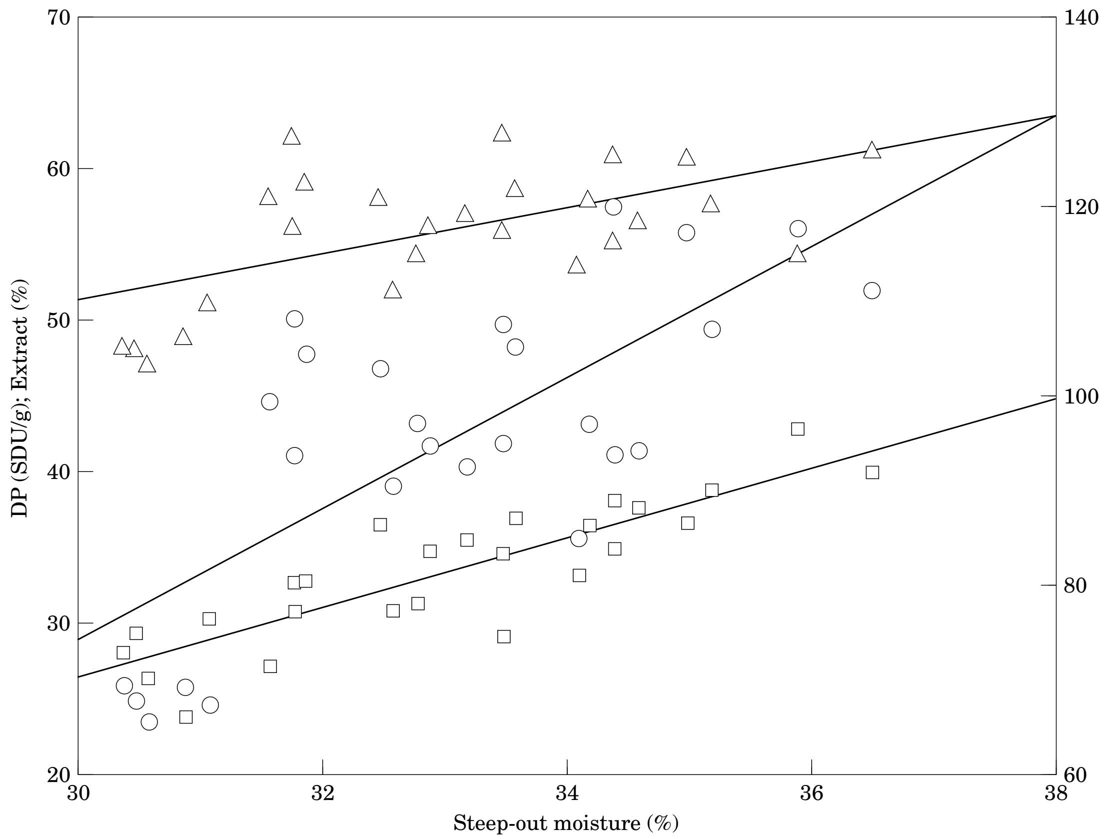

Figure 1 Relationship between steep-out moisture and sorghum malt quality (all data). □ = DP (SDU/g), ○ = FAN (mg/100 g), △ = Extract (%).

CONCLUSIONS

The findings of this study clearly indicate that in South Africa, commercial steeping practices are sub-optimal for sorghum. Sorghum malt quality is significantly affected by steeping time and temperature. Malt quality within the range of parameters studied, increases with steeping time (16–40 h) and the optimum steeping temperature is between 25 and 30 °C. Aeration during steeping was also shown to be necessary to maximise malt quality. The quality of the sorghum malt was found to be directly related to the steep-out moisture of the grain. Although further work is required, it is suggested that steep-out moisture may provide a means of estimating, at an early stage, the quality of finished malt. These findings have relevance for sorghum malting for both opaque and clear beer brewing.

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