Effect of Germination Moisture and Time on Pearl Millet Malt Quality – With Respect to Its Opaque and Lager Beer Brewing Potential

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ABSTRACT

J. Inst. Brew. 110(4), 320–325, 2004

The effect of germination moisture and time on pearl millet malt quality was investigated. Two pearl millet varieties SDMV 89004 and 91018 were germinated at 25°C under three different watering regimes for 5 days. As with sorghum malting, diastatic power, beta-amylase activity, free α-amino nitrogen (FAN), hot water extract and malting loss all increased with level of watering. However, pearl millet malt had a much higher level of beta-amylase and higher FAN than sorghum malt and a similar level of extract. Malting losses were similar or lower than with sorghum. Thus, it appears that pearl millet malt has perhaps even better potential than sorghum malt in lager beer brewing, at least as a barley malt extender, especially in areas where these grains are cultivated and barley cannot be economically cultivated. Also, its increased use in commercial opaque beer brewing, where sorghum malt is currently used, could be beneficial.

Key words: Beta-amylase, extract, FAN, malting, pearl millet, watering regime.

INTRODUCTION

Pearl millet (*Pennisetum glaucum* (L.) R.Br.) is a tropical cereal indigenous to Africa. It is uniquely adapted to cultivation in dry conditions[21]. Pearl millet is widely home malted in sub-Saharan Africa for small-scale brewing of traditional African (cloudy or opaque) beer. A small amount is industrially malted in Zimbabwe for commercial opaque beer brewing to supplement sorghum malt.

The malt used in sub-Saharan Africa for lager beer brewing is almost exclusively from barley. Since barley cultivation in this region is not generally economically feasible, much is imported from overseas, making it very expensive. Pearl millet could be an alternative to barley and sorghum malt, increasing malt availability in sub-Saharan Africa for both commercial opaque beer brewing and lager beer brewing at lower cost.

Pearl millet malting conditions have been established, in part, in our previous work[22]. However, very little is known about the potential of pearl millet malt for lager beer brewing. Agu and Obanu[1] found that pearl malt gave wort of lower specific gravity and lower extract than commercial (barley malt) wort, but the resulting beer was still acceptable. Muoria and Bechtel[16] found that pearl millet malt had diastatic power intermediate between sorghum malt and barley malt and suggested the addition of exogenous enzymes or other types of malt would be necessary for lager beer brewing.

This paper describes the effects of germination moisture and time on pearl millet malt quality in relation to sorghum and in respect of malt quality parameters for opaque beer and lager beer brewing. Germination moisture was specifically investigated as it strongly affects barley[2,3] and sorghum malt quality[6,15].

MATERIALS AND METHODS

Malting

Samples of two pearl millet varieties, SDMV 89004 and SDMV 91018 of good Germinative Energy were used, as previously described[22]. The total polyphenol content of these, as determined by the ISO method[23], was very low, 0.08% and 0.10% tannic equivalents, respectively. In view of the fact that single samples of each variety were used, effects will be referred to as sample effects and not variety effects. The pearl millet malting process was conducted as described[22]. However, three different watering regimes were used in the germination process:

1. Low watering regime – Just enough water was added to maintain the malt at a constant fresh weight. Twice daily, the nylon bags containing the germinating grains were weighed, immersed in a bucket of tap water (22–24°C) for 1 min, and then spin-dried (30 s at 300 × g), then weighed again.
2. Medium watering regime – Water was added to the malt to feel damp but not wet. There was no surface film of water on the malt. Twice daily, the bags were weighed, immersed in tap water for 10 min, then spin-dried and weighed again.
3. High watering regime – As for medium watering regime, but the spin-drying step was omitted, so as to keep the malt wet (i.e., the grain felt wet).

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Publication no. G-2004-1303-247

The grain was germinated for up to 5 days at a temperature of 25°C, as this had previously been found to be optimum for pearl millet[22].

Malt analyses

These were carried out on whole milled malt, including the external roots and shoots, as is done in opaque beer brewing and as would be desirable if the malt were to act as a major source of free amino nitrogen in lager beer brewing. The malt was milled for 45 s in a "beater-type" water-cooled coffee mill (Janke and Kunkel, Staufen, Germany).

Malting loss. Calculated as described[10,22].

Diastatic power (DP). Essentially according to the South African Bureau of Standards method for sorghum malt[24], but using distilled water as an extract, as described[22].

Beta-amylase. By the Betamyl method (beta-amylase assay kit) (Megazyme International, www.megazyme.com).

Free amino nitrogen (FAN). By the ninhydrin method as described[22].

Hot water extract. Samples of 6.0 g milled malt were incubated in 54 mL distilled water in sealed plastic centrifuge tubes at 60°C for 2 h. At 10 min intervals the contents of the tubes were mixed by inversion. After incubation, the tubes were cooled in water (20–23°C) for 30 min, and centrifuged at 1,500 *g* for 2 min. Forty mL of the clear supernatant was transferred into a 50 mL beaker. Specific gravity was measured by the gravimetric method as described by Morrall *et al.*[15] and sucrose calculated from the Plato table[25]. Extract was calculated as a percentage of malt dry weight.

Fat. By AOAC Method 14.018 procedure 7.056[26].

Statistical analysis

The malting treatments were replicated twice and three samples from each malting treatment were analysed. Analysis of variance with the least significant difference test was applied. For the sake of clarity, in the figures the mean data are shown without error bars.

RESULTS AND DISCUSSION

Green malt moisture

Pearl millet germinated well under all of the three watering regimes. However, root and shoot growth progressively increased with watering level. There was a significant effect ($p < 0.001$) of watering regime and germination time, and sample ($p < 0.05$) on green malt moisture. As expected and observed with sorghum[15], the higher the amount of water added the higher the green malt moisture (Fig. 1). Generally, SDMV 89004 had higher green malt moisture, especially with the medium watering regime. By 5 days germination the mean green malt moisture contents were 33.2, 48.0 and 60.0%, for SDMV 89004 and 35.3, 47.3 and 56.3% for SDMV 91018, with the low, medium and high watering regimes, respectively. The green malt moisture level for the low watering regime was similar to that reported by Dewar et al.[6] and Morrall et al.[15] malting sorghum under similar watering regimes, but lower for the medium and high watering regimes. The germination of pearl millet and sorghum at the low green malt moisture level may be in contrast to barley where for uniformity of germination a steeping regime that takes it to 42–46% moisture is required[2]. The lower green malt moistures at the medium and higher water regimes for pearl millet compared to sorghum are probably related to the fundamental differences in grain chemical composition[27]. The pearl millet grain is about one-third the size with a proportionally larger germ and pericarp and hence higher oil and insoluble fibre content, respectively[27].

Diastatic power

DP was affected significantly ($p < 0.001$) by germination time, watering regime and sample. As reported in our previous work[22], ungerminated pearl millet did not have any DP and the DP increased with germination time (Fig. 2). Germination with the high watering regime gave an initial higher level of DP. However, the rate of increase in DP at high moisture declined over longer periods of germination. Germination at medium moisture gave significantly higher ($p < 0.001$) DP than germination with high and low watering regimes after 5 days germination. This negative effect of the high watering regime on DP of pearl millet malts during the last days of germination has also been observed for sorghum[6,15,18,19]. The reason for the de-

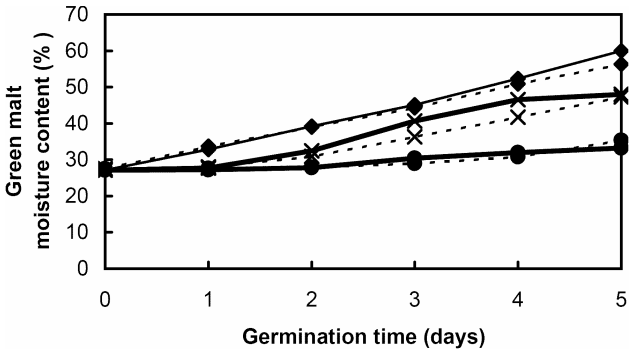

Fig. 1. Effects of germination time and watering regime on the green malt moisture content of pearl millet. SDMV 89004 (—) and SDMV 91018 (– –) varieties. ● – Low watering; × – Medium watering; ♦ – High watering.

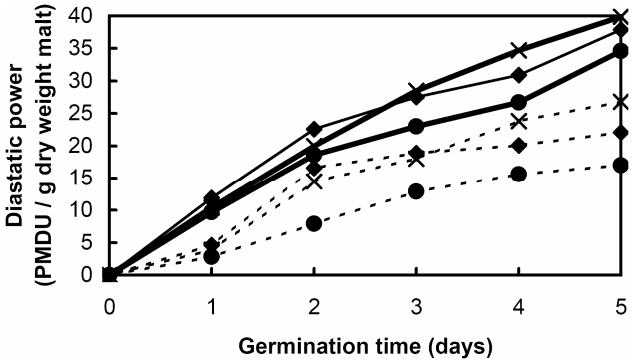

Fig. 2. Effects of germination time and watering regime on the diastatic power (DP) of pearl millet malt. SDMV 89004 (—) and SDMV 91018 (– –) varieties. ● – Low watering; × – Medium watering; ♦ – High watering.

cline in the rate of increase of DP with the high watering regime may be that high malt moisture contents cause proportionally greater enzyme denaturation when the malt is dried, even at relatively low drying temperatures[6].

Under all water regimes SDMV 89004 gave higher DP than SDMV 91018. Higher DP of SDMV 89004 than SDMV 91018 when germinated over the temperature range 25–35°C was reported in our previous work[22]. The higher DP was attributed to its slightly higher germinative energy.

Beta-amylase

As with DP, total beta-amylase activity was significantly affected ($p < 0.001$) by germination time and watering regime. As we reported previously but using a less specific assay[22], ungerminated pearl millet did not exhibit any beta-amylase activity (Fig. 3). The reason for using the Betamyl assay in this present work is that it is highly specific for beta-amylase. The substrate is dye-labelled penta- and hexa-dextrins, which are rapidly hydrolysed by beta-amylase but only slowly cleaved by alpha-amylase (www.megazyme.com). In our previous work[22], we assayed for beta-amylase using the sorghum malt DP method after inactivating alpha-amylase by chelating the calcium ions in the enzyme using ammonium oxalate. This assay is based on the assumption that after inactivation of alpha-amylase, all remaining amylase activity is due to beta-amylase. This assumption may not be correct since sorghum malt also exhibits other amylase activities, including limit dextrinase[29]. Comparison between beta-amylase activity values obtained using the assays is not possible because the assay conditions differ greatly.

Ungerminated sorghum also does not exhibit beta-amylase activity[30]. This is fundamentally different from barley where the ungerminated grain exhibits beta-amylase activity[3,13]. It appears that tropical cereal grains such as pearl millet, sorghum and maize possess only the "ubiquitous" form of beta-amylase, whereas temperate Triticeae cereals such as barley, wheat and rye also posses the "endosperm-specific" form which is present in these grains at seed maturity[31].

Generally, sample did not affect total beta-amylase activity. However, SDMV 89004 at high watering regime had significantly higher ($p < 0.05$) total beta-amylase activity than SDMV 91018. Total beta-amylase increased as germination time and moisture increased. As with DP, with the low watering regime, total beta-amylase activity was the lowest. However, in contrast to DP, overall, germination with the high watering regime gave the highest level of total beta-amylase activity. This difference suggests that it is the alpha-amylase enzyme that is inactivated at the high water regime. The mean highest total beta-amylase activity of 400 Betamyl units/g was recorded at 5 days germination with the high watering regime for SDMV 89004. Total beta-amylase activity of the pearl millet malts with all three water regimes was considerably higher than has been reported for sorghum malt (79 Betamyl units/g)[30] and only slightly lower than reported for barley malt (414 Betamyl units/g)[30]. The fact that pearl millet malt had higher beta-amylase activity than sorghum malt is of significance with respect to its potential for lager beer brewing since the generation of maltose is essential for a good fermentable wort[13,31].

FAN

Malt FAN, which is a source of nitrogen for yeast nutrition, is important in opaque beer brewing because the malt constitutes only a relatively small proportion of the cereal grist[5]. It is similarly important in lager and stout brewing processes that involve a high proportion of adjunct in the brewing process[12].

FAN was significantly affected ($p < 0.001$) by germination time and watering regime (Fig. 4). As was previously found[22], generally sample did not have any effect on malt FAN. Malt FAN increased as germination time increased as has also been found for sorghum[6,15,17] and finger millet[17]. Malt FAN increased with watering. Like DP and beta-amylase, germination at the low watering regime gave lowest malt FAN. Unlike DP, germination at high watering regime gave continuously higher malt FAN for both pearl millet varieties. This was also observed in sorghum[6,15]. The increase in FAN with watering regime could be due to the fact that high watering favours root and shoot growth, and the roots and shoots are particularly rich in FAN[6]. The highest observed level of FAN in the high water regime at 5 days germination was with SDMV

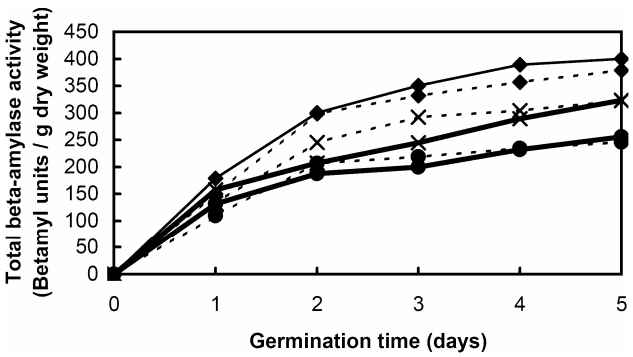

Fig. 3. Effects of germination time and watering regime on the total beta-amylase activity of pearl millet malt. SDMV 89004 (—) and SDMV 91018 (– –) varieties. ● – Low watering; × – Medium watering; ♦ – High watering.

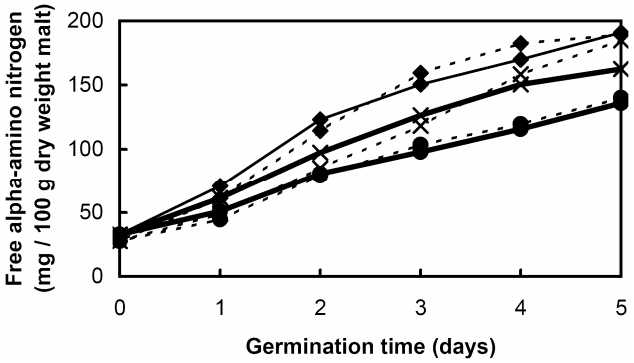

Fig. 4. Effects of germination time and watering regime on the FAN of pearl millet malt. SDMV 89004 (—) and SDMV 91018 (– –) varieties. ● – Low watering; × – Medium watering; ♦ – High watering.

89004, 199 mg/100 g, as against only 136 mg/100 g for the low watering regime. These values for FAN are high in comparison to those obtained for sorghum. In fact, the FAN value obtained for the watering regime after 5 days of germination is similar to that obtained for sorghum germinated for the same amount of time with high watering, 145 mg/100 g[15].

Extract

Malt hot water extract is particularly important in lager beer brewing since, unlike in opaque beer brewing[28], the malt normally comprises most or all of the cereal grist in the brewing process[11]. Extract was significantly affected ($p < 0.001$) by germination time, watering regime and sample (Fig. 5). Generally, SDMV 89004 malts gave higher extract than those from SDMV 91018. Extract, as with DP, FAN and beta-amylase activity, increased with germination time. This is in agreement with findings for sorghum[6,15,20], finger millet[17] and pearl millet[20]. The increase in hot water extract with germination time is an indication of the progress of modification (breakdown of the endosperm reserves, predominantly by amylase and protease activity) of the malt during germination[3]. Germination with the low watering regime gave continuously the lowest extract and the high watering regime gave the highest extract in both varieties. This has also been reported for sorghum[6,15]. Extract from the pearl millet malts at 5 days germination and high watering, 68.9% (SDMV 89004) and 59.6% (SDMV 91018), was generally similar to that found for sorghum malt (approx 68%) with high watering[15].

The generally similar extract from pearl millet malt compared to the sorghum malt is at first sight surprising since the germ in pearl millet grain is much larger and as a consequence, the starch content is lower, approx 67.0% as against 70.7% (both on a 12% moisture basis)[9]. The reason for the similar extract is probably related to the fact that when sorghum is wet cooked, protein digestibility[7,8,14] is reduced significantly. This is believed to be primarily due to prolamin proteins in the endosperm being cross linked by the application of wet heat[7]. This in turn appears to adversely affect sorghum starch gelatinisation[4] and hydrolysis[33]. In contrast, it does not appear that protein cross-linking happens to the same extent in pearl millet, as the protein digestibility of pearl millet is not greatly affected by wet cooking[14]. Hence, this could explain why extract, which is primarily a result of enzymic hydrolysis of starch[3], would be similar in pearl millet malt and sorghum malt, despite the difference in starch content between the two cereal grains.

Pearl millet malts have good beta-amylase activity, high FAN and reasonable extract. These indicate that they have some potential for lager beer brewing. A possible method to improve the extract content of millet worts was proposed by Nout and Davies[17] working with finger millet. They suggested that a small addition of barley malt could be used to simultaneously increase the beta-amylase activity in the mash. Additionally, extract could be improved by increasing alpha-amylase stability during mashing through the addition of calcium ions, as was shown for sorghum malt mashes[28]. Also of importance, with respect to the potential of pearl millet malt is the fact that malting considerably reduced grain fat content, from 6.4 to 3.1–3.4% (data not presented in figures). As stated, pearl millet grain is particularly rich in oil[27], which if not reduced in content could lead to beer rancidity problems as well as poor foam head retention[32].

Malting loss

Another key aspect of malting with regard to the potential of pearl millet is malting loss. Minimising malting loss is essential if pearl millet malting is to be economically viable. The effects of germination time, watering regime and sample on malting loss are shown in Fig. 6. Malting loss was significantly affected ($p < 0.001$) by germination time and watering regime. Malting loss increased with germination time. Germination with the low watering regime gave the lowest malting loss. As described, the low watering regime also gave the lowest malt DP, beta-amylase activity, FAN and extract. Malting loss increased progressively with the level of watering, as, in general, did beta-amylase activity, FAN and extract. The higher malting losses with the higher water regimes can be attributed higher green malt metabolic activity.

The highest malting loss, 9.2%, was recorded at 5 days germination with SDMV 89004 with the high watering

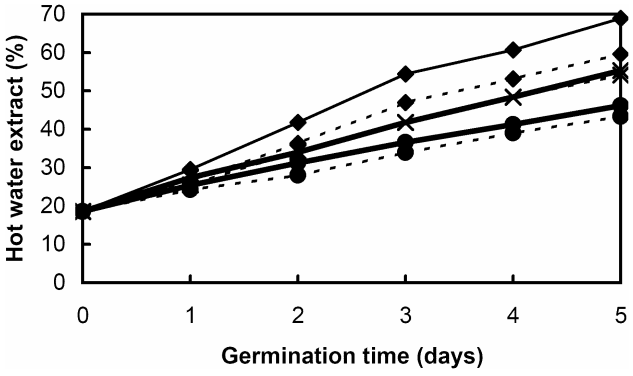

Fig. 5. Effects of germination time and watering regime on the hot water extract of pearl millet malt. SDMV 89004 (—) and SDMV 91018 (– –) varieties. ● – Low watering; × – Medium watering; ◆ – High watering.

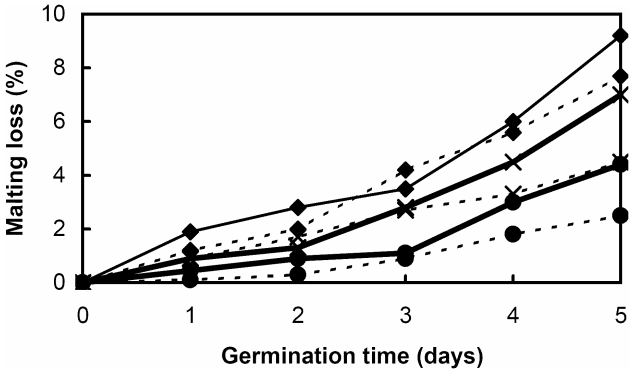

Fig. 6. Effects of germination time and watering regime on the malting loss of pearl millet. SDMV 89004 (—) and SDMV 91018 (– –) varieties. ● – Low watering; × – Medium watering; ◆ – High watering.

regime. Similar losses were reported for finger millet malting[17]. However, relatively larger losses have been reported for sorghum malting, with high watering regimes[15,19]. The larger malting losses reported for sorghum may be related to higher malt metabolic activity as a result of the generally longer steeping times used[15,19], up to 18 h, compared with 8 h in this work. It should be noted that the malting loss data reported here do not take into account additional losses that would occur if the external roots and shoots were removed, as is done with barley malt. Thus, the total malting losses (due to respiration plus removal of roots and shoots) for pearl millet malting would be rather higher than those reported for commercial barley malting of 6–12%[3].

CONCLUSIONS

As with sorghum malt, the quality of pearl millet malt is related to the level of watering during germination. However, high moisture levels also increase malting loss. In terms of its potential for lager brewing, pearl millet malt appears to have some advantages compared to sorghum as it has higher beta-amylase activity and higher FAN. This combined with its reasonable extract indicates that pearl millet malt could be used in lager beer brewing at least as a barley malt extender, and that it could be used to a greater extent, than is presently the case, in the brewing of commercial opaque beer.

With regard to commercial malting practice, the small size of pearl millet grain could pose a problem in pneumatic maltings because the grain can fall through the slots in the false floor of the germination vessel. In Zimbabwe, this has been solved by co-malting pearl millet with sorghum. Concerning the brewing process, the absence of a husk in pearl millet means that wort separation would have to be by means of a mash filter rather than a lauter tun.

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(Manuscript accepted for publication August 2004)