Effect of Malting Conditions on Pearl Millet Malt Quality

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ABSTRACT

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The effect of malting conditions on pearl millet malt quality in two varieties, SDMV 89004 and SDMV 91018, was investigated. Grain was steeped and germinated at four temperatures, 20°, 25°, 30° and 35°C, over 5 days. Generally, malt quality parameters (percentage of roots and shoots, diastatic power (DP), α- and β-amylase activity, free α-amino nitrogen (FAN), and malting loss) were significantly affected ($P < 0.001$) by germination temperature and time, as well as by variety. Malt FAN and malting loss were not affected by variety. A germination temperature of 25-30°C and germination time of 3-5 days were optimal. These conditions resulted in high DP, α- and β-amylase activity, good FAN and moderate malting loss. These malting conditions and the subsequent malt quality of pearl millet are similar to those reported for sorghum. Pearl millet malt can therefore be used for the production of sorghum type beers.

Key words: Amylase, diastatic power, free amino nitrogen, malting, malting loss, pearl millet.

INTRODUCTION

Pearl millet (*Pennisetum glaucum* (L) R.Br.), known as "hanzelo" (Rhonga), "mwahuva" (Shaangan), "mhala" (Xitswa) and "mexoeira" (Portuguese) in Mozambique, and as "leôtsa" (northern Sotho) and "lebelebele" (Tswana) in South Africa, is a very drought tolerant crop, grown primarily as a food grain in southern Africa by peasant farmers. In 1998, the SADC (southern African Development Community) regional production of pearl millet was about 410,000 tons[5].

In southern Africa, pearl millet is traditionally processed by malting and fermentation. Malted pearl millet is used to make weaning foods, with reduced viscosity, for infants. It is also used for brewing traditional beer called "uphutsu" in Mozambique, and other low-alcohol beverages, which are consumed especially during traditional ceremonies and weddings, community works, as well as by low-income people.

Little commercial pearl millet malting is carried out. However, the grain has potential in southern Africa, largely due to its drought tolerant characteristics, for malting for opaque and lager beer production and other purposes. Unlike barley and sorghum, little is known about the technology of millet malting. The limited work on millet malting has been mainly on finger millet[1,8,9,10,14, 24,26] with less being done on pearl millet.[6,11,13,20,25]

The aim of this investigation was to determine optimum pearl millet malting conditions.

MATERIALS AND METHODS

Two pearl millet varieties were used: SDMV 91018, purchased at Estação Agrária de Chockwé in Gaza Province, Mozambique, harvested in 1997; and SDMV 89004, kindly donated by SADC/ICRISAT, Matopos Research Station, Bulawayo, Zimbabwe, harvested in April 1998. These grains had good Germinative Energy (Table I).

Steeping and germination

Samples of pearl millet grain (5 kg) were washed, 4 to 5 times, in running tap water (22-24°C) to remove foreign material. The grain was then put into large nylon bags, closed with rubber bands and spin-dried (30 s at 300 × g) to remove excess surface-held water. After the spin-drying process, exactly 500 g of grain per sample was placed in nylon bags and closed with rubber bands. The grain in nylon bags was re-weighed, and then steeped in static water, 20, 25, 30 or 35°C, with a cycle of 2 h wet and 2 h air-rest, for a total of 8 h. During the air-rests, the grain was held in still air at 20–22°C. After the steeping period, the grain in nylon bags was spin-dried (30 s at 300 × g) and weighed.

The steeped grain was then germinated in the nylon bags for 1 to 5 d at one of four different temperatures: 20,

TABLE 1. Germinative energy of the two pearl millet varieties investigated.

	Germinative Energy (%)		
Variety	**24 h**	**48 h**	**72 h**
SDMV 89004	94.0	97.9	99.6
SDMV 91018	89.9	93.1	95.5

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25, 30 and 35°C. Germination was carried out in a water-jacketed incubator (Forma Scientific, Marrietta, Ohio, USA) in an atmosphere of near water-saturation with continuous flow of moist air. The malting bags were covered with wet cloths to maintain the water saturation. Twice daily, the malting bags were removed from the incubator, weighed, steeped for 10 min in tap water (22-24°C), spin-dried (30 s at 300 × g), re-weighed and returned to the germination cabinet.

Drying

After the predetermined malting times, two representative samples of the green malt were taken, weighed and placed in shallow stainless steel trays with fine mesh bottoms and dried in a forced draught oven (50°C for 24 h). After drying, the dry malt was weighed, allowed to cool for about 8 h, put in plastic bags and stored at 4°C.

Roots and shoots

Where stated, these were separated from the pearl millet malt kernels by rubbing the grain in a nylon bag of coarse mesh size, which allowed the roots and shoots to escape while retaining the kernels, as described by Morrall et al.[12] The weights of roots and shoots are expressed as a percentage of the total weight.

ANALYSES

Before analysis, the pearl millet malts, including roots and shoots, were milled for 45 s in a "beater-type" water-cooled coffee mill (Janke and Kunkel, Staufen, Germany).

Germinative Energy (GE)

Determined as described by Morrall et al.[12]

Diastatic power (DP)

The standard method for sorghum malt DP[27] was used with the following modifications. The peptone extraction was replaced by distilled water extraction since the pearl millet malt used was prepared from tannin-free varieties. Two g whole malt flour was used instead of 25 g and the extraction volume was 40 mL instead of 500 mL. The extraction was carried out in centrifuge tubes and the extraction time was reduced from 2.5 to 2 h. Results are expressed as Pearl Millet Diastatic Units (PMDU) per g dry weight malt, where PMDU are equal to Sorghum Diastatic Units (SDU).

Alpha-amylase

Determined according to the method of Preece (1947), as modified by Novellie[16] by inactivating β-amylase activity at 70°C in the presence of Ca^{2+} ions. The malt extracts were prepared as for DP. Calcium acetate (0.02 g) was added to 10.0 mL malt extract. Extracts were incubated at 70°C for 15 min. After incubation, extracts were cooled in ice for 10–15 min at 30°C. Enzyme activity was then determined by the DP procedure and expressed as PMDU.

Beta-amylase

The contribution of β-amylase to diastatic activity was estimated by inactivating α-amylase activity with ammonium oxalate, which binds with calcium ions in the α-amylase molecule[29]. Pearl millet extracts were prepared by extracting 1.00 g of malt with 40.0 mL 0.2 M am-

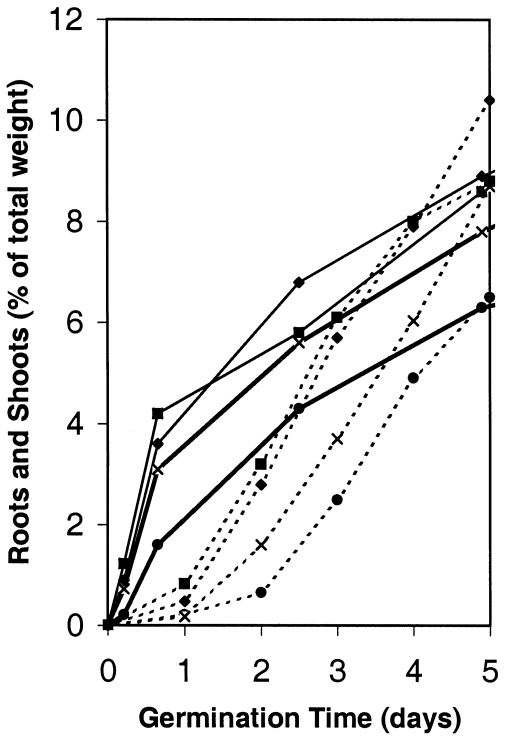

FIG. 1. Effects of germination time, temperature and grain variety on roots and shoots of pearl millet malt of SDMV 89004 (–) and SDMV 91018 (--) varieties (•--• 20°C; ×---× 25°C; ♦---♦ 30°C; ■---■ 35°C).

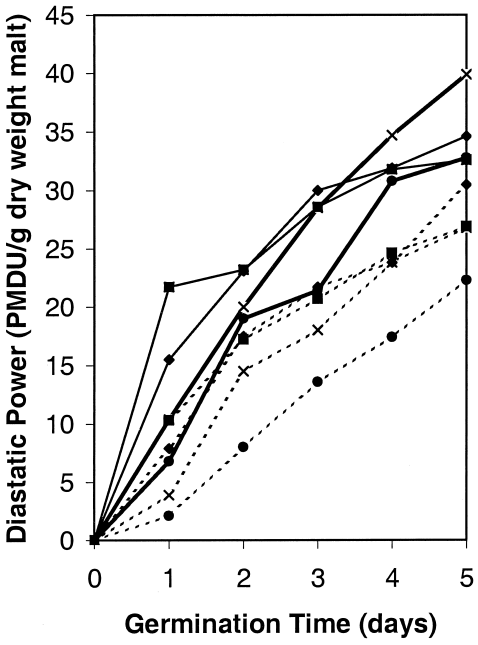

FIG. 2. Effects of germination time, temperature and grain variety on diastatic power (DP) of pearl millet malt of SDMV 89004 (–) and SDMV 91018 (--) varieties (•--• 20°C; ×---× 25°C; ♦---♦ 30°C; ■---■ 35°C).

monium oxalate for 90 min. The remaining enzyme activity, which is virtually all β-amylase, was then determined by the DP procedure and expressed as PMDU.

Free α-amino nitrogen (FAN)

One g of whole milled malt was added to 40.0 mL 5% trichloroacetic acid at 30°C. Extraction was carried out for 1 h at 30°C. At 15 min intervals the extraction tubes were swirled to suspend the contents. Ten mL of extract was centrifuged at 4,500 g for 10 min. After that, 1.0 mL of clear supernatant was diluted to 25 mL with distilled water. These samples were then subjected to the European Brewery Convention ninhydrin assay[4]. The results were expressed as mg FAN/100 g dry weight malt.

Malting loss

Total malting loss was calculated according to the method described by Gomez et al.[6]

Malting loss (%) = [(Initial grain dry weight - Dry malt weight)/Initial grain dry weight] × 100

Statistical analysis

Analysis of variance (ANOVA) with the least significant difference test (LSD-Test) was applied.

RESULTS AND DISCUSSION

The effects of germination time, temperature and variety on root and shoot growth are shown in Figure 1. The percentage of roots and shoots in pearl millet malt was significantly affected ($P < 0.001$) by germination time, temperature and variety.

Roots and shoots increased with germination time. Germination at 20°C gave the lowest root and shoot growth. Overall, germination at 30 and 35°C gave the highest root and shoot growth ($P < 0.05$). Generally, variety SDMV 89004 had higher root and shoot growth than SDMV 91018. This was expected since SDMV 89004 showed higher GE (Table I). However, the highest percentage of roots and shoots, 10.4%, was recorded at 5 days germination at 30°C with variety SDMV 91018. The roots and shoots values reported here are comparable to those found by other authors,[3] working with sorghum.

The effects of germination time, temperature and variety on DP are shown in Figure 2. DP, which is a measure of the joint α- and β-amylase enzymic activity[17,18], was also significantly affected ($P < 0.001$) by time, temperature of germination and variety. As with sorghum[17,19], non-germinated pearl millet did not have any DP. DP increased as germination time increased. Generally, the DP of malt germinated at 20°C was the lowest. Germination at 35°C gave an initially higher level of DP. However, the rate of increase in DP at 35°C declined over longer germination periods. Overall, germination at 30 and 35°C gave the highest DP ($P < 0.05$). The higher malt DP observed in variety SDMV 89004 compared to SDMV 91018 was expected since it had higher GE (Table I). In fact, variety SDMV 89004 gave about 30% higher DP than the SDMV 91018. Highest DP 40 PMDU/g was recorded at 5 days germination at 25°C with variety SDMV 89004. For sorghum beer brewing minimum malt

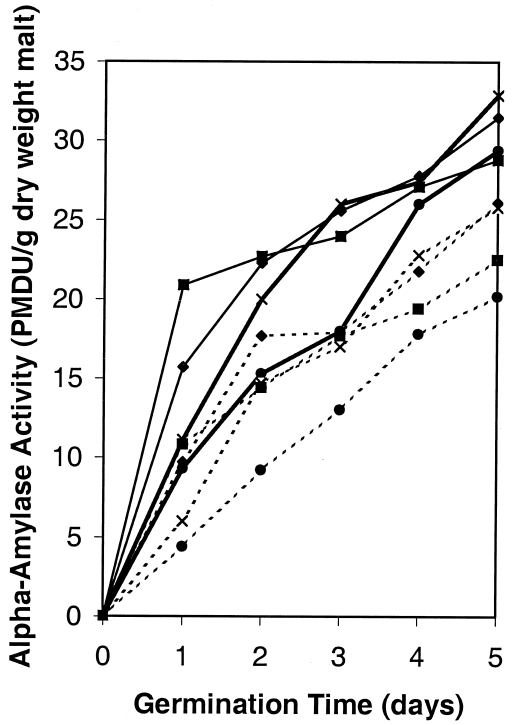

FIG. 3. Effects of germination time, temperature and grain variety on alpha-amylase activity of pearl millet malt of SDMV 89004 (–) and SDMV 91018 (--) varieties (•--• 20°C; ×---× 25°C; ♦---♦ 30°C; ■---■ 35°C).

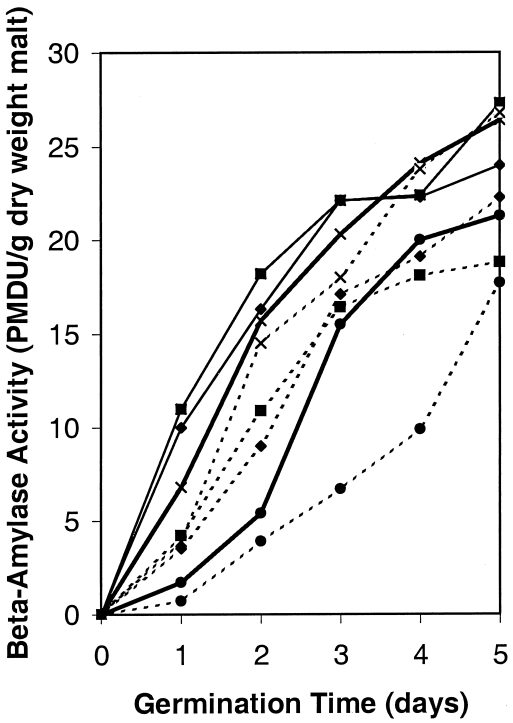

FIG. 4. Effects of germination time, temperature and grain variety on beta-amylase activity of pearl millet malt of SDMV 89004 (–) and SDMV 91018 (--) varieties (•--• 20°C; ×---× 25°C; ♦---♦ 30°C; ■---■ 35°C).

DP of 28 SDU/g is required for sorghum malt[2]. Hence, with respect to DP pearl millet is suitable for sorghum beer brewing.

The pearl millet malt DP values found in this research work are generally similar to those found by Gomez *et al.*[6] for pearl millet and slightly lower than those found by Morrall *et al.*[12] for sorghum.

The effects of germination time, temperature and variety on α-amylase activity are shown in Figure 3. As with DP, α-amylase activity was significantly affected ($P < 0.001$) by germination time, temperature and variety. There was practically no α-amylase activity in the non-germinated pearl millet. Alpha-amylase activity increased as the germination time increased. In general, α-amylase activity of pearl millet malt germinated at 20°C was the lowest. Germination at 35°C gave an initial higher level of α-amylase activity. However, as with DP, the rate of increase of α-amylase activity at 35°C decreased as the germination process continued. Overall, germination at 30 and 35°C gave the highest α-amylase activity, but 35°C was not significantly different from 25°C ($P > 0.05$).

The variety SDMV 89004 gave about 50% higher α-amylase activity than the SDMV 91018. The highest α-amylase activity 33 PMDU/g was recorded at 5 days germination at 25°C with variety SDMV 89004. The reason for this could be the higher GE shown by variety SDMV 89004.

These findings are in agreement with those of other authors working with sorghum[12,13,14,15,17,18,20,22] and millets[13,14,20,26]. Recently, Muoria and Bechtel[13] suggested that a germination temperature > 22°C would be more desirable for sorghum and pearl millet, than for barley, in order to obtain higher values of α-amylase. Singh *et al.*[26] found that, in finger millet, the level of α-amylase activity increased substantially when germination for 48-96 h was conducted at 30-35°C compared with germination at 20-25°C.

The effects of germination time, temperature and variety on β-amylase activity are shown in Figure 4. As with DP and α-amylase, β-amylase was significantly affected ($P < 0.001$) by time, temperature of germination and variety. The β-amylase activity of non-germinated pearl millet was negligible. Beta-amylase activity increased with germination time. As with DP and α-amylase, 20°C gave the lowest β-amylase activity for both pearl millet varieties. Generally, germination at 35°C produced a higher level of β-amylase activity during the initial germination period. However, as with DP and α-amylase, as the germination time progressed the rate of increase in β-amylase activity at 35°C slowed down. Overall, germination at 30 and 35°C gave the highest β-amylase activity ($P < 0.05$). However, for the variety SDMV 91018, germination at 25°C gave the highest β-amylase activity ($P < 0.05$).

The variety SDMV 89004 exhibited almost 25% higher β-amylase activity than the SDMV 91018. The highest β-amylase activity, 27 PMDU/g, was recorded at 5 days germination at 35°C with SDMV 89004 variety, again presumably related to the higher GE of this variety.

A difference between the hot (sorghum and millets) and temperate climate (for example barley) cereals and their

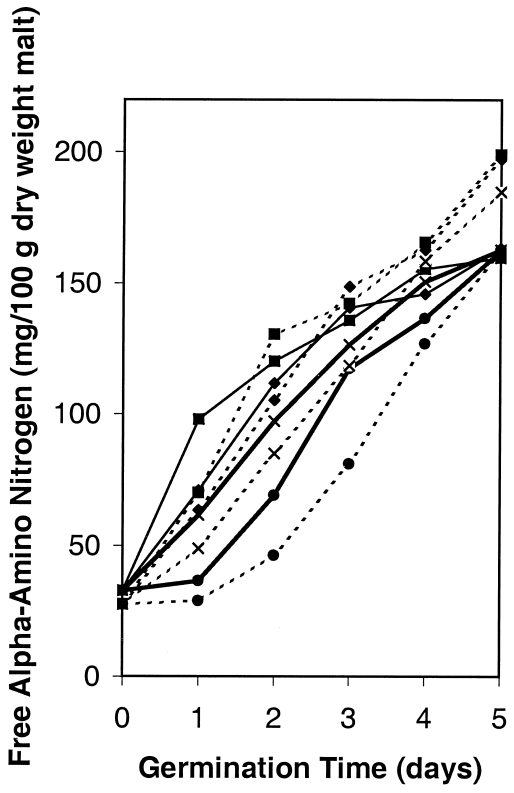

FIG. 5. Effects of germination time, temperature and grain variety on FAN of pearl millet malt of SDMV 89004 (–) and SDMV 91018 (--) varieties (●--● 20°C; ×---× 25°C; ♦---♦ 30°C; ■---■ 35°C).

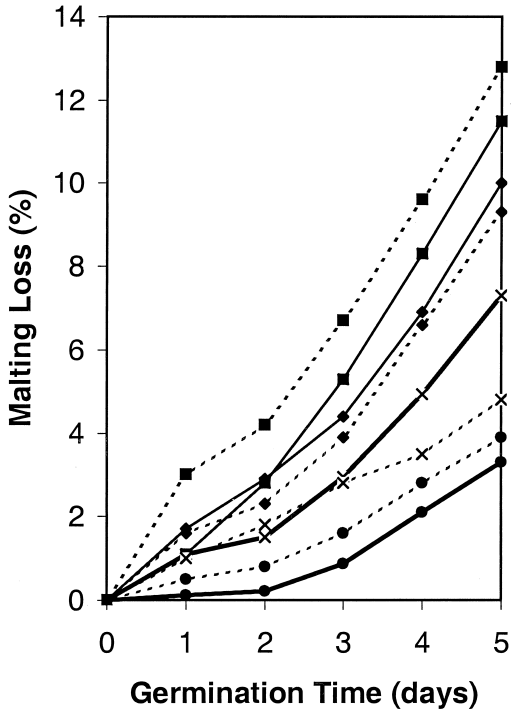

FIG. 6. Effects of germination time, temperature and grain variety on malting loss of pearl millet of SDMV 89004 (–) and SDMV 91018 (--) varieties (●--● 20°C; ×---× 25°C; ♦---♦ 30°C; ■---■ 35°C).

malts is the fact that non-germinated cereals indigenous to the tropical and sub-tropical areas of the world have no more than traces of β-amylase[19]. Both types of cereals have little α-amylase in non-germinated grains. Germination leads to the production of both amylases with α-amylase predominating[19,23]. Ungerminated temperate cereals have moderate amounts of β-amylase, but only traces of α-amylase[19]. On germination, α-amylase is formed and β-amylase, synthesized during temperate cereal (barley) development, is rendered fully active[7].

The effects of germination time, temperature and variety on malt FAN are shown in Figure 5. Malt FAN was significantly affected ($P < 0.001$) by time and temperature of germination. Variety did not have any effect on malt FAN. Ungerminated pearl millet grains contained some FAN, 32.9 and 27.6 mg/100g in variety SDMV 89004 and SDMV 91018, respectively. Malt FAN increased with germination time. The germination temperature of 20°C generally gave lower FAN. Overall, germination at 35°C gave the highest malt FAN ($P < 0.05$). Germination at 25 and 30°C gave intermediate malt FAN.

Although malt FAN was similar overall for both pearl millet varieties, malt FAN of SDMV 89004 at 5 days germination was generally lower than that of SDMV 91018. The highest level of FAN, 199 mg FAN/100 g malt, was recorded at 5 days germination at 35°C with variety SDMV 91018. This may be related to the fact that this variety had the highest percentage of roots and shoots, 10.4%, and these are a good source of malt FAN. Dewar *et al.*[3] reported that although roots and shoots represented only a relatively small proportion of the total weight of malt, their contribution to the total malt FAN was as high as 66%. Roots and shoots are known to be rich in various nitrogenous compounds[28]. During the germination process, the increase in the amount of FAN in roots and shoots is a result of translocation of the products of storage protein breakdown from the kernel[28].

A typical FAN specification for sorghum malt for sorghum beer brewing would be a minimum of 110 mg FAN/100g malt[2]. Hence, pearl millet malt is suitable for sorghum beer brewing with respect to FAN.

FAN development may vary among varieties, probably because of differences in major enzyme characteristics and rate of protein metabolism during malting, as well as variations in grain protein structure and degradability, and amino acid and peptide transport processes[21]. The fact that malt FAN was not affected by grain variety may suggest that the pearl millet varieties used in this research work had similar grain protein structure and degradability. In fact, the protein contents were very similar, 11.7 and 11.3% (db), for varieties SDMV 89004 and SDMV 91018 respectively.

The effects of germination time, temperature and variety on malting loss are shown in Figure 6. Malting loss was significantly affected ($P < 0.001$) by germination time and temperature. Variety did not have any effect on malting loss. Malting loss increased as the germination time increased. Germination at 20°C gave the lowest malting loss. Malting loss was directly temperature dependent. Overall, germination at 35°C gave the highest malting loss ($P < 0.05$). The germination temperature of 25 and 30°C gave intermediate malting loss. The highest malting loss, 12.0%, was recorded at 5 days germination at 35°C with variety SDMV 91018.

With regard to the effect of germination time on malting loss, the present findings are in agreement with publications on sorghum[3,12], and finger millet[14], which showed malting losses up to 12%. With respect to germination temperature, Dewar *et al.*[3] found 25-30°C to give relatively moderate malting loss in comparison with higher temperatures. Malleshi and Desikachar[10], working with finger millet, also found that malting loss increased with germination temperature.

CONCLUSIONS

The optimum malting conditions for high DP, α- and β-amylase activity, good FAN, and moderate malting loss are 25-30°C and 3-5 days germination. However, if the malting process is to be conducted in a short period of time, i.e. 1-3 days, the germination temperature should be higher, 30-35°C. The levels of DP, FAN, amylase activity and malting loss of pearl millet malts, which are similar to sorghum malts, represent an excellent potential for utilisation for sorghum beer brewing purposes. Variety affected most quality parameters, with variety SDMV 89004 producing better malt quality than variety SDMV 91018, possibly on account of its slightly higher GE.

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