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Effect of milling and mashing procedures on millet (*Pennisetum maiwa*) malt wort properties

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Abstract

Millet (*Pennisetum maiwa*) was malted for 5 days and mashed using the infusion, double-decoction and decantation mashing methods. Highest extract recovery was obtained in the decantation mashing system because in this mashing procedure, the enzymes of millet malt were protected and the starch adequately gelatinised. The decoction or decantation mashing method however, produced wort with lower values of soluble nitrogen and free amino nitrogen (FAN) products than the infusion mashing method because the proteins were partly denatured during the cooking process of the decoction or decantation mashing methods. The decantation mashing, in particular, produced wort that filtered more slowly. The wort also had a darker colour because of a greater degree of Maillard reaction. Wet milling marginally produced extracts with higher values of the parameters tested than dry milling, but both the wet and dry milling procedures maintained a constant mass balance of the soluble nitrogen and FAN products.

Keywords: Millet; Malting; Mashing; Wet milling; Dry milling wort

1. Introduction

The need to explore the brewing potential of different cereals, especially tropical crops, has been on the increase. This is most important now that it is anticipated that the earth is getting warmer. In most developing countries of the tropics however, the trial and use of indigenous raw materials is due to local economic difficulties [1]. The introduction and use of local raw materials into the conventional brewing practice will definitely necessitate the modification of existing brewhouse equipment, especially where the equipment was originally designed to handle barley malt. Also, the final product (beer) will be different from the well-known beer brewed from barley malt [2]. Sorghum is, however, the widely accepted cereal in use where barley malt is not readily affordable. The choice of sorghum is not surprising. It is probably because of the long history of using sorghum as a substitute for barley during World War II, when barley became very scarce [3]. Based on early trials, the use of sorghum in brewing and the acceptability of beer brewed with sorghum, extensive physiological work has been performed on sorghum since then, and has resulted in the research assessment of the full potential of brewing with sorghum [4–25]. Such detailed studies have not been carried out on millet.

Millet belongs to the same family as barley and sorghum and would be expected to show similar physiological changes to those of barley and sorghum during malting. Indeed, research studies have shown that millet could be used in brewing European-type lager beer [2,26,27]. Other studies have suggested that millet has other important qualities. For example, it was shown that millet malt produced wort that filtered faster than sorghum malt wort [28] and produced beers that had better foam properties than beers brewed from sorghum malt (Ref. [27] and H. Bryne, personal communication). While Moir [29] attributed beer quality to colour, clarity, foam appearance and flavour, compara-

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tive studies of barley, sorghum and millet showed that beer brewed from millet malt met these qualities [27].

Millet has some physical properties that are similar to those of sorghum, especially with regard to the gelatinisation temperatures of the starches of sorghum and millet [30]. The fact that a suitable mashing method has been developed for extracting sorghum malt, whose starch, like that of millet, gelatinises at a high temperature, suggests that millet malt would be extracted in a similar way. This study was, therefore, designed to evaluate whether similar mashing methods developed for extracting sorghum malt would be suitable for extracting millet malt. The standard mashing method developed for barley malt was unsuitable for sorghum malt because of differences in the gelatinisation temperatures of both cereal malts and not due to limitation in enzyme levels of barley and sorghum malts [13,15]. Bearing in mind the differences between the malts of barley and sorghum, the effects of different milling and mashing methods on wort composition and properties of millet malt were investigated.

2. Materials and methods

2.1. Grain/malt analyses

Grain and malt properties were analysed using recommended methods [31,32].

2.2. Germination of millet

Millet grains were steeped in water at 25°C for 16 h, followed by a 2-h air-rest and a further 16-h wet-steep and germinated at the same temperatures for 4 or 5 days. The grains were sprayed with water as required, turned daily to avoid root matting and kilned at 50°C for 24 h.

2.3. Grist preparation and mashing

Dried malt was rubbed between the hands to remove the rootlets and culms and crushed to fine grists using a Buhler–Miag mill (setting 2 or 7). Different milling procedures were also used (see Section 3). Dry or wet milled (pre-soaked malt) grist was then mashed using the infusion or double-decoction or decantation mashing method in order to determine the most suitable method for extracting millet malt. For dry milling, malt (4% moisture) was milled using a Buhler–Miag mill. In contrast, wet malt was dried to a moisture level of 7% and milled using a Buhler–Miag mill. When dry milling with steeping condition was used, dry malt (4% moisture) was pre-soaked in water for 1 h and the surface moisture dried at 50°C for 1 h to enhance milling without making a paste (moisture level was 6%). Similarly, wet malt (7% moisture) was also treated as described above (moisture level was 8.5%). In order to control both temperature and time, mashing was carried out in a thermostated water bath.

2.4. Infusion mashing at 65°C and decantation mashing

The infusion and decantation mashing were performed as described elsewhere [13,33].

2.5. Double decoction mashing

Some 50 g of grist was mixed with 360 ml of distilled water equilibrated at 40°C. The first decoction was performed by removing a fraction of the mash which was heated for 8 or 10 min in a boiling water bath and returned to the main mash to a temperature of 65°C for 30 min. A second decoction was performed as before, after which the temperature was raised to 75°C for 30 min. The mash was then cooled and filtered to obtain the wort.

2.6. Wort analyses

2.6.1. Wort filtration rate

The filtration rate of wort sample was determined by transferring the mashed sample into a fluted filter paper and checking the time for collecting 100 ml of sample following re-circulation of the first 20 ml of the filtered extract.

2.6.2. Wort viscosity

A wort sample was equilibrated in a Julabo water bath at 20°C and then injected into the Brookfield Digital Viscometer. Viscosity was determined using a correction factor.

2.7. Hot water extract

This was determined by feeding the wort sample into a density meter (Paar Digital Density Meter) at 20°C [13].

2.8. Total soluble nitrogen (TSN) and α-amino nitrogen (FAN)

Wort total soluble nitrogen was determined using the Kjeldhal method while free amino nitrogen (FAN) was determined by the Ninhydrin method [13].

3. Results and discussion

Table 1 shows some analytical properties of unmalted millet and the malt made from millet. When millet was malted for a period of 5 days, a marginal

Table 1
Properties of millet (*P. maiwa*) sample and malt mashed using the infusion method

	Millet grains	Millet malt
Moisture (%)	10.8	5.7
Total nitrogen (%)	1.7	1.4
Gelatinisation temperature (°C)	75	72
Thousand corn weight (g)	20.1	–
Germination energy (%)	96.0	–
Germination capacity (%)	98.0	–
Malting loss (%)	–	18.3
Diastatic power (°L)	–	34
Cold water extract (%)	–	20.7
Hot water extract ('as is') (l°/kg)	–	203
Hot water extract ('dry') (l°/kg)	–	215
Colour (°EBC)		6.0
TSN (%)		0.58
FAN (mg/l)		168

drop in the gelatinisation temperature of millet malt starch was observed. The gelatinisation temperature of millet malt starch is within the temperature range at which α-amylase would be active. This could possibly explain why a high value of hot water extract was obtained in the infusion mashing method (Table 1). The high soluble nitrogen and FAN products of the millet malt extract are worth noting. It would seem that the protein of millet was very susceptible to hydrolysis during malting and mashing. Indeed, an earlier report (Ref. [27] and H. Bryne, personal communication) confirmed that millet malt produced wort with excellent foam properties.

When different mashing methods were employed in extracting millet malt, it is clear from Table 2 that the double-decoction mashing produced more extract than the infusion mashing method reported in Table 1. It is also clear from Table 2 that the decantation mashing method produced higher extract yield than the double-decoction mashing method (Table 2) or the infusion mashing method (Table 1). In the double-decoction mashing method, portions of the malt starch would be gelatinised during the cooking process. In these portions of the cooked mash, the hydrolytic enzymes present in the mash are denatured. In contrast, in the decantation mashing, the enzymically active wort is removed and re-introduced into the gelatinised starch of millet malt after cooking and cooling. This, therefore, explains why higher extract yield was obtained in the decantation than in the decoction mashing method (see Table 2).

Table 2
Effect of mashing procedure on properties of millet malt wort

	Double decoction	Decantation
Wort specific gravity (20/20°C)	1.0262	1.0316
Hot water extract (l°/kg)	265	320
Colour (°EBC)	6.5	9.8
pH	5.4	5.4
TSN (%)	0.52	0.48
FAN (mg/l)	158	148
Filtration time (min) for 100 ml	28	22

It would appear however, that when the malt of millet was mashed in the decantation method, a higher degree of Maillard reaction occurred. This resulted in the wort obtained from the decantation mashing method developing a higher colour than the wort obtained from the decoction mashing method (Table 2), or the infusion mashing method (Table 1). The decantation mashing method also produced wort that filtered more slowly (Table 2). It is likely that the decrease observed for soluble nitrogen and FAN products of the double-decoction mashing method (Table 2), when compared with that of the infusion mashing (Table 1), was caused by denaturation of proteins and/or de-activation of enzymes in the portion of the cooked mash [17]. In addition, it is likely that the decrease in soluble nitrogen and FAN products in the wort of the decantation mashing was caused by a higher degree of denaturation of the proteins following the cooking of the separated grist in the decantation mashing [17].

In Table 3(a), the effect of dry or wet milling and grist particle size on millet malt wort properties, mashed using the double-decoction method, are shown. As expected, when the millet malt was milled to a fine particle size, more extracts were recovered than when the milling was coarse. It is interesting to note that wet milling gave higher extract and wort with lesser colour than dry milling for unknown reasons. When the decantation mashing was employed in mashing the malt grist (wet or dry milling), higher extract yields were obtained (compare Table 3(a) and (b)). The decantation mashing again produced wort with higher colour and viscosity. The reason for the higher viscous wort of the decantation mashing method is not known, but it is possible that during the cooking process in the decantation mashing method, viscous β-glucans are released. Although the enzymic worts were removed prior to cooking the solid materials in the decantation mashing and then re-introduced into the mash after cooling, the fact that the wort remained viscous confirm that β-glucan-degrading (β-glucanase) enzymes were not active during the mashing process [34].

It is interesting to note that neither dry nor wet milling and/or the method of mashing did not alter significantly the values of soluble nitrogen or FAN in the wort (compare Table 2 and Table 3(a) or (b)). It is also interesting to note that when the malt was ade-

Table 3
Effect of milling on millet malt wort properties

	(a) Decoction mashing				(b) Decantation mashing			
	Dry milling		Wet milling		Dry milling		Wet milling	
	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse
HWE ('as is') (l°/kg)	260	252	263	255	278	269	296	287
HWE ('dry') (l°/kg)	265	259	268	269	285	277	320	311
Colour (°EBC)	7.5	7.5	7.0	7.0	8.0	8.0	8.5	8.5
TSN (%)	0.52	0.52	0.53	0.53	0.48	0.48	0.48	0.48
FAN (mg/l)	158	157	158	156	147	146	147	147
Viscosity (cP)	1.25	1.10	1.19	1.02	1.32	1.29	1.22	1.18
Filtration time (min)/100 ml	29	24	28	23	30	26	29	24

Table 4
Effect of conditioned milling on millet malt wort properties (decoction)

	(a) Decoction				(b) Decoction			
	Dry milling[a] (+steeping condition)		Wet milling[a] (+steeping condition)		Dry milling[a] (+steeping condition)		Wet milling[a] (+steeping condition)	
	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse
HWE ('as is') (l°/kg)	277	269	276	268	316	308	310	309
HWE ('dry') (l°/Kg)	298	289	299	291	324	315	322	314
Colour (°EBC)	8.0	7.5	10.5	8.5	9.5	8.5	10.0	8.5
TSN (%)	0.52	0.52	0.53	0.53	0.48	0.48	0.48	0.48
FAN (mg/l)	161	160	162	160	152	149	150	148
Viscosity (cP)	1.19	1.00	1.16	1.14	1.22	1.15	1.20	1.10
Filtration time (min)/100 ml	29	24	28	23	24	20	25	22

[a] See Section 2.

quately wetted prior to milling, the hot water extract increased in both the decoction and decantation mashing procedures (see Table 4(a,b)). The reason for this observation is not clear and it is not known if the steeping condition activated some of the enzymes prior to mashing. If this proposal is correct, however, it would probably explain why the wort produced in Table 4(a,b) had higher values of extract and FAN products, even though the soluble nitrogen values remained fairly constant. This observation however, requires further investigation.

4. Conclusion

The results of this study showed that millet and sorghum malts require similar mashing procedure for optimal extraction. This is due to similar gelatinisation temperature of the starch of both cereals. Millet malt produced high extracts in the infusion mashing because of a slight decrease in the gelatinisation temperature of millet starch when millet was malted. However, higher extract recovery was achieved when millet malt was mashed using the decoction or decantation mashing because the starch of millet malt was gelatinised in the cooking process of these mashing methods. Although decantation mashing produced higher extract yields, the soluble nitrogen and hence the FAN products decreased slightly because the proteins were partly denatured when the solid materials were cooked. The wort of the decantation mashing was a little darker. In general, wet milling of millet malt produced a higher yield of extract than dry milling. Milling with steeping condition produced the highest extract yield and yields of other parameters tested. This study therefore confirmed that cereals whose starches have higher gelatinisation temperature than those of barley can be extracted adequately using the decantation mashing procedure.

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