The Effect of Mashing Methods on The Production of Non alcoholic Sorghum Malt Beverage

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ABSTRACT

Although sorghum(*Sorghum bicolor*) has been used traditionally to produce foods, malt and alcoholic beverages in Sudan, its structure and nutritional function have not been enough studied. Sorghum can be malted and processed into malted foods and beverages. The objective of this study was to study the effect of mashing methods on malt quality and wort composition to produce non-alcoholic sorghum malt beverage. Malting was carried out at 30°C for 5 days under non-aerated condition. Mashing methods included decantation at 80°C (wort A) and at 100°C(wort B). Wort composition in terms of α –amino nitrogen, total soluble nitrogen, reducing sugars, pH, colour, original gravity and viscosity were determined. The results of wort A were 114 mg/l, 43%, 39.42 mg/ml, 6.59, 9 EBC, 1.026 and 0.846 cP, respectively. Whereas the results of wort B were 125 mg/l, 53%, 41.67 mg/ml, 6.68, 11 EBC, 1.025 and 0.864 cP, respectively. Decantation mashing at 100°C produced much better results in terms of malt and wort properties than that at 80°C where boiling the mash at 100°C adequately gelatinized residual sorghum malt starch, since sorghum starch has a gelatinization temperature of 80°C.

Keywords: Sorghum malt beverages, decantation, total soluble nitrogen, reducing sugars, clour.

NTRODUCTION

Sudan is the third country in Africa and the seventh in the world's largest sorghum producer (Oluwakemi and Omodele, 2015). The annual sorghum production ranged between 2.2 and 4.2 million tons and is grown in 10-14, 000,000 acres. More than 75% of this production from rainfed sector. This makes sorghum, quantitatively the first most important cereal grain .

Foods prepared from sorghum can be grouped in two categories, traditional products and non-traditional industrial products. Unprocessed or processed grain can be cooked whole or decorticated and if necessary ground to flour by any of the traditional or industrial methods. A detailed classification of traditional foods from sorghum has been developed (Vogel and Graham, 1979; Rooney et al., 1986). They can be classified broadly into breads, porridges, steamed products, boiled products, beverages and snack foods (Rooney et al., 1986; Rooney and McDonough, 1987).

The primary goal of mashing is to complete the breakdown of proteins and starches that was begun during the malting process. This is accomplished by several groups of enzymes that degrade different substrates during a series of rests at specific temperatures. Some studies on mashing show that starch hydrolysing enzymes, α and β amylase, which developed during malting of sorghum appeared to be in low activities, when assayed using new standard methods (McCleary and Sheehan, 1987; McCleary and Codd, 1989). These seemingly low enzyme levels of sorghum malt are nevertheless sufficient to produce commercially acceptable yields of extract. However, an adapted mashing procedure developed for extracting sorghum malt which gelatinized sorghum starch and protected the enzymes of sorghum malt, must be used to extract sorghum malt if equivalent starch extract to that achieved for barley malt is to be realized.

Mashing of sorghum malt at 65°C rather than the decantation method resulted in the production of high levels of peptides (Agu and Palmer, 1997; Agu *et al.*, 1996). Brewing with sorghum malt would therefore require the development of a suitable mashing regime which would be quite different from that of barley malt (Dufour and Melotte, 1992).

MATERIALS AND METHODS

Preparation of samples

Seeds of local sorghum (*Sorghum bicolor* (L) Moench) cultivar known as *Feterita* were procured from a retail outlet Wad medani market, Sudan. The grains were carefully cleaned and freed from broken seeds and extraneous matter.

Wort Production

Wort was produced from the sorghum seeds, non-aerated germinated for 5 day at 30°C by two different mashing procedures according to Igyor *et al*. (2001) procedure as described below:

Decantation mashing at 80°C (wort A)

This mashing procedure is a slight modification of the infusion process. Briefly, 50 g of the grist were mashed in 360 ml distilled water at 45°C for 30 min. Thereafter, 150 ml of the clear ‘‘enzymic supernatant’’ were removed while the remaining mash was heated at 80°C and held at the same

temperature for 30 min and cooled below 50°C at which the clear ‘‘enzymatic supernatant’’ was re-added. The mash was stirred and temperature raised to 65°C as above. After 1 h at 65°C, the mash then heated to 75°C for 10 min and cooled, and the volume adjusted to 515 ml with distilled water were stirred well and filtered using filter paper.

Decantation mashing at 100°C (wort B)

This procedure is similar to that reported above except that the enzymatic wort was removed after mashing at 45°C and the residue was boiled at 100°C instead of being heated at 80°C. The total volume raise up to 515 ml with distilled water stirred well and filtered using filter paper.

Physicochemical properties of sorghum wort

Sorghum wort samples were analyzed to determine several physicochemical properties, these were:

Wort α -amino nitrogen was determined by Ninhydrin method. Sample was adequately diluted (1 ml sample in 100 ml distilled water) as recommended. Diluted sample or glycine standard solution, two milliliters, were mixed with one milliliter of ninhydrin colour reagent and heated for 16 min in a boiling water bath(Grant W 14, Grant Instrument (Cambridge) Ltd, Barrington, Cambridge). After cooling for 20 min at 20°C, 5 ml of diluting reagent were added. The absorbance was measured at 570 nm in a spectrophotometer (Spectrumlab 22 pc No. 08370). Blank solution contained all the reagents except the test solution that was substituted with distilled water. The result was obtained using following formula:

$$\frac{\text{Absorbance of standard}}{\text{Concentration of standard}} = \frac{\text{Absorbance of sample}}{\text{Concentration of sample}}$$

Total soluble nitrogen was determined by the Kjeldhal method. 1.0- 1.5g of malt was digested on a heater block (Tecator Digester System 1007 Digester). The distillation was effected in a Kjeldhal distillation unit (TecatorKjeltec System 1002 Distillation Unit), and titration of the resulting distillate was carried out using a Metrohm Herisan Multiburette E485 System (Agu and Palmer, 1997). Percentage of total soluble nitrogen was calculated using following formula:

$$\frac{\text{Titre} \times 0.0014 \times 6.25 \times \text{dilution factor}}{\text{Weight of sample}} \times 100$$

The reducing sugars values were determined using Lane and Eynon constant volume method (Ferdinand, 1979).

pH of wort was determined according to AOAC (1980) using a pH meter model (PHSJ-4A)standardized with buffer solution of pH 7.Approximately 25mL of wort were placed into a 50 ml beaker. The probe was inserted into the liquid and gently stirred until a stable pH was displayed.

Determination of wort colour was carried out using spectrophotometer (Spectrumlab 22 pc No. 08370) which was set at 430 nm with the visible light on, and zeroed using distilled water as blank. The samples were placed into a 10 mm silica cell, wiped clean and the intensity values recorded. The wort colour were compared to Lovibond scale colour chart (Jean, 1957).

Original gravity was determined by using an electrical balance. 100 cm^3 of wort were weighed in density bottle and the same volume of distilled water was weighed at 21°C.Original gravity was expressed mathematically as:

$$\rho_{wort} / \rho_{water}$$

Where ρ_{wort} is the density of the wort and ρ_{water} is the density of water
(Fellows, 2005).

Wort viscosity was determined using glass capillary viscometer (U-Viscometer). The driving force in the gravity operated glass capillary viscometer was the hydrostatic head. Viscosity of wort was expressed in centipoises (cP) and calculated as described by Steffe (1996) as below:

$$\mu_1 = (\rho_1/ \rho_2)\times(t_1/t_2) \times \mu_2$$

where $\mu \equiv$ viscosity
$\rho \equiv$ density
$t \equiv$ flow time through viscometer
subscripts 1 and 2 refer to wort and water respectively

RESULTS AND DISCUSSION

The objectives of mashing are to extract into solution, fermentable sugars, amino acids, vitamins, etc., from malt. Malt normally provides most of the potential fermentable materials and sufficient enzymes to generate a well-balanced fermentation medium (François *et al*., 2012).

Protein hydrolysis measured as α -amino nitrogen achieved suggests that effective enzymatic hydrolysis of the endosperm proteins occurred at the germination temperature.

α- Amino nitrogen of wort A and wort B were 114 mg/L and 125 mg/L, respectively (Table 1). The results were higher than that achieved by Abdulraheem *et al*. (2013) who found that α -amino nitrogen of red Sorghum malt grain which were sourced at a local market Abuja, Nigeria was 32.3mg/l but α-amino nitrogen of wort A and wort B were within the range of results obtained by Agu and Palmer (1997) who found that α- Amino nitrogen of sorghum wort germinated at 30°C for one day and mashed at 65°C were 91mg/L and 216 mg/L and for wort germinated at 30°C for five days and mashed at 65°C. Also α- amino nitrogen of wort A and wort B were within the range of the results achieved by Ijasan *et al*. (2011) who found that less α- amino nitrogen was 96 mg/L when sorghum malt germinated at 30°C for 5 days using the infusion method and high α- amino nitrogen was 196 mg/L when sorghum malt germinated at 28°C for 4 days using decantation methods. Odibo *et al*. (2002) also found that α- Amino nitrogen were 144 and 138 mg/L, respectively for two sorghum varieties studied with a view to producing wort and evaporated wort. Igyor *et al*. (2001) found in their studies the effect of malting temperature and mashing methods on sorghum wort composition and beer flavour free amino nitrogen ranged between 91- 177 (mg/L).EtokAkpan (2004) in his study on the changes in sorghum malt during storage reported that α -amino nitrogen levels dropped from 238 to 194 mg/L during the six month storage period.

Protein solubilisation measured as total soluble nitrogen also as well as protein hydrolysis measured as α -amino nitrogen achieved suggests that effective enzymic hydrolysis of the endosperm proteins occurred at the germination temperature.

Total soluble nitrogen of wort A and wort B were 0.43% and 0.53 %, respectively. Agu and Palmer (1997) found that the total soluble nitrogen of different sorghum varieties (white, yellow and red varieties) germinated for 5 days at 30˚C were 0.43%, 0.57%, 0.45% and 0.71%. Also the total soluble nitrogen of wort A and wort B were more than that obtained by Igyor *et al*. (2001) who found in their studies on effect of malting temperature and mashing

methods on sorghum wort composition and beer flavour, that the total soluble nitrogen was ranged between 0.32% to 0.43%. Odibo *et al*. (2002) studied two sorghum varieties with a view to producing wort and evaporated wort, found that the total soluble nitrogen were 0.66% and 0.56%. Also the results obtained were less than that achieved by Abdulraheem *et al*. (2013) who found that total soluble nitrogen of red Sorghum malt grain was 2.12%.

Figure (1): Germinated sorghum

Reducing sugar of wort A and wort B were 39.42 mg/ml and 41.67 mg/ml, respectively. Igyor *et al*. (2001) studied the effect of malting temperature (20°C and 25°C) and mashing method (infusion mash at 65°C, decantation/mash boiled at 80°C and decantation/mash boiled at 100°C) the reducing sugars of sorghum worts ranged between 186 and 422 µg/l. Owuama and Adeyemo (2009) reported the effect of exogenous enzymes sources, sweet potato (*Ipomeabatatas)* and yellow yam *(Discoreacayenesis)* concluded that an increase in the amounts of reducing sugar compared with the untreated malt on the sugar content of wort of a four sorghum varieties. Reducing sugar of untreated malt were 20, 20, 21 and 21 g/l for wort and *Ipomea*were 23, 31, 36 and 43 g/l and for wort and *Discorea* were 128, 97, 119 and 120 g/l. Avicor *et al*. (2015) recently reported that reducing sugar of sorghum wort at zero time of fermentation

was 86 when the quality characteristics of wort pitched with single and mixed Culture yeast strains during 24, 48 and 72 hours alcoholic fermentation. In early study Owuama and Asheno (1994) reported that three temperature regimes, 55°C, 55/65°C and 65°C, were used to kiln green malts of three varieties of sorghum, produced from grains steeped for different periods at 30°C. Maximum reducing sugar values for KSV variety (5.63 mg/ml), FFBL variety (5.89 mg/ml) and CHAKARA variety (5.57 mg/ml) were obtained from malts of grains steeped for 20 h and kilned at 55/65°C.

The pH which is the level of either acidity or alkalinity of any substance are very important as the body intake of either acid or alkaline are monitor and regulated, to avoid any excess take a disorder.

The pH of wort A and wort B were 6.59 and 6.68, respectively. The decantation mashing at 80°C (wort A) generally gave lower pH than the decantation mashing at 100°C (wort B). However, there was no clear difference of mashing procedures on pH of wort. the results were near to those reported by Odibo *et al*. (2002) who found that the pH of wort produced from two Nigerian sorghum varieties (SK 5912 and Fara fara) were 6.2 and 6.3, respectively. Malomo *et al*. (2012) found that the effect of commercial enzymes on pH of wort developed from replacement of malted barley (100%) with sorghum as adjunct 50%, 60%, 70%, and 80% were in range of 5.6 and 6.0 with no significant changes at all levels of replacements. Avicor *et al*. (2015) reported that both the fermentation time and inoculum type influenced pH of the fermenting wort. The decrease in pH value obtained by Nkiko *et al*. (2006) who found that pH of malted and un-malted sorghum wort were 5.62 and 5.73, respectively compared with malted barley and malted barley/sorghum adjunct which were 5.06 and 4.70, respectively. However, fermentation time decrease pH value of wort (Raji *et al*., 2014) who found that pH of Pre-fermentative wort of two local Nigerian varieties, red and white were 5.6 and 5.7, respectively.

The average wort colours for sorghum malt mashing at 80°C and mashing at 100°C were 9 EBC and 11 EBC and 4 – 6 on the Lovibond scale, respectively table (1).Odibo *et. al*. (2002) reported that the colour of wort produced from the higher nitrogen sorghum is darker than that obtained from the lower nitrogen sorghum. It is not conclusive at present whether a direct relationship exists between grain nitrogen per free amino nitrogen products and colour development during mashing. There is however, evidence to show that when the soluble nitrogen and/or sugars present in the extract are high, the colour of the extract might be high. EtokAkpan

(2004) reported that freshly kilned sorghum malt displayed high wort turbidity (4.9 EBC) which dropped to 0.95 EBC and 1 EBC after 2 and 6 months of storage, respectively.

Nandwa *et al.* (2013) in their study on Malted sorghum as a possible alternative to barley in beer industry found that the average wort colour for sorghum malt was 15.62 ±0.02 EBC and 6-8 on the Lovibond scale. The value was slightly higher compared to that of barley malt at 13-14 EBC (average value). Wort colour contributes directly to the clarity of final beer. Clarity affects certain final beer characteristics such as beer texture, turbidity and final beer colour.

Knowledge of the density of foods is important in separation processes and differences in density can have important effects on the operation of size reduction and mixing equipment. Density of liquids is a measure of mass per volume at a particular temperature can be expressed as specific gravity which is found by dividing the density of a liquid by the density of an equal volume of pure water at the same temperature. Specific gravity is widely used instead of density in brewing and other alcoholic fermentation where the term Original gravity is used to indicate the specific gravity of the liquor before fermentation (Fellows, 2005).

Original gravity of wort A and wort B were 1.026 and 1.025, respectively. These results were less than that achieved by Aniche and Anih (1994) who reported that specific gravity of wort samples from two malted sorghum varieties (SK5912 and KSW3) and barley were the same (1.04). Also the results were less than that of Odibo *et al.* (2002) who found that original gravity of mash of two sorghum varieties were 1.042 and 1.045, respectively. Avicor *et al.* (2015) recently reported that original gravity of sorghum wort at zero time of fermentation was 1.0416. Nkiko *et al*. (2006)

found that original gravity of wort made with un-malted sorghum, malted sorghum, malted barley and sorghum/barley malt adjunct were 1.004394, 1.04406, 1.04415 and 1.04412, respectively.
Viscosity plays an important role in theory of filtration and it is taken into account when designing the filters and setting the working pressures. Lowe *et al*. (2005) reported that a high viscosity makes beer filtration more difficult and may lead to starch hazes in the final beer. Severa *et al*. (2009) also wrote that viscosity is monitored in several different stages of beer production (supplied malt quality tracing, malt and wort quality determination, filtration monitoring, and final product evaluation). Beer has an almost ideally viscous behaviour and is therefore a Newtonian

liquid (Steffe, 1996). This makes it possible to determine the malt, beer, and filtered wort viscosity using relatively simple measuring principles.
The viscosity of wort A and wort B were 0.846 cP and 0.864 cP, respectively. The results were less than that of Severa *et al*. (2009) who reported that dynamic viscosity of wort gradually increased from 1.75 to 2.1 mPas during lager beer base processing which separated in 11 different stages, first stage at 5 min after mashing 52 °C and last stage at the end of wort boiling. Malomo *et al*. (2012) found that the effect of enzymes on the quality of beer/wort developed from proportions of sorghum adjuncts on viscosity ranged from 1.33 to 1.46. Igyor *et al.* (2001) in early study on the effect of temperature of malting and mashing methods on sorghum wort composition and beer flavour the less viscosity was 1.30 cP and high viscosity was 1.54 cP. Therefore, they observed from the results that the different mashing procedures did not change the viscosity of either sorghum malt wort produced from either the infusion or decantation mashing at 80°C. In contrast, a significant increase in wort viscosity of sorghum malt was observed when the decantation mashing was done at 100°C for unknown reasons. Although the wort β-glucan was not investigated, it is likely that other materials that caused an increase in wort viscosity were extracted at 100 °C. This required further investigations.

Table (1): Physicochemical properties of sorghum wort

Wort properties	Wort A[a]	Wort B[a]
α –Amino nitrogen (mg/l)	114	125
Total soluble nitrogen (%)	43	53
Reducing sugar (mg/ml)	39.42	41.67
pH	6.59	6.68
Colour (EBC)	9	11
Original gravity	1.026	1.025
Viscosity (cP)[b]	0.846	0.864

[a] Decantation mashing at 80 °C (wort A), Decantation mashing at 100 °C (wort B).
[b]cP centipoises

CONCLUSION

The study confirmed that decantation mashing at 100°C produced much better results in terms of malt and wort properties than at 80°C because boiling the mash at 100°C adequately gelatinized sorghum malt starch, since sorghum starch has a gelatinization temperature of 80°C. Further research is needed to- Introduce exogenous enzymes for mashing sorghum malt to yield more sugars in wort.

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تأثير طرق الاستخلاص على إنتاج مشروب ذرة خالي من الكحول

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ملخص الدراسة

تستخدم الذرة الرفيعة في السودان بطرق تقليدية لإنتاج الأغذية والمشروبات التقليدية المخمرة وغير المخمرة ولكن بالرغم من استخدامها الكبير إلا أن دراسة تركيبها وخصائصها التغذوية لم يتم البحث فيه بشكل كاف. الذرة الرفيعة يمكن أن تزرّع وتصنع على شكل أغذية ومشروبات بالوسائل الحديثة. هدف هذا البحث دراسة طرق الاستخلاص على مكونات المستخلص لإنتاج مشروب خالي الكحول. تم إنتاج الذريعة بالتزريع عند درجة حرارة 30 مْ لمدة 5 أيام تحت ظروف غير هوائية. استخدمت طريقة استخلاص المشروب على درجة حرارة 80 مْ (المشروب أ) و 100 مْ (المشروب ب). تم تقدير الفا امينو نتروجين و والنايتروجين الكلي الذائب و السكريات المختزلة و الأس الهيدروجيني واللون والكثافة واللزوجة لمستخلص الذرة وكانت نتائج المشروب (أ) 114 ملجرام/ لتر و 43% و 39.42 ملجرام/مللتر و 6.59 و EBC 9 و 1.026 و 0.846 سنتبواز على التوالي وكانت نتائج المشروب (ب) 125 ملجرام/ لتر و 53% و 41.67 ملجرام/مللتر و 6.68 و EBC 11 و 1.025 و 0.864 سنتبواز على التوالي. وجد أن الاستخلاص على درجة حرارة 100 مْ أدى لنتائج أفضل لخصائص مستخلص الذرة مقارنة بالاستخلاص على 80 مْ وذلك بسبب أن الغليان على درجة حرارة 100 مْ يودي إلى الجلتنة التامة لحبيبات نشا الزريعة بما أن درجة حرارة الجلتنة لنشا الذرة الرفيعة 80 مْ.