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Effect of varietal differences and germination period on some malting and brewing potentials of new improved sorghum varieties (SAMSORG17, SAMSORG14, and SAMSORG40) from Nigeria

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Abstract

The effect of varietal differences and germination period was studied to determine some malting and brewing potentials of three new improved sorghum varieties (SAMSORG17, SAMSORG 14 and SAMSORG40) in the brewing industry in Nigeria. Results showed that both variety and germination period had significant ($p < 0.05$) effect on sorghum malt quality parameters. The germination energy (GE) and germination index (GI) ranged from 97.21 ± 0.01 – 98.67 ± 0.05% and 0.95 ± 0.02 – 0.97 ± 0.03, respectively. The crude protein (CP), degree of steeping (DS) and malting loss (ML) were: 9.81 ± 0.02 – 10.94 ± 0.03%, 39.52 ± 0.09 – 42.58 ± 0.05% and 10.06 ± 0.37 – 12.91 ± 0.42%. The sorghum malt wort filtration rate (FR), specific viscosity (SV) and fermentable sugars as glucose (FSAG) ranged from 0.30 ± 0.02 – 2.21 ± 0.02 mL/s, 2.45 ± 0.02 – 2.71 ± 0.01 cP and 355.77 ± 0.02 – 414.44.± 0.01 mg/mL, respectively while the specific gravity (SG) and original extract (OE) were: 1.03 ± 0.11 – 1.05 ± 0.03 and 6.25 ± 0.06 – 11.75 ± 0.14%, respectively. Brewing potentials (which indicate malt quality) of sorghum varieties increased with increase in germination period reaching their peaks on the 5th day of germination except SV which decreased marginally with increase in germination period. On the basis of the results, a germination period of 5 days is recommended for malting the sorghum varieties studied in order to produce acceptable quality of malts for the brewing industry in Nigeria. In addition, variety SAMSORG40 showed more prospects for use as brewing malt than the other varieties.

Introduction

Sorghum is a major malting and brewing crop cultivar of tropical origin. It shares some anatomical and biochemical features with barley though with obvious physiological differences. These differences and deficiencies are higher malting losses, higher starch gelatinization temperature, lower diastatic power, lower activity of β-glucanase, lower free α-amino nitrogen (FAN), lower extract yield, higher wort and beer viscosities (Ogbonna, 2011). These differences which impact negatively on its malting properties, limit the full utilization of sorghum malt varieties in the brewing process for clear liquid beverage, without incurring the extra cost of exogenous enzymes.

In Nigeria, sorghum is abundantly available and cheap. During the period of ban on importation of barley malt, breweries were using sorghum at 100% adjunct level with the aid of mixtures of commercial microbial enzymes or addition of barley malt. However, today, as a result of the lift on the ban, they now utilize sorghum with barley malt at varying levels of substitution with little or no external microbial enzymes. A flurry of malting and brewing-related researches on sorghum as a possible substitute for barley malt was triggered off and accelerated during this period when the federal government of Nigeria banned the importation of barley malt into Nigeria as part of an austerity measure. However, lack of valid

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empirical data on sorghum varieties has impeded the effective selection of suitable sorghum varieties by some malting and brewing industries in Nigeria. This research project was part of efforts to aid local malting and brewing industries in the effective selection, application and utilization of sorghum varieties as available local raw materials to reduce their cost of production. A series of improved sorghum varieties of diverse genetic background (including the three being studied) has been developed and released by the sorghum breeding and research programmes of the Institute of Agricultural Research (IAR), Ahmadu Bello University, Samaru, Zaria, Nigeria (Aba *et al*., 2004). However, in Nigeria, information on sorghum grain variety characterization research for malting and brewing potentials is limited (or virtually non-existent).

Therefore, this work was initiated to evaluate the effect of varietal differences and germination period on some malting and brewing potentials of three new improved sorghum varieties (SAMSORG17, SAMSORG14 and SAMSORG40).

Materials and Methods

Grain samples

Three new improved varieties (SAMSORG17, SAMSORG14, and SAMSORG40) of *Sorghum bicolor* L. Moench, harvested in 2013, were obtained from the Seed Production Unit of the Institute of Agricultural Research (IAR), Ahmadu Bello University, Samaru, Zaria, Kaduna State.

Pericarp colour

The samples were visually evaluated for grain colour and comparisons made with known standard colours.

Size

The size index of the samples was determined according to Alonge (2008). This involved the measurement of the three principal and mutually perpendicular axes namely major (grain length, L), minor (grain width, W) and intermediate diameters (grain thickness, T) of 100 grains from each variety (Fig. 1) with digital micrometer screw gauge which had a precision of 0.001 mm (Mitutoyo Japan, No. 293-832). Their equivalent diameters (D_e) in mm were calculated using the following equation as reported by Aseogwu *et al*. (2006):

$$De\ (mm) = \frac{F_1 + F_2 + F_3}{3}$$

where F_1 = arithmetic mean diameter = (L + W + T)/3, F_2 = geometric mean diameter = $(LWT)^{1/3}$, F_3 = square mean diameter =

$$\left[\frac{(LW + WT + TL)}{3}\right]^{1/2}$$

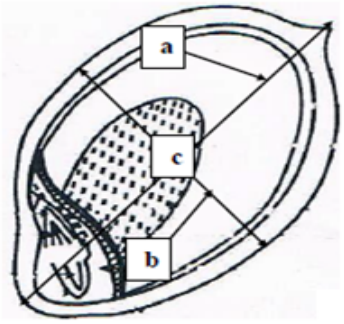

Figure 1.Mutually perpendicular axes of a sorghum grain (a) major diameter or length (b) minor diameter or width (c) intermediate diameter or thickness [from the surface towards the back of paper]

Shape

The shape characteristic of the grain samples is made up of roundness and sphericity. The roundness in mm was determined by the method of Alonge (2008) as follows:

$$Roundness\ (mm) = \frac{r}{R}$$

where r = intermediate radius, R = major radius.

The method of Mohsenin (1980) was applied to determine the sphericity in mm from the equation below:

$$Sphericity\ (mm) = \frac{LWT^{1/2}}{L}$$

where L = major diameter (length), W = minor diameter (width), T = intermediate diameter (thickness).

Thousand kernel weight

The thousand kernel weight (TKW) was determined according to the method reported by Kunze (2004). First, 1000 grains of a representative sample of each variety was weighed with a calibrated electronic balance which had a precision of 0.001 g (S. Mettler, JA 2003, No. SH0700313961). Thereafter, the thousand kernel weights (TKW) in g on dry basis were calculated as follows:

$$TKW\ (g) = \frac{w \times 1000 \times DM}{N \times 100}$$

where: w = weight of sample – weight of broken grains and foreign materials in g. N = total number of whole grains only (excluding broken and foreign grains and other foreign materials). DM = dry matter

= (100 – M) where M = moisture content of grain sample.

Endosperm colour, texture and type

The endosperm colour and texture of the samples were evaluated visually by a panel of 10 assessors. The relative proportion of the steely to mealy endosperm was evaluated according to a 5-scale rating system of Akingbala (1982) as reported by Adeola (2002). Twenty kernels selected at random were cut longitudinally and viewed under the best field of magnification with an optical microscope (Olympus CX21FS1, Olympus Corporation, Tokyo, Japan). The relative amounts of their corneous and floury endosperm portions were compared and rated from 1 (most corneous), 2 – 4 (intermediate) to 5 (most floury). Similarly, selected grains were cut into halves longitudinally and stained with 0.01% iodine solution as reported by Adeola (2002). Waxy endosperm stained purple red while non-waxy endosperm stained dark blue.

Analyses of sorghum grain and malt potentials

The raw sorghum and malt samples were analyzed for the following potentials: The oven drying method of EBC (1998) was used to determine the moisture content (MC). Five grams (5 g) of the samples were dried in a blast air oven (KX 350, Kexin International Co. Ltd) at 105ºC for 3 h and the weight difference expressed in %. The germination energy (GE) of the grain samples was evaluated by the Petri dish method of EBC (1998). This involved expressing in % the number of grains which germinated in a representative sample of 100 grains in 24, 48 and 72 h on a moistened double ply filter paper in a Petri dish in a dark chamber. The germination index (GI) in % of the samples was estimated according to the method demonstrated by Walker-Simmons and Ried (1998) as follows:

$$GI\ (\%) = \frac{Z_{n_1} + Y_{n_2} + \ldots + A_{n_Z}}{D \times N}$$

where: Z, Y … A = days of germination test in reverse order (from the last to the first), n_1, n_2, …, nz = number of seeds that germinated on the first to the last day of test, D = number of days of germination test, N = number of seeds used for germination test. The Kjeldahl method 955.04 of AOAC (2000) was used to determine the total nitrogen (TN) of the grain samples and converted to crude protein (CP) by a factor 6.25. Malting loss (ML) was determined according to IOB (1989) where the weight difference on dry matter basis between equal sample sizes of raw and malted grains were measured.

Malting procedure and experimental design

A time course malting was according to the procedures reported by Ogbonna *et al.* (2004) and Ezeogu and Okolo (1994). This involved an initial surface-sterilization with sodium oxochlorate(I) solution (NaOCl) containing 1.0% (v/v) available chlorine, for 40 min. Thereafter, 300 g batches of each variety were steeped in tap water at grain/water ratio of 1:2. Steeping was done for 45 h in three cycles, each cycle comprising of 6 h wet and 3 h dry at ambient temperature of ~28-30ºC. Germination at the same temperature regime was for 5 days. Sixty grams (60 g) of each sample was kilned daily at 50ºC for 16 h in a blast-air electric oven (KX 350, Kexin International Co. Ltd) to generate five malt samples per variety. For this study, the experimental design was a 3 (sorghum varieties) × 5 (germination time) factor factorial in a randomized complete block design (RCBD) with three replications.

Degree of steeping

The degree of steeping (DS) of the grain varieties was estimated according to modified Bernreuthier apparatus method reported by Kunze (2004). The Bernreuthier apparatus is a small, perforated metal cylinder with a long handle. Grain sample of known moisture content is weighed into the apparatus and steeped along with it for ease of draining excess water. At the end of the steeping process, the weight of water absorbed, X in g was first calculated from the equation below:

$$X\ (g) = \frac{w_1(w_0 + [w_2 - w_1])}{w_2}$$

where: w_1 = weight of grain before steeping in g, w_2 = weight of grain at the end of steeping in g, w_0 = initial weight of water in grain before steeping in g calculated as follows:

$$w_1 \times \frac{moisture\ content\ of\ sample\ in\ \%}{100}$$

Thereafter, the degree of steeping/attained moisture level, Y in % was calculated as follows:

$$Y\ (\%) = \frac{X}{w_1} \times 100$$

where: X = weight of water absorbed at the end of steeping in g, w_1 = weight of grain sample before steeping in g.

Milling, mashing and wort production

Fifty grams (50 g) of sorghum malt grist (particle size 0.21 mm), milled with a Q-link Electric Blender (Model QBL-20L40, Made in P.R.C) to pass a 0.21

mm sieve (mesh number 65 - Tyler approx. or 70 - U.S. approx.) of a Laboratory Sieve Shaker (Norstone Inc., Bridgeport PA, U.S.A), was mashed according to the decantation mashing method of EtokAkpan (1988), as reported by Agu and Palmer (1996). Saccharification was tested with 0.02 N iodine solution on cold mash samples. The mashes were filtered through Whatman No. 1 filter paper to generate wort samples.

Filtration rate

Volume of wort recovered per unit time during the mash filtration process was measured with a measuring cylinder and the filtration rate (FR) in mL/s was calculated as:

$$\text{FR (mL/s)} = \frac{v}{t}$$

where v is the volume of wort recovered (in mL) and t is the time of filtration (in s).

Specific viscosity

The specific viscosity (SV) was determined by the Ostwald viscometric method of IOB (1989).

Fermentable sugars as glucose

Fermentable sugars as glucose (FSAG) were determined according to the dinitro salicylic acid (DNS) method of Miller as reported by Gusakov *et al.* (2011). To 1.0 mL of wort sample (diluted ten-fold) was added 1.0 mL of the DNS reagent and incubated in a boiling water bath (GFL, Gazellschaft fur Labortechnik mbH, Germany) for 5 min for color development. After cooling to room temperature, about 0.5 mL of distilled water was added before its absorbance at 540nm was measured with a spectrophotometer (JENWAY 6405 UV/Vis. Spectrophotometer, Barloworld Scientific Ltd., Dunmow, Essex).

Specific gravity

Specific gravity (SG) was determined through the pycnometer bottle method as reported by Manning (1993). This involved measuring the ratio of masses of wort sample and an equal volume of distilled water at 20ºC/20ºC.

Original extract

The original extract (OE) in % was determined according to the inter-conversion formula between specific gravity (SG) and DP (Degrees Plato: ºP) at 20ºC as reported by Manning (1993) as follows:

$$\text{OE (\%)} = \left[\frac{SG - 1}{0.004}\right]$$

where SG−1 is the excess SG of the wort compared to water (known as brewer's points), 0.004 is the brewer's points factor equivalent to 1.0 DP or approximate value of the difference in SG of two sugar solutions with mass % difference of 1.0 on the Plato Sugar Table (Kunze, 2004).

Statistical analysis

All analyses were carried out in triplicate. Data generated were subjected to ANOVA using IBM SPSS (2012) to determine differences amongst the three varieties at five-day germination period. Treatment means were separated and compared by Least Significant Difference (LSD). Significant differences were accepted at $p < 0.05$ except where otherwise stated.

Results and Discussion

Grain characterization

The varietal characteristics of the sorghum grain samples are shown in Table 1. Differences in varietal characteristics of the samples were significant ($p < 0.05$) and reflected genetic divergence of sorghum genotypes (Alhassan and Adedayo, 2010). The various levels of testa pigmentation in the samples reflected the presence of condensed tannins (proanthocyanidins or procyanidins) which are identified to be polymers of flavonoids (Taylor *et al*., 2013). Hence, based on the levels of testa pigmentation observed in the varieties, the yellow variety could be properly classed as type III and the white and cream coloured varieties as type II tannin sorghums, respectively (Dykes and Rooney, 2000). Comprehensive data on the tannin contents of sorghum varieties is lacking (Taylor *et al.*, 2013). However, skin colour alone does not necessarily determine whether a variety contains tannin or not as there are many white coloured sorghum breeds which contain tannins while red, brown and other coloured types do not (Taylor *et al.*, 2013). Tannins are known to substantially inhibit important enzyme activities in malting and brewing (Beta *et al*., 2000).

The grains of the different varieties had variable shapes and sizes. Variety SAMSORG 14 was more spherical in shape than SAMSORG 17 and SAMSORG 40 while SAMSORG 40 was more roundish in shape than the others. Of the three varieties SAMSORG 14 was largest whereas SAMSORG 40 was smallest in size. The grains' shapes and sizes were significantly ($p < 0.05$) different among the three varieties. Roundness is a measure of the sharpness of the corners of a solid while sphericity indicates how the shape of an object deviates from a sphere (Barbosa-Canovas *et al.*, 2006). The endosperm textures of the three sorghum samples

Table 1. Characteristics of sorghum grain varieties[1]

Parameter	Variety		
	SAMSORG17	SAMSORG14	SAMSORG40
Pericarp colour	Yellow	White	Cream
Testa pigmentation	High	Moderate	Low
Shape[2]			
a. Sphericity (mm)	0.82 ± 0.25[a]	0.84 ± 0.21[a]	0.85 ± 0.28[a]
b. Roundness (mm)	0.57 ± 0.14[c]	0.61 ± 0.19[d]	0.62 ± 0.21[b]
Size[2]			
a. Major diameter (mm)	4.61 ± 0.11[a]	4.92 ± 0.21[f]	3.88 ± 0.12[d]
b. Minor diameter (mm)	4.54 ± 0.34[d]	4.89 ± 0.31[b]	3.85 ± 0.25[c]
c. Int.[3] diameter (mm)	2.62 ± 0.24[b]	2.98 ± 0.11[c]	2.42 ± 0.18[e]
d.Equiv.[4] diameter (mm)	3.86 ± 0.42[c]	4.21 ± 0.51[e]	3.35 ± 0.36[f]
Unit weight[2] (g)	0.06 ± 0.02[e]	0.04 ± 0.01[f]	0.03 ± 0.00[h]
TKW[5] (g db)	36.88 ± 0.01[f]	35.27 ± 0.02[g]	22.53 ± 0.01[g]
Endosperm texture[2]	2.50	3.00	3.50
Endosperm colour	White	White	White
Endosperm type	Non-waxy	Non-waxy	Non-waxy

[1]Means of triplicate determinations ± SD.
[2]Means of 100 observations ± SD.
[3]Intermediate.
[4]Equivalent.
[5]Thousand kernel weight.
[abc]Means with different superscripts on the same row are significantly different at $p < 0.05$.

varied in the relative proportion of their steely to mealy endosperm. The endosperm of SAMSORG17 sample was most steely (2), that of SAMSORG40 sample was most floury (3.5) while SAMSORG14 sample endosperm was intermediate (3) of the three sorghum samples (Table 1). Endosperm texture is an indication of grain hardness and has been used as a technique for its estimation (ICC, 2011).

However, variety SAMSORG 17 with a significantly ($p < 0.05$) higher thousand kernel weight (TKW) indicated more extract potential than the other samples. Most importantly, varietal characteristics such as grain shape and size have been identified to affect rate of water absorption and germination energy during steeping (Ilori, 1991). Small kernels take up water much more quickly than large ones (Kunze, 2004). Additionally, endosperm texture and intrinsic enzymes' activities play dominant roles in the rate of endosperm hydration and modification during steeping and germination (Chiremba *et al*., 2013) and by implication malt quality. The steely endosperm has low hydration value (Dale *et al*., 1990; Chandra *et al*., 1999) and Psota *et al*. (2007) showed that grain hardness (which reflects increasing level of steeliness) adversely affected accessibility of hydrolytic enzymes to the starchy endosperm of malting barley. Steeping should not only give optimal germination; it should equally cause optimal hydration of the starchy endosperm thereby encouraging enzyme formation and metabolic transformations of its food reserves (Kunze, 2004). Differences in steely/mealy distribution influence the different degrees to which the endosperms of the different sorghum varieties malt (Chiremba *et al*., 2013).

Potentials of sorghum grain varieties

The result of the malting potentials of the sorghum grain varieties are shown in Table 2. The moisture content (MC) of samples ranged from 8.73 ± 0.24% for variety SAMSORG 17 to 10.69 ± 0.31% for SAMSORG 14. Variety SAMSORG 40 had the highest germination energy (GE) of 98.67 ± 0.05% while SAMSORG14 had the highest germination index (GI) of 0.97 ± 0.03. Similarly, SAMSORG17 had the lowest GE of 97.21 ± 0.01% and GI of 0.95±0.02, respectively. The GEs and GIs were high and reflected good germination potentials and did not vary significantly among the varieties. Francakova *et al*. (2012) identified GI as the most reliable physiological indicator of the malting potential of a cereal grain. This index gives maximum weights to grains that germinate rapidly.

Total nitrogen (TN) and crude protein (CP) values

Table 2. Properties of sorghum grain varieties[1]

Sample variety	Property (%)					
	MC	GE	GI	TN	CP	DS
SAMSORG 17	8.73 ± 0.04[a]	97.21 ± 0.01[a]	0.95 ± 0.02[ab]	1.75 ± 0.03[a]	10.94 ± 0.03[a]	39.52 ± 0.09[a]
SAMSORG 14	10.69 ± 0.06[b]	98.67 ± 0.09[c]	0.97 ± 0.03[bd]	1.63 ± 0.06[b]	10.19 ± 0.05[c]	41.53 ± 0.07[b]
SAMSORG 40	10.67 ± 0.07[c]	98.67 ± 0.05[d]	0.96 ± 0.05[cd]	1.57 ± 0.01[c]	9.81 ± 0.02[b]	42.58 ± 0.05[c]

[1]Means of triplicate determinations ± SD.
[abc]Means with different superscripts on the same column are significantly different at $p < 0.05$.
MC, moisture content; GE, germination energy; GI, germination index; TN, total nitrogen; CP, crude protein; DS, degree of steeping.

of the sorghum varieties ranged from 1.57 ± 0.11 and 9.81 ± 0.22% for variety SAMSORG 40 to 1.75 ± 0.23 and 10.940 ± 0.35%, for variety SAMSORG. The effect of variety on the properties of sorghum grain varieties was significant ($p < 0.05$) except for the GEs and GIs while treatment had no significant effect.

Degree of steeping

The results of the degree of steeping (DS) of the sorghum varietal samples are shown on Table 2. Within 45 hours of steeping, there was a rapid increase of 77.91% from 8.73 ± 0.04% initial moisture to out-of-steep moisture of 39.52 ± 0.09% in SAMSORG 17 variety; 74.26% from 10.69±0.06% initial moisture to out-of-steep moisture of 41.53 ± 0.07% in SAMSORG 14 variety; and 74.94% from 10.67 ± 0.07% initial moisture to out-of-steep-moisture of 42.58±0.05% in SAMSORG 40 variety. The DS of the three sorghum varieties was consistent with the results of 37 – 43% reported by Ogbonna *et al.* (2003) and Ogbonna *et al*. (2004) for the same sorghum varieties. However, there is a direct relationship between steeping time and out-of-steep moisture with sorghum malt quality (Morall *et al*., 1986). The effect of variety on the degree of steeping of the sorghum samples was significant ($p < 0.05$) whereas treatment was not.

Malting potentials of sorghum varieties

The result of some malting potentials of the sorghum varieties are displayed on Fig. 2. The moisture content (MC) of the malt samples were: 5.08 ± 0.03% for SAMSORG 40, 5.98 ± 0.04% for SAMSORG 14 and 5.08 ± 0.03% for SAMSORG 40 varieties. The trend of malting loss (ML) and total nitrogen (TN) observed in the sorghum malt varieties showed that SAMSORG40 malt varieties with the lowest total mean nitrogen content of 1.48 ± 0.06%

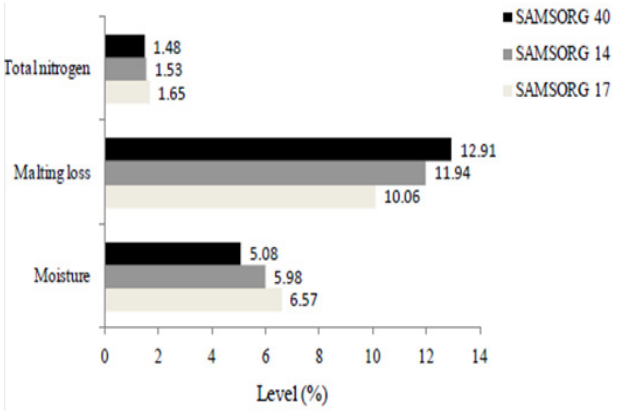

Figure 2. Some malting properties of sorghum varieties

had the highest total mean malting loss of 12.91 ± 0.42% whereas SAMSORG 17 with the highest total mean total nitrogen of 1.65 ± 0.08% had the lowest total mean malting loss of 10.06 ± 0.37%, SAMSORG 14 malt variety with total mean total nitrogen content of 1.53 ± 0.08% had a total mean malting loss of 11.94 ± 0.36%. Low TN values are indication of high modification and vice versa. Ogu *et al.* (2004) observed that this relationship of high malting loss with low total nitrogen content is associated with the peculiar modification and proteolytic pattern in sorghum malt as a result of the translocation of more nitrogen materials to its roots and shoots during malting. Malting loss reflects dry matter losses through respiration, rootlet and shoot growths (Beta *et al.*, 1995). The effect of variety and germination period on moisture content of the malt varieties was significant ($p < 0.05$). However, the effect of variety and germination period on their malting loss and total nitrogen was not significant.

Brewing potentials of sorghum varieties

Table 3 shows result of the effect of variety and germination period on some brewing potentials

Table 3. Effect of variety and germination period on some brewing potentials of sorghum malt varieties[1]

Sample variety	GP (days)	FR (mL/s)	SV (cP)	FSAG (mg/mL)	SG[2]	OE (%)
SAMSORG	1	1.07 ± 0.02^{a}	2.59 ± 0.02^{a}	355.77 ± 0.02^{a}	1.04 ± 0.10^{a}	10.75 ± 0.12^{a}
17	2	1.75 ± 0.01^{b}	2.55 ± 0.02^{b}	367.39 ± 0.01^{b}	1.04 ± 0.11^{b}	10.75 ± 0.13^{b}
	3	1.25 ± 0.03^{c}	2.55 ± 0.01^{c}	391.15 ± 0.01^{c}	1.03 ± 0.12^{c}	8.75 ± 0.06^{c}
	4	1.23 ± 0.02^{d}	2.52 ± 0.01^{d}	403.05 ± 0.00^{d}	1.05 ± 0.15^{d}	11.25 ± 0.12^{d}
	5	2.21 ± 0.02^{e}	2.52 ± 0.01^{e}	406.28 ± 0.03^{e}	1.05 ± 0.03^{d}	11.25 ± 0.12^{e}
SAMSORG	1	0.30 ± 0.02^{a}	2.71 ± 0.01^{f}	393.72 ± 0.02^{f}	1.03 ± 0.11^{c}	6.25 ± 0.05^{c}
14	2	0.42 ± 0.03^{b}	2.70 ± 0.02^{g}	390.90 ± 0.02^{g}	1.04 ± 0.12^{d}	10.25 ± 0.13^{b}
	3	0.43 ± 0.01^{c}	2.69 ± 0.03^{h}	376.07 ± 0.01^{h}	1.04 ± 0.15^{f}	10.75 ± 0.15^{d}
	4	0.27 ± 0.01^{d}	2.68 ± 0.02^{i}	388.21 ± 0.03^{j}	1.04 ± 0.13^{e}	10.50 ± 0.14^{k}
	5	0.48 ± 0.02^{e}	2.66 ± 0.04^{j}	403.11 ± 0.02^{c}	1.04 ± 0.12^{g}	11.00 ± 0.16^{b}
SAMSORG	1	0.79 ± 0.02^{cd}	2.48 ± 0.03^{ef}	378.92 ± 0.00^{dg}	1.04 ± 0.12^{jk}	9.00 ± 0.02^{f}
40	2	1.35 ± 0.01^{ef}	2.47 ± 0.01^{cd}	387.71 ± 0.01^{ef}	1.04 ± 0.13^{fi}	10.00 ± 0.11^{g}
	3	1.13 ± 0.02^{dg}	2.46 ± 0.02^{jk}	382.76 ± 0.02^{dc}	1.04 ±0.12^{gd}	9.75 ± 0.12^{e}
	4	1.17 ± 0.01^{fi}	2.46 ± 0.01^{gd}	408.75 ± 0.03^{kj}	1.05 ±0.14^{hk}	11.50 ± 0.15^{h}
	5	1.55 ± 0.03^{jk}	2.45 ± 0.02^{fc}	414.44 ± 0.01^{cd}	1.05±0.13^{mn}	11.75 ± 0.14^{c}

[1]Data are means of triplicate determinations ± SD.
[abc]Means with different superscripts on the same column are significantly different at $p < 0.05$.
GP, germination period; FR, filtration rate; SV, specific viscosity; FSAG, fermentable sugars as glucose; SG, specific gravity; OE, original extract.

of sorghum malt varieties studied. The brewing potentials of the sorghum samples measured varied with increasing germination period. The filtration rate (FR), fermentable sugars as glucose (FSAG), specific gravity (SG), and original extract (OE) increased with increase in germination period peaking on day 5 of germination. Conversely, the specific viscosity (SV) decreased with increase in germination period dropping to the minimum value on day 5 of germination.

The highest recoverable worts among the three sorghum varieties were at a FR of 2.21 ± 0.02 mL/s for SAMSORG17, 1.55 ± 0.03 mL/s for SAMSORG40 and 0.48 ± 0.02 mL/s for SAMSORG14. From the results, significant ($p < 0.05$) variations in FRs of wort samples were evident across the wort samples. The filtration rate (FR) for all the wort samples was observed to be slow and never completed within an hour. This coincided with the positive iodine staining properties of the mash (purple colour) which was indicative of inadequate amylolysis at the grist particle size (0.21 mm) mashed. Poor filtration characteristics have been associated with viscous substances in worts including starch, proteins and cell wall material (Verbruggen *et al*., 1998). The FR of the three wort samples varied significantly ($p < 0.05$) between varieties and germination times.

The sorghum wort varieties gave the lowest SV values on day 5 of germination. Among the three varieties studied, SAMSORG40 had the lowest SV of 2.45 ± 0.02 cP, SAMSSORG17 had a SV of 2.52 ± 0.01 cP while SAMSORG14 had the highest SV of 2.66 ± 0.04 cP. Apparently, all the wort varieties showed only marginal decrease in SV. This suggested that the endo-β-glucanases levels necessary to bring about a significant reduction in the SV of the sorghum varieties were not optimal during the malting period. The practical reality in the industry about the SV of sorghum malt wort is that while the measured value seems to be low on paper, the wort in process exhibits all characteristics of high SV including poor wort run-off during lautering and impaired flow. Similarly, proportional reductions in SV across the three varieties with germination period were slight. This ranged from 1.74% for SAMSORG17 and 2.13% for SAMSORG14 to 3.36% for SAMSORG40 malts.

The viscosity of wort is influenced by several factors including non-starchy polysaccharides and cell wall materials such as celluloses and hemicelluloses, proteins, poor and incomplete saccharification of starch as a result of poor and limiting β-amylase activity (Dale *et al.*, 1990; Dykes and Rooney, 2000). Beta *et al.* (1995) reported some strong correlations between viscosity reduction and starch ($r = -0.70$; $p < 0.01$); viscosity reduction and α-amylase activity ($r = -0.98$; $p < 0.01$) and viscosity reduction and α/β-amylases ratio ($r = -0.74$; $p < 0.01$) in sorghum malt cultivars. However, Verbruggen (1998) established no direct relationship between glucuronoarabinoxylans (GAX) or pentosans (which are the predominant endosperm cell wall material in sorghum), and filtration and viscosity behaviour of sorghum malt worts. The SV of wort samples varied significantly ($p < 0.05$) between varieties. In contrast, germination time had no significant effect on the SV of wort samples.

The FSAG increased with increase in germination period reaching the peak in the various sorghum wort samples on day 5 of germination. The highest FSAG levels of 414.44 ± 0.01 mg/mL was yielded by SAMSORG40 wort sample. Within the same period, SAMSORG14 wort sample gave FSAG of 403.11 ± 0.02 mg/mL whereas SAMSORG17 gave an intermediate FSAG value of 406.28 ± 0.03 mg/mL. This indicated an increase in amylolytic activities especially the α- and ß-amylases as well as α- and ß-glucosidases which control the production of fermentable sugars in the wort during mashing. Additionally, the nature of the starches in the different varieties of sorghum may have influenced their enzyme digestibility and contributed in the levels of FSAG recorded in the wort samples. Differences in the response to heat treatment by the starches of the sorghum malt samples were observed during mashing. Variety SAMSORG40 malt starch exhibited some form of soft and malleable characteristics while SAMSORG 17 and SAMSORG14 malt starches showed tough and elastic characteristics when subjected to the same thermal treatments. Further comprehensive research studies are required to confirm these differences. The effect of variety and germination time on the FSAG content of wort samples was not significant.

The SG and OE values of the sorghum wort samples studied increased with increasing germination period reaching the maximum on day 5 of germination period. SAMSORG17 wort varieties gave the highest SG and OE levels of 1.05 ± 0.03 and 11.25 ± 0.12%, respectively. Similarly, SAMSORG40 wort varieties had SG and OE levels of 1.05 ± 0.14 and 11.75 ± 0.14% and SAMSORG14 wort varieties yielded SG and OE levels of 1.04 ± 0.42 and 11.00 ± 0.16%, respectively. The result suggested that, perhaps, more modification of endosperm materials may have occurred in SAMSORG40 malt samples than in both SAMSORG17 and SAMSORG14 malts during germination. The effect of variety and germination time on SG was significant ($p < 0.05$) and not significant on the OE of all the wort samples.

Conclusion

The study revealed significant variations in the grain quality (kernel characteristics, germination energy and index, degree of steeping, crude protein, etc.) and malt quality (malting loss, FR, SV, FSAG, SG and OE) parameters among the varieties. Malting factor of germination period had significant ($p < 0.05$) effect on malt quality irrespective of varietal differences. Malting loss increased with germination period. However, key brewing potentials including FR, SV, OE and FSAG (improved α- and ß-amylase activity) which indicate malt quality peaked on the fifth day of germination. On the basis of the results, a germination period of 5 days is recommended for malting the sorghum varieties studied in this work in order to produce acceptable quality of malt for the brewing industry.

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References

Aba, D.A., Idem, N.U.A., Marley, P.S. and Maigida, D.N. 2004. Sorghum. In: N.U.A. Idem and F.A. Showemiwo, eds., Cereal Crops of Nigeria: Principles of Production and Utilization, Ade Commercial Press, Zaria, Nigeria, pp. 38-78.

Adeola, A.A. 2002. The effect of kernel size and texture on the malting properties of sorghum. Journal of Food Technology in Africa 7: 78–81.

Agu, R.C. and Palmer, G.H. 1996. Enzymic breakdown of endosperm proteins of sorghum at different malting temperatures. Journal of the Institute of Brewing 102: 415 – 418.

Akingbala, J.O. 1982. Effect of physico-chemical properties of sorghum starch and endosperm on the quality of a traditional food. Texas, U.S.A: A&M University, PhD thesis.

Alhassan U. and Adedayo A. 2010. Genetic diversity in malting quality of some sorghum genotypes (*Sorghum bicolor* Moench). PAT. 6: 51-60.

Alonge, AF. 2008. Some engineering properties of cashew nut relevant to its processing. Proc. 2nd International Conference of Engineering Research and Development (ICERD), Benin-city: University of Benin, Nigeria, pp. 771-779.

Asoegwu, S.N., Ohanyere, S.O., Kanu, O.P. and Iwueke, C.N. 2006. Physical properties of African oil bean seed *(Pentaclethra macrophylla)*. Agricultural Engineering International: the CIGR Ejournal, Manuscript FP 05 006, Vol. VIII.

Association of Official Analytical Chemists (AOAC). 2000. Official Methods of Analysis. AOAC International, Washington D.C.

Barbosa-Cánovas, G.V., Juliano, P. and Peleg M. 2006. Engineering properties of foods, In: Food Engineering, G.V. Barbosa-Cánovas, ed. UNESCO EOLSS Publishers, Oxford, UK. Downloaded from *http://www.eolss.net/EolsssampleAllChapters.aspx* on 13/03/2013.

Beta, T., Rooney, L.W., Marovatsang, L.T. and Taylor JRN. 2000. Effect of chemical treatments on polyphenols and malt quality in sorghum. Journal of Cereal Science 31: 295–302.

Beta, T., Rooney, L.W., and Waniska, R.D. 1995. Malting characteristics of sorghum cultivars. Cereal Chemistry 72: 533–538.

Chandra, G.S.C., Proudlove, M.O. and Baxter, E.D. 1999. The structure of barley endosperm. an important determinant of malt modification. Journal of the Science of Food and Agriculture 79: 37-46.

Chiremba, C., Siwela, M., Rooney, L.W. and Taylor, J.R.N. 2013. Hardness changes and endosperm modification during sorghum malting in grains of varying hardness and malt quality. Cereal Chemistry 90: 138-144.

Dale, C.J., Young, T.W., and Omole, T. 1990. Small scale mashing experiments with grist containing high proportions of raw sorghum. Journal of the Institute of Brewing 96: 403-409.

Dykes, L. and Rooney, L.W. 2006. Sorghum and millet phenols and antioxidants, Journal of Cereal Science 44: 236–251.

EtokAkpan, O.U. 1988. Biochemical studies of the malting of sorghum and barley, Edinburgh, Scotland: Heriot-Watt University, Ph.D thesis.

European Brewery Convention (EBC). 1998. Analytica-EBC. Fachverlag Hans Carl, Nurnberg, Germany.

Ezeogu, L.I. and Okolo, B.N. 1994. Effects of final watersteep and air rest cycles on malt properties of three improved Nigerian sorghum cultivars. Journal of the Institute of Brewing 100: 335-338.

Francakova, H., Liskova, M., Bojnanska, T. and Mareček, J. 2012. Germination index as an indicator of malting potential. Czech Journal of Food Science 30: 377–384.

Guskakov, A.V., Kondratyeva, E.G. and Sinitsyn, A.P. 2011. Comparison of two methods for analysing reducing sugars in determination of carbohydrate activites. International Journal of Analytical Chemistry 2011: 1-4.

IBM SPSS. 2012. Data Analysis Software. Version 21 for windows. Downloaded from *www.ibm.com/software/analytics/spss/* on 20/12/2014.

Ilori, M.O. 1991. The use of sorghum for beer brewing in Nigeria. Technovation 11: 27-37.

Insitute of Brewing (IOB). 1989. Recommended Methods of Analysis. The Society, London.

International Association for Cereal Science and Technology (ICC). 2011. Estimation of sorghum grain texture. International Association for Cereal Science and Technology Standard 176 ICC, Vienna. Downloaded from *http://www.icc.or.at/standards_methods/176* on 23/01/2015.

Kunze, W. 2004. Technology Brewing and Malting. VLB, Berlin, Germany. 3rd ed., pp. 97-124.

Manning, M.P. 1993. Understanding specific gravity and extract, Brewing Techniques. Downloaded from *http://morebeer.com/brewingtechniques/library/backissues/issue1.3/manning.html* on 26/09/2014.

Mohsenin, N.N. 1980. Physical Properties of Plant and Animal Materials. Gordon and Breach, New York.

Morall, P., Boyd, H.K., Taylor, J.R.N. and Vander-Walt, W.H. 1986. Effects of germination time, temperature and moisture on malting sorghum. Journal of the Institute of Brewing 92: 435-445.

Ogbonna, A.C., Obi, S.K.C. and Okolo, B.N. 2004. Optimization of proteolytic activities in malting sorghum. Process Biochemistry 39: 711-716.

Ogbonna, A.C., Obi, S.K.C. and Okolo, B.N. 2003. Protein modification in malting sorghum. World Journal of Microbiology and Biotechnology 19: 495-503.

Ogbonna, A.C. 2011. Current developments in malting and brewing trials with sorghum in Nigeria: A review. Journal of the Institute of Brewing 117: 394 – 400.

Ogu, E.O., Odibo, F.J.C., Agu, R.C. and Palmer, G.H. 2004. Malting studies of some selected brewing sorghum varieties. MBAA Technical Quarterly 41: 386-389.

Psota, V., Vejrazka, V.K., Famera, O. and Hrcka, M. 2007. Relationship between grain hardness and malting quality of barley (*Hordeum vulgare* L.). Journal of the Institute of Brewing 113: 80-86.

Taylor, J.R.N., Dlamini, B.C. and Kruger, J. 2013. 125th Anniversary review: The science of the tropical cereals sorghum, maize and rice in relation to lager brewing, Journal of the Institute of Brewing 119: 1-14.

Verbruggen, M.A., Beldman, G. and Voragen, A.G.J. 1998. Enzymatic degradation of sorghum glucuronoxylans leading to tentative structures. Carbohydrate Research 306: 275-282.

Walker-Simmons, M.K. and Ried, J.L. 1998. Preharvest Sprouting in Cereals American Association of Cereal Chemists Press, St. Paul, MN.