

Full Length Research Paper

Evaluation of brewing potentials of grains, malts and worts of some sweet sorghum and sorghum varieties

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Received 10 April, 2019; Accepted 14 May 2019

Little or no attention has so far been paid to using sweet sorghum malt for commercial beer brewing. Thus, three sweet sorghum varieties (SSV) and four sorghum varieties (SV) were analyzed for brewing quality. Variations were observed in their thousand grain weights (22.8 to 58.7 g), grain moisture contents (12.5 to 20.5%), germination energies (99.0 to 100%) and germination capacities (99.7 to 100%). After 4-day germination, radicle lengths of seedlings were 2 to 5 fold of plumules. Remarkable variations existed in their water sensitivity (7.1 to 27.6%) and grain protein contents (7.0 to 11.8%). Malts moisture contents (8.6 to 13.8%), malting losses (16.3 to 26.0%) and malts protein contents (12.2 to 19.5%) differed among cultivars. Cold water extracts (CWE) (3.8 to 8.8%) and hot water extracts (HWE) (8.8 to 17.5%) varied with cultivars. HWE were 1.5 to 3-fold of CWE. Diastatic powers (DP) were substantially higher in SSV (123.7 to 136.7°) compared to SV (111.8 to 117°). Amyloglucosidase (AMG) activities were detected in SSV malts but not in SV. α -Amylases activities in both SSV and SV malts were about 2 to 4-fold of β -amylases. Generally, DP in SV malts = α -amylase + β -amylase activities. But DP in SSV malts > α -amylase + β -amylase + AMG activities, thus, suggesting synergism between the enzymes. SSV showed similar wort yields with SV. Reducing sugars in wort of SSV (12.3 to 15.6 mg/ml) were higher than those of SV (6.2 to 10.5 mg/ml). Malts and worts analyses suggest that SSV have greater beer brewing potentials than SV.

Key words: Diastatic power, amylase, amyloglucosidase, sweet sorghum, malt, wort.

INTRODUCTION

The potential of sorghum as a viable alternative substrate for beer brewing, particularly in the tropics where barley does not thrive well, has been recognized (Palmer et al., 1989; Owuama, 1999). In Nigeria, improved sorghum varieties have been cultivated in large scale over several years to address brewery industry demands for sorghum. This approach has helped Nigerian government conserve

large amounts of valuable foreign exchange reserves spent on importing barley malt. Presently, malts from sorghum varieties (*Sorghum vulgare*) are used for commercial beer brewing in Nigeria and little or no attention has been paid to using malts from sweet sorghum varieties (*Sorghum bicolor* [L] Moench). Traditionally in Northern Nigeria, sweet sorghum varieties

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are cultivated in limited quantities, in small portions of land, usually close to farmer's residence, and commonly harvested for their sugary stalks and consumed. Although, there are some reports on malting *S. bicolor* grains (Hassani et al., 2014; Bekele et al., 2012), much more extensive literature exists on large scale commercial cultivation of sweet sorghum varieties, because of their sugary stalks which are exploited for bioenergy and ethanol production (Regassa and Wortmann, 2014). Sorghum varieties with acceptable malt qualities such as, diastatic power, malting loss and total soluble nitrogen are desirable for brewing beer (Owuama, 1999). Diastatic power is a reflection of the activities of diastatic enzymes in malt that comprise activities of α -amylase, β -amylase and amyloglucosidase (AMG) (encompasses α -glucosidase and limit dextrinase) (MacGregor et al., 1999). Malts with high levels of diastatic enzymes are known to yield increased reducing sugar levels in wort and enhance its fermentability (Delcour and Verschaeve, 1987). α -Amylases (endo-acting) hydrolyze α -1,4-glycosidic linkages in starch molecules yielding dextrins, oligosaccharides, maltose and glucose. β -Amylases (exo-acting) hydrolyze β -1,4 linkages yielding beta-limit dextrins and maltose, while AMG or glucoamylases (gamma-amylases) (exo-acting) hydrolyze both α -1,4 and branching α -1,6-linkages yielding glucose. Limit dextrinase hydrolyses alpha-limit dextrins, amylopectin and beta-limit dextrins, and has been purified from sorghum malt (Hardie et al., 1976; Sanni and Fatoki, 2017). Alpha glucosidase in sorghum malt contributes to glucose production in wort by hydrolyzing terminal α -1, 4 linked D-glucose residues to release glucose (Agu and Palmer, 1997). Among the diastatic enzymes, AMG has been shown to exhibit synergistic activity with α -amylase in starch hydrolysis, yielding glucose (Presečki et al., 2013; Zhang et al., 2013). As well, limit dextrinase and α -glucosidase are known to have synergistic activity with β -amylase and α -amylase respectively, in solubilizing starch (MacGregor et al., 1999).

Due to the use of malts from sorghum varieties for commercial beer brewing with little or no attention paid to sweet sorghum varieties, this work therefore reports on the assessment of brewing potentials of some sweet sorghum varieties based on their grain characteristics, malt qualities and wort properties vis-à-vis those of sorghum varieties.

MATERIALS AND METHODS

Three sweet sorghum varieties, sweet 'Takanda', sweet mace Maikanya, and sweet white Moskwa and 4 sorghum varieties, Farin dawa, Jigari, Fara fara, and Red Moskwa were obtained from sorghum farms in Girei and Guyuk, Adamawa State, Nigeria.

Nitrogen content of grain was determined using Kjeldahl method while protein content was obtained by multiplying the nitrogen content by 6.25. Germination energy, germination capacity and water sensitivity were determined using a modification (that is, at 30°C) of ASBC method (Anon, 1997).

Malts were produced (by steeping grains for 18 h, germinating for

four days at 30°C and kilning at 55°C for 6 h and then 65°C until the rootlets became friable. Rootlets were removed by rubbing between palms), and percentage malting loss determined as described by Owuama and Asheno (1994).

Vegetative malt loss (%) was calculated as shown below.

$$\text{Vegetative malt loss (\%)} = \frac{\text{wt of kilned malt with sprouts} - \text{wt of kilned malt without sprouts}}{\text{wt of kilned malt with sprouts}} \times 100$$

Total nitrogen content of malt was determined using Kjeldahl method and protein content was obtained by multiplying the nitrogen content by 6.25.

Cold water extract (CWE) was determined by modified methods of Taylor and Daiber (1988) and Subramanian et al. (1995). Briefly, 5 g malt flour was dissolved in 25 ml of distilled water containing 0.02% CaCl_2 and kept for 1 h at room temperature (30°C). The mixture was centrifuged for 5 min at 3,000 \times g and the supernatant transferred to a 50 ml volumetric flask. The sediment was further extracted twice with 10 ml and then 5 ml for 30 min and each time centrifuged for 5 min. The supernatants were pulled and made up to 50 ml, then mixed thoroughly, and were filtered using Whatman No. 1 filter paper. 10 ml cold water extract was transferred into pre-weighed aluminum foil cup and evaporated to dryness at 110°C in hot air oven. The aluminum foil cup was then cooled in a dessicator and weighed. CWE in g/100 ml was calculated as follow:

$$\text{CWE (g/100 g)} = \text{Weight of dried 10 ml extract} \times 100$$

Hot water extract (HWE) was determined by modified methods of Taylor and Daiber (1988) and Subramanian et al. (1995). Briefly, 5 g malt flour was dissolved in 25 ml of distilled water containing 0.02% CaCl_2 and kept for 1 h at 60 \pm 1°C. The mixture was centrifuged for 5 min at 3,000 \times g and the supernatant transferred to a 50 ml volumetric flask. The sediment was further extracted twice, first with 10 ml and then 5 ml for 30 min during each extraction. The supernatants were pulled and made up to 50 ml, then mixed thoroughly and filtered using Whatman No. 1 filter paper. 10 ml hot water extract was transferred into pre-weighed aluminum foil cup and evaporated to dryness at 110°C. The aluminum foil cup was then cooled in a desiccator and weighed. HWE in g/100 g was calculated as follows:

$$\text{HWE (g/100 g)} = \text{Weight of dried 10 ml extract} \times 100$$

Wort preparation

21% of mash was maintained at 50°C for 30 min, then 65°C for 30 min, and subsequently 70°C for 30 min, and finally the temperature was raised to 80°C to inactivate the enzymes.

Reducing and total sugars were determined using Lane and Eynon constant volume technique. Non-reducing sugars were obtained by subtracting the reducing sugars from the total sugars. Total soluble nitrogen content was determined using the Kjeldahl method. Protein content was determined by multiplying the total nitrogen value by a factor of 6.25. Percentage wort yield (as is) was determined as described by Taylor and Daiber (1988).

Percentage wort yield (dry basis) was determined by centrifuging mash at 3,000 \times g for 10 min. Sediment was then dried in hot air oven at 110°C to constant weight. The value was calculated as follows:

$$\text{Wort yield (dry basis) [\%]} = \frac{\text{Weight of mash} - \text{weight of dry sediment}}{\text{Weight of mash}} \times 100$$

Determination of diastatic power

Diastatic power of the sorghum malts was determined using a

Table 1. Grain properties of different sweet sorghum varieties and sorghum varieties.

Characteristics	Sorghum cultivar						
	SSTK	SSMM	SSWM	SFD	SJ	SRM	SFF
1000 grain wt.(g)	22.8	58.7	45	31.5	27.6	55	34.8
Moisture content (%)	20.0	12.5	12.6	12.7	13.5	20.5	13.5
Germination energy (%)	100	99.3	99.7	99.0	99.6	99.5	99.9
Germination capacity (%)	100	99.7	99.8	99.9	100	99.7	99.9
Water sensitivity (%)	9.2	12.3	18.7	8.0	27.6	10.5	7.1
Total nitrogen content (%)	1.24	1.96	1.12	1.12	1.40	1.40	1.9
Protein content (%)	7.8	12.3	7.0	7.0	8.8	8.8	11.8
Steeped-out moisture (%)	24.3	32.9	29.0	28.6	41.2	22.4	26.0

SSTK - Sweet sorghum Takanda, SSMM-Sweet sorghum 'Mace maikanya', SSWM-Sweet sorghum 'White Moskwa', SFD-Sorghum 'Farin dawa', SJ-Sorghum 'Jigari', SRM-Sorghum 'Red Moskwa', SFF- Sorghum 'Fara fara'.

slightly modified malt carbohydrase method (JECFA, 1971). Briefly, 0.2 M acetate buffer pH 5 and 2% acetate buffer starch solution were prepared as described in JECFA (1971). Malt infusion was prepared at 30°C for 2.5 h following the method of JECFA (1971). Diastasis and Blank correction solution for diastatic power were carried out at 30°C for 30 min as described in JECFA (1971). Titrations were done following Fehling's (or Soxhlet) solution procedure and the malt diastatic power, in degree, was calculated (both 'As is' and 'Dry basis'), using the methods of JECFA (1971).

Alpha amylase activity was determined by slight modification of diastatic method. Briefly, 0.5×10^{-3} mg/ml mercuric chloride (inhibits β -amylase activity) (Etokakpan and Palmer, 1990), was added into buffered starch solution and mixed prior to the addition of malt infusion. Mercuric chloride was also added in the Blank Correction Solution. Titrations were done following Fehling's (or Soxhlet) solution procedure and the malt α -amylase activity, in degree, was calculated (both 'As is' and 'Dry basis'), using the methods of JECFA (Anon, 1971).

Beta-amylase activity was determined by slight modification of diastatic method. Briefly, 0.1M ammonium oxalate (inhibits α -amylase activity) (Delcour and Verschaeve, 1987), was added into buffered starch solution and mixed prior to the addition of malt infusion. Ammonium oxalate was also added in the Blank correction solution. Titrations were done following Fehling's (or Soxhlet) solution procedure and the malt β -amylase activity, in degree, was calculated (both 'As is' and 'Dry basis'), using the methods of JECFA (Anon, 1971).

Amyloglucosidase activity was determined by slight modification of diastatic method. Briefly, 0.5×10^{-3} mg/ml mercuric chloride and 0.1M ammonium oxalate were added into buffered starch solution and mixed prior to the addition of malt infusion. Mercuric chloride and ammonium oxalate were also added in the Blank Correction Solution. Titrations were done following Fehling's (or Soxhlet) solution procedure and the malt amyloglucosidase activity, in degree, was calculated (both 'As is' and 'Dry basis'), using the methods of JECFA (Anon, 1971).

RESULTS

The results are the mean values of three experiments. The different varieties of sorghum showed varying grain properties (Table 1). The thousand grain weight of both SSV and SV ranged from 22.8 to 58.7 g, germination energy (GE) (measures percentage of grains expected to

germinate fully at the time of test) fell between 99.3 and 100%, and germination capacity [GC] (used to determine if seeds that did not germinate in the GE test are dormant or dead, that is, measures percentage of viable corns in a sample) was within 99.7 to 100 %. Water sensitivity of the grains varied among SSV (9.2 to 18.7%) and SV (7.1 to 27.6%). The SSV grains showed percentage moisture contents of 12.5 to 20% while those of SV were between 13.5 and 20.5%. The total nitrogen contents of SSV varied slightly from those of SV, and fell within 1.12 to 1.96%, while their proteins values were between 7.0 and 12.3%. Percentage steep-out moisture varied considerably with different SSV and SV and ranged from 22.4 to 41.2% (Table 1).

Sorghum malts characteristics varied among SSV and between SSV and SV (Table 2). Vegetative outgrowths or sprouts after 4-day germination period of the grains revealed remarkably different plumule and radicle lengths for the various SSV and SV. The radicles were about 2 to 5-fold longer than the plumules among SV and about 3 to 4.5-fold longer among SSV. Vegetative outgrowths in both SSV and SV showed no clear relationship with the size of grains (as reflected by 1000 grain weight), vegetative loss and malting loss (metabolic plus vegetative loss). However, the vegetative loss correlates with DP (dry basis) of SSV, but not with those of SV (Table 3). The percentages malting loss differed among the varieties and generally lower among SSV (16.3 and 17.8%) than those of SV (16.4 to 26.0%). Percentage malt moisture content of SSV and SV showed virtually similar variations, and ranged from 9.0 to 13.8%. HWE and CWE (which are soluble products including sugars and amino acids of enzyme hydrolysis from malting process) varied with the SSV and SV. There were substantial differences between CWE and HWE of malts among various sorghum cultivars. HWE values were about 1.5 to 3 fold higher than CWE in both SSV and SV. Percentage malt total nitrogen in both SSV and SV malts varied considerably between 2.0 and 3.1% while their

Table 2. Characteristics of malts from different sweet sorghum varieties and sorghum varieties.

Characteristics	Sorghum cultivar						
	SSTK	SSMM	SSWM	SFD	SJ	SRM	SFF
Plumule/radicle length (cm)	1.5 (4.8)	3.3 (8.8)	1.3 (5.7)	2.8 (7.0)	2.9 (5.7)	1.5 (7.2)	1.8 (7.3)
Malting loss (%)	17.8±5.8	16.3±6.7	17.8±7.2	25.4±8.4	26.0±8.6	16.4±8.2	23.6±9.1
Vegetative loss (%)	8.9±4.6	10.1±5.8	9.5±6.4	13.3±7.1	11.2±9.3	7.2±7.7	13.0±8.5
Malt moisture content (%)	13.8±8.0	12.3±6.9	9.0±7.8	8.6±6.8	11.8±8.8	9.4±8.2	13.4±7.7
Cold water extract (g/100g)	5.0±4.9	7.5±5.7	3.8±6.2	8.8±7.9	6.3±5.5	5.0±6.0	7.5±9.2
Hot water extract (g/100g)	8.8±8.7	17.5±7.5	11.3±5.8	15±6.4	17.5±4.9	10.0±5.5	11.3±8.7
Malt total nitrogen (%)	2.4±9.2	2.8±8.6	2.2±6.3	3.1±7.2	2.0±7.1	2.0±6.1	2.2±8.3
Protein content (%)	15.0±8.9	17.5±8.2	13±6.0	19.5±7.5	12.3±6.9	12.2±5.8	13.0±7.9

SSTK - Sweet sorghum Takanda, SSMM-Sweet sorghum 'Mace maikanya', SSWM-Sweet sorghum 'White Moskwa', SFD-Sorghum 'Farin dawa', SJ-Sorghum 'Jigari', SRM-Sorghum 'Red Moskwa', SFF- Sorghum 'Fara fara', Radicle length in parenthesis.

Table 3. Malt carbohydrase activities of sweet sorghum varieties and sorghum varieties.

Malt carbohydrase	Activities in malt sorghum cultivars						
	SSTK	SSMM	SSWM	SFD	SJ	SRM	SFF
Diastatic power (As is) ^o	123.7±3.7	132.9±4.2	136.7±3.2	112.6±2.9	111.8±4.4	117.0±3.6	114.0±4.1
Diastatic power (dry basis) ^o	143.8±3.2	151.5±3.8	150.2±3.4	123.2±2.7	126.7±3.9	129.0±5.2	131.0±4.4
Alpha amylase (As is) ^o	71.8±5.4	74.2±4.6	83.2±5.1	85.2±4.7	78.8±4.3	82.6±5.5	85.2±4.9
Alpha amylase (dry basis) ^o	83.3±5.1	84.6±4.2	91.5±5.7	93.2±5.3	89.3±3.7	90.7±4.6	97.0±5.2
β-amylase (As is) ^o	27.2±6.6	26.6±7.2	26.6±6.4	27.1±4.9	26.4±5.4	25.2±6.2	28.0±4.7
β-amylase (dry basis) ^o	31.6±5.8	30.2±6.5	29.2±5.5	30.5±3.8	29.9±4.9	27.8±5.3	32.1±4.2
Amyloglucosidase (As is) ^o	14.5±8.6	20.6±7.8	21.3±6.9	ND	ND	ND	ND
Amyloglucosidase (dry basis) ^o	16.8±7.6	23.5±6.6	23.4±6.3	ND	ND	ND	ND

ND – Not detected, SSTK - Sweet sorghum Takanda, SSMM-Sweet sorghum 'Mace maikanya', SSWM-Sweet sorghum 'White Moskwa', SFD-Sorghum 'Farin dawa', SJ-Sorghum 'Jigari', SRM-Sorghum 'Red Moskwa', SFF- Sorghum 'Fara fara'.

proteins ranged from 12.2 to 19.5%. CWE apparently correlated with total nitrogen and protein contents in malts from SSV but not those from SV (Table 2).

In Table 3, the diastatic powers, α-amylases and β-amylases differed among and between SSV and SV. There were remarkable differences in diastatic powers as well as α-amylase activities of malts between various sorghum cultivars. SSV had higher diastatic powers (123.7 to 136.7°) compared with those of SV (111.8 to 117.0°). The α-amylase activities of SSV (71.8 to 83.2°) were greater than their β-amylase activities (26.6 -27.2°). Similarly, α-amylase activities in SV malts (78.8 to 85.2°) were higher than their β-amylase activities (25.2 to 28.0°). α-Amylase activities in SV were 70 to 75% of DP and substantially higher than 56 to 61% of DP in SSV. Also, β-amylase activities in SV were 22 to 25% of DP and slightly higher than 19 to 22% of DP in SSV. However, malts of SSV showed amyloglucosidase (AMG) or glucoamylase activities of 14.5 to 21.3° while no AMG activity was detected in SV malts. AMG activities in SSV malts were 12 to 16% of their DP. α-Amylases activities in both SSV and SV malts were 2 to 4-fold those of β-amylases. In SSV, α-amylases activities were 3.6 to 5-fold those of AMG while the β-amylase activities were 1.2

to 1.9 fold those of AMG activities. Generally, DP in SV malts were equal to α-amylase plus β-amylase activities, but in SSV, the sum of α-amylase, β-amylase and AMG activities were less than the DP.

In Table 4, the percentage wort yields (dry basis) of both SSV and SV fell within 93.0 and 95.4%, and were 1.2 to 1.5-fold of the percentage wort yields (wet basis) (61.2 to 78.7%). The reducing sugars in SSV (12.3 to 15.6 mg/ml) were remarkably higher than those from SV (6.2 to 10.5 mg/ml). As well, the total sugars in SSV (16.3 to 22.0 mg/ml) were substantially higher than those in SV (12.3 - 13.2 mg/ml). The non-reducing sugars ranged from 2.2 to 6.4 mg/ml and differed considerably in both SSV and SV, but had no clear correlation with reducing sugars. The total soluble nitrogen contents in SSV worts (0.16 to 0.19%) were slightly higher than those in SV worts (0.08 to 0.16%). Similarly, the protein contents in SSV worts (1.0 to 1.2%) were higher than those in SV worts (0.5 to 1.0%).

DISCUSSION

There were remarkable differences among and between

Table 4. Properties of Worts from different sorghum cultivars.

Property	Sorghum cultivars						
	SSTK	SSMM	SSWM	SFD	SJ	SRM	SFF
Wort yield (%) [as is]	76.0±1.2	61.2±2.3	64.9±1.6	66.4±1.4	78.7±3.2	69.9±1.5	67.5±2.6
Wort yield (%) [dry basis]	93.0±0.8	94.1±1.3	95.4±0.7	94.1±2.5	95.9±2.6	93.6±1.9	94.6±3.3
Reducing sugar (mg/ml)	12.3±1.1	15.6±2.1	15.6±1.4	10.5±3.0	8.5±3.3	7.2±2.8	6.2±2.3
Total sugar(mg/ml)	16.3±1.4	22.0±3.1	17.8±2.2	13.2±1.7	13.0±2.9	10.8±3.1	12.3±2.8
Non-reducing sugar (mg/ml)	4.1±1.7	6.4±2.6	2.2±1.8	2.7±3.4	4.5±3.6	3.6±2.3	6.1±3.0
Total soluble nitrogen (%)	0.16±2.2	0.19±1.7	0.19±1.4	0.11±2.3	0.08±0.9	0.16±1.3	0.16±2.1
Protein content (%)	1.0±2.3	1.2±1.8	1.2±1.6	0.7±2.5	0.5±0.8	1.0±1.4	1.0±2.3

SSTK - Sweet sorghum Takanda, SSMM-Sweet sorghum 'Mace maikanya', SSWM-Sweet sorghum 'White Moskwa', SFD-Sorghum 'Farin dawa', SJ-Sorghum 'Jigari', SRM-Sorghum 'Red Moskwa', SFF- Sorghum 'Fara fara'.

SSV and SV thousand grain weights (22.8 g to 58.7 g), however they differed slightly from earlier observations (Subramanian et al., 1995), apparently due to varietal differences in grain sizes, storage period and conditions (Owuama, 1999). Thousand grain weights of the various sorghum grains did not correlate with percentage grain moisture content, and percentage steep-out moisture apparently due to morphological and physiological variations of the different sorghum cultivars (Badau et al., 2006). The variations in vegetative outgrowth or sprouts (plumule and radicle lengths) after germination from SSV and SV seedlings showed unclear correlation with the size of the grains (as reflected by 1000 grain weight), and this could be attributed to different physiological activities among the various cultivars of sorghum used in this work (Svenson et al., 2011). The percentage moisture contents which varied among and between SSV and SV grains (12.5 to 20.5%), compare favourably with earlier report by Owuama and Asheno (1994). The variations in moisture content of grains may be attributable to differences in sorghum cultivar, storage conditions, maturity and age of grains (Owuama, 1999). The grains percentage germination energies (99.3 to 100%) and germination capacities (99.7 to 100 %) fell within acceptable viability level for sorghum grains used in malting (Agu and Palmer, 2013). The water sensitivity for SSV (9.2 to 18.7%) and SV (7.1 to 27.6%), were less than 30% indicating that the grains were not water sensitive (Davidson et al., 1976; Anon, 1997). There seems to be no clear relationship between grain moisture content and water sensitivity among the different varieties of sorghum.

Higher percentage malt nitrogen as well as protein contents observed in the sorghum malts vis-à-vis the percentage grain nitrogen and proteins are consistent with earlier reports and are attributable to carbohydrase activity during germination resulting in increased nitrogen content (Agu and Palmer, 2013). Specific protein level and high grain size are usually required by maltsters to produce good quality malt from barley grains (Magliano et al., 2014). Malting loss of SV and SSV ranged from 16.3 to 26.0% and fell within those reported for sorghum malts

(Owuama and Asheno, 1994; Subramanian et al., 1995). The lower malting loss among SSV is desirable for producing brewing malt as more carbohydrates are available for malt enzymes hydrolysis during mashing that would increase wort sugar content (Agu and Palmer, 2013). The malting loss among the different sorghum varieties showed no direct correlation with vegetative loss which considerably varied among SSV and between SSV and SV. As well, vegetative outgrowths showed no proportional relationship with vegetative loss. However, the vegetative loss correlates with DP of SSV malts, but not with those of SV. These observations may be due to physiological variations among different sorghum cultivars as partly reflected in different respiratory activity and sizes of vegetative outgrowths during germination. Imbibed sorghum grains are known to accumulate in their embryo higher levels of gibberellic acid (GA) which controls α -amylase and protein syntheses, and also the function of endosperm during germination (Shakoor et al., 2016).

Diastatic enzymes in malt comprise α -amylase, β -amylase and AMG or glucoamylases (α -glucosidase and limit dextrinase) (Evans et al., 2010). In sorghum malts, diastatic power has been shown to vary with varieties of sorghum and usually comprise mainly α -amylase and β -amylase (Muoria et al., 1998). However, in this work, DP of SSV comprised AMG, α -amylase and β -amylase activities and were substantially higher than DP of SV (comprising α -amylase and β -amylase activities). This difference is apparently due to the presence of AMG in SSV. Although a wide range of DP have been observed among varieties of sorghum (Subramanian et al., 1995), the higher DP in SSV may be attributed to AMG synergistic activity with amylases. Addition of AMG in mash has been shown to increase diastatic power and increase wort glucose and total fermentable sugars equivalents (Pozo-Insfran et al., 2004), apparently because of the synergistic activity between α -glucosidase and α -amylases (Wong et al., 2007), and between limit dextrinase activity and β -amylases activity (MacGregor et al., 1999). However, in SV malts, the sum of the activities

of α -amylases and β -amylases, is virtually equal to DP, thus suggesting additive reaction. Although, there were remarkable differences in α -amylase activities of malts from SV (70 to 75% of DP) and SSV (56 to 61% of DP), the α -amylase activities in both sorghum cultivars were generally 2 to 4-fold those of β -amylase activities. This observation compares favourably with that of Taylor (1992). The observed β -amylase activities in SV (22 to 25% of DP) and in SSV (19 to 22% of DP) are consistent with the report of Aisien et al. (1983). In SSV malts, DP was 6 to 9-fold of AMG activities compared with activities of α -amylases (3.5 to 5-fold of AMG) and β -amylases (1.2 to 1.9-fold of AMG). The disparity in the DP of different SSV may be a manifestation of varying synergistic activities influenced by ratios of their AMG to amylases activities (Wong et al., 2007; MacGregor et al., 1999).

Diastatic power in SSV is directly proportional to wort yield (dry basis) apparently due to hydrolytic activities of diastatic enzymes breaking down mash carbohydrates and bringing more hydrolysates into solution. Generally, DP of both sorghum types showed correlation with the total soluble nitrogen (TSN) in wort although the nitrogen values were higher in SSV than SV. The higher TSN in the malts of SSV and SV compared with their worts is consistent with the release of nitrogen during mashing by carbohydrase activity (Agu and Palmer, 2013). However, no clear relationship was observed between DP and total soluble nitrogen in sorghum wort (Agu and Palmer, 2013). The variation in observations may be attributable to varietal differences among the sorghum cultivars used. HWE increased with total sugars in wort and this could be attributed to temperature of extraction for HWE which encouraged enzymic activities and consequently the hydrolysis of more malt starch and protein (Agu and Palmer, 2013). However, HWE had no clear relationship with malting loss or DP. These observations are consistent with earlier report by Subramanian et al. (1995). CWE related positively with non-reducing sugar in SSV but not in SV. It is not clear why it is so but it may be a reflection of the differences in the nature of their starch granules. Sweet sorghum varieties have been shown to have larger granule size, higher water solubility index, lower amylose content and lower swelling power than grain sorghum. As well, the amylose content of sweet sorghum is lower than that of grain sorghum (Ahmed et al., 2016).

In conclusion, SSV have higher DP and reducing sugars than SV. Unlike SV, SSV had AMG activity which apparently contributed to higher DP, perhaps due to synergistic activity with amylases. The α -amylases activities in malts of SSV and SV were virtually similar, and higher than the β -amylases activities in both sorghum cultivars. SSV generally had less malting loss compared with SV. Thus, SSV apparently have greater potential for producing quality malts for brewing beer than SV. It is expected that the production of good quality SSV malts will greatly reduce if not completely eliminate the need to combine barley malts with SV malts in brewing

beer, as is presently the case in Nigeria. Eventual use of 100% SSV malt for beer brewing would inevitably enable Nigeria conserve foreign exchange reserve spent on barley malt importation. Given the use of SSV stalks for commercial production of sugar, the additional use of their grain for producing quality malt for beer brewing will invariably encourage farmers in Northern Nigeria to produce more SSV to meet industrial demands and consequently increase their profit margins.

CONFLICT OF INTERESTS

The author has not declared any conflict of interest.

ACKNOWLEDGEMENT

The author wish to acknowledge the technical assistance of Aguh S., Ishaku J., Ahinda D. J. and Thompson J. in carrying out this work. There is no research grant or any other funding for this research.

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