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Determination of malting conditions, proximate and biochemical properties of sorghum/millet grains and malts

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Abstract

The potential of sorghum and millet grains in the production of malts for beverage making were investigated. The grains were steeped for 50 h and germinated for 5 days at room temperature to produce the malts. Proximate analysis results showed that the crude protein contents in sorghum (11.3%) and millet (10.8%) malts were significantly ($p<0.05$) higher than that of sorghum (10.36) and millet (8.58%) grains. Cereal grains (sorghum, millet) were higher in fat (6.83 and 7.30%), ash (2.41 and 3.16%), fibre (3.31 and 2.63%), moisture (9.93 and 9.95%) and total carbohydrate (71.63 and 53.35%) contents when compared with the malts. Results for malting characteristics of the grains showed that sorghum had significantly ($p<0.05$) higher germination energy (82.53%), germination capacity (90.50%) diastatic power ($32^{O}L$) and lower malting loss (13.50%) than millet grains: 76.6%, 85.67%, 27 ^{O}L and 18.47% respectively. Sorghum malt recorded higher Hot water extract (203.4 L^{o}/kg), Alpha amylase activity (88.62 Unit/mg protein/min), Total soluble solids (12.18 % sucrose,) with corresponding lower Cold water extract (24.35%), water sensitivity (8.12%) and titratable acidity (1.50%) than millet malt with 180 L^{o}/kg, 85.15 Unit/mg protein/min, 11.01% sucrose, 42.52%, 11.10% and 1.65% respectively. This study showed that sorghum grain has a better potential than millet for use as malting material in beverage making.

Keywords: cereals, malting conditions, sorghum, millet

Introduction

Sorghum and millet are critical to the West Africa's food security, producing grain for human consumption and fodder for livestock consumption in the harsh climatic condition. Globally, approximately 500 million people consume sorghum. Nigeria is the world's largest producer, with annual production of 11.7 million MT of grain sorghum, accounting for 18.5 percent of global production.

Millet is consumed by approximately 130 million people in sub-Saharan Africa, 78 percent as a staple food, with 20 percent destined for fermented drinks and other uses, and only 2 percent as livestock feed [1]. In 2016, global production of millet was 28.4million tonnes, led by India with 36% of the world total. Nigeria is the fifth producer of millet in the world as at 2016 with an annual tonnage of 1.5 million [2].

Malting is the limited germination of cereal grains in moist air under controlled conditions. Hydrolytic enzymes are produced during malting. These enzymes modify the cereal grain structure so that the grain is more soluble during the mashing process [3]. Sorghum and millet grains can be processed into many products. One method that transforms the grains into nutritious foods for children and adults is malting [4]. Malting is associated with barley, but other grains have been malted to produce high quality malt based food products. Sorghum and millet have been malted to produce alcoholic beverages and weaning foods [5, 6], 'brewing' malt (malta) type non-alcoholic beverages, cereal and confectionery flavoring and coloring, and 'power flour'-enzyme active flour to' 'thin' infant porridges [7]. Sorghum and millet malts are presently used to produce large quantities of European type lager beers [8, 9]. Moir [10] attributed beer quality to colour, foam appearance and flavor. Comperative studies of barley, sorghum and millet showed that barley brewed from sorghum and millet met these qualities [11]. In addition, millet, like sorghum, is one of the raw materials that can be used to produce gluten free beer [12].

Several authors [13, 14] have documented malting parameters required for screening of grains, such as physiochemical characteristics, germination properties, malting loss and diastatic power. The physicochemical characteristics of pearl millet cultivars grown in northern Nigeria have been reported [15]. However most of the information required for screening of grains for malting is under reported in this environment. Therefore the objectives of this study were to determine the optimum malting conditions suitable for our local environment and malting parameters of the grains. Hopefully these information will be very useful to maltsters and beverage processors.

Materials and methods

Materials

Millet grains (*Pennisetum typhoides*) and sorghum grains (*Sorghum bicolor* L. Moench) were purchased from Orba market, Nsukka, Nigeria.

Methods

Chemical analysis

Analysis of the moisture, crude protein, fat, ash, fibre, and

total carbohydrate contents of sorghum / millet grains and malts were performed according to standard methods [16]. The pH and titratable acidity of the malt were determined using standard assays [16]. The method of James [17] was used to determine the total soluble sugar (as %Sucrose) content.

Determination of optimum malting conditions for the cereal grains

Moisture Content as a function of steep time

Eight petri-dishes lined with filter papers at their bottom were provided and filled with equal volumes of water. Twenty grams (20 g) of the grains were cleaned and steeped at room temperature in each of the petri-dishes for various times (10-80 h) with eight hourly change of steep liquor. At the end of each steep period, the grains were drained, surface water blotted with filter paper, then the moisture content determined.

Determination of optimum Steep time

The grains (20 g) were steeped at various times (10-80 h) as described above. Each of the eight set was allowed to germinate for 4 days in a dark cupboard and then kilned for 48 h at 55^0C, after which the malt's diastatic power was determined.

Determination of optimum germination period

The gains (20 g) were steeped for 50 h and germinated for various periods (1-7 days) in a dark cupboard, later kilned for 48 h at 55^0C and the malt's diastatic power determined.

Determination of effects of kilning at 45^0C and varying drying time on moisture content of the malts

Samples of malted grains at optimum malting conditions (50 h steeping and 5 days germination) were kilned at various periods (12, 24, 36, 48, and 60 h) at 45^0C and moisture content determined

Determination of malting loss as a function of germination period

The grains (20 g) were steeped for 50 h and germinated for various periods (1-7 days) then the resulting malting losses per nth day of germination determined.

Production of sorghum and millet Malts

One kilogram of each of the grains was cleaned and steeped in ordinary tap water for 50 h at room temperature as follows: 8 h steeping: 2 h air rest: 8 h steeping: 2 h air rest. Air rests were done by draining off the steep water. After the last 2 h air rest, the grains were placed on a cotton cloth sterilized with sodium hypochlorite (3.5% in 175 mL distilled water), covered with jute bag and germinated at room temperature with water sprinkled at intervals and turning the grain to avoid matting. The green malt were harvested after 5 days of continuous germination and dried in a hot air oven at 45^0C for 48 h. The polished malts were milled into flour and sieved through 1 mm mesh screen and packaged in plastic containers and stored in a cool place.

Determination of Germination Characteristics of Sorghum and Millet Grains

Determination of thousand corn weight

A thousand corn weight of the grain samples were determined according to the method of Institute of Brewery [18]. Twenty grams (20g) samples were weighed out after removal of foreign matter and half corns. The number of corns in each sample counted and moisture content determined. The weight of 1000 dry corns in gram (g) was calculated as thus:

$$\frac{[W \times 1000 \times DM]}{[N \times 100]}$$

Where W = total weight of cereal grains taken; DM = dry matter percentage of the grains;
N = total number of corns counted.

Germination energy

The germination energy was determined following the method of the Institute of Brewery [18]. One hundred barley kernels grains were placed on two filter papers (Whatman No. 1) wetted with 4 ml of distilled water placed at the bottom of a Petri dish, taking care to ensure that all the kernels were in good contact with the moist filter papers. The Petri dish was then covered and incubated at an average temperature of 30^0C for 24-48 h. The kernels that sprouted at the end of the incubation were counted and expressed as germination energy.

GE (%) = 100-N

Where GE = Germination Energy; N = number of ungerminated grains.

Germination Capacity

The Germination capacity of the grains was determined using the hydrogen peroxide method [19]. One hundred grains of sorghum or millet were placed in a 100 ml glass beaker containing 0.75% hydrogen peroxide (H_2O_2) solution and steeped at 30^0C for 48 h. The steep water was strained off and the sprouted grains separated from unsprouted ones and counted. The unsprouted grains were then transferred onto moist filter paper (whatman No 1) in petri dishes covered with another moist paper filter and the lid replaced. The dishes were then wrapped in jute bag and allowed to germinate at ambient temperature for about 24 h while water was sprinkled at intervals. Newly germinated grains were counted and the result added to the first. The Germination Capacity (GC) was calculated as follows:

$$GC(\%) = \frac{200-N}{2}$$

Where N =Number of ungerminated grains.

Malting Loss

The percentage malting loss of the malted samples was determined according to the method described by Novellie and Schutte [20]. A thousand kernel weight of the original (unmalted) grain was determined on a dry weight basis before malting. After malting, the thousand kernel weight of the malted sample was also determined after removal of the roots and shoots by hand-threshing and moisture by heating (dry weight basis). The malting loss was calculated as follows:

$$Malting\ loss\ (\%) = [\frac{100(Co-Cn)}{Co}]$$

Where Co = 1000 – kernel weight of the unmalted grain; Cn = 1000 – kernel weight of the malt on the nth day of germination.
Then, the malting yield was calculated by subtracting the malting loss from 100.

Water sensitivity
Two lots of 100 grains each were grown on filter papers (Whatman No.1) in petri dishes (9 cm diameter); one moistened with 4 ml and the other with 8 ml water. The difference in the number of grains that germinated in the two Petri dishes was noted as the water sensitivity value [21, 14].

Diastatic power
Diastatic power was determined using the ferricianide method [18]. Malt extract was obtained by extracting with water for 2 h in a temperature controlled water bath (Model NoDK 600 Gulflex England). About 3 mL of the unfiltered malt extract supernatant was transferred into a 250 mL Erlenmeyer flask containing 100 mL buffered starch solution maintained at 30^0C in a water bath. After 1 h thorough mixing, 5 mL portion of digested starch solution was mixed with 10 mL of alkaline ferricianide and left to stand in boiling water for 20 min. On cooling to 30°C, 25 mL acetic acid salt and 1 mL potassium iodide solutions were added and the solution titrated with 0.05 mol/L sodium thiosulphate solution to the complete disappearance of the blue colour thus formed. Blank was prepared by titrating the undiluted 2% starch solution against 1 ml of mixed Fehling's solution A and 2 ml of Fehling's solution B using methylene blue indicator as described above. The diastatic power (Dp) was calculated as follows:

Dp (IOB) = B-A (23+200/250x1/C).

Where, A = Volume of sodium thiosulphate used for direct titration; B = Volume of sodium thiosulphate used for blank determination; C = Volume of unfiltered malt extract used for digestion.

The diastatic power (Dp^0IOB) was converted to Dp (^{0}L) as follows:

Dp (^{0}L) = (Dp^0IOB) x1.1

Alpha-amylase activity
This was determined according to AOAC [16]. Two grams of each of the malt flours was mixed with 10 ml of iced water and centrifuged for 10 min at 800 rpm to obtain the supernatant enzymes extract. About 4 ml of phosphate buffer (pH 6.6), 1 ml sodium chloride and 1 ml of the enzyme extract were mixed with 5 ml of soluble starch solution in a test tube, and aliquots (0.2 ml) of the reacting mixture were taken. The aliquot was placed in the cuvette of a colorimeter and the absorbance measured.

Cold water extract
Cold water extracts (CWE) of the malts were determined according to the Institute of Brewery [18] methods of analysis. Ten grams (10 g) grounded malt was digested with 200mL of distilled water containing 12 mL of 0.1 N ammonia for 3 h at 20°C, stirring at half hourly intervals. The resulting solution was filtered and the specific gravity of the filtrate measured at 20°C. The CWE was then calculated as follows:

$$CWE\ (\%) = \frac{G \times 20}{3.86}$$

Where CWE= Cold water extract; G = the excess degrees of gravity of the filtrate taking water at 20°C as 1000 (G=1000×SG-1)

Hot water extract
Hot water extract (HWE) was determined by the procedure described in the method of the Institute of Brewery [18]. Fifty grams (50 g) ground malt was mixed with 360 mL distilled water previously heated to about 68°C so as to ensure an initial mash mix temperature of 65°C for 1 h. The mixture was then quickly cooled to 20^0C (with ice chips) and the volume made up to 515 mL with distilled water. The mixture was filtered and the specific gravity of the filtrate determined at 20°C with specific gravity bottle within one hour of collecting the sample.

The Extract (E) 'as-is' expressed as litre degrees/kg = G x 10.13.

Where G = excess degrees of gravity of the filtrate taking water at 20°C as 1000.
G = 1000 (SG-1).

Statistical Analysis
The means, standard deviations and analysis of variance (ANOVA) of all the data obtained from the study were computed using the Statistical Package for Social Science (SPSS) version 17. Analysis of Variance was specifically performed to detect significant differences ($p<0.05$) among the sample means followed by the application of Least Significant Difference test (LSD) for the separation of significant means.

Results and discussion
Germination properties of sorghum and millet malts
Table 1 shows the germination properties of the cereal grains. The values of 33.3 g and 6.8 g 1000-kernel weight obtained respectively for sorghum and millet grains were smaller compared to 37-47 g for barley earlier reported [22]. However, since these grains are smaller in size, it is expected that their weight will be smaller. There were significant variations in the germination properties of the cereal grains ($p<0.05$). Germination energy (GE) of 82% and 76%, germination capacity (GC) of 90% and 85%, and malting loss of 13.5 % and 18.7 % were obtained for sorghum and millet grains respectively. Germination energy measures percentage of grains expected to germinate fully at the time of test and germination capacity is 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. Water sensitivity of the grains ranged from 8.12% to 11.10% and therefore, the grains were not water sensitive. Water sensitivity is used to control steeping program [21]. Maltsters avoid water sensitive grains or have to adjust the steeping regime to overcome the condition. The germination properties are useful in selecting grains for malting [21]. Hough *et al.* [19] reported that grains intended for malting should have satisfactory germination properties

of over 90%. Sorghum showed good potential for use as malting grain. High germination capacity, germination energy and malting yield and/or low malting loss are indicators of good malting barley [23]. Physiological and structural differences of the grains may be responsible for the differences in their malting characteristics [24].

Table 1: Germination properties of sorghum and millet malts

Property	Sorghum malt	Millet malt
Thousand kernel weight (g)	33.43^{a}±0.61	6.95^{b}±0.15
Germination energy (%)	82.53^{a}±0.30	76.76^{b}±0.35
Germination capacity (%)	90.50^{a}±0.40	85.67^{b}±0.49
Malting loss (%)	13.50^{a}±0.30	18.47^{b}±0.37
Water sensitivity (%)	1.12^{a}±1.35	2.10^{a}±1.10
Malt yield (%)	87.70^{a}±0.36	72.76^{b}±0.35

Results are the means of three replications. Values carrying different superscripts in the same row are significantly different (p>0.05)

Proximate composition of sorghum / millet grains and malts

Table 2 shows the results of proximate composition of Sorghum, millet grains and malts. The moisture content of sorghum and millet grains (9.93 and 9.95%) are significantly (p<0.05) higher than the malts (7.50 and 6.53%). This could be attributed to loss of water during kilning which involves drying of the green malt in a kiln at 45^{0}C for 24 h. The crude protein contents of millet grains (8.58%) and sorghum grains (10.36%) were significantly (p>0.05) lower in the millet malt (10.8%) and sorghum malt (11.30%). This could be attributed to improvement in Free Amino Nitrogen (FAN). The FAN content of the malt is a product of both the catabolic processes which degrade the storage proteins into peptides and amino acids and anabolic processes which synthesize them into new proteins during germination [25]. FAN is produced during malting by the action of endogenous proteinase and peptidase enzymes on the protein reserves of the grain [26] and the breakdown products are collectively referred to as FAN. Tatsadjien *et al.* [27] reported increase in protein content during prolonged germination of sorghum.

The fat content of millet and sorghum grains (7.30 and 6.83%) were significantly (p<0.05) high when compared with the malts (2.75 and 2.40%). This is due to increased activity of the lipolytic enzymes. They hydrolyze fats to simpler products which can be used as a source of energy for the developing embryo. Similar results were observed for millet [28] and sorghum malts [29]. This decrease in fat content implies increased shelf-life for the malts compared to the cereal grains. Malting of millet and sorghum grains decreased the fibre content from 2.63 and 3.31% to 1.48 and 3.11% as shown on Table 2. This could be attributed to loss of pericarp layers of the grains which are rich in fibre during germination [30].

There were significant (p<0.05) decrease in the ash content of millet and sorghum grains (3.16 and 2.41%) when compared to the malts (1.20 and 1.30%). This is expected because during soaking and germination processes, the pericarp or aleurone layer was lost thus resulting in the much decrease. Most mineral elements reside either in the pericarp or aleurone layer of the grains.

The total carbohydrate content of the millet and sorghum grains (53.35 and 71.63%) were significantly (p<0.05) lower than the resulting malts (47.93 and 54.40%). The observed decrease in carbohydrate content could be as a result of metabolism due to high level of amylase activities. The amylases break down complex carbohydrates to simpler and more absorbable sugars which are utilised by growing seedlings during the early stages of germination [31]. The decrease in the total carbohydrate content corroborated by same observation made [28, 32].

Table 2: Proximate composition of sorghum / millet grains and malts

Parameters	Grains		Malts	
	Millet	Sorghum	Millet	Sorghum
Moisture content (%)	9.95^{a}±0.39	9.93^{b}±0.56	6.53^{c}±0.15	7.50^{c}±0.10
Protein (%)	8.58^{a}±0.45	10.36^{b}±0.1	10.8^{b}±0.30	11.30^{c}±0.10
Fat (%)	7.30^{b}±0.20	6.83^{c}±0.25	2.75^{a}±0.05	2.40^{a}±0.09
Fibre (%)	2.63^{b}±0.20	3.31^{b}±0.16	1.48^{a}±0.18	3.11^{b}±0.17
Ash (%)	3.16^{c}±0.35	2.41^{b}±0.16	1.20^{a}±0.10	1.30^{a}±0.10
Total carbohydrate (%)	53.35^{a}±0.53	71.63^{c}±0.25	47.93^{b}±0.15	54.40^{d}±0.26

Results are the means of three replications. Values carrying different superscripts in the same row are significantly different (p<0.05)

Optimum malting conditions of the cereal grains

Fig. 1-5 present the optimum malting conditions of the cereal grains. The variation of moisture content (%) against steeping time (h) is shown in Fig. 1. The result indicates a sharp rise in water uptake during the first 10 hours. Further steeping above 20 hours showed marginal increases. It is evident from the results that sorghum grains absorbed moisture faster than millet grains and this may be due to its relative large corn size. Dahlstron *et al.* [33] observed that larger corns absorb water more rapidly than smaller ones initially, and the difference in water absorption after 24 h is marginalized. Also Hartong and kretschmer [34] found that samples of grains that absorbed water faster gave better malts than grains that absorb water more slowly.

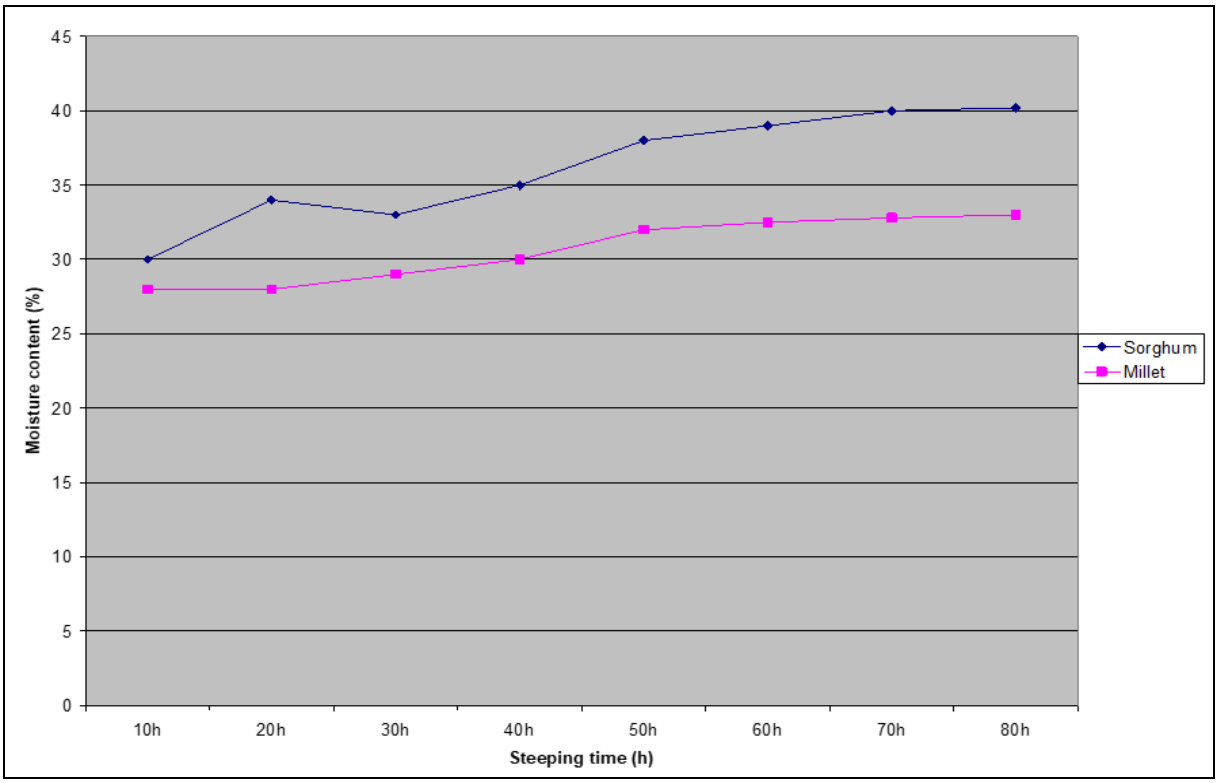

Fig 1: Moisture content (%) against steeping time (h)

The result obtained from the plot of diastatic power (^oL) against steep time (h) (Fig. 2) showed that the optimum steep time was 50 h. At this time, maximum values of diastatic power were obtained for the grains after 5 days of germination. Furthermore, extrapolating the 50 h optimum steep time to results of the plot of moisture content (%) against time (h) as shown in Fig. 1 gave variously 38% and 33% moisture contents for sorghum and millet grains respectively. Nout Davis [8] obtained 45% moisture content after 35 h and 20 h of steeping sorghum 'Andivo' and sorghum 'igumba' respectively. Taylor and Robbins [35] showed that high germination moisture gave the highest malt *beta*-amylase activity. Aisien and Ghosh [36] reported that the optimum moisture content for rapid germination of Guinea corn (*sorghum vulgare)* was between 35 and 40%, at optimum temperature of 22^0C. Dewar *et al.* [37] found that sorghum malt diastatic power (combined *alpha*- and *beta*-amylase activity) increased with time of steeping and was directly related to steep-out moisture. Ezeogu and Okolo [38] found that steeping regime, and in particular the use of air-rests enhanced sorghum malt quality, including *beta*-amylase activity. It is probable that use of air-rests simply provides more oxygen and hence more rapidly increases seedling metabolic activity. Steeping involves immersing the grains in water until they have imbibed a suitable amount of water at a temperature of about 30-40^{o}C to support growth and biochemical changes during germination [19].

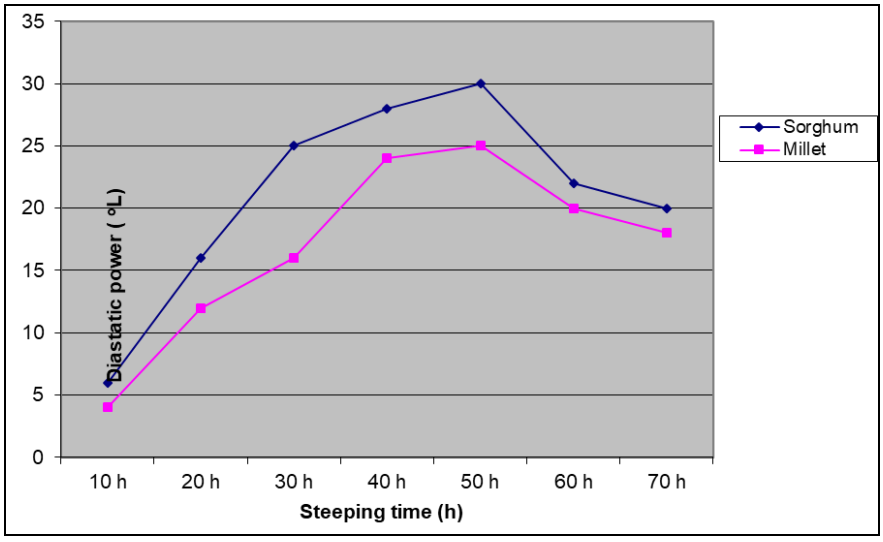

Fig 2: Diastatic power (^{0}L) against steeping time (h) after 5 days of germination

Fig. 3 shows the plot of Diastatic power (DP) (^{0}L) against germination period (days). The optimum germination period of 5 days was obtained after steeping the grains for 50 h with intermitent use of air-rests. Diastatic power of 32^{o}L

and 27°L were obtained respectively for sorghum and millet malts under the same stipulated malting conditions. The result shows that there was no diastatic power measurable in ungerminated grain but rises sharply from 1-3 days reaching its peak after 5 days of germination. This suggests that diastatic enzymes absent in ungerminated grain developed with germination [35, 39]. In general, the DP of the malts increased with increasing germination time to about 5 days (Fig. 3) This is in agreement with what has been reported by others [37, 5]. Germination process promotes the production of a number of enzymes, notably α-amylase and β-amylase, which convert the starch in the grain into sugar [40].

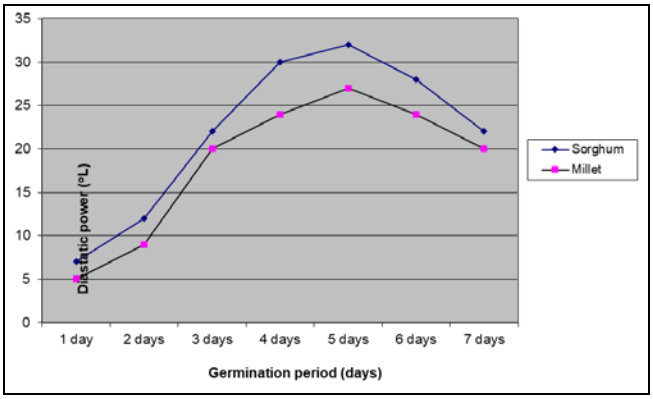

Fig 3: Diastatic power (^{0}L) against germination period (days) after 50 h of steeping

Another key aspect of malting with regard to the potential of sorghum/ millet is malting loss. Minimizing malting loss is essential if sorghum/ millet malting is to be economically viable. Fig. 4 shows the result of malting loss (%) measurements during the various periods of germination (days). The result showed that the malting loss of grains increased with increase in germination period. Significant increases in malting loss were observed between 2-4 days of germination, which correspond to the periods of significant drop in kernel weights during germination. The ranges of 12 – 16% and 16 – 20% malting losses were obtained respectively for sorghum and millet malts within 4 to 7 days of germination. The malting losses for barley have been given as 6 – 12% [19] and 11-18% [22] respectively. The high malting loss of the millet grains could be due to excessive serration during steeping leading to grains growing uncontrollably during germination [19]. It should be noted that the malting loss data reported here do not take into account additional losses that would occur if the external roots and shoots were removed, as is done with barley malt. Thus, the total malting losses (due to respiration plus removal of roots and shoots) for millet/sorghum malting would be rather higher than those reported for commercial barley malting of 6–12% [41]. The malting losses observed in the test were adequate because an average of 10 -15 % respiration / metabolic loss is expected in a well malted sorghum with good diastatic power [42].

Malting loss could also result from long steeping period as materials tend to be leached into the steep water. Malting loss which is comprised of physiological, moisture and vegetative loss is inversely related to the malt yield. Sorghum with less malting loss recorded higher malt yield. Malt yield is a critical factor in malting as it reflects the amount of extract obtainable from the cereal grain concerned.

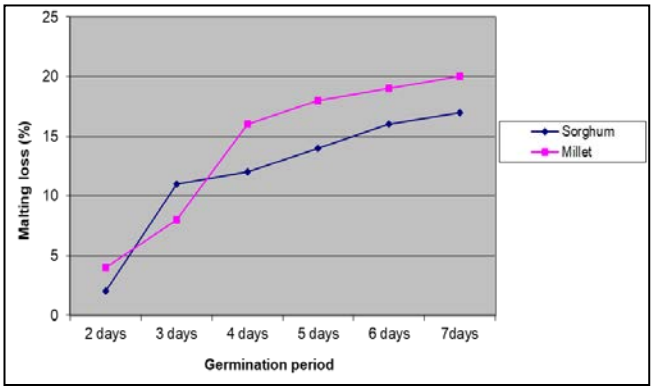

Fig 4: Malting loss (%) against germination periods (days)

Results of kilning studies (Fig. 5) show that moisture release is reciprocally related to moisture absorption. Significant loss in moisture was recorded after 12 h of kilning at 45^{0}C. With regards to moisture level in relation to storage qualities of malts, optimum kilning can be carried out at 45^{0}C for 24 – 48 h depending on the moisture level of the green malt and the moisture content of the malt required. The effect of temperature on the malt characteristics was not investigated, however, other workers [8, 20] showed that only kilning at 70^{0}C resulted in a significant loss in diastatic activity. Kilning at 50^{0}C to 60^{0}C caused only negligible destruction.

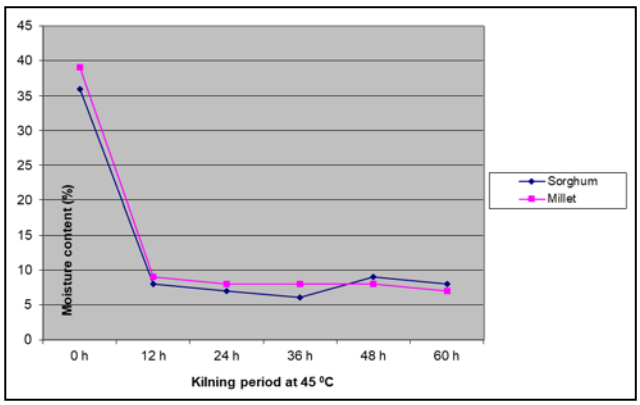

Fig 5: Moisture content (%) against kilning periods (h) at 45^{0}C

Biochemical properties of sorghum and millet malts

Table 3 shows the results of biochemical properties of sorghum and millet malts. Alpha-amylase varied significantly ($p<0.05$) from 85.15 unit/mg protein/min for millet to 88.62 unit/mg protein/min for sorghum. Sorghum diastatic power (DP), 32.61°L is significantly ($p<0.05$) higher than millet (DP), 27.23 ^{O}L. The titratable acidity (as % lactic acid) varies from 1.50% for sorghum to 1.65% for millet, while total soluble solids (as % sucrose) vary from 11.01% for millet to 12.18% for sorghum. Hot water extract (HWE) and cold water extract (CWE) are soluble products including sugars and amino acids of enzyme hydrolysis from malting process. Sorghum malt had CWE (24.35%), HWE (203.45 L°/kg) while millet had CWE (42.2%) and HWE (180.42 L°/kg). Generally, low CWE, HWE and high diastatic power (DP) are indicative of good malting characteristics. Hough *et al* [19]. reported values of 307 L°/kg (HWE), 18.6% (CWE) and 63 ^{O}L (DP) for barley malt. The high CWE obtained in this study may be due to malting at high temperature, 30°C as against 15^{0}C for barley [43], as well as high moisture content achieved by springing of water.

Table 3: Biochemical properties of sorghum and millet malts

Property	Sorghum malt	Millet malt
Alpha amylase activity (Unit/mg protein/min)	88.62 [a]±1.70	85.15 [b]±2.10
Diastatic power (^oL)	32.61 [a]±1.20	27.23 [b]±1.64
Cold water extract, CWE (%)	24.35 [a]± 2.73	42.52 [b]±1.45
Hot water extract, HWE (L^o/kg)	203.45 [a]±5.43	180.42 [b]±4.61
Titratable acidity (%)	1.50 [a]±0.08	1.65 [a]±0.23
Total soluble solids TSS(as % sucrose)	12.18 [a]±1.17	11.01 [a]±1.20
pH	5.31 [a]±0.71	5.17 [a]±1.02

Results are the means of three replications. Values carrying different superscripts in the same row are significantly different ($p<0.05$). Analyses were carried out after 5th day of germination.

Conclusion

The objective of the present study was to produce malt principally from locally available cereal grains for food beverages industrial applications. Malting and malt's quality characteristics of the grains studied indicated that sorghum showed good potential for use as malting grain than millet. Results diastatic power, hot water extract, and cold water extract obtained for sorghum /millet malt's were inadequate for good malt qualities in lager beer brewing, but showed good promise in other beverages production. Further cultivar screening of sorghum and millet grains and studies on the optimum malting modification conditions need to be undertaken before final certification of the cultivars for malting purposes.

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