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Evaluation of the Grain and Malting Properties of Four Recently Improved Sorghum Varieties

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ABSTRACT

Improving the utilization of sorghum in beer brewing has led lots of researchers carrying out studies on different varieties of sorghum. The aim of the study is to evaluate the malting properties of the four recently improved sorghum varieties (Samsorg 46, 47, 48 and 49). In this study, four recently improved Nigerian sorghum varieties were subjected to several tests, these include determination of a thousand corn weight, moisture content, germinative capacity, germinative energy and water sensitivity, tannin, Protein estimation, cold water extract (CWE), hot water extract (HWE), diastatic power and amylase activities using standard methods. The results obtained showed variations among the sorghum varieties in most of the parameters assessed. Samsorg 49 gave the highest weight (34.1g), for germinative capacity, variety Samsorg 46 gave the highest value (99.5%), Samsorg 46 and 48 were the most water sensitive (98%), Samsorg 46 gave the highest value for CWE (50.60%) while Samsorg 49 gave highest value for HWE (284.86%). The four grains had no tannins present. Samsorg 46 (10.02%) had the highest protein content while Samsorg 48 had the least (9.25%). The malt quality of the sorghum varieties increased with increase in germination days. Moisture content and protein content of the malts decreased with germination days, with Samsorg 48 having the lowest value (8.4%) and (6.03%) respectively. CWE, HWE and diastatic power, increased as the germination days increased with highest value in SAMSORG 46 (50.60%), Samsorg 49 (284.86%) and Samsorg 48 (14.23^{o}L) respectively. More works need to be done, to completely evaluate their overall suitability, with various enzyme formulations to produce mashes and wort with higher brewing potentials.

Keywords: cereals, sorghum, malting, brewing.

INTRODUCTION

Barley malts have always been known to be the chief and most dependable raw material for beer production due to the development of large range of enzymes during malting and low starch gelatinization temperature. In tropical brewing, the use of sorghum as a replacement for barley in beer brewing has been effective (Archibong *et al*., 2015). Sorghum, unlike barley, is very well adapted to the semi-arid and sub-tropical conditions prevailing over most of the African continents. The African climate is not suitable for the growth of barley because it is a temperate crop. This poses a major problem as barley grain or malt must be imported, hence there are increasing prices due to high global demand and shipping costs, leading to some valuable foreign exchange expense and increase in the price of the beer beyond the reach of most Africans. Importation is also disadvantageous to local farmers as it denies them potential markets (Fali *et al.*, 2019).

To improve the utilization of sorghum in beer brewing, a lot of studies have been carried out. Such studies however were limited to morphology and ultra-structure enzyme development and extraction as well as mashing (EtokAkpan, 2004). In Nigeria, the Institute for Agricultural Research, Samaru established in 1922 has produced over 40 improved sorghum varieties. These varieties have improved nutrients and high resistance to disease and pest. Among these new sorghum varieties were some whose malts possess beneficial qualities for beer brewing, such as good diastatic power, α- and β-amylase activities and extract recovery (Ezeogu and Okolo, 1995). These qualities of sorghum malts for brewing are further enhanced by the incorporation of starch hydrolyzing enzymes such as amylases during mashing (Archibong and Onuora, 2010). Among the different varieties of sorghum, there are those with waxy endosperm that contain more than 95% amylopectin and a relatively weak protein matrix (Pozo-Insfran *et al*., 2004). These sorghums are more susceptible to hydrolysis by amylolytic and proteolytic enzymes, and also to degradation in the ruminal system of domestic animals, properties that increase their processing potential and nutritional value. All these characteristics in addition to the tendency to gelatinize more rapidly than regular endosperm types, make waxy sorghums more attractive as potential sources of industrial brewing material. In contrast to barley, sorghum malt has less diastatic amylase and glucanase activities and requires a higher temperature for starch gelatinization (Pozo-Insfran *et al*., 2004).

The malting quality of a grain is regarded as its potential to develop the correct balance of enzyme systems under controlled germination conditions. During malting, grains develop cell wall-degrading enzymes (for friable malt), amylolytic enzymes (α- and β- amylases) that will convert the cereal starch into fermentable sugars and proteolytic enzymes (which modify grain storage proteins) to produce assimilable nitrogenous materials for adequate yeast growth and fermentation (Igyor, *et al.,* 1998). The conventional mashing temperatures used to extract barley

malt are unsuitable for sorghum malt because starch molecules of sorghum gelatinise at 70-80^{0}C, while those of barley malt gelatinise between 63 and 64^{0}C (Igyor, 2006). So far, over 10,000 varieties of sorghum are in existence, and more varieties are being developed through continuous plant breeding research to select desired characteristics in the new varieties, all for the different utilitarian purposes mentioned above (Nnamchi *et al*., 2014). Most of these sorghum varieties differ in their pigmentation, size, structure, texture, hardness and biochemical characteristics. Various sorghum varieties were used in earlier studies; these represent only a small portion of the total number of improved sorghum grain varieties presently in existence (Nnamchi *et al*., 2014). Therefore, it is needful to continuously evaluate the malting and brewing properties of newly improved sorghum varieties.

The aim of the study is to evaluate the grain and malting properties of the four recently improved sorghum varieties which were released in August 2018.

MATERIALS AND METHODS

Sample Collection and Sample Preparation

Four improved sorghum varieties (Samsurg 46, Samsurg 47, Samsurg 48 and Samsurg 49), were obtained from the Institute of Agricultural Research, Ahmadu Bello University Samaru, Zaria, Kaduna State, Nigeria. The grains were sorted and screened by hand to remove broken or damaged grains and foreign materials before being used for analysis.

Grain and Malt Analysis:

Thousand Corn Weight: was determined according to the recommended methods of analysis of the Institute of Brewing (IOB, 1991).

Moisture Content: of grains and malts was determined according to the recommended method of analysis of American Society of Brewing Chemist (ASBC, 1958).

Germinative Capacity: was determined according to the recommended methods of Analysis of the Institute of Brewing (IOB), 1991; (Hydrogen Peroxide and Peeling Reference Method).

Germinative energy (G.E.) and water sensitivity (W.S.): were determined according to the recommended methods of Analysis of the Institute of Brewing (IOB), 1991). Germinative energy = G.E (4ml) %Water sensitivity = W.S (8ml) %.

Presence of tannins: were determined according to Waniska *et al*., (1992) on Practical methods to determine the presence of tannins in sorghum.

Nitrogen and protein: were estimated using the Micro Kjeldahl method for determination of nitrogen (Association of Official Analytical Chemists AOAC, 1980).

Cold Water Extract (CWE): was determined according to the Recommended Methods of Analysis of the Institute of Brewing (IOB), 1991.

Hot Water Extract (HWE): was determined according to Decantation Method of Etokakpan (1992).

Diastatic Power and Amylase Activities: were estimated according to Diamylase Procedure described by Etokakpan and Palmer (1990).

Malting of grains: Steeping and Sprouting of Sorghum Grains was done according to the method described by Agu and Okeke (1991). After kilning, the malts were detached from the rootlets by hard rubbing with the hands. The malts were stored for further analysis.

STATISTICAL ANALYSIS

Each analytical determination was carried out in triplicates with average mean recorded. Data were subjected to One way Analysis of Variance (ANOVA) using SPSS (Statistical Pacakage for Social Sciences).

RESULTS

Grains Analysis

The chemical and physical properties of unmalted sorghum varieties are given in Table 1 below. The result of 1000 corn weight of the grains indicated that, Samsorg 49 had the highest weight (34.1g) followed by Samsorg 46 (29.1g), Samsorg 48(29.1g) and the least being Samsorg 47 (28.9g). The moisture content of the sorghum varieties was 15.7%, 12.7%, 12.6% and 12.5% for Samsorg 46, 47, 48 and 49 varieties respectively. The protein content in the grains used in this study were 10.02%, 9.89%, 9.25% and 9.85% for Samsorg 46, 47, 48 and 49 respectively. Concerning germinative capacity which measures the ability of grains to germinate, Samsorg 46 and Samsorg 48 had the highest germinative capacity (99.5%) each while Samsorg 47 had 95%, Samsorg 49 had 96%.

Germinative energy gives indication of metabolic rate and subsequent effect on malting rate and yield (extent of dormancy of grains). The highest value of germinative energy of the grains (100%) was recorded in Samsorg 49, followed by Samsorg 48 (99%), and then Samsorg 46 (97%), the least was Samsorg 47 (96%). For water sensitivity Samsorg 47 was seen to be the most resistance to water with a value of (91%), followed by Samsorg 49 (96%), then Samsorg 48 (97%), finally Samsorg 46 (99%). The sorghum varieties were all tannin free as none was detected. The cold-water extract Samsorg 46 had 6.04, Samsorg 47 (3.91), Samsorg 48 (5.88) and Samsorg 49 (2.23). The hot water extract (HWE) of the different varieties gave the following result Samsorg 46 had 57.28, Samsorg 47 (79.15), Samsorg 48 (57.54) and Samsorg 49 (82.33). The hot water extracts are considerably higher than that of the cold water extracts.

Table 1: Some grain quality properties of the sorghum varieties

Parameters	Samsorg Sorghum Varieties			
	46	47	48	49
Germination Energy (%)	97±0.60	96±0.60	99±10	100±0.00
Germination Capacity (%)	99.5±0.50	95±1	99±1	96±2
Water sensitivity (%)	98±0.80	83±2	98±0.5	97±2
1000 corn weight (g)	29.1±1	28.9±0.4	30±2	34.1±0.50
Moisture content (%)	15.7±0.30	12.7±0.30	12.6±0.50	12.5±0.60
Protein Content (%)	10.02±0.10	9.89±0.01	9.25±0.20	9.85±0.20
Cold Water Extract (CWE) (%)	6.04±0.20	3.91±0.10	5.88±0.20	2.23±0.30
Hot Water Extract (HWE) (%)	57.28±0.80	79.15±1	57.54±1	82.33±0.60
Presence of Tannins (%)	0	0	0	0
Natural Colour	Cream	Cream	Cream	Cream

MALT ANALYSIS

The analysis for each of the malted variety gave the moisture contents to decrease as the day of germination increased. At the end of the 5th day of germination after kilning (table 6), SAMSORG 46 variety was seen to have the highest moisture content (12.9%), Samsorg 47 (10.0%), Samsorg 49 (9.0) and lowest being Samsorg 48 (8.4%).

Samsorg 46 variety was seen to have the highest value in cold water extract (50.60%) and Samsorg 49 had the highest value in hot water extracts (284.86%). This increase was seen to be consistent throughout the 5 days of germination.

The protein content in the four varieties was seen to decrease as the day of germination increased. At the 5th day of germination, Samsorg 46 variety was seen to be the highest (6.65%), followed by Samsorg 49 variety (6.46%), Samsorg 47 (6.09%) and Samsorg 48 variety (6.03%) being the lowest.

From the tables (tables 2,3,4,5 and 6), it can be seen that diastatic power increased as the germination days increased. Samsorg 48 variety was seen to increase from 4.14^{o}L at day 1 to 14.23^{o}L at day 5 showing the highest value, Samsorg 47 variety increased from 3.44^{o}L at day 1 to 12.08^{o}L at day 5, Samsorg 49 variety increased from 2.55^{o}L at day 1 to 11.95^{o}L at day 5 and Samsorg 46 variety was seen to have the lowest value with an increase from 2.94^{o}L at day 1 to 11.26^{o}L at day 5.

Table 2: Malt Analysis Day 1

Parameters	Samsorg Sorghum Varieties			
	46	47	48	49
Moisture Content (%)	13.77±0.30	10.93±0.50	9.30±0.30	9.66±0.30
Cold Water Extract (CWE) (%)	26.29±0.20	27.87±0.20	24.16±0.10	7.34±0.20
Hot Water Extract (HWE) (%)	106.45±0.10	106.45±0.10	89.14±0.30	127.66±0.20
Protein Content (%)	9.04±0.02	9.10±0.02	9.11±0.04	9.07±0.02
Diastatic Power (^{o}L)	2.94±0.02	3.44±0.02	4.14±0.02	2.55±0.10

Table 3: Malt Analysis Day 2

	Samsorg Sorghum Varieties			
Parameters	**46**	**47**	**48**	**49**
Moisture Content (%)	13.24±0.30	10.62±0.30	8.87±0.20	9.26±0.30
Cold Water Extract (CWE) (%)	31.45±0.20	29.76±0.10	29.76±0.10	17.48±0.10
Hot Water Extract (HWE) (%)	141.83±0.10	171.32±0.20	133.73±0.10	185.52±0.20
Protein Content (%)	8.66±0.02	8.33±0.02	8.05±0.05	8.53±0.10
Diastatic Power(^{o}L)	3.08±0.03	3.9±0.10	4.62±0.03	3.19±0.02

Table 4 Malt Analysis Day 3

	Samsorg Sorghum Varieties			
Parameters	**46**	**47**	**48**	**49**
Moisture Content (%)	13.14±0.10	10.32±0.03	8.85±0.10	9.54±0.20
Cold Water Extract (CWE) (%)	32.23±0.30	34.95±0.04	35.45±0.30	36.97±0
Hot Water Extract (HWE) (%)	178.27±0.10	195.86±0.40	160.08±0.03	181.32±0.10
Protein Content (%)	8.39±0.01	7.87±0.03	7.62±0.03	7.82±0.10
Diastatic Power(^{o}L)	4.67±0.10	5.87±0.03	6.53±0.50	4.49±0.02

Table 5: Malt Analysis Day 4

	Samsorg Sorghum Varieties			
Parameters	**46**	**47**	**48**	**49**
Moisture Content (%)	13.05±0.05	10.05±0.05	8.50±0.50	9.08±0.03
Cold Water Extract (CWE) (%)	35.28±0.20	38.05±0.02	36.48±0.02	38.03±0.02
Hot Water Extract (HWE) (%)	213.77±0.03	220.83±0.03	181.31±0.03	252.36±0.03
Protein Content (%)	7.08±0.10	6.69±0.10	6.31±0.10	7.00±0.10
Diastatic Power(^{o}L)	9.34±0.10	10.26±0.10	11.46±0.04	10.37±0.10

Table 6: Malt Analysis Day 5

	Samsorg Sorghum Varieties			
Parameters	**46**	**47**	**48**	**49**
Moisture Content (%)	12.94±0.10	10.01±0.03	8.43±0.03	9.02±0.02
Cold Water Extract (CWE) (%)	50.60±0.40	45.32±0.30	42.12±0.10	34.78±0.10
Hot Water Extract (HWE) (%)	249.21±0.20	231.00±0.20	245.15±0.20	284.86±0.20
Protein Content (%)	6.65±0.04	6.09±0.02	6.03±0.02	6.46±0.04
Diastatic Power(^{o}L)	11.26±0.03	12.08±0.03	14.23±0.02	11.94±0.06

DISCUSSION

Sorghum has been shown by different authors to have a wonderful potential for various food and industrial uses including brewing (Taylor *et al*., 2006; Ogbonna, 2011). Most of these are derived from its physiological robustness and its ability to withstand extreme environmental circumstances, such as drought and heat tolerance (Taylor *et al*., 2006; Ejeta and

Knoll, 2007). The key consideration for sorghum just as other cereals should be the possession of an adequate and requisite content of the fundamental nutritional requirements. Buyers of malting grains are generally said to prefer grains that have a higher germination rate, larger kernel size, a good hectolitre weight and the correct protein level, among other qualities, including being free from mold infestations. (DAF, 2007).

The four sorghum varieties investigated in this work all showed good germinative and grain quality properties as reflected in Table 1. The grains had germinative energies that ranged from 96-100% which agreed with those previously obtained using indicated reference varieties by Ezeogu and Okolo (1994) and were also above values previously recommended as acceptable for malting grains (Nnamchi *et al.*, 2014). Barley has been reported to have germinative energy of 90 ± 2.4% and the grains studied exceeded this value (Nnamchi *et al.*, 2014).The sorghum grain varieties assessed showed that they were viable as they all had germinative capacities greater than 90%, which agrees with reports that has been given for sorghum previously. These values were also comparable to those (over 94%) previously reported for barley (Nnamchi *et al.*, 2014). The germinative energies and capacities noted for the sorghum varieties used in this study were about the same as several varieties of sorghum studies by Iwuno and Odibo, (2015). The grains were shown to have water sensitivity greater than 80% that was reported by Ezeogu and Okolo (1994). Water sensitivity is a quality that shows the water tolerance capacity of grains (Ezeogu and Okolo 1994). Water sensitivity indicates how well a specific grain type can fit into a steeping schedule. Water-sensitive grains will most likely require the incorporation of an air rest period during their steeping or shorter steeping times (Bamforth, 2002). However, the values for water sensitivity of Samsorg 46, Samsorg 48 and Samsorg 49 varieties were higher than sorghum varieties reported by Archibong and Onuora, (2010), except for Samsorg 47 which fell within the range. This indicates that these varieties are viable and suitable for malting purposes.

The 1000 corn weight of the sorghum varieties varied between 30g (Samsorg 48) to 34.1g (Samsorg 49). Due to genetic diversity of sorghum, kernels can vary widely in size and shape, with 1000 kernel weight for sorghum varying from 30g to 80g (Schober and Bean, 2008). One very important property to consider with grains for malting and brewing is grain size: bigger grains or kernels are often preferred because they contain proportionately less husk and therefore higher starch content than smaller ones (Bamforth, 2002).

The moisture content of the sorghum varieties studied was in the range of 12.5% for Samsorg 49 and 12.6% for Samsorg 48. The result for moisture content obtained in this study falls within range of those obtained by Archibong *et al.,* (2015). Dewar *et al*., (1997) mentioned that the moisture content of grains may vary depending on the grain size, season of growth and variety. The protein concentration for the sorghum varieties in this study was high when

compared to the general accepted figure for cereals, about 7.5% (Ogbonna, 2011). It may be that these varieties have been bred for high protein content since they are used for food. Proteins influence the whole brewing process not only in the form of enzymes but also in combination with other substances such as polyphenols. As enzymes they degrade starch such as β-glucans, and proteins, in combination with other substances such as seen in protein-protein linkages, they stabilize foams and are responsible for mouth feel and flavor stability, and in combination with polyphenols, they are thought to form haze. As amino acids peptides and sal ammoniac, they are important nitrogen sources for yeasts (Steiner *et al*., 2011). The protein contents reduced with increased germination days. This could be as a result of the production of protease enzymes during malting and subsequent initiation of protein degradation during malting period. During malting, storage proteins are partially degraded by proteinases into amino acids and peptides which are critical for obtaining high-quality malt and therefore high quality wort and beer (Steiner *et al.*, 2011).

Cold water extract (CWE) is a general reference for water soluble materials already formed during malting and easily extracted with cold water, including readily available sugars and amino acids located in the malt endosperm. CWE has been referred to as extracts formed in malts when enzyme activities have been inhibited (Nnamchi *et al*., 2014). Values for CWE obtained here do not differ much from those previously reported for some varieties of sorghum (Ogbonna, 2002, 2011), but they are slightly lower than those reported by Ogu *et al*. (2006). In addition, they are similar to those reported for barley when malted at 17 °C (Nnamchi *et al*., 2014). CWE is a useful malt property that predicts the degree of modification achieved during malting, especially as it concerns the soluble nitrogen content of malt (Nnamchi *et al*., 2014).

The hot water extracts (HWE) seem to be considerably higher than that of the cold water. This increase could be as a result of the action of heat in freeing up the starch molecules. Hot water extract (HWE) is one of the key attributes considered when determining the malting quality and performance of brewery grains (Nnamchi *et al*., 2014). It is said to be the major determinant of wort quality (Jacobs, 2010). This no doubt is because malt quality is determined by the nature of sugars produced during the malting process. Glucose and maltose were found by Nnamchi *et al*., (2014) to be the main sugars in the HWE, although more glucose forms during sorghum germination than maltose. This is opposite to what occurs in germinating barley. Comparatively higher HWE values have been reported elsewhere (Ogu *et al*., 2006).

After malting of the sorghum varieties, the effect of germination days on their moisture content, cold and hot water extracts, protein content and diastatic power showed that the moisture contents decreased as the day of germination increased. The decrease in moisture content is in agreement with the different varieties of sorghum

analysed by Archibong *et al*., (2015). The storage conditions of the grains are critical for malting because when the seeds are properly stored, their malting traits are enhanced and the longer duration of the sorghum varieties in this study is quite suitable for mashing and brewing operations (Iwuno and Odibo, 2015). Values for CWE obtained with sorghum malts from day 1 to day 5 do not differ significantly from some sorghum varieties previously reported (Ogbonna 2002; 2011), but they were slightly lower than those reported by Ogu *et al*., (2006).

However, the value for the hot water extract above 88% for the malts varieties across the days were higher than that reported by Archibong *et al*., (2010). The hot water extract values as seen across the 5 days of germination showed increasing trends with the increase in germination days, and reaching the maximum value at the 5^{th} day of germination, with Samsorg 49 having the higher value. This suggests that grain size influences HWE quality, a reinforcement of the fact that bigger grains contain higher carbohydrate content than smaller ones (Bamforth, 2002). Cold and hot water extract are very important parameters in the brewing industry. They measure the amount of sugars broken down and released during the malting process. Higher extracts indicate higher modification (Archibong *et al*., 2015). Cold Water Extract of the sorghum malts shows that the values increased as germination days increases, reaching maximum values after 5 day germination. The values of the hot water extracts are considerably higher than that of the cold water extracts of the sorghum malts analyzed.

Finally, the diastatic power value of the sorghum malts increased with increasing germination days. This could be as a result of incorporated air rest cycles and the release of free reducing sugars. The sorghum malts showed that they all have low diastatic power, similar results of low diastatic power for other sorghum varieties have been reported (Agu and Palmer, 1997). Diastatic power of sorghum has been reported by Dewar *et al*., (1997) to increase with time. Diastatic power is especially important in the case of sorghum malt as the level of the beta-amylase enzyme in sorghum is intrinsically low (Dewar *et al*., 1997). Diastatic power is not meaningful when malts are rich in β-amylase (Iwouno and Odibo, 2015). β-amylase enzyme is synthesized during grain development and appears in mature grain both in the free and the bound forms (Evans *et al*., 1997; Yin *et al*., 2002).The increase in diastatic power of all malted grain is due to the conversion of the bound form of β-amylase to the active Free State through proteolytic cleavage which occurred during grain germination (Guerin *et al*., 1992; Georg-Kraemer *et al*., 2001). Arends *et al*., (1995) reported that variation in diastatic power of barley is also affected by complex interaction between the different amylase enzymes and other malting and brewing parameters. Moneke *et al*., (2009) suggested that diastatic power may be strongly dependent on the variety of the sorghum cultivar, steep liquor, and germination period. Tropical cereal malts are however low in β-amylase when

compared with barley malt (Owuama and Adeyemo, 2009).

Conclusion

In this study, some grain and malt parameters of four improved Nigerian sorghum varieties were assessed and variable results were obtained with each variety for the different parameters measured. It was observed that the improved varieties used in this study can be used for malting, with the best being Samsorg 49 in terms of germinative energy and capacity, water sensitivity, corn weight, moisture and protein content, cold and hot water extract. On the whole, the grains have qualities that fell within the acceptable ranges for grains that could be exploited for malting and brewing-related objectives, although the diastatic power which is very important in brewing showed to be below that required for the sorghum varieties to be termed self-converting. From the analysis of the malts produced by the improved grains it can be said that the malts from Samsorg 48 and 49 produced better malts when assessed using their extracts. Further research is needed to use other types of malting schemes to maximize the sorghum varieties malt quality and to employ genetic engineering to improve endogenous enzymes of the sorghum varieties.

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