Moisture Dependence of Some Properties of Malted Sorghum Grains

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Abstract: This study presents the results on the effects of moisture dependence on some properties of a variety of malted sorghum grains commonly used in a brewery in Nigeria. Properties which were determined at different moisture levels (14 - 35 %, wet basis) include physical dimensions, sphericity, 1000 grains weight, bulk density and specific heat. Results showed that for all properties studied, there were marked differences as moisture content varied from 14 % to 35 %. An exemption to this was the 1000 grains weight where no noticeable trend was observed. Results obtained in this study would be useful for design of processes, equipment and machines for handling, preservation and processing malted sorghum grains.

Key words: Malted sorghum grains • Properties • Moisture content

INTRODUCTION

The malt industry produces ingredients for a number of food and beverage industries including industries dealing with baking, brewing, breakfast cereals and distilled products. The most common malted cereal grain is barley but cereal grains such as corn, wheat, rice, sorghum, rye and oats are also used traditionally to make different kinds of malts [1].

In Nigeria, sorghum grains were mainly used as food crops until the early 80’s when a ban was placed on the importation of barley. Industrialists then found malted sorghum grains to be an adequate alternative to barley malt and sorghum malt became a substitute in industries that depended solely on the use of barley. Sorghum grain became a preferred alternative because the grain is cheaper to source, readily available and undergoes modifications during malting which are similar to that of barley grains. Although the ban on barley has since been lifted, the use of sorghum malt wholly or as a supplement with barley has continued. Presently large industries such as Guinness Nigeria Limited and Cadbury Nigeria Limited use sorghum malt as raw materials for their produce. There is therefore a high demand for malted sorghum grains with few suppliers to meet this need [2].

To exploit and improve the utilization of sorghum as a malt product a lot of studies have been carried out. Such studies have however been limited to issues like morphology and ultra structure, enzyme development and extraction as well as the mashing features of the sorghum grains when malted. A review of these studies has been reported in literature [3]. Studies have been carried out on the changes in sorghum malt during storage [4], while the effect of kernel size and structure on the malting properties of sorghum has also been investigated [5].

For many industries that are involved in post harvest processing of agricultural and biological commodities, a number of unique processing, handling and storage requirements exist which influence the design and operations of such industries. These requirements largely depend on the characteristics of the product being processed. Information on such for malted sorghum grains is scarce in literature. Hence, the aim of this study was to investigate some processing, handling and storage properties of malted sorghum grains at different moisture levels. The results of this study would provide baseline data in the design of processing, handling and storage sorghum malting facilities.

MATERIALS AND METHODS

The malt grains used for the study were obtained from the agro-allied division of the International Breweries Limited, Ilesha, Osun State, Nigeria. A yellow coloured, hybrid variety of sorghum malt (SK5912, SSV3) was used. The initial moisture content of the grains was determined by drying triplicate samples of 10g in an oven at 130°C for 18 hours [6]. Desired moisture levels were prepared by
adding calculated amounts of distilled water to batches of the malt grains, sealing them in polythene bags and keeping them in a refrigerator for at least one week to enable the moisture distribute itself uniformly throughout the samples. Samples were brought out of the refrigerator twenty four hours before use to allow defreezing gradually and equilibrating. The moisture contents of the adjusted malted sorghum grains were then confirmed by using the oven drying method.

Size of the malted sorghum grains was determined by randomly selecting fifty malt grains from each of the moisture levels and measuring the length (L), width (W) and thickness (T) with the use of a 0.01mm precision vernier caliper. All measurements were conducted at a room temperature of 26°C. The sphericity and surface area were then be calculated from the values of the length, width and thickness using the expressions:

\[ Sphericity = \left( \frac{L \times W \times T}{L} \right)^{\frac{1}{3}} \]  

(1)

The geometric mean diameter (GDM) and surface area were also obtained from the values of the physical dimensions using the expressions:

Geometric mean diameter(GDM) = \( \left( L \times W \times T \right)^{\frac{1}{3}} \)  

(2)

Surface area = \( \pi (GDM)^3 \)  

(3)

The 1000 grains were randomly selected from the malted sorghum batches and the 1000 grain mass was measured with the use of an electronic balance of accuracy ± 0.01g. This was repeated five times for each moisture level.

A procedure which is representative of the standard hectoliter method was adopted for the determination of the bulk density. An empty cylindrical container of known volume was filled with the malt grains and leveled to obtain uniformity. The container was tapped vertically down on a table for thirty times to achieve uniformity. The excess on the top of the cylinder was removed with the use of a knife edge. The container and content was then weighed using an electronic balance. This procedure was repeated twenty times for grains at each moisture level and mean values determined. Bulk density, \( \rho_b \), was then calculated as the ratio of weight of malt grains to volume of the container.

The method of mixtures was used to determine the specific heat of the malt grains. Thirty grams from each conditioned batch of grains were selected randomly, placed in test tubes and sealed with cotton wool to maintain constant moisture levels. The grain temperature was obtained and grains were then poured into a well insulated calorimeter and fifty gram of ice water added. The temperature of water was taken just before it was poured into the calorimeter. The water and grains in the calorimeter was thoroughly mixed and temperature changes were monitored until equilibrium was reached. Temperature readings were continued for 4 - 5 minutes after equilibrium and specific heat of the samples was determined using the equation [7],

\[ C_g = \frac{(C + M_c C_w) \left( T_e - t' R \right) - T_c}{m_g \left( T_g - \left( T_e - t' R \right) \right)} \]  

(4)

Where

- \( C_g \) = Specific heat of the malt grains, \( kJ K^{-1} g^{-1} \)
- \( C \) = Heat capacity of calorimeter, \( kJ K^{-1} \)
- \( M_c \) = Mass of cold water, kg
- \( C_w \) = Specific heat of water, \( kJ K^{-1} g^{-1} \)
- \( T_e \) = Equilibrium temperature, K
- \( t' \) = Time for grain and water to come to equilibrium, sec
- \( R' \) = Rate of temperature fall of the mixture after equilibrium has been reached, K sec\(^{-1} \)
- \( M_g \) = Mass of grain, kg
- \( T_g \) = Initial temperature of grain, K

**RESULTS AND DISCUSSION**

The initial moisture content of malted sorghum grains obtained from the breweries was found to be 14 %, wet basis. Grains were conditioned to four additional moisture levels of 20 %, 25 %, 30 % and 35 %, wet basis, respectively. These moisture levels were chosen as moisture ranges usually used in the processing, handling and storage of food produce.

A summary of the physical dimensions and other properties derived from these dimensions is shown in Table 1. Results showed that the increase in size as moisture content increases was more pronounced along the intermediate diameter (thickness). Overall percent increases of 2.04 %, 6.67 % and 15.63 % were obtained for the length, width and thickness, respectively, as the moisture content increased from 14 % to 35 %, wet basis. The expansion of soybeans was also found [8] to be most along their intermediate diameters in comparison to the other two diameters. The uneven expansion along the different axes has been explained to be probably due to different cell arrangement in the biological materials.
Table 1: Average values for physical dimensions

<table>
<thead>
<tr>
<th>Moisture Content, %, wet basis</th>
<th>Length, mm</th>
<th>Width, mm</th>
<th>Thickness, mm</th>
<th>GDM, mm</th>
<th>Surface area, mm²</th>
<th>Sphericity, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>4.90 (0.03)</td>
<td>4.50 (0.03)</td>
<td>3.20 (0.02)</td>
<td>4.07</td>
<td>52.04</td>
<td>83.06</td>
</tr>
<tr>
<td>20</td>
<td>4.90 (0.04)</td>
<td>4.50 (0.03)</td>
<td>3.30 (0.03)</td>
<td>4.12</td>
<td>53.32</td>
<td>84.08</td>
</tr>
<tr>
<td>25</td>
<td>4.90 (0.04)</td>
<td>4.60 (0.03)</td>
<td>3.60 (0.03)</td>
<td>4.27</td>
<td>57.28</td>
<td>87.14</td>
</tr>
<tr>
<td>30</td>
<td>4.90 (0.04)</td>
<td>4.60 (0.03)</td>
<td>3.70 (0.04)</td>
<td>4.31</td>
<td>58.36</td>
<td>87.96</td>
</tr>
<tr>
<td>35</td>
<td>5.00 (0.03)</td>
<td>4.80 (0.03)</td>
<td>3.70 (0.04)</td>
<td>4.40</td>
<td>60.82</td>
<td>88.00</td>
</tr>
</tbody>
</table>

* Standard deviations in brackets

For all moisture levels studied, the length of the malted sorghum grains ranged from 0.38 cm to 0.58 cm, the range of the breadth was from 0.38 cm to 0.54 cm while thickness of the grains was from 0.24 mm to 0.44 mm. Malted sorghum grains used for this study, however, appeared to have larger physical dimensions on the average than values reported for unmalted sorghum grains [9, 10]. It is also important to note that sorghum grains are known to show considerable diversity in color, shape, size and certain anatomical components [11], hence malted sorghum grains from different sorghum varieties are also expected to be diverse in terms of physical characterization. Malted sorghum grains were rounded with average sphericity values ranging from 83.06 % to 88.00 % within the moisture range studied. The surface area of grains was calculated to be from 52.04 to 60.82 mm².

The 1000 grain mass of the malted sorghum grains at moisture content values from 14 % to 35 % is shown in Fig. 1. 1000 grains mass values ranged from 45.8 g to 50.2 g on the average. There was no noticeable trend in terms of the change in 1000 grains mass as the moisture content increased. This could be as a result of the use of ungraded grains for the study. 1000 grains mass of malted sorghum grains however fell within the range of 35 - 45 g preferred for barley malt [12]. Results for the 1000 grain mass obtained were also higher than reported values (10 - 30 g) for unmalted sorghum grains given in literature [10-12].
Bulk density values of the malted sorghum grains increased from 0.67 to 0.73 as the moisture content increased from 14% to 30% (Fig. 2). Bulk density was however observed to decrease (0.71) at moisture content of 35%, wet basis. To further investigate this phenomenon the moisture level was increased to 40%, wet basis and bulk density observed; a further decrease to 0.67 was obtained. This phenomenon has also been observed by other researchers [13, 14]. The relationship between bulk density and moisture content was obtained in the form of a polynomial equation:

$$\rho = -2E-05 M^3 + 0.0013 M^2 - 0.0246 M + 0.8135$$

where $\rho$ is the bulk density and $M$ is the moisture content. The coefficient of determination ($R^2$) was 0.9427.

The variation of specific heat of the malted sorghum grain with moisture content is shown in Fig. 3. It was observed that specific heat of the malt grains increased linearly as moisture content increased from 14% to 35%, wet basis. The relationship between specific heat and moisture content was obtained as:

$$\text{Specific heat} = 0.0787M + 0.2193$$

with $R^2$ = 0.9906.

CONCLUSIONS

- The length, width and thickness of malted sorghum grains increased as moisture content increased from 14% to 35%, wet basis. The increase was more pronounced along the intermediate diameter (thickness) than other principal axes.
- Malted sorghum grains were rounded with average sphericity values ranging from 83.06% to 88.00% within the moisture range studied. The surface area of grains was calculated to be from 52.04 to 60.82 mm².
- The 1000 grain weight values ranged from 45.8g to 50.2g on the average. There was however no noticeable trend in 1000 grain weight within the moisture content range studied.
- Bulk density increased as moisture content increased from 14% to 30%, wet basis, peaked at 30% with a value of 0.73 g/cm³ and then decreased as moisture content increased from moisture content 35% to 40%, wet basis.
- Specific heat increased from 1.30 to 2.90 kJ/kg·K within the moisture content ranges studied.

REFERENCES

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