A COMPARATIVE STUDY ON CHARACTERIZATION OF PROCESSED AND UNPROCESSED SORGHUM FLOURS

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ABSTRACT

The effect of physical, technological and functional properties of unprocessed, germinated and dry roasted grains and flours of sorghum were studied in the year 2023. The physical properties of the grains such as length, breadth, length/breadth ratio, thousand grain weight showed that, germinated grains measured minimal results as the stores were utilized for sprouting. Germinated sorghum yielded 94.6%, whereas, unprocessed and roasted yielded 91% of the total flour yield. The technological properties of the flours were analyzed as quality indicator. Bulk density, oil and water holding capacity, and swelling capacity of the roasted flour were higher in quality when compared to unprocessed flour. Optical property indicated that roasted flour was darker and germinated sorghum flour was lighter than unprocessed flour. FTIR of germinated sorghum flour showed stronger peaks indicating the presence of polysaccharides. TGA of germinated sorghum flour exhibited maximum reaction zone due to changes in saccharides and dextrin. Roasted sorghum flour showed better properties that increase hardness, whereas, germinated flour soften the food product. Sorghum flour showed less than 7 x 10⁻¹ CFU/g at day 180.

Keywords: Germination, Property analysis, Roasting, Sorghum flour and grain

INTRODUCTION

India is the prime capital for consuming and producing millets and sixth largest producer of sorghum (Sorghum bicolor [L.] Moench) globally. Millet is a staple food in Indian food basket. Consumption of millet in daily diet have been decreased over the period of time due to lack of knowledge, increased cooking time, and insufficient number of processed food items (Llopart and Drago, 2016). Government and food manufacturers became more aware to increase the consumption and utilization of millets, particularly sorghum, to help farmers to cultivate more resilient crops and make population to overcome hunger, metabolic syndrome and climate change (Kane-Potaka et al. 2021). Sorghum is a gluten-free cereal substitute with high nutrient profile packed with micronutrients and a good source of fiber, protein, antioxidants, and bioactive compounds, but anti-nutritional factors such as phytic acid and tannin, prevent from reaching its full

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nutritional potential. The effects of several wet and dry processing techniques, including steeping, fermentation, germination, roasting, and popping at different temperature and time span on these antinutritional factors of sorghum flour were proved to have impact on the structural and chemical characteristics (Paliwal and Sharma, 2022; Anjitha et al., 2021). The primary phenolic compounds in sorghum are tannins, phenolic acids and 3-deoxyanthocyanidins with good potential of antioxidant activity. Consuming whole sorghum improves gut health, lowers the risk of chronic diseases, and is used as a promising natural multifunctional additive in a wide range of food applications. (Birhanu, 2021). This study was carried out with an attempt to improve the physical, technological, and functional qualities of white sorghum grains through soaking, germination, and roasting to utilize in food processing and production industry.

MATERIAL AND METHODS

Selection of sorghum grains

White variety of sorghum is highly available and consumed largely as compared to red or yellow colored sorghum. Good quality of white variety sorghum grains were purchased from supermarket in Coimbatore, Tamil Nadu.

Processing of selected sorghum grains

The whole sorghum grains were washed, cleaned and sorted to remove husk and other impurities and dried below 12 °C. Conventional preliminary processing like soaking, germination and roasting were done to enrich the physical, technological and functional properties. Sorted sorghum grains were soaked for eight hours and dried by spreading in muslin cloth to remove the excess moisture. Then dried sorghum grains were tied in white muslin cloth for germination for 35 h as suggested by Olamiti et al. (2020). Then the germinated grains were shade dried for 6 h till the moisture attained 12 percent and ground into fine flour in milling machine and kept in air-tight container for further investigation. Clean dried white sorghum grains were dry roasted in iron pan for 12 minutes at 90 °C till few grains popped and the roasted grains were kept undisturbed till it reaches 25 °C to facilitate grinding. Then the roasted grain was milled and sieved through 3 mm mesh as recommended by Ranganathan et al. (2014) and preserved in an airtight container for future study.

Physical properties of grains

Physical properties of the selected and processed grains were analyzed to measure the quality. Thickness (mm), length (mm), breadth (mm), length / breadth ratio, thousand grain volume (ml) and thousand grain weight (g) were measured by the standardized procedure of Khatoniari and Das (2020).

Technological properties of flour

Technological properties of flour was determined to identify the difference among unprocessed, germinated and roasted sorghum flour. Bulk density (g/ml), swelling capacity (ml/g), water holding capacity (ml/g) and oil holding capacity (ml/g) were determined by using the procedure that was followed by Akinola et al. (2017). Standard AOAC procedure was used to analyze moisture by AOAC 930.15 and ash by AOAC 942.05 standards.

Optical properties of sorghum flour

The colour of unprocessed, germinated and roasted sorghum flour was analyzed through Laboratory Scale Food Colorimeter and different values of L*, a* and b* were obtained. L* values, 0 - 100 indicates lighter to darker shades of the taken sample. Positive value of a* refers to greenness and negative shows the presence of redness, whereas, positive and negative values of b* indicates yellowness and blueness.

Functional properties of the flour
The functional groups of the unprocessed and processed sorghum flour were determined through the peaks obtained from Shimadzu Miracle 10 Fourier Transform Infrared spectrophotometer. 0.5 g of sample was utilized to determine the spectra and the peaks were found between 4000 cm⁻¹ to 450 cm⁻¹ wave numbers at 16 runs per scan.

The crystalline or amorphous nature of sorghum flour was measured by patterns through X – Pert Pro, PANalytical model X-Ray Diffraction (XRD). 5 g of fine sample was loaded and operated at 30 mA and 45 kV between the scanning regions from 10° to 79° 2 theta with continuous step size of 0.01 at 5.71 seconds. The Debye-Scherrer formula, \( D = \frac{K \lambda}{\beta \cos \theta} \), has been applied to estimate the average crystallite size of sorghum flour, where, \( D \) is the crystalline size, \( \lambda \) is X-ray wave length of Cu, \( \beta \) is full width at its half maximum and \( k \) is dimension less shape factor with fixed value of 0.94.

**Thermal properties of the flour**

Thermal property analysis of unprocessed, germinated and roasted sorghum flour was identified by Thermo Gravimetric Analyser (EXSTAR/C300) to analyze the percentage of thermal degradation as the flour undergoes certain physiochemical changes with change in temperature. Sample taken was treated from 20 °C to 1000 °C with increase in 20 °C per minute in alumina pan.

**Microbial evaluation of the flour**

Total Plate or microbial count was analyzed by modified procedure of Makawi et al. (2019). 9 ml of sterile peptone water (0.1%) and 1 g of sample were mixed. To create sequential 10 fold dilutions, 1 ml of the homogenate was diluted with 9.0 ml of water that contained 0.1% peptone, by pour plate method suitable serial dilutions in duplicate with plate count agar to make \( 10^1 \) to \( 10^6 \) dilutions and incubated at 35 °C for 48 ± 2 h. Colonies were counted when less than one-quarter of the dish is overgrown by spreading that is unaffected and multiply that number by the dish’s total area.

**RESULTS AND DISCUSSION**

**Grain yield of sorghum**

500 g of cleaned and sorted sorghum were milled which yielded 91 percent of fine flour. Ninepercent were coarse flour when sieved in 3 mm mesh. 500 g of sorghum were germinated and the sprouts were grown upto 1.5 to 1.8 cm after 35 h of germinating and the weight of the grains were increased by absorbing water in the initial stage. After shade drying for six hours, the weight was reduced as the stores were utilized during germination and yielded 94.6 percent. Whereas, 500 g of roasted sorghum

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<thead>
<tr>
<th>S.No.</th>
<th>Sample Taken (g)</th>
<th>Processing Time</th>
<th>After Processing (g)</th>
<th>Flour yield after drying( g)</th>
<th>% of Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sorghum - Unprocessed</td>
<td>500</td>
<td>Unprocessed</td>
<td>500</td>
<td>475</td>
</tr>
<tr>
<td>2</td>
<td>Sorghum – Germinated</td>
<td>500</td>
<td>8 h soaking and 35 h Germination</td>
<td>548</td>
<td>473</td>
</tr>
<tr>
<td>3</td>
<td>Sorghum – Roasted</td>
<td>500</td>
<td>12 mins</td>
<td>450</td>
<td>455</td>
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</table>
yielded 91 percent due to increase in hardness of endosperm while browning and change in gelatinization of starch while popping. (Anjitha et al. 2021). After milling, germinated sorghum flour was soft in nature as compared to unprocessed and roasted flour and the total grain yield was depicted in Table 1.

**Physical properties of sorghum grains**

Physical properties of sorghum were determined through standardized procedures to check the quality of selected and processed sorghum grains and the results were presented (Table 2). The length, breadth and length to breadth ratio of unprocessed and roasted sorghum were similar and those of germinated sorghum were reduced in size. Slight loss in thickness of the grains during germination was also noticed. Maximum thousand grain weight was observed in unprocessed sorghum, whereas, minimum was obtained in germinated sorghum. Thousand grain volume was ranged between 36 ml and 44 ml and the highest was noticed in germinated sorghum. Thousand grain weight was 29.6±0.32 g, 23.2±1.09 g, and 26.4±0.82 g for unprocessed, germinated, and roasted sorghum, respectively. Thousand grain volume was 36±1.12 ml, 44±2.32 ml, and 41±2.01 ml for unprocessed, germinated, and roasted sorghum, respectively. Khatoniar and Das (2020) observed the physical dimensions of major millets and among them proso millet exhibited better properties.

**Technological properties of flour**

Technological properties namely, bulk density, swelling capacity, water and oil holding capacity of the flours were analysed and tabulated (Table 3). Bulk density and swelling capacity was higher in unprocessed sorghum flour than germinated and roasted flour. Water and oil holding capacity of roasted sorghum flour is higher followed by germinated and unprocessed flour as it is considered as the important factor for the formulation of food products as well as a thickening agent. Akinola et al. (2017) found that bulk density and water holding capacity was reduced during malting and fermentation as compared to unprocessed pearl millet. Germinated and roasted sorghum flour exhibited better technological properties as compared to other major millets (Khatoniar and Das, 2020). Germinated sorghum flour contains more moisture and ash content followed by roasted and unprocessed flour.

**Optical properties of the sorghum flour**

Optical property of sorghum flours were evaluated (Table 4). The properties were evaluated thrice, and presented as mean and standard deviation. Analysis was done in triplicates, reported as mean ± standard deviation and the results were tabulated in Table 4. The *L were ranging from 42.63 to 47.83, whereas, a* and b* were 4.81 to 9.5 and 3.05 to 10.49, respectively. The lightness (*L) is highest

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Quality Parameters</th>
<th>Sorghum Unprocessed</th>
<th>Sorghum Germinated</th>
<th>Sorghum Roasted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Length (mm)</td>
<td>0.61±0.012</td>
<td>0.52±0.12</td>
<td>0.61±0.20</td>
</tr>
<tr>
<td>2</td>
<td>Breadth (mm)</td>
<td>0.69±0.01</td>
<td>0.57±0.20</td>
<td>0.69±0.04</td>
</tr>
<tr>
<td>3</td>
<td>Length / Breadth ratio</td>
<td>0.88±0.40</td>
<td>0.91±0.54</td>
<td>0.88±0.40</td>
</tr>
<tr>
<td>4</td>
<td>Thickness (mm)</td>
<td>0.59±0.02</td>
<td>0.57±0.03</td>
<td>0.59±0.10</td>
</tr>
<tr>
<td>5</td>
<td>Thousand grain Weight (g)</td>
<td>29.6±0.32</td>
<td>23.2±1.09</td>
<td>26.4±0.82</td>
</tr>
<tr>
<td>6</td>
<td>Thousand Grain Volume (ml)</td>
<td>36±1.12</td>
<td>44±2.32</td>
<td>41±2.01</td>
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* Mean ± SD Values
in sorghum gminated flour with 47.83 ± 0.35 value which showed lighter than unprocessed and roasted flour. Germinated sorghum flour showed the most reddish and yellowish shade with 4.83 and 3.05 values, respectively. The product developed with roasted sorghum flour provides intense optical property as compared to unprocessed and germinated flour. Olamiti et al. (2020) declared that prolonged malting and fermentation times resulted in lighter flour, while shorter malting and fermentation times resulted in denser flour. Sorghum exhibited high L* content around 72.02 and 73.72, a* content within 2.50 and 3.30, and chrome content between 13.10 and 14.82.

**Functional properties of the sorghum flour**

Functional properties of the unprocessed, germinated and roasted sorghum flours were determined by Fourier transform infrared (FTIR) spectroscopy from 4000 cm⁻¹ to 450 cm⁻¹. Unprocessed sorghum flour contains medium O-H peaks at 3873.06 to 3718.76 cm⁻¹ and weak C–H band at 3502.08 to 3363.86 cm⁻¹, whereas, germinated sorghum flour contains strong peaks at 3834.40 cm⁻¹ and roasted sorghum flour shows medium peaks at 3718.76 to 3834.40 cm⁻¹ showed the presence of vibrational peaks due to bound water and moisture content in flour (Olamiti et al. 2020). Medium C–H peaks at 2306.86 to 2970.38 cm⁻¹ region were present in all the three flours. Medium carbonyl stretch peak at 1697 to 1643 cm⁻¹ for unprocessed and weak peak at 1689 cm⁻¹ region shows the presence of lipids and germinated flour doesn’t contain carbonyl stretch. Strong C=C stretching peaks at 1519 cm⁻¹ for unprocessed and 1527 cm⁻¹ for germinated and roasted sorghum flour shows the presence of the amide II from N – H bending that confirms the presence of protein. Unprocessed sorghum flour contains strong peak at 1519 cm⁻¹ and weak peaks at 1080 to 1458 cm⁻¹ shows the

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<th>Table 3. Technological properties of the sorghum flour (n=3)</th>
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Mean ± SD

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<th>Table 4. Optical properties of the sorghum flour (n=3)</th>
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Mean ± SD
presence of O - H, C - O and C - C bonds which is saturated primary alcohol ring and germinated and roasted flour showed minimum weak peak at these region shows the denaturation of organic compounds. Unprocessed sorghum flour showed more peaks at 416 to 995 cm\(^{-1}\), whereas, germinated flour showed at 416 to 725 cm\(^{-1}\) and roasted showed between 424 and 810 cm\(^{-1}\) confirming the presence of amylose and amylopectin.

A medium peak at 1743.65 cm\(^{-1}\) present in unprocessed sorghum flour showed the presence of tannin and there are no peaks at 1700 to 1400 cm\(^{-1}\) confirming the absence of tannin in germinated and roasted flour (Lin et al., 2021). Steeping and fermentation of sorghum flour does not have impact on structural property but phytic acid and tannin content were reduced upto 21–52 percent due to first-order degradation kinetics due to conventional processing (Paliwal and Sharma, 2022). Malted and fermented pearl millet flour showed increased protein content due to protein synthesis as compared to unprocessed flour (Akinola et al., 2017).

Crystalline nature and crystal size of the processed and unprocessed sorghum flour was determined through X-Ray diffraction. Unprocessed sorghum flour showed main reflection at 11.8, 13.6, 15.3, 16.1, 19.1, 20.9, 21.3, 22.7, 23.7, 25.1, 31.2, 38.7, 40.6, 41.7, 44.0, 60.8, 61.0 and exhibited sharp peaks that indicated crystalline structure of the flour with a crystal size of 88.92 nm calculated by Debye-Scherrer formula, whereas, germinated sorghum flour exhibited peaks at 12.0, 15.3, 19.1, 21.1, 22.4, 24.9, 25.5, 27.6, 31.3, 32.1, 36.3, 38.5, 54.3 regions with 55.91 nm crystal size and the
peaks were low and diffused due to crystalline disruption of the double helices that influences the nature of flour.

Roasted sorghum flour showed sharp peaks at 13.1, 15.6, 16.8, 19.8, 22.3, 24.7, 25.3, 32.0, 38.4, 40.4, 43.6, 40.1 exhibited 65.25 nm crystal size. The changes in peak was noted in fermentation and malting of sorghum and pearl millet (Olamiti et al., 2020). Inclusion of water and other ingredients is determined by the particle size of flour. The smaller particle size, increases the water absorption property (Akinola et al., 2017).

**Thermal properties of the flour**

Thermal properties of unprocessed, germinated and roasted sorghum flours were analyzed through Thermo Gravimetric analyzer to evaluate the physicochemical changes and thermal degradation. 3.66 mg, 5.42 mg and 4.67 mg of unprocessed, germinated and roasted sorghum flour was taken in the alumina pan and thermally degraded from 24 °C to 1000 °C. No change was found till 50 °C. Gradual weight loss was found till 100 °C shows the thermal degradation of moisture. At 300 °C, first zone of thermal degradation in unprocessed, germinated and roasted sorghum flour were observed as a weight loss of 40.4 percent, 33.3 percent and 33.1 percent, respectively. The second zone of changes were enormous which showed a weight loss of 36.7 percent, 42.3 percent and 49.4 percent, respectively in unprocessed, germinated and roasted sorghum flour. A total loss of 94.3 percent, 91.5 percent and 93.8 percent was noticed with a residue of 0.20 mg, 0.46 mg and 0.28 mg, respectively in unprocessed, germinated and roasted sorghum flour. Wang et al. (2021) observed the physicochemical changes in cereal and tubers starch between 100 °C to 320 °C due to changes in saccharides and dextrin compounds.
Microbial evaluation of the flour

Microbial evaluation was done by total plate count for 180 days in the interval of 45 days. Sorghum flour grind in sterile and aseptic environment showed zero CFU/g at day 1 and minimal colony counts at 180 day. Unprocessed, germinated and roasted sorghum flour showed $1 \times 10^{-1}$, $2 \times 10^{-1}$ and $0 \times 10^{-1}$ on the day 45, $2 \times 10^{-1}$, $4 \times 10^{-1}$ and $1 \times 10^{-1}$ on the day 90 and $4 \times 10^{-1}$, $5 \times 10^{-1}$ and $1 \times 10^{-1}$ on the day 135. Unprocessed, germinated and roasted sorghum flour showed $5 \times 10^{-1}$ CFU/g, $7 \times 10^{-1}$CFU/g and $3 \times 10^{-1}$ CFU/g at the end of the 180 days. Germinated sorghum flour showed gradual increase in colony count as per the increased level of moisture content and water activity, whereas, roasted sorghum flour showed the minimal colony count. According to the Food Safety and Standards (Labelling and Display) Regulations (2020) total plate count of millet and millet products should not be more than 1,000 CFU/g.

CONCLUSIONS

This research studied the properties of sorghum flour by conventional processing methods so that one can develop products and increase the usage of this underutilized millet. Processed sorghum grains and flours influenced the functional property, optical property and technological property to reinforce food processing companies for standardizing baked and extruded products. Germinated flour might endure the preparation of smooth baked products, whereas, roasted flour can be used in the preparation of extruded crispy products when compared to unprocessed sorghum flour.

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