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Effect of fermentation on the functional properties of sorghum flour

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Abstract

Sorghum flour was fermented by the traditional Sudanese method of fermentation for 24 h, taking samples every 8 h, and selected functional properties were studied. Results showed that fermentation increased the protein solubility of sorghum flour in the acidic range (pH 2–4). Fermented sorghum flour had a least gelation concentration of 6% after 16 h of fermentation, while it was 18% for unfermented sorghum. Fermentation also increased oil-binding capacity, emulsifying capacity and emulsifying stability, while it decreased the water-binding capacity. Sorghum flour, fermented or unfermented, showed no foam capacity.

Keywords: Sorghum flour; Fermentation; Functional properties

1. Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is a crop that is widely grown all over the world for food and feed. It is one of the main staples for the world's poorest and most insecure people. It is a key staple in many parts of the developing world, especially in the drier and more marginal areas of the semi-tropics. Various processing methods are used for preparation of foods from sorghum; among them, fermentation is a unique method for food preparation in Sudan and in Africa in general.

Information is available on the predominant microorganisms involved in the fermentation of sorghum flour (Abdel Gadir & Mohamed, 1977; Hamad, Bocker, Vogel, & Hammes, 1992; Mohammed, Steenson, & Kirleis, 1991) and on its nutritive value (Axtell et al., 1981; Eggum, Monowar, Bach Knudsen, Munck, & Axtell, 1983; Elkhalifa & El Tinay, 1994, 1995; El Tinay, Abdel Gadir, & El Hidai, 1979). After fermentation, in vitro protein and starch digestibilities increased significantly, as well as available lysine, leucine, isoleucine and methionine, while tannin content and phytic acid decreased during fermentation of sorghum flour.

Celiac disease continues to be a major health problem in many countries. As a result of this, various efforts are being made to solve this problem through the introduction of methods for increased utilisation of less popular foodstuffs.

Recently, there has been increased interest in sorghum as a gluten-free cereal to substitute the gluten-rich cereals in the diet of people suffering from celiac disease. The functional properties of sorghum proteins can be used to define how flour proteins can be used to supplement or replace more toxic protein sources. There is, however, no information on the functional properties of fermented sorghum flour and this information is essential for determining potential uses of this product in food formulation. The aim of this study was to determine the functional properties of fermented and unfermented sorghum flour.

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2. Materials and methods

2.1. Materials

A low-tannin sorghum cultivar (Tabat), obtained from the Food Research Centre, Shambat, Sudan, was used in this study. The seeds were carefully cleaned and ground in a hammer mill to pass through a 0.4 mm screen, and the flour was stored in polyethylene bags at 4 °C.

2.2. Fermentation of sorghum

Sorghum flour was fermented according to the traditional method practised by the Sudanese housewife, as described by El Tinay, El Mehdi, and El Soubki (1985). Fermentation was earned out at 37 °C for periods of 0, 8, 16, and 24 h. After a distinct incubation period, the samples were dried in a hot air oven (Heraeus UT 5042, Germany) at 60 °C for 16 h. Dried samples were ground to pass a 0.4 mm screen and stored in polyethylene bags at 4 °C prior to analysis.

2.3. Protein solubility

Protein solubility was determined in the pH range 2–12 for both fermented and unfermented sorghum flour. A one gramme sample was dispensed in 60 ml distilled water and the pH was adjusted with NaOH or HCl using a pH meter (766 Calimatic/Germany). The dispersion was continuously stirred in an orbital shaker at 150 rpm for 2 h at 25 °C, and then centrifuged (Sigma Laborzentrifugen, Osterode, Germany) at 2000*g* for 20 min. The supernatant was collected and the soluble protein was determined by the procedure of Lowry, Rosenbrough, Fair, and Randall (1951). The percentage of soluble protein was calculated and plotted against the corresponding pH values.

2.4. Least gelation concentration

The least gelation concentration was determined by the method of Coffman and Garcia (1977) as modified by Akubor and Chukwu (1999). Using flour concentrations of 2%, 4%, 6%, 8%, 10%, 12%, 14%, 16%, 18% and 30% (w/v).

2.5. Bulk density

Bulk density (BD) was determined by the method of Wang and Kinsella (1976). Ten grammes of the tested flour were placed in a 25 ml graduated cylinder and packed by gentle tapping of the cylinder on a bench top, ten times, from a height of 5–8 cm. The final volume of the test flour was measured and expressed as g/ml.

2.6. Water- and oil-binding capacity

Two grammes of each flour sample were weighed into a pre-weighed centrifuge tube and 20 ml of distilled water were added. For oil binding, 20 ml sunflower oil were added. Samples were vortexed and allowed to stand for 30 min at 25 ± 2 °C before being centrifuged at 4000*g* for 25 min. Excess water or oil was decanted by inverting the tubes over absorbent paper and samples were allowed to drain. The weights of water and bound oil samples were determined by difference.

2.7. Emulsifying activity and stability

The method of Yasumatsu et al. (1972) was used. Emulsions were prepared with 1g of each sample, 50 ml of cold distilled water (4 °C) and 50 ml of sunflower oil. The flour samples were dispersed with a Waring blender. Each blended sample was divided equally into 50 ml centrifuge tubes. One centrifuge tube was directly centrifuged at 4000*g* for 10 min while the other was centrifuged under the same conditions after heating in a water bath at 80 °C for 30 min and cooling to room temperature (25 °C). The height of the emulsified layer, as a percentage of the total height of material in the unheated tubes, was used to calculate the emulsifying activity and stability, respectively, using the following formulas:

$$\text{Emulsion activity}\ (\%) = \frac{\text{height of emulsion layer}}{\text{height of whole layer}} \times 100,$$

$$\text{Emulsion stability}\ (\%) = \frac{\text{height of emulsion layer after heating}}{\text{height of whole layer}} \times 100.$$

Height was measured in centimetres using a transparent graduated ruler.

2.8. Foaming capacity

The foam capacity was determined by the method of Narayana and Narsinga Rao (1982) using two grammes of each sorghum flour sample.

2.9. Statistical analysis

Two separate batches, for a particular treatment, were taken and analysed separately and the figures were then averaged. Although sample material was of one season, it is not expected that significant variation in functional properties would occur among several seasons. Data were assessed by analysis of variance (ANOVA) (Snedecor & Cochran, 1987) and by Duncan's

multiple range test with a probability $P \leqslant 0.05$ (Duncan, 1955).

3. Results and discussion

3.1. Protein solubility profile

Protein solubility characteristics are influenced by factors such as origin, processing conditions, pH, ionic strength and the presence of other ingredients (Kinsella, 1979). The protein solubility profiles at various pH-values of unfermented and fermented sorghum flour are shown in Fig. 1. The unfermented sorghum flour had minimum protein solubility at pH 4, while the minimum protein solubility for all fermented samples was at pH 6. These results showed that fermentation was shifting the solubility of sorghum proteins by 2 pH units. The protein of the fermented samples was more soluble at the isoelectric pH than was the control. This could be attributed to structural changes in the protein of the fermented samples. It could also be due to inactivation of anti-nutritional factors (phytates) caused by the fermentation. Highest solubilities occurred at pH 12 and values determined were 76.7%, 57.3%, 55.2% and 55.2% for unfermented, 8-, 16-, 24-h fermented sorghum flour, respectively. At pHs 2–4, fermented sorghum flour had higher protein solubility than unfermented. The high solubility at pHs 2–4 for fermented sorghum flour could be attributed to proteolytic activity in fermenting seeds, yielding peptides and free amino acids, which increase nitrogen solubility in water (Beuchat, 1976). It was observed that the increase in solubility in the fermented samples beyond pH 6 was not as high as in the unfermented sample. This may be due to the exposure of some hydrophobic groups in fermented samples, which may cause reduction in solubility. The magnitude of protein solubility was in the following order 8 h > 16 > 24. According to Kinsella (1979), seed proteins, which are soluble at pH 4–8, could be used in "vegetable milk" beverages; this might also be considered for sorghum.

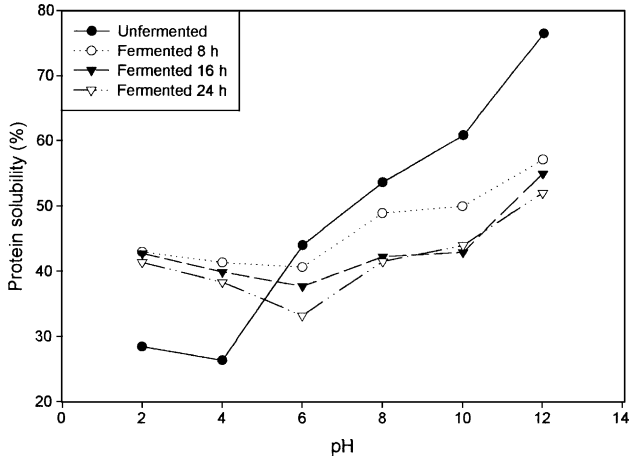

Fig. 1. Protein solubility profiles of fermented and unfermented sorghum flour.

3.2. Least gelation concentration

The ability of fermented and unfermented sorghum flour to form gel was measured. The least gelation concentration (marked as + in Table 1) for fermented samples was 8, 6 and 6% for the three fermentation periods 8, 16 and 24 h, respectively, while it was 18% for the unfermented sorghum flour (Table 1). The least gelation concentration reported for legume flours was 14% for lupin seed proteins (Sathe, Salunke, & Deshande, 1982), and 6% for defatted sesame seeds (Inyang & Nwadimkpa, 1992). Gelation is an aggregation of denatured molecules. Fermentation may have denatured the sorghum proteins and, thus, caused more aggregation than in the unfermented sorghum flour. These results suggest that fermented sorghum flour would be a good gel-forming or firming agent, and would be useful in food systems such as pudding and snacks which require thickening and gelling.

3.3. Bulk density

Fermentation of sorghum flour for 24 h decreased the bulk density of the sorghum flour by about 10% (Table 2). The decrease in bulk density of fermented flour would be an advantage in the preparation of infant foods. Fermentation has been reported as a useful and traditional method for the preparation of low bulk weaning foods (Desikachar, 1980).

3.4. Water- and oil-binding capacity

Fermentation significantly decreased ($P \leqslant 0.05$) the water-binding capacity of sorghum flour by about

Table 1
Gelation properties of fermented sorghum flour

Flour concentration % (w/v)	Fermentation time (h)			
	0	8	16	24
2	–	–	–	–
4	–	–	±	±
6	–	±	+	+
8	±	+	+	+
10	±	+	+	+
12	±	+	+	+
14	±	+	+	+
16	±	+	+	+
18	+	+	+	+
30	+	+	+	+

–, Not gelled; ±, gelled slightly; +, gelled.

Table 2
Selected functional properties of fermented sorghum flour

Properties	Fermentation time (h)			
	0	8	16	24
Bulk density (g/ml)	0.73 ± 0.004^{a}	0.68 ± 0.001^{b}	0.67 ± 0.000^{b}	0.66 ± 0.001^{b}
Water-binding capacity (g/2g sample)	4.69 ± 0.064^{a}	4.41 ± 0.071^{b}	4.37 ± 0.049^{b}	4.40 ± 0.000^{b}
Oil-binding capacity (g/2g sample)	3.43 ± 0.042^{c}	3.70 ± 0.007^{a}	3.49 ± 0.007^{c}	3.59 ± 0.028^{b}
Emulsifying capacity (%)	49.39 ± 0.863^{b}	50.79 ± 1.117^{ab}	52.83 ± 0.467^{a}	51.62 ± 0.474^{a}
Emulsifying stability (%)	47.28 ± 0.403^{c}	50.00 ± 0.000^{b}	52.11 ± 0.735^{a}	50.33 ± 0.460^{b}
Foaming capacity (%)	0	0	0	0

Values are means ± SD.
Values with the same superscript letter in a row are not significantly different ($P \leqslant 0.05$).

7% after 16 h of fermentation (Table 2). In contrast it increased the oil-binding capacity of the flour by the same percentage after only 8 h of fermentation (Table 2). Water absorption capacity gives an indication of the amount of water available for gelatinization. Lower absorption capacity is desirable for making thinner gruels. Generally, sorghum flour, fermented and unfermented, has a higher water- and oil-binding capacity than flours such as raw fluted pumpkin with 0.37 g/g water-binding capacity (Giami & Bekebain, 1992) and *Deturium microcarpum* seed flour with 0.75 g/g oil-binding capacity (Akpata & Miachi, 2001). The higher oil-binding capacity of sorghum flour suggests that this flour would be useful in formulation of foods where an oil holding property is an important consideration.

3.5. Emulsifying capacity and stability

The efficiency of emulsification by flour varies with the type, concentration and solubility of the proteins (Achinewhu, 1983). Results showed that sorghum flour had high emulsion activity and stability; fermentation had significantly increased ($P \leqslant 0.05$) the emulsion activity and stability of the sorghum flour (Table 2). The increase of the emulsion activity was 3%, 7% and 4% for the three fermentation times, 8, 16 and 24 h, respectively, while the emulsion stability was increased due to fermentation by 5% ,9% and 6% for the three fermentation times, respectively (Table 2). Emulsion properties are useful in food systems such as mayonnaise, salad dressing and frozen desserts.

3.6. Foaming capacity

Sorghum flour, either fermented or unfermented, showed no foaming capacity at all. This was also reported for cowpea powder (Okaka & Potter, 1979). These results showed that sorghum flour proteins in solution increase the surface tension of the water and consequently reduce the formation of foam.

4. Conclusion

The traditional Sudanese method of fermentation of sorghum significantly improved the functional properties of sorghum flour. As previous studies have shown that fermentation improved the nutritive value of sorghum flour, therefore, it would be possible to design some new foods based on sorghum flour for people suffering from gluten-intolerance disease. Further studies are needed in this area.

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