EFFECT OF ADDING SORGHUM FLOUR ON THE PHYSICAL AND CHEMICAL PROPERTIES OF BREAD

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Introduction

Wheat is considered as the one of the most important cereal crop used in making bread. The gradual increase in the population of Egypt as well as the bread consumption, substantial in Egyptian diet imposed to import large amounts of wheat. In the last twenty years the national production of sorghum increased, while in the same period its consumption per head decreased [11].

Sorghum flour contains less protein and ash, but more oil and fiber than wheat flour. All indispensable amino acids are present in both flours, but in varying amounts. Leucine including isoleucine is found in the highest and tryptophan in the lowest concentration [18, 27].

Baking of Baladi bread did not appreciably alter gross chemical composition, but markedly reduced the amounts of starch and phytic acid (Mahmoud, R.). The nutritive value of bread protein was reduced during baking [5]. The concentrations of all indispensable amino acids were decreased, but to different rates (Mahmoud).

This study was carried out in order to find out the possibilities of substituting part of wheat flour with sorghum flour in making bread.

Materials and methods

Materials

Wheat "Triticum Vulgare" variety Giza 155 and sorghum "Sorghum Vulgare" variety Giza 114 were used in this study. Wheat grains were obtained from Assuit University farm, while sorghum grains were obtained from the Ministry of Agriculture, Cairo.

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Methods

Flour milling

Two hundreds kilograms of wheat grains and one hundred kilogramrs of sorghum grains were thoroughly cleaned, and both foreign seeds and othes materials were removed by hand picking followed by sieving. The grains were conditioned at 14 to 16% moisture content by wetting with tap water. The tempering process was completed by mixing and storing the moist grains for 14 hours. The grains were separately milled in a local stone mill. The flours were sieved to obtain 82% extraction. The flours were well mixed and stored in cloth bags for 15 days to homogenize moisture.

Flour mixing

The moisture content in flours was adjusted to 14% before mixing. The flour mixtures were prepared by mixing two, three, and four parts per weight of sorghum flour with eight, seven and six parts of wheat flour, respectively.

Bread making

The Baladi bread, which is the most commonly consumed Egyptian kind of bread, was made from either wheat flour or wheat—sorghum flour mixtures. The technique of bread making was similar to that ordinary in commercial production. The dough was fermented using the spontaneous method of fermentation. In this method, the starter was made by hand mixing 400 grams of sour dough, which was fermented dough of 24 hours with 2 kilograms of flour and about one liter of water; and placed in wooden box for six hours. The main dough was prepared by thoroughly hand mixing 1.5 kg of flour.

Starter was made with 10 kg flour, 100 g table salt and the needed amount of water kneaded for 25 minutes. The dough was left for 90 to 120 minutes followed by dividing it to pieces weighing about 185 grams each. The soft dough pieces were placed on wooden boards covered with wheat bran. The pieces were then kneaded, pressed, and flattened into discs of 20 cm diameter. The loaves were proofed for 60 minutes and baked at 320 to 350 °C for about 2 minutes in side flue oven. Two samples of bread were prepared.

Physical tests

Wet and dry gluten, sedimentation number, Brabender farinograph tests, and extensograph tests were carried out on wheat flour and wheat—sorghum flour mixtures according to A.O.A.C, 1966 [1].

Gross chemical analysis

The wheat flour, wheat—sorghum flour mixtures, sorghum flour, wheat bread, and wheat—sorghum breads were chemically analyzed for the distinctive chemical constituents. The bread loaf samples were prepared by cutting into small pieces, drying at room temperature for 72 hours, grinding to 20 mesh and storage at 18 °C (19). The following chemical components were determined in the flour and prepared bread samples.

Moisture was determined using a drying oven method as outlined in AOAC, 1966 (1).

Crude fat was extracted with petroleum ether as described in AOAC, 1966 (1).

Crude protein: The total nitrogen was measured by the micro-Kjeldahl method as explained by Pearson, 1962 [24]. The values were multiplied by a factor of 5.7 to calculate the wheat flour, flour mixtures, and bread crude protein contents, and by a factor of 6.25 to calculate the sorghum crude protein contents as recommended by AOAC, 1966 [1].

Starch was determined after acid hydrolysis of the samples to convert it to dextrose. The dextrose yield was measured according to the Lane and Eynon's method as painted out in AOAC, 1966 [1].

Reducing and nonreducing sugars were estimated using the alkaline ferricyanide method as outlined in AOAC, 1966 [1].

Crude fiber was estimated according to the method discussed in AOAC. 1966 [1].

Ash was determined by the method adopted in AOAC, 1966 [1].

Calcium was measured using the method described by Jackson, 1958. [15].

Phytic acid was estimated in terms of phosphorus content, using the method recommended in Modern Cereal Chemistry and modified by Rizk, 1958 [26].

Determination of essential amino acids

The essential amino acids were qualitatively and quantitatively determined in the flour and bread samples by paper chromatography technique as described by Block et. al., 1958 [3], and modified by Mahmoud, 1971. [18].

Examination of organoleptic qualities of bread

In order to evaluate the bread's organoleptic qualities, Fino bread was prepared using straight dough method. The dough was prepared by mixing 100 parts of flour and 1.5 parts of yeast with half of the required water according to the Farinograph test. Three parts of sugar and 1.5 parts of table salt were dissolved in the remaining amount of water and then added to the dough.

The final dough's temperature was adjusted to 26 °C, then placed into containers (tinplate cans 20×11×8 cm) smeared with fat. The containers were transferred to fermentation cabinet at 30 °C and 95% relative humidity. The dough was punched twice by hand every one hour in the cabinet. The dough was rolled and placed away from air for 20 minutes and cut, then scaled off in 450 grams. Then the dough was fermented for 6 minutes at 35 °C at 98% relative humidity. The breads were baked at 240 °C for 30 minutes.

The loaf volumes were measured by displacement of small seeds after cooling for one hour at room temperature. Loaf weighing was also carried out after cooling. Specific volume, i.e. volume of one gram bread in cubic centimeter was calculated.

The colour of crust and crumb, texture, flavor, and odour of all kinds of bread were valuated subjectively by a panel at the same time. Scoring for these properties was carried out according to assigned scores ranging from zero to 10, where zero was given to repulsive samples, while 10 was given to ideal samples.

Results and discussion

1. *Physical properties of wheat–sorghum doughs*

Table 1 represents the results of wet and dry gluten, sedimentation value and farinograph and extensograph data of wheat flour and wheat—sorghum flour mixtures.

The wet and dry gluten contents as well as the sedimentation values of the flour mixtures were markedly lower than those of wheat flour, and the sedimentation value of the flour mixtures gradually decreased as the added amount of sorghum flour increased. Generally, the influence of sorghum flour on the physical properties of wheat flour might be due to the dilution of wheat flour gluten as well as to changes in gluten and protein properties. Pinckiney et. al., 1957 [25] found a high by significant positive correlation between sedimentation value and both protein constant and gluten quality of wheat flour.

The farinograph results indicated that the water absorption of flour mixtures was slightly lower than that of wheat flour. This value gradually decreased as the percentage of sorghum flour increased. The addition of sorghum flour to wheat flour did not change its mixing time in minutes, required to form stable dough. The results revealed that mixing 2 parts of sorghum flour to 8 parts of wheat flour decreased its stability while mixing 3 or 4 parts of sorghum flour with 7 or 6 part of wheat flour, respectively, increased this period.

The stability is an important index for the strength of the flour. The weakening value of the wheat dough almost doubled upon addition of any

Table 1

The physical properties of wheat flour and wheat—sorghum flour mixtures
(Flour extraction = 82%)
(Calculated for 14% moisture)

Physical tests* \ Sorghum flour % (w/w)	00	20	30	40
GLUTEN %				
a) Wet	30.86	25.16	21.59	14.13
b) Dry	12.18	10.59	9.35	6.09
Sedimentation volume	18.9	7.6	6.6	5.7
a) Water absorption %	63.7	63.0	62.4	60.9
b) Mixing time (min)	2.50	2.50	2.50	2.50
c) Stability (min)	1.50	1.25	1.75	1.75
d) Weakening (B. U.)	100	190	190	190
e) Valorimeter number	51	38	40	40
Extensograph results				
a) Energy (cm^2)	61.30	43.70	33.20	25.70
b) Resistance to extention (BU)	240	240	220	240
c) Extensibility (mm)	156	120	100	77
d) Proportionality number	1.54	2.00	2.20	3.12

* The results are averages of two samples and the tests were done in duplicates

test percentage of sorghum flour. This value indicates the loss of dough structure. The valorimeter number which summarizes the farinograph data indicated that the strength of wheat dough decreased when sorghum flour was added to the wheat flour. Such observations could be attributed to the increases in the for the dough to be stable as well as to the dryness and tonghness of the dough obtained from the flour mixtures [17].

The extensograph results revealed that the dough energy was pronouncedly reduced upon partial replacement of wheat flour with sorghum flour. Such energy gradually and markedly decreased as the amount of wheat flour in the mixtures decreased. Addition of sorghum flour to wheat flour did not cause noticeable changes in its resistance to extension. The extensibility of wheat dough gradually and noticeably decreased by increasing the added quantity of sorghum flour in contrast to proportionality number which gradually and pronouncedly increased. These changes probably resulted from sorghum flour increasing the distances between gluten particles preventing the production of the regular gluten network, in addition to the competition between sorghum flour and gluten for an absorbing water.

2. *Gross chemical composition of wheat–sorghum mixtures*

Table 2 show the moisture, fat (ether extracts), crude protein, starch, reducing and nonreducing sugars, crude fiber, ash, calcium, and phytic acid phosphorus present in wheat and sorghum flours as well as their mixtures. These chemical constituents were calculated on solids weight basis.

Table 2

Gross chemical composition of wheat, sorghum flours and wheat—sorghum flour mixtures
(Flour extraction = 82%)
(Calculated on dry weight basis)

Constituents* \ Sorghum flour % (w/w)	00	20	30	40	100
Moisture (%)	10.43	10.44	10.45	10.51	10.90
Crude fat (%)	1.25	1.70	2.09	2.17	3.87
Crude protein (%)	12.35	11.62	11.28	10.96	9.19
Starch (%)	7.758	78.02	78.86	79.53	81.07
Reducing sugars (%)	0.49	0.43	0.40	0.38	0.31
Non-reducing sugars (%)	2.68	2.50	2.36	2.22	1.48
Crude fiber (%)	0.42	0.43	0.46	0.46	0.50
Ash (%)	1.34	1.38	1.45	1.52	1.84
Calcium (mg/100 g)	26.45	26.83	25.07	24.68	23.84
Phytic acid phosphorus (mg/100 g)	128.12	127.40	127.26	126.87	125.40

* The results are averages of two samples and the tests were done in duplicates

All examined flour samples contained about ten per cent moisture.

Sorghum flour had about 30 times as much crude fat as had wheat flour. As the amount of sorghum flour in the flour mixtures increased the crude fat gradually and markedly increased. These results are in general agreement with those reported by several investigators [23, 27].

Wheat flour had more of crude protein than had sorghum flour and their mixtures. The protein contents of flour mixtures gradually decreased as the amount of wheat flour present in the mixtures decreased. These data are in general agreement with those presented earlier [13, 18].

Sorghum flour contained slightly more starch but markedly less reducing and nonreducing sugars than did wheat flour.

Addition of increasing amounts of sorghum flour to wheat flour gradually increased their starch but decreased their sugars.

The crude fiber and ash present in sorghum flour were slightly more than in wheat flour and their mixtures. Gradual dilution of wheat flour with sorghum flour slightly and gradually increased their crude fiber and ash. These results are in general agreement with those reported earlier [13, 18, 27].

Wheat flour had slightly more calcium and phytic acid than had sorghum flour. The addition of increasing amounts of sorghum flour to wheat flour gradually and slightly decreased their calcium and phytic acid contents. These results may be due to the correlation of calcium and phytic acid to ash and crude fiber [10].

Generally, these changes in the chemical composition of wheat flour after mixing with sorghum flour could be attributed to the variations in the chemical composition of wheat and sorghum flours.

3. *The essential amino acids of wheat and sorghum flour*

The concentration of essential amino acids in the protein hydrolyzates of wheat and sorghum flours as well as their mixtures are seen in Table 3. Their concentrations were calculated as percentage of protein.

Table 3

The essential amino acids of wheat and sorghum flours, and wheat—sorghum flour mixtures
(Flour extraction = 82%)
(Percentage of protein)

Amino acids* \ Sorghum flour % (w/w)	00	20	30	40	100
Arginine	3.95	3.85	3.54	3.02	2.04
Histidine	2.21	2.24	2.27	2.29	2.35
Leucine + isoleucine	14.07	13.45	12.74	11.86	10.37
Lysine	2.49	2.41	2.35	2.19	1.56
Methionine	1.13	1.12	1.11	1.00	0.91
Phenylalanine	4.50	3.58	3.20	2.79	2.26
Threonine	2.91	2.81	2.74	2.62	2.00
Tryptophan	1.03	0.81	0.72	0.62	0.05
Valine	4.67	4.35	4.21	4.09	3.73

* The results are averages of two samples and the tests were done in duplicates

The data indicated that the ten assayed essential amino acids were present in the protein of these flours, but in various concentrations. These variations may be due to the kind of cereal grains flour as well as to the concentration and the kinds of protein in these flours. These findings were reported earlier [20, 22, 28]. The biological value of the flour protein depends upon the number and quantity of the essential amino acid present. The protein of wheat flour was found to contain the following amino acids in decreasing order: leucine–isoleucine mixture, valine, phenylalanine, arginine, threonine, lysine, histidine, methionine, and tryptophan. In the sorghum flour protein this order changed to leucine–isoleucine mixture, valine, histidine, phenylalanine, arginine, threonine, lysine, methionine and tryptophan.

The concentrations of all tested amino acids were higher in wheat flour protein than in sorghum flour protein except that of histidine which was lower.

Addition of increasing amounts of sorghum flour to wheat flour slightly and gradually decreased lysine, methionine, and threonine, but did no noticeably change to its histidine content. Partial replacement of wheat flour with increasing quantities of sorghum flour moderately decreased arginine, leucine–isoleucine mixtures and valine while their phenylalanine and tryptophan were markedly reduced. This may be due to the lower concentration of these flour amino acids in the sorghum flour protein than in the protein of wheat flour.

4. *Gross chemical composition of breads*

The moisture, crude fat, crude protein, starch, reducing and nonreducing sugars, crude fiber, ash, calcium, and phytic acid phosphorus present in the Baladi bread made from wheat flour and wheat sorhgum flour mixtures are seen in Table 4.

Table 4

Gross chemical composition of Baladi bread from wheat flour and wheat—sorghum flour mixtures
(Flour extraction = 82%)
(Calculated on dry weight basis)

Constituents* \ Sorghum flour % (w/w)	00	20	30	40
Moisture (%)	33.50	35.88	38.32	37.04
Crude fat (%)	0.62	0.67	0.68	0.71
Crude protein (%)	12.96	12.21	11.91	11.38
Starch (%)	73.57	72.63	74.10	74.28
Reducing sugars (%)	1.66	2.25	3.02	3.38
Nonreducing sugars (%)	1.19	1.04	1.02	0.52
Crude fiber (%)	0.79	0.96	1.05	1.12
Ash (%)	1.71	2.41	2.43	2.50
Calcium (mg/100 g)	30.35	30.50	30.90	32.77
Phytic acid phosphorus (mg/100 g)	77.50	76.50	73.43	71.25

* The results are averages of two samples and the tests were done in duplicates

The chemical composition of the bread reflected that of the flour from which it was made, in addition to changes that might occur during the baking process.

Generally, bread was found to contain less crude fat than the flour. This might be due to extraction of most flour lipids by the fat solvent and

difficulties of extraction of bread lipids because they became tightly bound with bread protein [21]. Gradual substitution of wheat flour with sorghum flour gradually and slightly increased the crude fat detected in the breads.

The protein content of bread was higher than that of the flour from which it was made. This could be attributed to the presence of bran which coated the loaves, bottom [18, 26]. Additions of increasing amounts of sorghum flour to wheat flour caused gradual reductions in the bread protein.

The starch and nonreducing sugars of the bread were markedly lower, while the reducing sugars were pronouncedly higher than those of the flour from which the bread was made. The decreases in the bread starch might be due to the degradation in flour starch resulting from the diastatic action during fermentation [7, 26]. The decreases in the nonreducing sugars of bread might be caused by yeast fermentation before enzymatic formation of maltose

The increases in the reducing sugars of bread might have resulted from conversion of starch to glucose [7]. Mixing of wheat flour with sorghum flour caused no marked changes in the bread starch. This treatment caused gradual increases in the reducing sugars and gradual decreases in nonreducing sugars of bread.

The crude fiber and ash present in the bread were noticeably higher than those in the flour, due to addition of sodium chloride to the flour during dough preparation as well as covering the loaves bottom with wheat bran [18]. Increasing the added amount of sorghum flour to wheat flour caused gradual increases in the bread crude fiber and ash contents.

The bread had more calcium than flour owing to the presence of bran. Addition of sorghum flour to wheat flour slightly and gradually increased the bread calcium content.

Phytic acid decreased in the bread due to its destruction by phytase during fermentation and baking process [16, 18, 26]. Wheat — sorghum bread had less phytic acid than had wheat bread. As the sorghum flour increased the bread phytic acid contents gradually decreased.

5. *The essential amino acids of breads*

The concentrations of essential amino acids in the proteins of Baladi bread made from wheat flour and wheat–sorghum flour mixtures are illustrated in Table 5.

The indispensable amino acids present in the flours were qualitatively and quantitatively determined in the breads in order to follow changes that might occur during the baking process. Generally, the amino acid composition of bread reflected that of the flour from which it was made, aside from the losses during baking processes.

The concentrations of these amino acids in the bread protein were, in

Table 5

The essential amino acids of Baladi bread made from wheat flour and wheat—sorghum flour mixture
(Flour extraction = 82%)
(Percentage of protein)

Amino acids* \ Sorghum flour % (w/w)	00	20	30	40
Arginine	2.87	2.57	2.26	2.00
Histidine	1.72	1.67	1.60	1.58
Leucine + isoleucine	12.89	12.10	11.55	10.76
Lysine	1.69	1.65	1.54	1.20
Methionine	0.83	0.84	0.82	0.74
Phenylalanine	3.72	2.65	2.51	1.98
Threonine	2.45	2.38	2.30	2.21
Tryptophan	0.74	0.54	0.45	0.30
Valine	4.06	3.65	3.48	3.27

* The results are averages of two samples and the tests were done in duplicates

decreasing order: leucine–isoleucine mixture, valine, phenylalanine, arginine, threonine, histidine, lysine, methionine and tryptophan.

The data revealed that all the essential amino acids decreased during baking, but to different degrees. The losses in lysine, tryptophan, methionine, arginine, histidine, threonine and phenylalanine were higher than in other amino acids. Lysine, tryptophan, methionine, histidine, threonine and phenylalanine were involved in the browning reaction, while leucine, isoleucine, and valine were not [8]. The losses of amino acids during baking affected mainly the crust proteins, due to the millard-type reaction, i.e. the reaction of sugars with amino acids [2, 14].

Arginine, leucine–isoleucine mixture, lysine, phenylalanine, tryptophan, and valine were essential amino acids in the bread the most affected by the addition of sorghum flour to wheat flour. Their concentrations decreased as the amount of sorghum flour added to wheat flour increased. The other amino acids did not noticeably change. The variations of essential amino acids content in the breads were due to the variations of these amino acids in flours as well as to the quality and quantity of their proteins.

6. *The organoleptic qualities*

The organoleptic qualities of wheat bread and wheat—sorghum breads are shown in Table 6.

The bread loaves prepared from mixtures of wheat and sorghum flour had less weights and smaller volumes than those made from wheat flour.

Table 6

The organoleptic qualities of fine bread made from wheat flour and wheat—sorghum flour mixtures
(Flour extraction = 82%)

Qualities \ Sorghum flour % (w/w)	00	20	30	40
Baking results*				
a) Weight g	415	410	405	389
b) Volume cm^3	1120	950	910	820
c) Specific volume (cm^3/g)	2.70	2.32	2.27	2.12
Panel results (scores**)				
a) Crust colour (10)	10	8	7	5
b) Crumb colour (10)	10	9	8	7
c) Grain cell structure (10)	10	5	4	4
d) Texture (10)	10	4	4	3
e) Flavour (10)	10	6	4	2
f) Odour (10)	10	6	4	2
TOTAL (60)	60	38	31	23

* The results are averages of two samples composed of fine loaves each
** The results are averages of two samples judged by ten testers each

These changes became more noticeable as the amounts of sorghum flour mixed to wheat flour increased. The changes in the loaves volume are due to the changes in the quality and quantity of protein [5, 6, 9].

The colour of crust and crumb of wheat bread was whiter and brighter than for wheat-sorghum breads. These differences might result from the variations in the maltose present in flours [12].

The bread made from wheat flour had good normal grain, excellent, uniform cell structure and fine texture. The grains of wheat—sorghum bread crumb were compact and the texture was slumby and coarse. These changes were due to the low qualities and quantities of sorghum flour protein.

Both flavour and odour of wheat bread were ideal. Addition of sorghum flour to wheat flour gradually deteriorated the flavour and odour of the breads. This might be due to the inherent flavour and odour of the sorghum flour.

Generally, the organoleptic qualities of wheat sorghum breads gradually worsened as the sorghum flour content increased.

Summary

The effect of addition of sorghum flour on the physical and chemical properties of wheat flour and bread baked therefrom was studied, and so was the quantity of essential amino acids.

Addition of sorghum flour decreased the gluten, protein, sugar and phytic acid contents in flour and bread, while increased crude fat and ash.

Water absorption and extensibility of the doughs as well as loaf volume and weight were decreased. Most essential amino acids decreased due to sorghum addition.

Results recommend to mix wheat flour with up to 20% by weight with sorghum flour in bread making. This flour mixture will not noticeably affect the nutritive value and organoleptic qualities of bread.

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