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Effect on Protein Quality of Supplementing Wheat Flour with Chickpea Flour[1]

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ABSTRACT

Physical properties of dough made from combinations of 80%-extraction HRW wheat flour and 0, 5, 10, 15, and 20% chickpea flour were studied in the farinograph and extensigraph. Egyptian bread made with the flour combinations was scored for aroma, crust and crumb color, texture, flavor, and over-all acceptability by five Egyptian judges. Objective tests included weight, volume, and crust and crumb color (percent reflectance). Protein quality of the bread was measured by a rat-growth study. Physical properties of the dough were not affected to any extent by levels of chickpea flour. The only significant difference in organoleptical scores was for crumb color ($\alpha = 0.05$), and the only significant difference in objective measurements was for crust color ($\alpha = 0.05$). Percent weight gain of rats fed 20% chickpea flour diets was significantly higher than that of rats fed diets with 0, 10, and 15% chickpea flour. There were significant increases in feed consumption at the 15 and 20% levels of chickpea flour. Rats fed diets with 10 and 20% chickpea flour had measured PER's of 1.46 and 1.56, significantly better than that of rats fed diets with 0% chickpea flour.

In many diets, cereals make a greater contribution than any other food group to both energy and protein content. The Middle Eastern countries depend mainly on wheat and to a lesser extent on millets, maize, and barley for protein. About two-thirds of the available protein comes from wheat in the form of bread. The bread consumed in Egypt is called Eish-Ballady and is made with 80- to 85%-extraction wheat flour, starter (yeast), salt, and water, without addition of milk or fat.

In Egypt cost plays a large part in the kind of food consumed, and animal protein is beyond the economic means of many people. Hence, it is important to develop protein mixtures that use local inexpensive foods, such as cereals and legumes, acceptable to the population and with high nutritional value. We investigated (a) acceptability of Egyptian bread and physical properties of dough

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made from wheat flour supplemented with chickpea flour and (b) quality of the bread protein.

MATERIALS AND METHODS

Hard red winter wheat was milled to obtain flour of 80% extraction. Chickpeas obtained from the N. K. Hurst Co., Indianapolis, Indiana, were milled into flour with an average particle size of 431 μ. Wheat and chickpea flours were analyzed for moisture and protein (N X 5.70 for wheat flour and N X 6.25 for chickpeas) by AACC Methods (1) and for 17 amino acids with a Beckman 120B amino acid analyzer. Tryptophan was not determined because the acid hydrolysis used destroys tryptophan, and no separate analysis was made.

Egyptian bread (Fig. 1) was prepared from the following combinations: wheat flour (WF), 100, 95, 90, 85, and 80%; chickpea flour (CF), 0, 5, 10, 15, and 20%.

Ingredients were 200 g. flour, 8 g. starter, 3 g. salt, and 180 ml. water at 90°F. The starter was made by dissolving 25 g. dry yeast in 100 ml. water at 90°F. and adding 100 g. wheat flour. It was covered and left at room temperature for 3 days before use.

The bread procedure follows:

1. Place flour in McDuffee bowl of Hobart mixer, Model A-200.
2. Mix starter, salt, and water in a beaker, add to flour.
3. Mix for 1 min. at first speed and for 7 min. at second speed.

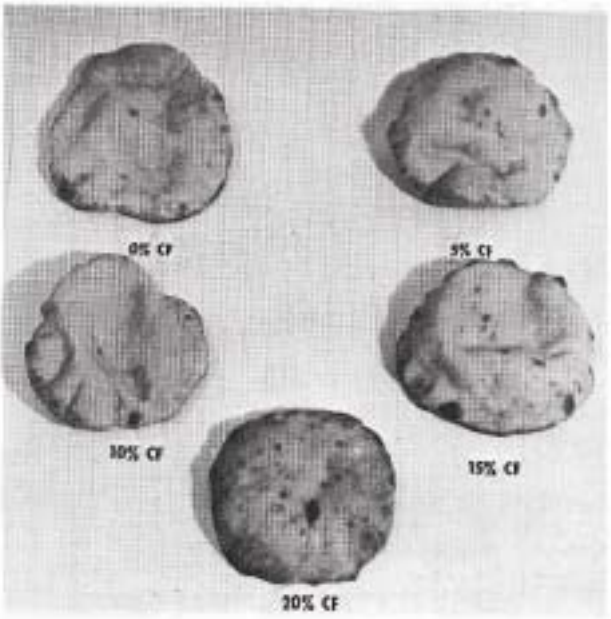

Fig. 1. Egyptian bread made with combinations of wheat flour (WF) and chickpea flour (CF).

4. Transfer dough from mixer bowl to shallow pan.
5. Ferment dough for 4 hr. at 90°F. in fermentation cabinet.
6. Cut dough into two loaves weighing 150 g. each and place each on 15 g. of shorts on a cookie sheet.
7. Dust dough with flour and flatten it by patting with fingers; place in a drawer to rest for 10 min. at room temperature.
8. Ferment for 30 min. at 100°F. in proofing cabinet.
9. Bake at 500°F. for 10 min. in reel oven in which four pans of water were placed to develop steam.

The baking was done as a balanced incomplete block design, designated as type V by Cochran and Cox (2), with k = 3, t = 5, and b = 20. Thus two loaves of bread made from three different wheat-chickpea flour combinations were baked on each of 20 days.

The bread was cooled to room temperature and objective measurements were made on duplicate loaves as follows: (a) volume of loaf by rapeseed displacement, (b) weight of loaf, and (c) crust and crumb color (Photoelectric reflection meter).

The bread was scored for aroma, crust color, crumb color, texture, flavor, and over-all acceptability by a panel of five male Egyptian students. The score card was based on a scale of 1 (very poor) to 7 (excellent).

Physical properties of dough made from the various flour combinations were measured by Brabender Farinograph and Brabender Extensograph.

Additional loaves of bread from the five flour combinations were baked for use in a rat-growth study. The loaves were sliced with an electric knife and dried in a single layer on trays at room temperature (75° to 76°F.) for 72 hr. The dry bread was ground in a Kenmore meat grinder and analyzed for moisture, protein, ash, fat, and fiber according to AACC Approved Methods (1). Diets made with the bread were adjusted to contain: 9.0% protein, 8.0% fat, 5.0% ash, 1.0% vitamin mix, 6.1% water, and 1.2% fiber according to AOAC procedures (3). A reference standard protein (ANRC reference casein) diet was included as diet VI.

Thirty-six male, weanling rats of the Sprague-Dawley strain were divided into six groups with similar total weights. Food and water were provided *ad libitum* for a 2-day adjustment period and a 28-day experimental period. Weekly weight gain and food intake were recorded. Protein efficiency ratios as measured and as corrected to a casein PER of 2.50 were calculated.

Organoleptic and objective evaluations of the bread were subjected to analysis of variance, followed by use of Fisher's LSD with $\alpha = 0.05$ when the F-test rejected the hypothesis of equal treatment means. Rat weight gains and protein efficiency ratios also were subjected to analysis of variance.

RESULTS AND DISCUSSION

Physical Properties of Dough

Increasing the percentage of chickpea flour in the dough had little effect on any of the farinograph characteristics, including arrival time, peak time, stability, tolerance index, and departure time. However, stability and departure time of the dough showed a slight decrease as the percentage of chickpea flour increased. As with the farinograph, the characteristics of the extensigraph, including extensibility

and resistance to extension, were not affected to any extent by increasing the percentage of chickpea flour.

Objective Evaluation

The adjusted means for the crust and crumb color (percent reflectance), weight, and volume of the bread are shown in Table I. In contrast to the organoleptic data there was a significant difference in crust color, but not in crumb color. Increasing the percentage of chickpea flour produced an essentially linear decline in crust color. Although changes in percentage of chickpea flour did not significantly affect the weight, when all five percentages were considered together, the mean weight with 0% chickpea flour was significantly ($\alpha = 0.05$) higher than for any of the other four percentages of chickpea flour. Increasing the percentage of chickpea flour produced an essentially linear decline in volume, but the differences were not significant.

Organoleptic Evaluation

The adjusted mean scores for aroma, crust and crumb color, texture, flavor, and over-all acceptability of the bread are presented in Table II. There was a significant difference in scores for crumb color ($\alpha = 0.05$). Crumb color became darker with

TABLE I. ADJUSTED MEANS FOR CRUST AND CRUMB COLOR (PHOTOELECTRIC REFLECTION METER), WEIGHT, AND VOLUME OF EGYPTIAN BREAD MADE WITH WHEAT FLOUR (WF) AND CHICKPEA FLOUR (CF)

Bread	Crust Color %	Crumb Color %	Weight g.	Volume ml.
100% WF, 0% CF	66.1	53.2	129.2	705.5
95% WF, 5% CF	64.2	55.6	122.1	697.4
90% WF, 10% CF	58.5	56.2	121.7	708.9
85% WF, 15% CF	59.3	54.0	120.4	679.3
80% WF, 20% CF	57.2	55.3	121.4	656.5
$LSD_{0.05}$	3.6	...	...	...

TABLE II. ADJUSTED MEAN SCORES[a] FOR AROMA, CRUST AND CRUMB COLOR, TEXTURE, FLAVOR, AND OVER-ALL ACCEPTABILITY OF EGYPTIAN BREAD MADE WITH WHEAT FLOUR (WF) AND CHICKPEA FLOUR (CF)

Bread	Aroma	Crust Color	Crumb Color	Texture	Flavor	Over-All Acceptability
100% WF, 0% CF	4.8	4.3	5.0	4.6	4.7	4.5
95% WF, 5% CF	4.6	4.7	4.8	4.5	4.7	4.6
90% WF, 10% CF	4.6	4.7	4.7	4.7	4.9	4.7
85% WF, 15% CF	4.7	4.6	4.6	4.7	4.6	4.6
80% WF, 20% CF	4.5	4.9	4.3	4.7	4.6	4.6
$LSD_{0.05}$	...	...	0.3	...	...	...

[a]Range 1 (very poor) to 7 (excellent).

each increase in percentage of chickpea flour. There were no significant differences in scores for aroma, crust color, texture, flavor, and over-all acceptability. However, flavor and over-all acceptability scores reached their maximum with bread made with 10% chickpea flour, then decreased as more chickpea flour was added.

Protein and Amino Acid Content

Protein and amino acid composition, as analyzed for the wheat flour and chickpea flour and as calculated for the wheat-chickpea flour combinations, is given in Table III.

The protein content of the wheat flour was 12.2%, which is in the upper portion of the range of 9.9 to 14.0% protein content of hard wheat flour given by Griswold (4). The protein content of the chickpea flour was 15.9%, which is less than the 17.8% found by Adolph et al. (5) or the 20.5% given in Agriculture Handbook No. 8 (6).

Comparison of the analyzed amino acid composition of the wheat flour and of the chickpea flour with that of the FAO pattern (7), casein (8), and NRC minimal requirements for the growing rat (9) indicated that lysine was the most limiting essential amino acid in wheat protein and methionine the most limiting in chickpea flour. In all the wheat-chickpea flour combinations, lysine was found the most limiting amino acid and methionine was second. However, no combination was limiting in total S-containing amino acids. King (10) and Bressani et al. (11) mentioned that lysine was the most limiting amino acid in wheat, followed by tryptophan, methionine, isoleucine, valine, and threonine.

TABLE III. PROTEIN AND AMINO ACID COMPOSITION OF WHEAT FLOUR (WF), CHICKPEA FLOUR (CF), AND WHEAT-CHICKPEA FLOUR COMBINATIONS

Protein and Amino Acids	100% WF	100% CF	95% WF, 5% CF	90% WF, 10% CF	85% WF, 15% CF	80% WF, 20% CF
	%	%	%	%	%	%
Moisture	15.3	9.1	14.5	13.8	13.0	12.2
Protein[a]	12.2	15.9	12.4	12.6	12.8	12.9
Amino acids[b]						
Alanine	0.415	0.715	0.429	0.445	0.460	0.475
Arginine	0.543	1.269	0.579	0.616	0.652	0.688
Aspartic acid	0.612	1.847	0.674	0.736	0.797	0.859
Cystine	0.423	0.354	0.420	0.416	0.413	0.409
Glutamic acid	5.154	2.631	5.028	4.902	4.776	4.649
Glycine	0.483	0.663	0.492	0.501	0.510	0.519
Histidine	0.300	0.410	0.306	0.311	0.316	0.322
Isoleucine	0.550	0.721	0.558	0.567	0.576	0.584
Leucine	0.936	1.226	0.950	0.965	0.980	0.994
Lysine	0.325	1.228	0.370	0.415	0.460	0.506
Methionine	0.249	0.185	0.246	0.243	0.303	0.236
Phenylalanine	0.567	1.028	0.590	0.613	0.636	0.659
Proline	1.543	0.624	1.497	1.451	1.405	1.359
Serine	0.658	0.811	0.666	0.673	0.681	0.689
Threonine	0.374	0.615	0.386	0.398	0.410	0.422
Tyrosine	0.357	0.504	0.339	0.364	0.379	0.386
Valine	0.572	0.737	0.580	0.588	0.597	0.605

[a]N X 5.70 for wheat flour and N X 6.25 for chickpeas.

[b]Tryptophan was not determined.

TABLE IV. AVERAGE WEEKLY FEED CONSUMPTION, WEEKLY PERCENT WEIGHT GAIN, AND PROTEIN EFFICIENCY RATIO DURING 28 DAYS

Diet	Feed Consumed g.	Weight Gain %	PER as Measured	PER as Corrected to Casein: 2.50
Diet I: 100% WF, 0% CF	67.9	11.9	1.18	0.96
Diet II: 95% WF, 5% CF	68.7	14.9	1.39	1.13
Diet III: 90% WF, 10% CF	69.2	14.5	1.46	1.18
Diet IV: 85% WF, 15% CF	73.3	14.3	1.40	1.14
Diet V: 80% WF, 20% CF	81.7	17.6	1.56	1.27
Diet VI: Casein	107.4	33.8	3.08	...
$LSD_{0.05}$	3.2	3.0	0.24	...

Biological Evaluation of the Bread Protein

The average weekly percent gain in body weight of rats on diet VI (casein) was significantly higher than that of any other diet (Table IV). The percent weight gain for diet V (20% CF) was significantly higher than those for diets I (0% CF), III (10% CF), or IV (15% CF). Also, the percent weight gain for diet II (5% CF) was significantly higher than that for diet I (0% CF). The percent weight gains among diets II (5% CF), III (10% CF), and IV (15% CF) were not significantly different. The percent weight gain the second week was significantly higher than that of the first week. There was no significant difference in percent weight gains between the third and the fourth week, but they were below that of the first week.

The amount of feed consumed by rats fed diet VI (casein) was significantly higher than that of any of the other diet groups (Table IV). The rats on diet I (0% CF) consumed the least amount of feed. With increasing amounts of chickpea flour, the amount of feed consumed also increased, but was significant only for diets IV (15% CF) and V (20% CF). The amount of feed consumed increased significantly each week as the animals became older.

Protein efficiency ratios (PER's) as measured and PER's as corrected to casein are given in Table IV. The casein diet (VI) had a measured PER of 3.08. That compares favorably with the average PER of 2.85 ± 0.44 reported by Derse (12) for 10 collaborators who tested ANRC reference casein and the PER of 2.4 for casein reported by Maleki and Djazvyeri (13).

The measured PER for diet I (0% CF) was 1.18. Various workers (14,15,16) reported PER's of wheat flour ranging from 1.1 to 1.69. In contrast, Derse (12) reported a much lower average PER of 0.56 ± 0.15. Variations may be due to different levels of flour extraction. Diet VI (casein) had the highest measured PER (3.08), significantly higher than that of any of the other diets. The measured PER's (1.56 and 1.46) for diets V (20% CF) and III (10% CF) were significantly better than that (1.18) of diet I (0% CF), but there were no significant differences among measured PER's of diets I (0% CF), II (5% CF), and IV (15% CF). Although the PER for diet IV appears to be out of line, linear regression analysis indicated that, on the average, PER increased approximately 0.10 with each additional 5% of chickpea flour in the diet.

The corrected PER for diet I (0% CF) was 0.96, which was somewhat higher than

the average corrected PER of 0.49 ± 0.13 for flour reported by Derse (12) for 10 collaborators or the corrected PER of 0.57 ± 0.05 for 65% extraction flour given by Maleki and Djazvyeri (13).

The addition of 5, 10, 15, and 20% chickpea flour to the wheat flour corresponds to the addition of 0.05, 0.09, 0.14, and 0.18% of lysine as percent of sample. These additions were accompanied by 18, 27, 28, and 61% increases in growth and increases in PER of 18, 24, 19, and 32%, respectively. Sure (16) mentioned that the addition of 0.4% L-lysine to whole-wheat flour was accompanied by a 140% increase in growth and an increase of 20% in PER. Addition of 20% CF (0.18% lysine) to the wheat flour raised its PER from 1.18 to 1.56. Senti et al. (17) stated that the addition of 0.1% lysine to whole-wheat flour raises its PER from around 1.1 to 1.3 up to 1.8 to 1.9.

The maximum weight gain of rats fed the bread diets was observed with diet V which was supplemented with 20% chickpea flour (0.18% lysine). Yang et al. (18) mentioned that maximum weight gain was noted in rats receiving a wheat-flour diet supplemented with 0.20% lysine as compared to those receiving wheat-flour diet supplemented with 0.25, 0.50, and 1.0% lysine.

In conclusion, supplementing the wheat flour with 10 or 20% chickpea flour produced a significantly higher PER. These levels of supplementation had little effect on either the physical properties of the dough and bread or the palatability of the bread. In spite of the significant decrease in score for crumb color with increasing percentages of chickpea flour, there was no significant difference in over-all acceptability scores.

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