Utilization of Aqueous By-Products from Starch for Improving Bread Quality

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ABSTRACT

Aqueous by-products of corn gluten water (CGW), rice gluten water (RGW), and rice steep water (RSW), which resulted during the manufacture of starch by the wet milling of corn and rice, were added in amounts corresponding to 17–50 mg of N/100 g of flour. Addition of these by-products improved the physical properties of the unyeasted dough, such as resistance to extension, extensibility, water absorption, and mixing requirement, and improved the pasting of a 10% suspension of flour. Moreover, added CGW, RGW, and RSW improved the quality of Balady and European breads and increased their protein content. The amino acid content of Balady bread, after addition of CGW, RGW, and RSW, was analyzed quantitatively. The nutritional value of Balady bread proteins was almost the same, the only deficiencies being in the amino acids threonine, methionine, isoleucine, and lysine.

The well-known Maillard reaction between sugars and amino acids is important for the production of carbonyl compounds responsible for aroma in bread (Rooney et al 1967). That fact leads to the possibility that the addition of amino acids into the bread formula substantially increases the carbonyl compounds responsible for this purpose. This hypothesis was confirmed by Salem et al (1967), who demonstrated that the addition of various amino acids produced different carbonyl compounds and that the aroma of the bread changed accordingly. They found that the intensity of bread crust color was influenced by the type of amino acids used. Aqueous by-products resulting during the manufacture of starch by wet milling of rice and corn contained considerable free amino acids and were recommended to be added to the flour (bread formula) for improving bread quality (El-Saied 1981). Moreover, the effect of these added by-products on the quality of Balady and European breads, and chemical analyses of the two types of breads and their nutritive values were performed based on the amino acid composition.

MATERIALS AND METHODS

Samples of corn gluten water (CGW) of protein content 0.44 g/100 ml, and total solids 3.5 g/100 ml were supplied by the Egyptian Company of Starch and Glucose Manufacture, Torah, Cairo, and kept in plastic containers at 10°C. Samples of rice steep water (RSW) of protein content 0.41 g/100 ml and total solids 4.4 g/100 ml as well as rice gluten water (RGW) of protein content 0.58 g/100 ml and total solids 3.2 g/100 ml were supplied by the Egyptian Company for Starch, Yeast, and Detergents Manufacture, Alexandria, Egypt, and were kept in plastic containers at 10°C.

Physical Tests on Dough and Slurries

Extensibility, dough resistance to extension, and dough strength were measured by the Brabender Extensigraph (AACC 1962). Water absorption and mixing requirement of unyeasted dough were measured by the Brabender Farinograph (AACC 1962). In these two tests, either water was added as control, or the tested by-products were added to the flour to produce a dough of suitable consistency (at 500 BU). Pasting of a 10% suspension of flour in water as control (Aurman 1972) or in water including the amount of by-product with the desirable nitrogen content was measured in a Brabender Amylograph while the temperature of the suspension was raised at a constant rate of 1.5° C/min from room temperature (20–95°C and then maintained at 95°C).

Breadbaking

Two types of breads were baked: Balady and Egyptian. For Balady bread, which is the type preferred in Egypt, the following formula was used: 100 g of wheat flour (72% extraction, 10.5% protein), 1 g of sodium chloride, 0.5 g of compressed bakers' yeast (*Saccharomyces cerevisiae*), and either 72 ml of water for the control or 72 ml of water at 30°C, including the volume of the aqueous by-products with the desirable nitrogen content (17–50 mg of N). The ingredients of every treatment were mixed with a mechanical dough mixer for 25 min and left to ferment at 30°C for 30 min. Pieces (180 g) were then cut off, rolled into balls, and flattened by hand to a diameter of 18 cm and left at 30°C for 15 hr before being baked at 450–500°C for 2 min.

The formula for European bread was 100 g of wheat flour (72% extraction, 10.5% protein), 1.0 g of sodium chloride, 2.5 g of compressed bakers' yeast (*Saccharomyces cerevisiae*), and either 58 ml of water at 30°C for the control or 59.6 ml of water at 30°C, including the volume of the CGW with the desirable nitrogen content (17–40 mg N). The ingredients were mixed and fermented for 3 hr. After an additional 25 min, the dough was molded, placed in baking pans, and proofed for 55 min at 30°C and 75% relative humidity. Loaves were baked for 25 min at 230°C.

Evaluation of Bread Quality

Balady bread was evaluated in terms of crust color, taste, and appearance, whereas European bread was evaluated for color, texture, and grain. These characteristics were judged subjectively by a panel of 10 members from the Grain and Bread Technology Research Section, Agricultural Research Center. Every member gave scores from 0 to 5 for each measurement; thus the total possible score for the three measurements was 15.

The diameter of Balady bread loaves was measured. The weights and volumes of the two types of bread loaves were measured so that their specific volumes could be calculated.

TABLE I
Extensigraph Tests of Unyeasted Dough After Addition of Starch Aqueous By-Products

	Extensigraph Tests		
Dough Treatment	Extensibility (mm)	Resistance to extension (BU)[a]	Strength (cm^2)
Water (control)	78	870	110
Corn gluten water	92	930	160
Rice steep water	89	910	150
Rice gluten water	93	900	140

[a] Brabender units.

TABLE II
Farinograph tests of Unyeasted Dough After Addition of Corn Gluten Water

Dough Treatment	Farinograph Tests Water Absorption (%)	Mixing Time (min)	Dough Weaking (BU)[a]	Dough Stability (min)
Water (control)	58.0	1.50	140	5.5
Corn gluten water	59.6	1.75	170	5.5

[a] Brabender units from leaving 500-Brabender line to middle of curve after 12 min.

TABLE III
Effect of Adding Corn Gluten Water (CGW) on Pasting Properties of Flour Slurries

Flour Treatment	Pasting Temperature (°C)	Peak Viscosity (BU)[a]
Water (control)	69.0	220
Water including 20 mg N as CGW	67.5	240
Water including 30 mg N as CGW	66.0	250
Water including 40 mg N as CGW	65.5	260
Water including 50 mg N as CGW	65.5	270

[a] Brabender units.

TABLE IV
Quality of Balady Bread After Addition of Starch Aqueous By-Products

Bread Property	Water (control)	Corn Gluten Water (mg N/100 g flour) 17	34	50	Rice Steep Water (mg N/100 g flour) 15	30	46	Rice Gluten Water (mg N/100 g flour) 10	20	30
Crust color[a]	3.2	4.0	4.5	4.5	3.8	4.4	4.6	4.1	4.5	4.7
Taste[a]	3.0	3.0	4.0	4.5	3.4	4.0	4.6	3.3	4.1	4.5
Appearance[a]	3.5	3.5	3.9	4.3	3.6	4.0	4.3	4.0	4.0	3.9
Total score	9.7	10.5	12.4	13.3	10.8	12.4	13.5	11.4	12.6	13.1
Average loaf diameter (cm)	15.0	15.0	15.5	17.0	17.0	17.0	18.0	18.0	18.0	18.0
Average specific volume	3.76	4.29	4.80	4.91	4.12	4.74	4.90	4.75	4.75	5.00

[a] Mean of measurement.

TABLE V
Quality of European Bread After Addition of Corn Gluten Water

Bread Property	Water (control)	Corn Gluten Water[a] 17	25	34	40
Color[b]	4.0	4.0	4.2	4.5	4.5
Texture[b]	4.5	4.5	4.5	4.5	4.5
Grain[b]	4.0	4.4	4.4	4.4	4.5
Total score	12.5	12.9	13.1	13.4	13.5
Average specific volume	3.22	3.30	3.43	3.48	3.56

[a] Containing mg N/100 g flour.
[b] Mean of measurement.

Amino Acid Pattern of Balady Bread

Amino acid composition in dried bread samples was determined by hydrolyzing with HCl (6*N*) (Bailey 1967). The hydrolysate was evaporated under vacuum until almost dry, dissolved in HCl (0.1*N* containing 12.5% sucrose), and analyzed for amino acid composition with a Technicon amino acid analyzer (Juliano et al 1964). The Technicon standard mixture of 2.25 mmol of each amino acid was used in calibrating the 75-cm and 0.62-cm diameter column. The average reproducibility of recovery obtained for the 17 amino acids was 100 ± 3%. Results were expressed as grams of amino acid per 16 g of N, which is the same as the data expressed as percent of the protein content. The samples were analyzed for Kjeldahl nitrogen (AOAC 1965) from which protein content was calculated using the specific factor. Total free amino acids were determined by ninhydrin reaction (Lee and Takahashi 1966).

RESULTS AND DISCUSSION

Extensigraph Tests

When water added to the flour as control was replaced with the same volume of CGW, RSW, or RGW, the unyeasted dough stretched before breaking (extensibility), and the dough strength and resistance to extension were increased. CGW gave larger values than RSW and RGW (Table I).

Farinograph Tests

Table II shows that the water absorption, mixing time, dough weakening, and dough stability were slightly influenced by addition of CGW instead of water to the flour with the same volume.

Pasting Properties

Pasting temperature and pasting viscosity of a 10% suspension of flour in water as control or in water including the volume of CGW with 20–50 mg of N are presented in Table III. Addition of CGW decreased the pasting temperature and increased the peak viscosity of the flour slurry. Low pasting temperature and increased peak viscosities are notable by increasing CGW added to the flour.

Effect of Adding Starch By-Products on Bread Quality

CGW, RGW, and RSW were added in amounts corresponding to 17–50 mg of N/100 g of flour. Palatability for Balady bread is given in Table IV. These results indicate that addition of these by-products increased quality scores of Balady bread. Excellent data were obtained by replacing the water added to the flour (72 ml/100 g of flour) with the same volume of CGW or RSW (50 and 46 mg N/100 g of flour, respectively), or by adding RGW in amounts corresponding to 30 mg N/100 g of flour. Similar observations were obtained when CGW was used for European breadmaking (Table V). This apparently is due to the suitable amounts of free amino acids present in these by-products as reported by El-Saied (1981), who recommended their addition for this purpose. Considerable amounts of the free amino acids alanine, glycine, leucine, isoleucine, methionine, and phenylalanine are found in CGW, RGW, and RSW (El-Saied 1981), which are responsible for aroma (Wick et al 1964). The same conclusion was confirmed by other investigators (Johnson and El-Dash 1969, Salem et al 1967) who reported that condensation of free amino groups and reducing sugars during baking is the most important reaction responsible for bread crust formation and bread flavor. Moreover, increasing the free amino acid group by means of proteolysis in the dough markedly increased crust color and intensified bread aroma but did not influence bread taste (Johnson and El-Dash 1969). The data shown in Tables IV and V are in excellent agreement with those of Tadeusz et al (1971), who reported that addition of gluten hydrolysates in amounts corresponding to 25–150 mg of N/100 g of flour improved the organoleptic properties of bread, and some increases of carbonyl compounds of bread and its quality was notable.

Nitrogen and Total Free Amino Acid Contents of Bread

Table VI shows the nitrogen and free amino acid contents of Balady bread after addition of CGW, RGW, and RSW in amounts corresponding to 17–50 mg N/100 g of flour. Table VII indicates

TABLE VI
Nitrogen and Total Free Amino Acid Contents of Balady Bread (dry weight basis) After Addition of Starch Aqueous By-Products

Analysis (%)[a]	Water (control)	Corn Gluten Water[b]			Rice Steep Water[b]			Rice Gluten Water[b]		
		17	34	50	15	30	46	10	20	30
Nitrogen content	1.83	1.83	1.86	1.89	1.86	1.87	1.89	1.87	1.88	1.89
Total free amino acids	0.23	0.31	0.34	0.53	0.30	0.40	0.52	0.40	0.59	0.84

[a] Mean of three determinations.
[b] Milligrams N/100 g flour.

TABLE VII
Nitrogen and Total Free Amino Acid Contents of European Bread (dry weight basis) After Addition of Corn Gluten Water

Analysis (%)[a]	Water (control)	Corn Gluten Water[b]			
		17	25	34	40
Nitrogen content	1.97	1.97	2.00	2.00	2.04
Total free amino acids	0.40	0.52	0.58	0.64	0.79

[a] Mean of three determinations.
[b] Containing mg N/100 g flour.

these analyses for European bread after addition of CGW in amounts corresponding to 17–40 mg of N/100 g of flour. The nitrogen and total free amino acid contents were slightly affected by addition of these by-products for both Balady and European breads.

Amino Acid Pattern of Balady Bread

The amino acid composition of the different bread samples after acid hydrolysis indicated the presence of at least 17 amino acids, which is the same number as the control had. These by-products contained considerable levels of free amino acids, but they were added in amounts not exceeding 50 mg of N/100 g of flour and probably condensed with sugars during baking. The aroma and the crust color were formed as stated by other investigators (Johnson and El-Dash 1969, Salem et al 1967). The predominant amino acids in all bread samples were glutamic acid and proline, whereas the other amino acids were found in variable amounts. Similar observations were obtained by many investigators (El-Saied and Abdel-Moneim 1981, Hepburn et al 1960, Stevens et al 1963) regarding wheat flour of different extraction. On the other hand, the cystine content increased slightly when these by-products were added. Gluten complex has elasticity properties of unique value for baking bread. The elastic properties that are developed as the by-products are mixed appear to involve sulfhydryl groups, possibly their oxidation to disulfide bonds leading to the formation of new bonds (Kent 1975). The data of Table VIII agreed with those of McDermott and Pace (1957), who showed that when flour is baked into bread, the amino acid composition is almost the same. The nutritional value of Balady bread proteins is almost the same; the proteins are deficient only in threonine, methionine, isoleucine, and lysine.

Proteolytic enzymes are used to improve the bread quality by increasing the free amino groups that react with sugars during baking for the production of crust color and aroma in bread, but bread taste is not influenced (Johnson and El-Dash 1969). On the other hand, addition of free amino acids failed to provide a pleasing total bread aroma, probably because the ratio of amino acids required for acceptable bread aroma was critical, and knowledge concerning it was unavailable (El-Dash and Johnson 1967). From the present study, addition of aqueous by-products resulting during the starch manufacture by the wet milling of corn and rice that contain considerable amounts of free amino acids (El-Saied 1981) in amounts corresponding to 20–50 mg of N/100 g of flour had the ratio of amino acids required for acceptable bread aroma of Balady and European breads. Other factors that affect consumer acceptability, such as specific volume, taste, shape, grain, texture, and color of the bread crust and crumb, were improved by this treatment. These by-products can be used more cheaply than

TABLE VIII
Amino Acid Composition of Balady Bread After Addition of Starch Aqueous By-Products (G Amino Acid/16 N on Dry Weight Basis)

Amino Acid	Water (control)	CGW[a] (50 mg N)	RGW[b] (30 mg N)	RSW[c] (46 mg N)	FAO 1973 Provisional Pattern
Aspartic acid	4.13	4.00	3.90	4.06	...
Theronine[d]	2.24	2.62	2.40	2.43	3.02
Serine	4.96	3.68	3.78	4.93	...
Glutamic acid	34.40	34.94	33.49	33.62	...
Proline	11.68	11.36	11.68	12.00	...
Glycine	3.20	3.52	3.30	3.10	...
Alanine	3.20	3.02	3.04	3.52	...
Valine[d]	4.16	4.03	4.00	4.26	4.54
Cystine	1.92	2.46	2.08	2.08	...
Methionine[d]	1.60	1.46	1.60	1.50	2.42
Isoleucine[d]	3.68	3.65	3.52	3.80	4.54
Leucine[d]	5.76	7.04	6.82	5.86	5.15
Tyrosine	2.88	2.24	2.11	2.24	...
Phenylalanine[d]	4.32	4.80	4.96	4.70	3.02
Lysine[d]	2.62	2.62	2.40	2.46	4.54
Tryptophane[d]	–[e]	–[e]	–[e]	–[e]	1.15
Histidine	1.94	2.26	2.16	2.10	...
Arginine	4.06	3.36	3.73	4.26	...
Protein content (%)	11.46	11.83	11.86	11.83	...

[a] Corn gluten water; mg N/100 g flour.
[b] Rice gluten water; mg N/100 g flour.
[c] Rice steep water; mg N/100 g flour.
[d] Essential amino acid.
[e] No value available.

proteolytic enzymes and give superior results; bread taste is not influenced when proteolytic enzymes are used (Johnson and El-Dash 1969).

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