Incorporation of Corn Gluten Meal and Soy into Various Cereal-Based Foods and Resulting Product Functional, Sensory, and Protein Quality[1]

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ABSTRACT

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Corn gluten meal (CGM), a co-product of the corn wet-milling industry, was incorporated, both alone and in combination with soy flour, into sugar cookies, white pan bread, pasta, and extruded snacks. Functional, sensory, and protein properties of the products were analyzed. CGM appeared to affect the functional properties of bread and extruded products more than those of cookies or pasta, where soy seemed to have more of an effect. The addition of CGM to these foods resulted in less desirable flavor ratings for all products except the cookies and for texture in all except the pasta. The four products all possessed in vitro digestibilities greater than 80%. Also, computed protein efficiency ratio values of the cookies, bread, and extruded product were higher than those of the initial flours and CGM, individually.

Maize, or corn, is used extensively as a feed grain. The main nonfeed use of corn is wet milling (Wall and Paulis 1978). In 1985, 830 million bushels of corn were utilized by the wet-milling industry (Anonymous 1985) to separate pure starch from protein and other corn constituents (Lasztity 1984). The increased demand for starch and resulting rapid growth of the wet-milling industry is a result of the development of high-fructose corn syrups and of new starch derivatives (Casey 1978). Typically, 25–30% of wet-milled corn ends up as feed products (Watson and Yahl 1967, Anonymous 1982).

Corn gluten meal (CGM), obtained after the germ, oil, bran, and starch are extracted from the shelled corn (Sternberg et al 1980, Anonymous 1982), is one of the most valuable by-products of wet milling, typically containing 60% protein on a dry basis (db). This protein is composed mainly of zein (68%) and maize glutelin (27%), containing only 1.2% globulins (Watson and Yahl 1967). Typical of cereal grains, gluten meal protein is low in lysine and tryptophan content, although it is rich in methionine (Wall and Paulis 1978, Lasztity 1984). CGM is valued in cattle feeds because it provides a high level of rumen bypass protein (Wall and Paulis 1978, Anonymous 1982). It also is highly digestible. About 99% of the sulfur amino acids are available for growing chicks (Sasse and Baker 1973). Wet corn gluten is bright yellow due to xanthophylls and thus is a pigment source for poultry. CGM typically contains about 50–70% moisture, and on a dry basis it contains 15–18% fat, 20–25% carbohydrate, 3.5% fiber, and 1–2% ash. Of the fat, 20–30% is in the form of free fatty acids. Because of its high unsaturated fatty acid content, CGM typically has strong odors and flavors and a tendency to develop oxidative rancidity (Sternberg et al 1980). It is, therefore, difficult to incorporate CGM into foods for human consumption, but it would make the wet-milling process more economical if expanded markets could be found.

Previous work has been done with a linear program designed to 1) develop and test mathematical models that blend protein sources and base ingredients to achieve predetermined nutritional and functional characteristics in various food systems and 2) develop and test a mathematical model that provides predictions of protein quality based on the profile of essential amino acids and in vitro protein digestibility (Hsu et al 1977a,b). CGM is a protein source that has not previously been incorporated into this model.

CGM is already produced in large amounts (approximately 1.6 billion pounds was shipped in the United States in 1985), and production is expected to continue to increase because of the increased demand for high-fructose corn syrup. For this reason, and because of the high protein content and amino acid availability of CGM, we decided to investigate the effects of adding it at varying levels to four cereal-based products. Previous work showed that CGM and soy flour can be successfully coextruded to produce a uniquely textured product (Neumann et al 1984). Because of this, and because soy is a protein source previously considered in the linear model with an amino acid profile complimenting that of CGM, it was decided to incorporate varying concentrations of soy flour into the same four products, alone and in combination with the CGM. Functional, sensory, and nutritional data were collected for these products, and this information was added to the linear model to predict parameters for products containing CGM at other levels.

MATERIALS AND METHODS

Four different cereal-based products were produced. CGM and soy flour, both individually and in combination at various concentrations, replaced part of the normal grain portion of the experimental formulations. The CGM (68.4% protein and 1.5% ash, db) was obtained from Archer Daniels Midland in Clinton,

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IA; soy flour (57.6% protein and 5.9% ash, db) was from Archer Daniels Midland in Decatur, IL.

Cookies

To be consistent with work previously done for the linear programming model, sugar cookies were made according to the method of Fogg and Tinklin (1972). A control cookie containing only all-purpose wheat flour (Sexton brand; 13% protein, db) was made along with three test formulas. Ingredients on a percentage flour weight basis were: flour (all-purpose wheat), 100.00; sugar (granulated, cane), 99.34; hydrogenated shortening, 62.25; eggs (whole), 31.79; cream of tartar, 2.05; soda, 1.26; salt, 0.53; cinnamon, 0.99; and sufficient water to adjust flour moisture to 14%. Three test cookies were made by substituting various proportions of CGM and soy for the wheat flour. One experimental cookie contained 20% CGM, one 20% soy flour, and the third 20% CGM and 20% soy flour. Cookies were cut 9 mm thick, 42.9 mm in diameter, and baked for 10 min at 204.4° C (400° F).

Spread factors for cookies were determined by AACC method 10-50D (1983).

To determine their surface texture scores, cookies were compared to a reference set developed in this laboratory. This reference set is a series of 10 cookies prepared by AACC method 10-50D (1983), containing progressively more sugar and showing increased surface cracking.

Bread

To be consistent with previous work, control breads were made using the straight-dough formula and procedure of Marnett and co-workers (1973). The formula for the control bread was, on a percentage of flour weight basis, as follows: wheat flour, 100; water, 62.7 (adjusted for optimum absorption); yeast, 3.0; yeast food, 0.25; shortening, 2.0; salt, 2.25; sugar, 4.5; and sodium stearoyl lactylate, 0.5. Loaves of 200 g were made. Bread flour (Pillsbury's Best) at 13.8% protein and 0.8% ash (db) was used in the control. Experimental treatments included breads containing 10, 20, and 30% CGM; 10, 20, and 30% soy flour; 5% CGM, 5% soy; 10% CGM, 10% soy; and 15% CGM, 15% soy.

Specific volumes were calculated after determining loaf volumes by rapeseed displacement by dividing loaf volumes by their respective weights.

Bread firmness was determined 24 hr after baking with an Instron universal testing machine model TM, using a 38-mm diameter indenter and a crosshead speed of 1.0 cm/min. Firmness was measured as the slope of the second straight portion of the compression line (Bashford and Hartung 1976).

Extruded Puffs

A control extruded puff product was made from 100% corn grits (22% moisture and 8.9% protein, db) obtained from Gooch Foods, Lincoln, NE. Experimental treatments contained 10, 20, and 30% CGM; 10, 20, and 30% soy; 5% CGM, 5% soy; 10% CGM, 10% soy; and 15% CGM, 15% soy. Products were extruded through a C. W. Brabender (South Hackensack, NJ) laboratory-scale extruder with a ¾-in. diameter barrel at 160° C. Screw speed was 150 rpm, and the die was 3 mm in diameter.

Puff ratio was calculated by taking the average product diameter, ($\bar{d}$), squaring it, and then dividing by the square of the die diameter. Puff ratio = $(\bar{d})^2/(\text{die diameter})^2$.

Pasta

Control macaroni was made with 100% durum semolina containing 15.0% protein (db) obtained from Gooch Foods, Lincoln, NE. Experimental treatments were produced containing 10 and 20% CGM; 10 and 20% soy; 5% CGM, 5% soy; and 10% CGM, 10% soy. The semolina was blended at speed no. 1 in a Kitchen-Aid model K45 mixer, slowly adding water and mixing about 2 min until the water was evenly distributed and small, uniform beads were formed. The soy or CGM or combination was then added and mixed for an additional 30 sec. The dough was extruded at 31.5% total moisture in a laboratory-scale La Parmigiana pasta extruder fitted with a brass macaroni die. The 10 and 20% CGM samples were extruded at 31.0% total moisture because of the low absorption of the CGM. Macaroni used for two tests—the volume increase upon cooking and color analysis—was dried overnight at 40° C. The remaining pasta was dried for 1 hr at room temperature and then frozen in plastic bags until analysis.

Pasta cooking quality was determined by measuring cooked weight, cooking loss, volume increase, and cooked firmness of the product after cooking, all under standardized conditions. Cooked weight, cooking loss, and cooked firmness were measured according to the procedures of Vasiljevic and Banasik (1980).

Volume increase upon cooking was measured as the difference between the amount of kerosene displaced by 10 g of uncooked dried macaroni and by 10 g of cooked macaroni; both were broken into small pieces. Results were multiplied by 10 and recorded as volume per 100 g.

Color Analyses

Color of all products was measured using a Hunterlab Tristimulus colorimeter model D-25 M-9 (Hunter Associates Laboratory, Inc., Fairfax, VA). Three scales, the *L*, *a*, and *b*, were recorded, where an *L* value of 100 is white and one of 0 is black; a high positive *a* value is red, and a high negative a value is green; and a high positive *b* value is yellow, and a high negative *b* value is blue. A yellow reference plate (no. C2-6073) was used for calibration. Slices of bread and cookies were placed directly over the window. Extruded puffs and pasta were first ground and then placed in a uniform layer over the window for reading.

Sensory Analyses

All cookie and pasta samples were subjected to sensory analyses. The control, 20% CGM, 20% soy, and 10% CGM/10% soy bread samples were evaluated. The control, 30% CGM, 30% soy, and 15% CGM/15% soy extruded puffs were likewise evaluated, following procedures of Larmond (1977). Panelists were untrained

Cookie

APPEARANCE
1 2 3 4 5 6 7 8 9
Too smooth and fine — Pleasant — Too coarse and rough

TEXTURE
1 2 3 4 5 6 7 8 9
Too smooth — Desirable — Too grainy

AROMA
1 2 3 4 5 6 7 8 9
Little or no odor — Pleasant — Strong or unpleasant

FLAVOR
1 2 3 4 5 6 7 8 9
Little or no flavor — Agreeable — Too strong

Additional comments:

Bread

APPEARANCE
1 2 3 4 5 6 7 8 9
Too open — Even, uniform — Too dense

AROMA
1 2 3 4 5 6 7 8 9
Little or none — Plesant — Too strong, disagreeable

TEXTURE
1 2 3 4 5 6 7 8 9
Too smooth — Desirable — Too coarse, grainy

FLAVOR
1 2 3 4 5 6 7 8 9
Not enough — Agreeable — Too strong

Additional comments:

Extruded Product

APPEARANCE
1 2 3 4 5 6 7 8 9
Too small, compact — Pleasant, desirable — Too big, fluffy

AROMA
1 2 3 4 5 6 7 8 9
No aroma — Pleasant — Too strong

TEXTURE
1 2 3 4 5 6 7 8 9
Too hard — Desirable — Too airy

FLAVOR
1 2 3 4 5 6 7 8 9
Not enough — Good, desirable — Too strong

Additional Comments:

Pasta

APPEARANCE
1 2 3 4 5 6 7
Pale — Normal — Too Dark

TEXTURE
1 2 3 4 5 6 7
Soft — Normal — Too firm, chewy

FLAVOR
1 2 3 4 5 6 7
None — Normal — Too Strong

OVER-ALL SCORE
1 2 3 4 5 6 7
Dislike — Like very much

Which sample is the best? __ The worst? __

Fig. 1. Questionnaires used for sensory evaluations of cookies, breads, extruded products, and pasta.

on these specific products but were familiar with these types of sensory panels. A minimum of 19 panelists participated in the cookie, bread, and extruded product analyses. The analyses were performed in isolated booths in a standard taste panel kitchen under red lights. The lights were used to mask the yellow color caused by addition of CGM. Appearance scores were determined to evaluate surface texture, not color, which was determined by the Hunter colorimeter.

Cookies, bread, and extruded puffs were analyzed for appearance, aroma, texture (mouthfeel), and flavor on descriptive scales of 1–9, where 5 was the most desirable, and the extremes were undesirable. The extruded product samples were coated with oil and cheddar cheese flavoring (Land O'Lakes, Minneapolis, MN) for the sensory evaluations. These samples were presented to panelists on paper plates marked into four sections, each labeled with three-digit number codes for the samples. The samples were evaluated at room temperature. For each sample, one-quarter of a cookie, one-fourth of a slice of bread, and three or four extruded product pieces were provided each panelist. Pasta was cooked for 4 min, drained, and evaluated while still warm. It was analyzed by nine panelists for appearance, texture, flavor, and an overall score on descriptive scales of 1 to 7, where 4 was most desirable. Figure 1 contains the questionnaires used for each of the four products.

Kjeldahl nitrogen (AACC method 46-12) was determined on the starting ingredients (soy flour, CGM, all-purpose flour, bread flour, corn grits, and semolina) and on the 20% CGM/20% soy cookies; the 15% CGM/15% soy bread; the 15% CGM/15% soy-extruded product and the 10% CGM/10% soy pasta. Amino acid analyses, in vitro digestibilities, and computed protein efficiency ratios (CPERs) were obtained for these same samples following AOAC procedures 43.264, 43.265, and 43.266, respectively (AOAC 1984).

Analyses of variance were performed on data collected for each product, and means were separated by Duncan's multiple range test (5% level of probability) (Steel and Torrie 1980).

To illustrate the effects on appearance caused by addition of CGM, photographs show control products and samples containing the highest levels of CGM incorporated.

RESULTS AND DISCUSSION

Cookies

Spread ratios were not generally significantly different ($P>0.05$) between the control and the protein-fortified cookies. The surface scores of cookies containing soy were significantly higher, showing more surface cracking, than those of the control or of the cookies containing only CGM ($P<0.05$). There were significant differences ($P<0.05$) among samples for color on all three scales, with the CGM-containing cookies being darker, more red, and more yellow than the control or soy-containing cookies. Sensory evaluation showed no significant differences ($P>0.05$) among samples evaluated for either appearance or aroma, but the texture ratings were significantly less desirable (more grainy) for samples containing CGM ($P<0.05$). The flavor of the 20% soy cookies was less strong than of the 20% CGM/20% soy cookies ($P<0.05$) (Table I). Figure 2 shows the appearance of the control and 20% CGM cookies.

Bread

The addition of either CGM or soy decreased loaf volumes significantly ($P<0.05$). Loaf firmness was also significantly increased ($P<0.05$) with the addition of 30% CGM, 20% soy, and a combination of 15% CGM and 15% soy. Color by all three scales was significantly different ($P<0.05$), becoming darker when 20% CGM and 20% CGM/20% soy was added, more red when 30% soy or any CGM was added, and more yellow when CGM or soy or both were added. When sensory characteristics were analyzed, significant differences ($P<0.05$) for all attributes, except appearance, were noted. Panelists judged surface texture, and not color, under the red lights. This may explain why no differences

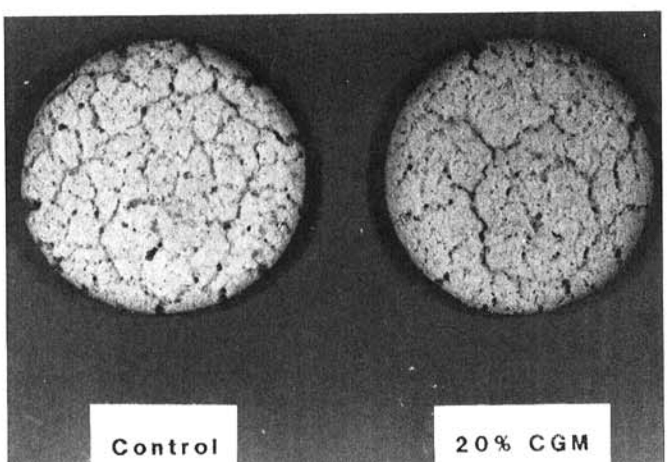

Fig. 2. Sugar cookies containing 100% all-purpose wheat flour (control) and having 20% of the flour substituted by corn gluten meal.

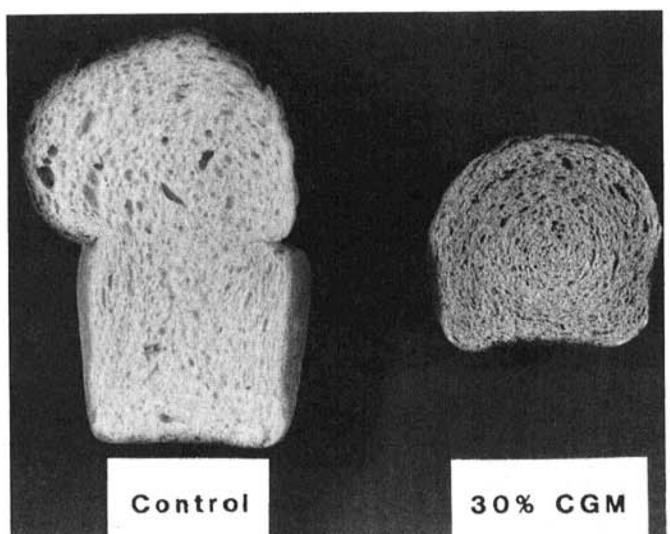

Fig. 3. Bread containing 100% wheat bread flour (control) and having 30% of the flour substituted by corn gluten meal.

TABLE I
Functional and Sensory Characteristics of Cookies Made With Varying Levels of CGM[a] and/or Soy[b]

Treatment	Spread Ratio	Surface Score	Taste Panel[c] Appearance	Aroma	Texture	Flavor	Hunter Colorimeter Values *L*	*a*	*b*
Control (100% all-purpose wheat)	7.24 a	7.28 a	5.14 a	4.83 a	5.38 a	5.45 ab	58.15 a	3.22 a	18.99 a
20% Soy	6.26 b	7.78 b	5.14 a	5.02 a	5.17 a	4.81 b	55.85 a	3.09 a	19.35 a
20% CGM	6.83 ab	7.39 a	5.57 a	4.48 a	6.48 b	5.39 ab	52.39 b	5.26 b	23.52 b
20% CGM + 20% soy	6.55 ab	7.78 b	5.86 a	5.10 a	6.30 b	6.19 a	50.98 b	5.10 b	23.60 b

[a] CGM = Corn gluten meal.
[b] Results are means of three replicates. Means in a column followed by the same letter are not significantly different from each other ($P>0.05$).
[c] Sensory parameters are outlined in Fig. 1.

were found in appearance, even though bread made with CGM did not rise nearly so much as control bread, probably because of the dilution of the wheat gluten. When CGM or soy or both were added, the aroma became stronger, the texture coarser, and the flavor stronger. All these attributes were even more pronounced when CGM was added at 20% flour weight ($P<0.05$).

Results of the bread analyses are summarized in Table II. Figure 3 shows the control and the 30% CGM bread.

Extruded Puffs

Puff ratio decreased with the addition of either CGM or soy, although the decrease was more marked when CGM was added. Lightness values decreased with the addition of CGM or CGM combined with soy. Redness values increased only slightly with the addition of CGM or soy. Yellowness values decreased slightly with the addition of CGM or soy, perhaps because of the normal yellow color of the corn grits. Aroma was not judged to be significantly different ($P>0.05$) for any of the extruded snacks. However, the three samples evaluated were all judged to be too small and compact in appearance and to have a harder, less desirable texture than the control ($P<0.05$). Interestingly, panelists rated the flavor of the three experimental samples higher than the control sample, which they rated as not having adequate flavor. Table III shows the results for the extruded snacks and Figure 4 the control and 30% CGM puffs.

Pasta

Average cooked pasta weights showed significant differences ($P<0.05$) among samples, the soy-containing samples having lower cooked weights than the control or those containing only CGM. Likewise, the soy-containing samples showed a significantly greater ($P<0.05$) cooking loss than the control. There was little difference in wet volumes.

Pasta firmness was measured as the area (g × cm) under the shear curve (Walsh 1971). A tough or firm pasta had a larger area than a soft or mushy pasta. The pasta containing soy flour was more firm than the control, whereas that containing only CGM was less firm ($P<0.05$). The Hunter L values decreased with increasing CGM concentration, the dark yellow of the CGM making the pasta look much darker than the control ($P<0.05$). Samples became more red with increasing CGM concentration and more yellow with addition of CGM or soy ($P<0.05$). The pasta analysis results are summarized in Table IV.

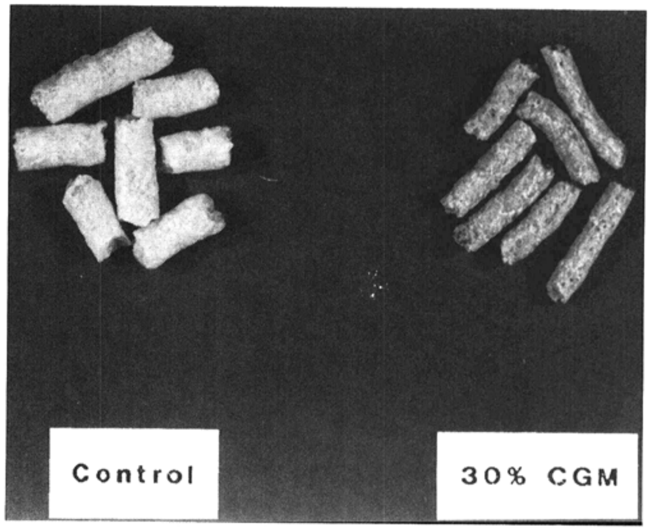

Fig. 4. Extruded puffs made from 100% corn grits (control) and having 30% of the grits substituted by corn gluten meal.

TABLE II
Functional and Sensory Characteristics of Bread Made With Varying Levels of CGM[a] and/or Soy[b]

Treatment	Specific Volume (ml/g)	Firmness[c] (gF/cm)	Taste Panel[d] Appearance	Aroma	Texture	Flavor	Hunter Colorimeter Values L	a	b
Control (100% bread flour)	5.32 a	461.09 a	4.36 a	4.16 a	4.11 a	3.84 a	70.59 ab	−2.74 a	13.67 a
10% Soy	4.15 bc	596.20 ac					73.76 a	−2.69 a	17.23 b
20% Soy	3.26 d	943.33 bc	5.22 a	5.05 ab	5.04 b	5.09 b	71.05 ab	−2.06 ab	19.92 c
30% Soy	2.95 d	1279.87 bd					68.29 abc	−1.69 bf	19.64 c
10% CGM	3.83 c	574.94 ac					66.42 abc	0.01 c	26.52 de
20% CGM	3.07 d	881.79 abc	5.25 a	7.14 c	6.50 c	7.33 c	63.56 bcd	2.38 d	30.09 f
30% CGM	2.20 e	1613.09 d					56.68 d	4.27 e	29.91 f
5% CGM + 5% soy	4.28 b	479.42 a					65.68 abc	−1.23 f	22.37 g
10% CGM + 10% soy	4.06 bc	480.77 a	4.74 a	5.82 b	5.24 b	5.74 b	64.48 bcd	0.68 g	25.78 e
15% CGM + 15% soy	3.02 d	1058.65 b					61.39 cd	2.24 d	28.15 d

[a] CGM = Corn gluten meal.
[b] Results are means of three replicates, two loaves per treatment. Means in a column followed by the same letter are not significantly different from one another ($P>0.05$).
[c] gF = Grams of force.
[d] Sensory parameters are outlined in Fig. 1.

TABLE III
Functional and Sensory Characteristics of Extruded Puffs Made With Varying Levels of CGM[a] and Soy[b]

Treatment	Puff Ratio	Taste Panel Appearance	Aroma	Texture	Flavor	Hunter Colorimeter Values L	a	b
Control (100% corn grits)	9.40	5.29 a	4.55 a	4.71 a	3.60 a	75.48	−1.59	34.66
10% Soy	7.34					77.01	−1.07	32.67
20% Soy	6.39					74.21	0.14	30.81
30% Soy	5.09	3.88 b	4.25 a	3.50 b	3.87 ab	74.60	−0.01	26.61
10% CGM	6.92					65.87	−0.64	30.57
20% CGM	5.48					64.75	0.07	30.99
30% CGM	4.08	2.39 c	4.16 a	3.39 b	4.95 b	66.63	0.47	32.02
5% CGM + 5% soy	8.85					71.71	−1.29	30.81
10% CGM + 10% soy	6.14					69.32	0.03	31.65
15% CGM + 15% soy	4.08	2.33 c	4.18 a	2.31 c	4.53 ab	61.13	1.18	29.79

[a] CGM = Corn gluten meal.
[b] Means in a column followed by the same letter are not significantly different from one another ($P>0.05$).
[c] Sensory parameters are outlined in Fig. 1.

TABLE IV

Functional and Sensory Characteristics of Pasta Made with Varying Levels of CGM[a] and Soy[b]

Treatment	Cooked Weight (g)	% Cooking Loss	Wet Volume (cm³/100 g)	Tenderness (Area under the curve, cm²)	Hunter Colorimeter Values		
					L	*a*	*b*
Control (100% semolina)	29.2 a	6.8 a	286.7 a	27.9 ac	76.14 a	−2.30 a	14.87 a
10% Soy	27.2 bc	10.0 bc	263.3 a	40.5 b	75.19 a	−1.81 a	15.99 b
20% Soy	26.4 c	10.6 b	283.3 a	40.1 b	75.32 a	−2.03 a	17.83 c
10% CGM	28.9 ad	7.0 a	263.3 ab	23.8 c	65.68 cd	0.51 c	24.06 e
20% CGM	29.2 a	8.6 cd	263.3 ab	24.0 c	64.24 d	0.73 c	25.41 f
5% CGM + 5% soy	28.1 bd	7.7 ad	283.3 a	31.4 a	70.64 b	−0.70 b	21.47 d
10% CGM + 10% soy	26.8 c	8.9 cd	236.7 b	40.1 b	68.03 bc	0.23 bc	23.86 e

[a]CGM = Corn gluten meal.

[b]Results are means of three replicates. Means in a column followed by the same letter are not significantly different from one another ($P > 0.05$).

TABLE V

Crude Protein, In Vitro Digestibility, and Computed Protein Efficiency Ratio of Starting Ingredients and of Products Containing Corn Gluten Meal and Soy

Sample	Crude Protein % (dry basis)	In Vitro Digestibility (%)	CPER[a]
Corn gluten meal	68.40	77.71	0.51
Soy flour	57.60	78.61	0.78
All-purpose flour	13.40	85.55	0.71
Bread flour	13.77	85.15	0.75
Corn grits	8.93	78.95	...
Semolina	15.04	87.64	0.85
Cookies (20% CGM/20% soy)	12.80	84.14	1.35
Bread (15% CGM/15% soy)	24.44	83.24	1.25
Extruded product (15% CGM/15% soy)	24.90	81.77	1.18
Pasta (10% CGM/10% soy)	23.77	84.03	0.67

[a]CPER = Computed protein efficiency ratio.

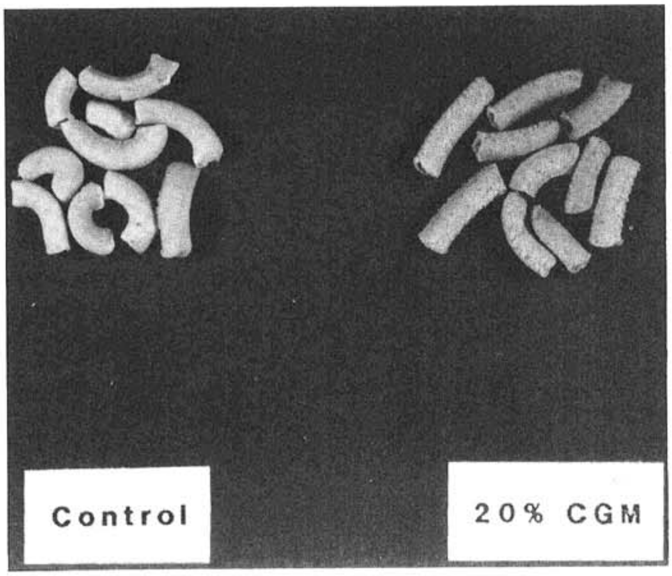

Fig. 5. Pasta made from 100% durum semolina (control) and having 20% of the semolina substituted by corn gluten meal.

The taste panel results showed little difference among samples for texture. All experimental samples were rated darker than the control. The flavor rating increased with addition of soy or CGM; samples containing 10% or more CGM were rated too strong in flavor. The overall scores were less desirable when CGM was added. Figure 5 shows appearance differences between control and 20% CGM pasta samples. (Sensory parameter criteria are outlined in Figure 1.)

Protein Results

Protein contents of the starting ingredients and four finished foods are shown in Table V, as are in vitro digestibilities and final CPERs. The values obtained for the corn grits did not fit the parameters established for the CPER program, and thus no CPER was calculated for this ingredient. The digestibilities of all products tested were relatively high. The CPERs were all relatively low, ranging from 0.51 for the CGM to 1.35 for cookies having 20% of the wheat flour substituted by CGM and 20% substituted by soy. When protein sources were combined in the cookies, bread, and extruded product the resultant CPER was higher than for the flours or CGM alone.

Linear Programming Model

The linear programming model considered CGM as a partial replacement for all-purpose flour, bread flour, corn grits, and semolina in cookies, bread, extruded puffs, and pasta, respectively, in competition with soy flour. The results predicted that CGM could be substituted for 85% of the all-purpose flour in cookies and still yield acceptable functional characteristics, and that the color of the cookie (*L* scale) was the limiting constraint. The substitution of 85% CGM for all-purpose flour would be expected to decrease the CPER by about 38%. It was also predicted that CGM could substitute for 10.4% of the bread flour in bread, 7.9% of the corn grits in extruded puffs, and 10.6% of the semolina in pasta, with tenderness, puff ratio, and appearance being the limiting functional constraints, respectively. The CPERs of the respective products in these cases would be expected to be lowered by 23, 10, and 21%. In all these cases, CGM could be substituted at the levels determined for less cost than the normal starting ingredient. To determine whether the linear programming model correctly predicted all limiting constraints, additional work would need to be done.

CONCLUSIONS

The addition of CGM to foods resulted in less desirable flavor ratings by taste panelists in all products except the cookies, and for texture in all except the pasta. CGM also lowered functional characteristics of bread and extruded puffs, whereas soy had more of a detrimental effect on cookies and pasta.

Although the panelists assigned them lower scores, the addition of CGM to these cereal-based foods did not make them unacceptable. Future work on this project will focus on removing color and odor compounds based on the extraction method reported by Neumann et al (1984) in order to improve functional and sensory properties of cereal products supplemented with CGM.

ACKNOWLEDGMENTS

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LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC. Method 10-50D, revised October

1984; Method 46-12, revised November 1983. The Association: St. Paul, MN.
ANONYMOUS. 1982. Corn Wet-Milled Feed Products, 2nd ed. Corn Refiner's Association, Inc., Washington, DC.
ANONYMOUS. 1985. Feed Outlook and Situation Yearbook. National Economic Research Service. U.S. Dep. Agric.: Washington, DC.
ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS. 1984. Official Methods of Analysis, 14th ed. The Association: Arlington, VA.
BASHFORD, L. L., and HARTUNG, T. E. 1976. Rheological properties related to bread freshness. J. Food Sci. 41:446.
CASEY, J. P. 1978. The future for corn wet milling. Food Technol. 32(1):72.
FOGG, N. E., and TINKLIN, G. L. 1972. Influence of glandless cottonseed flour on quality, acceptability, and amino acid content of sugar cookies. Cereal Sci. Today 17(3):70.
HSU, H. W., SATTERLEE, L. D., and KENDRICK, J. G. 1977a. Computer blending predetermines properties of protein foods. I. Experimental design. Food Prod. Dev. 11(7):52.
HSU, H. W., SATTERLEE, L. D., and KENDRICK, J. G. 1977b. Computer blending predetermines properties of protein foods. II. Results and discussion. Food Prod. Dev. 11(8):70.
LARMOND, E. 1977. Laboratory Methods for Sensory Evaluation of Food. Publ. 1637. Canada Department of Agriculture: Ottawa.
LASZTITY, R. 1984. Maize proteins. In: The Chemistry of Cereal Proteins. CRC Press, Inc.: Boca Raton, FL.
MARNETT, L. F., TENNEY, R. J., and BARRY, V. D. 1973. Methods of producing soy-fortified breads. Cereal Sci. Today 18(2):38.
NEUMANN, P. E., JASBERG, B. K., WALL, J. S., and WALKER, C. E. 1984. Uniquely textured products obtained by co-extrusion of corn gluten meal and soy flour. Cereal Chem. 61(5):439.
SASSE, C. E., and BAKER, D. H. 1973. Availability of sulfur amino acids in corn and corn gluten meal for growing chicks. J. Anim. Sci. 37(6):1351.
STEEL, R. G. D., and TORRIE, J. H. 1980. Principles and Procedures of Statistics, 2nd ed. McGraw-Hill: New York.
STERNBERG, M., PHILLIPS, R. D., and DALEY, L. H. 1980. Maize protein concentrate. In: Cereals for Food and Beverage. Recent Progress in Cereal Chemistry. G. E. Inglett and L. Munck, eds. Academic Press: New York.
VASILJEVIC, S., and BANASIK, O. J. 1980. Quality testing methods for durum wheat and its products (Booklet). Dept. of Cereal Chemistry and Technology, North Dakota State University: Fargo, ND.
WALL, J. S., and PAULIS, J. W. 1978. Corn and sorghum grain proteins. In: Advances in Cereal Science and Technology. Vol. 2. Y. Pomeranz, ed. Am. Assoc. Cereal Chem.: St. Paul, MN.
WALSH, D. E. 1971. Measuring spaghetti firmness. Cereal Sci. Today 16(7):202.
WATSON, S. A., and YAHL, K. R. 1967. Comparison of the wet milling properties of *opaque-2* high-lysine corn and normal corn. Cereal Chem. 44:488.

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Yeast Strains

Of the five yeasts examined, one yeast (FRI 802) was selected