Utilization of Durum Bran and Its Effect on Spaghetti[1]

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ABSTRACT

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Pulverized durum bran was added to semolina in amounts of 0–30%, and the blends were processed into spaghetti. All samples met spaghetti quality cooking test standards. In sensory analyses, the 10% bran spaghetti received the most favorable ratings for spaghetti containing bran. Flavor of the 10% bran spaghetti was preferred over the no-bran spaghetti by panelists with bread preferences of greater than two-thirds for whole wheat and/or bran breads. All nutritional constituents (protein, insoluble dietary fiber, phytic acid, calcium, iron, magnesium, manganese, phosphorus, and zinc) were

significantly higher (probability [PR] = 0.95) in 10% bran spaghetti than in the no-bran spaghetti. A 10% bran spaghetti provided almost $3\frac{1}{2}$ times the dietary fiber than did the no-bran spaghetti and increased calcium content by 40% (the smallest mineral increase) and manganese by 150% (the greatest mineral increase). Of the six minerals assayed, zinc showed an overall increase in concentration from the unprocessed bran-semolina blends to the cooked spaghetti. The concentration levels of manganese and iron varied; and those of calcium, magnesium, and phosphorus decreased.

In recent years there has been a trend toward higher fiber diets. Fiber benefits a wide range of interrelationships in the gastric, cardiac, and metabolic systems (Spiller and Amen 1975; Kelsay et al 1978, 1979a,b). The major gastric benefit is relief from bowel diseases (Burkitt 1972, Findlay et al 1974, Smith et al 1981). Cardiac benefits are less well defined, and are bran-class dependent, but include lowering serum cholesterol levels and perhaps reducing heart attacks (Eastwood 1969, Trowell 1972, Jenkins et al 1975). Bran improves nutritional properties such as fiber, fats, proteins, vitamins, and minerals (MacMasters et al 1978, Ziegler and Greer 1978).

Antinutritional effects of bran have been reported, such as cation binding, which may result in decreased mineral availability and accelerated loss of certain body minerals (McCance and Widdowson 1942a; Reinhold et al 1976a,b; Ismail-Beigi et al 1977, Rendleman 1982; Rendleman and Grobe 1982). Historically, phytic acid was considered the major constituent in bran and whole wheat responsible for di- and trivalent mineral deficiency disorders in monogastric animals (McCance and Widdowson 1942a,b; Hoff-Jorgensen et al 1946, Hussain and Patwardhan 1959, Reinhold et al 1973). But today, uncertainty exists whether phytate, fiber, or a combined effect is the major factor in mineral absorption (Reinhold 1975, Reinhold et al 1975, Davies et al 1977, James et al 1978, Erdman 1979, Cheryan 1980, Fairweather-Tait 1982, Thompson and Weber 1982).

Mineral binding is mainly influenced by pH, mineral concentrations, and mineral derivative solubilities (Jackman and Black 1951, Vohra et al 1965, Oberleas 1973, Thompson and Weber 1979). The main effect of mineral binding is decreased availability; pH exerts two effects—it controls mineral solubility and determines wheat constituent binding ability.

Approximately 60% of the phytic acid present in durum wheat occurs in the bran (Tabekhia and Donnelly 1982). O'Dell et al (1972) found approximately 87% of the phytic acid in soft wheat was associated with the aleurone layer. In the milling process, the aleuone layer separates with the bran. The average phytate content

of six durum wheat cultivars was 1.09 g/100 g wheat, and the respective bran phytate content was 3.37 g/100 g bran (Tabekhia and Donnelly 1982). Most studies indicate 2 g or more of phytate per day will reduce mineral bioavailability, primarily iron, magnesium, zinc, and calcium (McCance and Widdowson 1942b, Reinhold et al 1973, Morris et al 1980, Obizoba 1981).

The U.S. Department of Agriculture and the U.S. Department of Health and Human Services issued dietary guidelines in 1980 that recommended decreased dietary consumption of sodium, total fat, and simple carbohydrates and an increased consumption of fiber and complex carbohydrates (USDA and USDHHS 1980). Pasta is low in sodium, fat, and simple sugars and contains a high level of complex carbohydrates (Nutrition Research and Education Committee of the National Pasta Association 1984). To help meet this recommendation, we incorporated different levels of durum bran in spaghetti and evaluated cooking, sensory, and nutritional qualities of the products.

MATERIALS AND METHODS

Samples
Samples consisted of four durum wheats grown in 1980. The cultivars were Vic, Crosby, and Mexicali. Mexicali samples were from Arizona and the Imperial Valley of California; Vic and Crosby were grown in North Dakota.

Milling
Samples were milled on a 55-cwt pilot mill specifically flowed for producing semolina as described by Shuey et al (1980). For each sample, semolina was collected from six purifiers; the six streams were combined and blended.

The bran particle size was reduced by hammer-milling through a 1.5/64 in. sieve (Jacobson Machine Works, Inc., hammermill model 66-B, Minneapolis, MN).

Particle Size
Bran particle sizes were measured in triplicate with the Microtrac particle-size analyzer (Leeds and Northrup Co., Largo, FL) which uses a laser beam. The mean particle size of the hammer-milled bran ranged from 152–168 μm.

Bran and Semolina Blending
Semolina and hammer-milled bran were weighed (db) and blended 20 min in a cross-flow blender (Patterson-Kelley Co., East Stroudsburg, PA). Blends contained 0, 10, 15, 20, 25 or 30% bran. All blends were prepared in duplicate for each cultivar ($n = 48$).

Mixograph
Mixograms (10 g) were obtained in duplicate for semolina and bran-semolina blends by using 56–66% absorption, a spring setting of 9, and a 2 cm/min chart speed.

Spaghetti Samples

Samples (2 kg) were processed into spaghetti using a DeMaco semi-commercial vacuum extruder and the following conditions: 3–5 min premix (for 0–30% bran samples, respectively) in a Hobart mixer, 31.5% absorption, 37° C die temperature, 20 rpm extrusion rate, and a vacuum of 50 cm Hg. Spaghetti was dried at 40° C in an experimental pasta dryer (Gilles et al 1966). The relative humidity decreased linearly from 95 to 60% during the entire 18-hr drying cycle. Spaghetti diameters were measured at several locations on nine strands of each sample, and the average reading at each location was used.

Spaghetti Quality

Spaghetti (10 g) was broken into approximately 5-cm lengths and cooked 12 min in 300 ml of distilled water. Spaghetti quality tests were performed in duplicate. Cooked weight was expressed in grams. Cooked firmness (gcm) was measured with an Instron universal testing machine as described by Walsh (1971). Cooking loss (%) is the material solubilized into the cooking water during cooking.

Sensory Evaluation

Cooked samples were served warm to panelists 15 min before morning and afternoon coffee breaks. Seven samples were evaluated by each panelist: spaghetti containing 0, 10, 15, 20, 25, and 30% bran, and one random duplicate. Randomized, coded samples were arranged on white plates and evaluated in individual booths. Nine separate tasting sessions were held, with a maximum of six panelists per session; in all, there were 35 men and 16 women on the volunteer panel. All but one of the panelists had been in the United States for at least nine months, and nine panelists were of foreign ethnic background. All panelists were familiar with the traditional spaghetti product. Samples were rated graphically for flavor, texture, and color. Scores were later assigned in relation to the no-bran sample rating. Panelists were also asked to cite their brown bread (whole wheat or bran bread) preference (%) and white bread preference (%).

Residue Water pH

Hydrogen-ion activity was measured in duplicate on the water remaining after cooking spaghetti samples. The residue water was cooled to room temperature and measured directly.

Nutrient Tests

Nutrient tests were duplicated for the unprocessed blends and the cooked spaghetti. The cooked spaghetti was oven dried 18 hr (45° C) and ground on a Udy mill (1-mm screen). Neutral detergent fiber, moisture, and Kjeldahl protein (N × 5.7) were determined by AACC methods (1983).

AOAC methods (1980), using wet digestion and atomic absorption spectroscopy (Perkin-Elmer atomic absorption

spectrophotometer, model 603), were used to determine Ca, Fe, Mg, Mn, and Zn. The HCl concentration was halved to standardize results with National Bureau of Standards 1567 and 1568, wheat and rice flour, respectively. Total phosphorus was determined colorimetrically as described by Pons et al (1953), which is a modification of the Fiske and Subbarow method (1925). Standards were used to verify procedure accuracy.

Phytic acid was determined in duplicate by the reversed-phase high performance liquid chromatography (HPLC) method of Graf and Dintzis (1982), which measures phytic acid directly by the refractive index. Rather than using the suggested Soxhlet defatting step, 1-g samples (db) were weighed directly into 50-ml centrifuge tubes with teflon-lined screw caps, 25 ml of hexane added, the tubes shaken 4 hr on a Burrell wrist action shaker, centrifuged, and the hexane siphoned off by aspiration. The remaining hexane (approximately 1 ml) was evaporated under an N_2 stream using a Meyer N-evap analytical evaporator. Dowex 1-X8 (100–200 mesh) was used rather than AG 1-X8 (200–400 mesh), and columns were regulated with a peristaltic pump using an average flow rate of 0.7 ml/min. Instead of freeze-drying column aliquots, they were evaporated under N_2 at 35° C. The HPLC flow rate was 1.1 ml/min rather than 1.5 ml/min.

Statistical Analysis

Data were analyzed using a statistical analysis system with the Student-Newman-Keuls range test on means as described by the SAS Institute (1982). All means tests were run at the 5% probability level.

The data presented are the mean data for Crosby, Vic, Arizona-grown Mexicali, and California-grown Mexicali samples. The root mean square error was included to indicate data variability. The California-grown Mexicali was used for all photographs of samples.

RESULTS AND DISCUSSION

Bran-Semolina Blends

In mixograph studies of all combinations of semolina and bran, absorption requirements increased as the concentration of bran increased. Also, the development time, or the time required for the mixogram curve to reach maximum peak height, increased. This is illustrated in Figure 1. Although doughs are not fully developed when spaghetti is processed, this increase in development time indicated a need to lengthen the spaghetti processing premixing time for samples containing higher bran levels. Also, preliminary work showed uneven coloration in the 30% bran cooked spaghetti with a 3-min premix; the longer premix eliminated the uneven coloration.

Processed Spaghetti

The processed spaghetti is shown in Figure 2a. Checking refers to fissures or cracks in the spaghetti strands. Checking was greatest in the 10% bran samples, followed by the no-bran samples. As bran levels increased above 10%, checking decreased. The strands weakened by checking are more susceptible to shattering and breakage. Spaghetti diameter ranged from 1.56 to 1.66 mm and was not affected by the addition of bran at the levels studied. A decrease in diameter would have indicated bran weakened the gluten network, causing spaghetti to stretch as it dried on the rods. Individual spaghetti strands are shown in Figure 2b. Addition of bran caused a rough texture which made diameter difficult to measure.

Cooked Spaghetti

Cooking quality. Figure 3 shows the mean effect of bran incorporation on cooked weights. The 29.9 g cooked weight for the no-bran sample was significantly higher than for all samples with bran. The 10 and 15% bran levels and the 20 and 25% bran levels were not significantly different. The 30% bran mean weight (27.4 g) is slightly lower than is generally considered an adequate cooked weight, although Winston (1971) has reported cooked weights lower than 25 g acceptable for 100% semolina spaghetti. These data do not necessarily indicate a loss in water-holding capacity (not
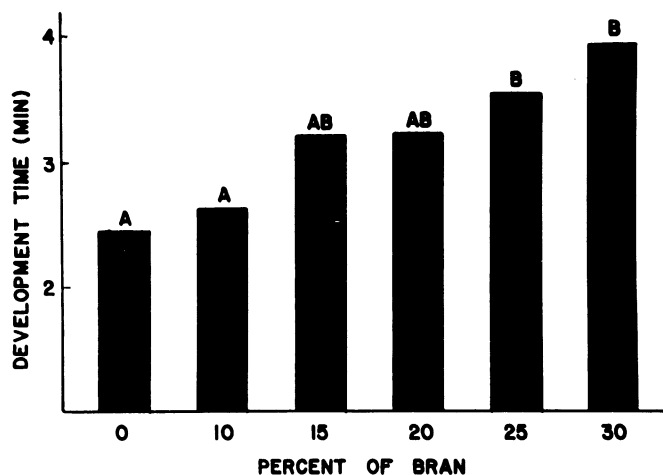
Fig. 1. Means test for mixogram development times of bran-semolina blends (*PR* = 0.95). Root mean square error = 0.49.

measured), because the bran-containing spaghetti did show higher cooking losses.

Firmness scores decreased as bran levels increased (Fig. 4). This may be caused by the diluting effect of bran on gluten cohesiveness. The 7.53 gcm mean for no-bran spaghetti was significantly higher than for all other samples. Bran levels of 10 and 15% were not significantly different, but the firmness score for the 20% level was significantly different from all other samples. Bran levels of 25 and 30% were not significantly different. All firmness scores were within our usual standards, but the 30% bran mean score (5.99 gcm) was borderline.

Bran-containing samples had higher cooking losses as shown in Figure 5. Means for cooking loss were significantly different and ranged from 5.9% for no-bran to 8.5% for 30% bran. By our departmental standards, less than 8% cooking loss is acceptable, although Winston (1971) reported losses up to 10.3% for 100% semolina spaghetti. Higher cooking losses in bran-containing
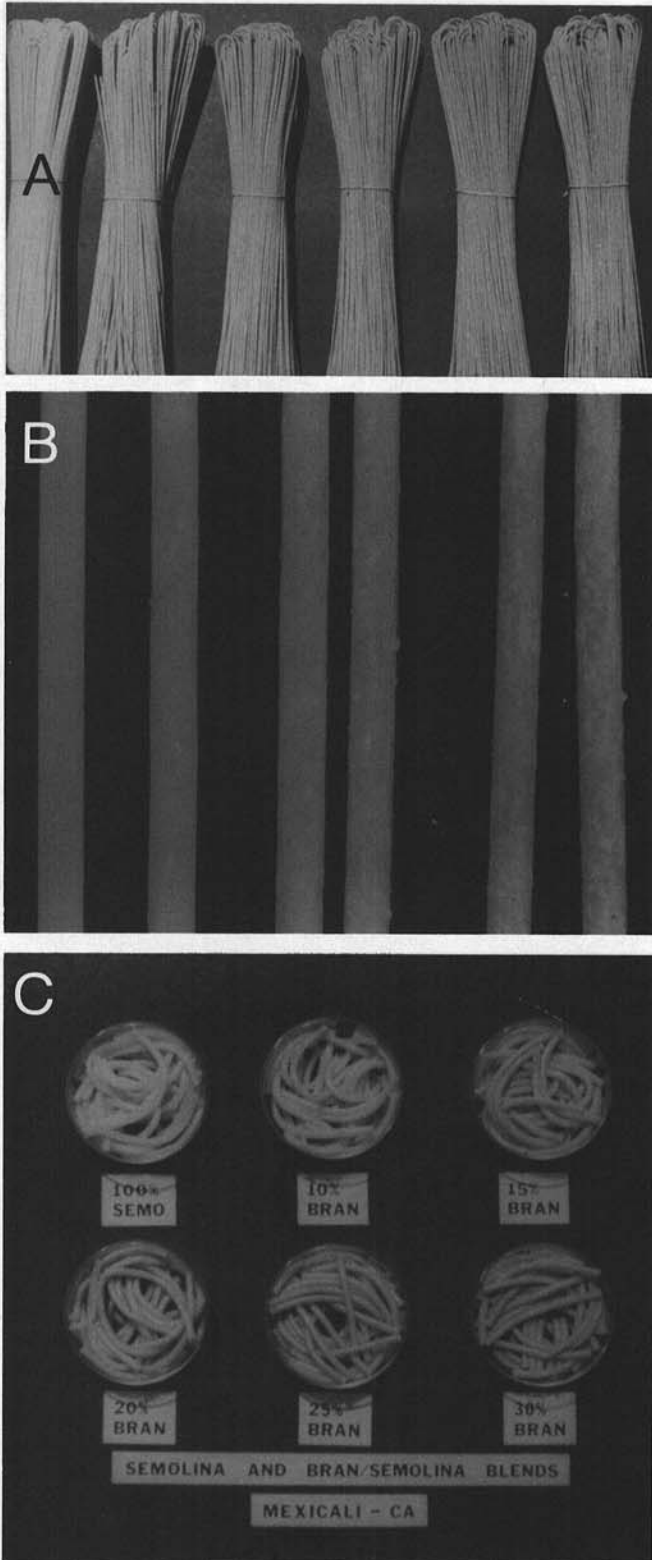

Fig. 2. Spaghetti processed from bran-semolina blends (0% bran at left, increasing to 30% bran at right): **A**, processed spaghetti; **B**, single spaghetti strands; and **C**, cooked spaghetti.
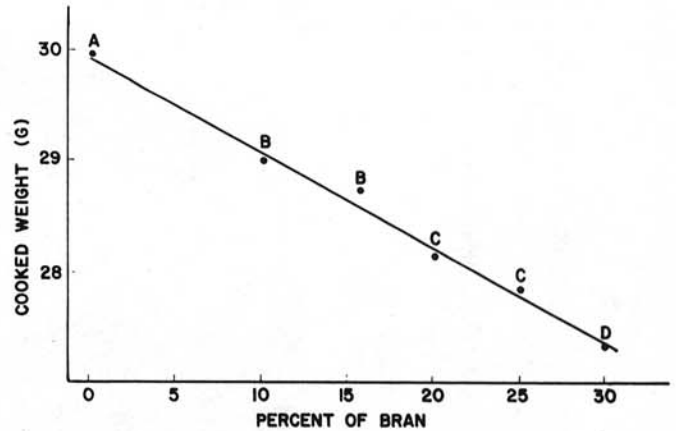

Fig. 3. Means test for mean spaghetti cooked weights ($PR = 0.95$). Root mean square error = 0.40.
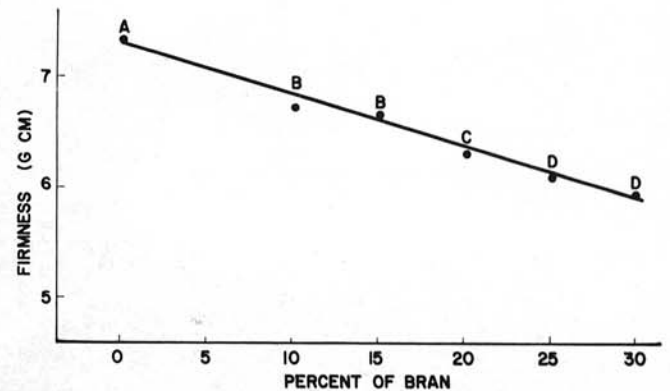

Fig. 4. Means test for mean spaghetti firmness ($PR = 0.95$). Root mean square error = 0.17.
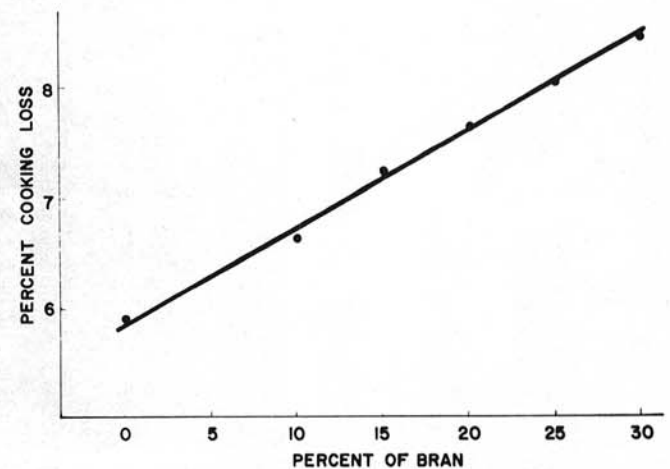

Fig. 5. Means test for mean spaghetti cooking losses. All cooking loss means were significantly different ($PR = 0.95$). Root mean square error = 0.21.

spaghetti may result from higher amounts of water-soluble components in bran (MacMasters et al 1978, Kunerth and Youngs 1984). Also, gluten dilution may enhance particle loss into the cooking water. Cooking loss indicates the degree of disintegration during cooking.

Sensory Evaluations

Cooked spaghetti samples are shown in Figure 2c. These products were not designed to replace traditional spaghetti, but to offer a broader spectrum of products for those people wishing to increase the level of fiber in their diets. The comprehensive results for the taste panel are shown in Figure 6. For flavor, texture, and color the no-bran spaghetti was rated significantly higher than all other samples. The spaghetti with 10% bran was second best. Differences in flavor and texture were indistinguishable between 15 and 20% bran or 25 and 30% bran samples. All color scores were significantly different. Color scores for 20–30% bran were less than half the no-bran spaghetti score. The analysis of variance showed that the sex of the panelists significantly affected their color responses ($PR > F = 0.01$, where F = variance ratio). Samples containing bran were scored higher for color by women than by men. However, male and female panelists rated flavor and texture consistently. There was no significant interaction between sex of the panelist and bran level evaluation or time of day and bran level across these three variables, which indicates the panelists rated parameters consistently. Bran levels were significantly different ($PR > F = 0.01$) for all three parameters, which agrees with the means test groupings shown in Figure 6.

Sensory evaluation scores were regrouped according to brown bread (whole wheat or bran bread) preferences of low, medium, or high. Panelists who preferred brown bread $\leq 1/3$ of the time were grouped into class one, those with preferences of $\geq 1/3$ but $\leq 2/3$ were in class two, and those with preferences of $> 2/3$ were grouped into class three. These divisions placed 33.3% of the panelists in class one, 35.3% in class two, and 31.4% in class three.

Figure 7 shows that as brown bread preference levels increased, flavor scores increased. The panelists in class three preferred the flavor of the 10% bran over the no-bran spaghetti. Texture preference by brown bread class is shown in Figure 8. Again, samples were scored higher by class three panelists. Two panelists commented that samples with higher bran levels had a gritty mouthfeel. The analysis of variance for flavor, texture, and color by brown bread class is shown in Table I. All three parameters were rated consistently as indicated by the insignificance of brown bread class and percent bran interaction terms. That brown bread class grouping cannot be used to predict color scores is indicated by the insignificance of the $PR > F$ value.
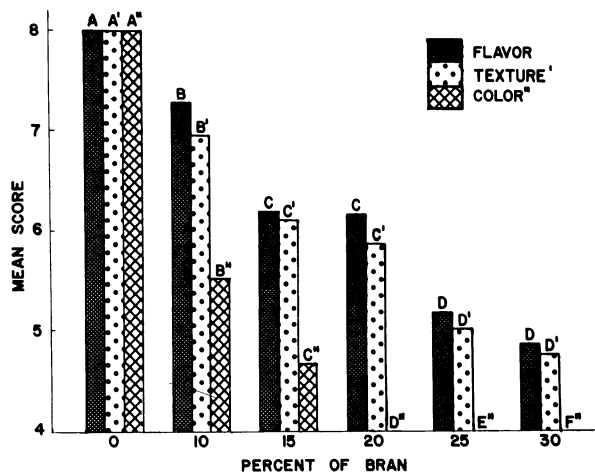

Fig. 6. Means test for comprehensive taste panel scores for flavor, texture and color ($PR = 0.95$). Flavor root mean square error $= 1.14$, texture root mean square error $= 1.34$, and color root mean square error $= 1.27$.
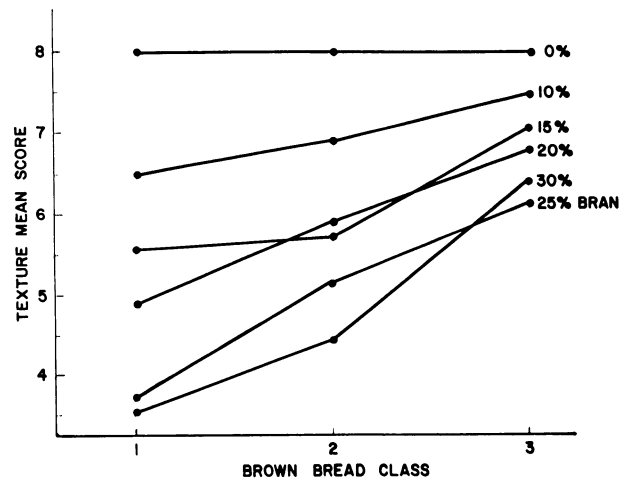

Fig. 7. Flavor preference by brown bread class.

Fig. 8. Texture preference by brown bread class.

TABLE I
Analysis of Variance for Flavor, Texture, and Color
by Brown Bread Class

		Flavor		Texture		Color	
Source	DF	SS[a]	$PR > F$	SS	$PR > F$	SS	$PR > F$
Brown bread class (A)	2	133.8036	0.0001	143.7175	0.0001	12.0962	0.1983
% Bran (B)	5	354.9422	0.0001	366.5961	0.0001	904.5257	0.0001
A * B	10	31.5504	0.5502	51.2746	0.3363	16.6232	0.9224
Error	329	1176.6857		1483.8699		1223.6223	
Corrected Total	346	1705.5650		2062.6003		2160.0568	
Root Mean Square Error		1.89		2.13		1.93	

[a]SS = sum of squares.

Protein

As expected, samples containing bran had higher protein levels. Table II shows the means for cooked spaghetti samples, which ranged from 12.3 to 13.5% protein; all means differed significantly. Table II also shows that protein levels increased from the unprocessed bran-semolina blends to the cooked spaghetti. This may be due to the loss of starch and other soluble materials during cooking. Compared to the no-bran level, adding bran at a 10% level did not significantly change the percent protein gain. No significant differences were observed in percent protein gain between the 15 and 25% bran levels and between the 20 and 30% levels. The greater percent protein gain in the cooked spaghetti (0 and 10% bran) is due to the combined effect of more water-soluble protein in bran (MacMasters et al 1978) and the percentage gain calculation. Note that percentage gain is a relative number, dependent upon the initial amount present. For example, if 10 parts are available and one additional part becomes available, there is a 10% gain. However, if 20 parts are available and one additional part becomes available, there is only a 5% gain.

Insoluble Dietary Fiber (Neutral Detergent Fiber)

The mean insoluble dietary fiber levels and fiber losses are shown in Figure 9. Means for insoluble dietary fiber in cooked spaghetti ranged from 1.09% for no-bran to 10.1% for 30% bran. All fiber means were significantly different from each other. Samples with higher bran levels lost a smaller percentage of fiber during cooking than samples with less bran. All means for fiber loss were significantly different. A 10% bran spaghetti would provide about 3.5 times more fiber in the diet than a no-bran spaghetti.

Minerals

Cooked spaghetti was assayed for calcium, phosphorus, zinc, iron, manganese, and magnesium, and the data are presented in Table III. These nutrients are essential minerals with well-defined biological roles. As expected, no-bran samples had the lowest mineral concentrations, which increased as bran levels increased. For the various levels of bran, all mineral concentration means were significantly different. Increase in mineral content for bran-containing samples was lowest for calcium, with about a 40% increase for the 10% cooked spaghetti and 100% increase for the 30% cooked spaghetti. Manganese increased the most, at 150% and almost 500% for the 10 and 30% cooked spaghetti, respectively.

The assay of the distilled water used for cooking detected only two of the minerals: 20 ppm Ca and 13 ppm Mg. These are insignificant in comparison to the sample concentrations.

Residue Water pH

The pH of the distilled water after boiling and cooling was 6.0. The mean pH of the residue water after cooking the spaghetti ranged from 5.6 to 6.2 (Table IV). Invariably, as bran levels increased, pH increased. The 30% bran pH mean of 6.2 was significantly higher than all other samples. Neither the pH values for residue water of 20 and 25% bran spaghetti nor the means for 15 and 20% bran residue water pH were significantly different. Residue water pH means for 0 and 10% bran were significantly lower than all other samples.

Comparison of Minerals in Unprocessed Bran-Semolina Blends and Cooked Spaghetti

The next series of figures (10–12) shows the changes in mineral content from unprocessed bran-semolina blends to cooked spaghetti. All means of mineral changes were significantly different.

Magnesium and calcium losses are shown in Figure 10. The no-bran spaghetti sustained a magnesium loss of about 25%. As spaghetti bran concentrations increased, a plateau was reached where magnesium loss stabilized at about 5% for 25 and 30% bran.

The same trend was observed for calcium, with the 0% bran having about a 40% loss and 25 and 30% bran spaghetti only about

TABLE II
Protein Content (%)[a] of Cooked Spaghetti and Protein Change (%) from Unprocessed Bran-Semolina Blends to Cooked Spaghetti

Bran[b] (%)	Mean Protein Content[c] of Cooked Spaghetti (%)	Protein Increase[c] (%)
0	12.3 f	2.8 a
10	12.7 e	2.7 a
15	12.9 d	1.5 b
20	13.0 c	0.9 c
25	13.3 b	1.5 b
30	13.5 a	0.6 c
Root mean square error	0.04	0.28

[a] 14% moisture basis.
[b] Forty-eight samples were analyzed per bran level.
[c] Means with the same letter are not significantly different ($PR = 0.95$).

TABLE III
Mineral Content[a] of Cooked Spaghetti

Bran[b] (%)	Ca (ppm)	P (%)	Zn (ppm)	Fe (ppm)	Mg (ppm)	Mn (ppm)
0	274.0 a[c]	1.18 a	21.4 a	13.4 a	261 a	5.7 a
10	374.4 b	1.74 b	37.1 b	28.1 b	612 b	14.5 b
15	417.5 c	2.23 c	39.7 c	41.5 c	833 c	20.2 c
20	442.1 d	2.50 d	45.1 d	47.9 d	1009 d	24.4 d
25	486.6 e	2.84 e	52.2 e	56.2 e	1250 e	29.5 e
30	534.4 f	3.22 f	58.1 f	60.9 f	1455 f	34.4 f
Root mean square error	18.92	0.04	1.12	1.74	24.37	0.80

[a] Dry basis.
[b] Forty-eight samples were analyzed per bran level.
[c] Means with the same letter are not significantly different ($PR = 0.95$).

TABLE IV
pH of Cooked Spaghetti Residue Water

Bran (%)	Mean pH[a]
0	5.6 e
10	5.9 d
15	6.0 c
20	6.1 bc
25	6.1 b
30	6.2 a
Root mean square error	0.05

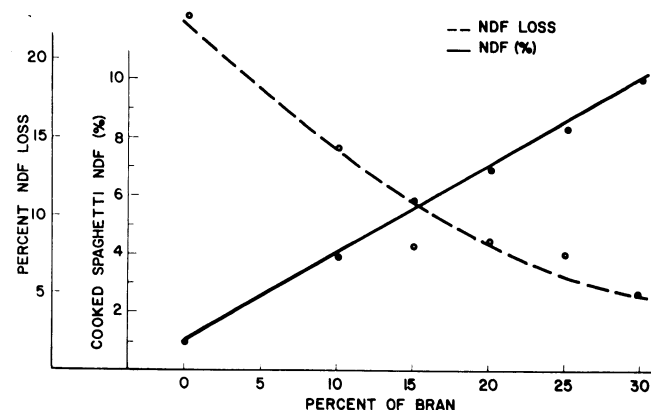[a] Means with the same letter are not significantly different ($PR = 0.95$).

Fig. 9. Means test for insoluble dietary fiber (NDF) percent in cooked spaghetti and percent NDF loss ($PR = 0.95$). All means for NDF content and NDF loss were significantly different, root mean square error = 0.23 and 0.18, respectively.

a 10% loss. Dietary fiber has been reported to bind calcium, so less calcium loss in cooking would be expected at higher bran levels (James et al 1978). At the pH values of the residue water, calcium, magnesium, and their derivatives would be less soluble for the higher bran samples. Jackman and Black (1951) reported calcium phytate bran derivatives to be highly soluble for pH values less than 6.2 and magnesium phytate derivatives highly soluble below pH 9.0. Clydesdale and Camire (1983) found almost twice as much calcium and magnesium were bound at pH 6.8 than pH 5.0 (25% calcium bound and 10% magnesium bound).

Figure 11 shows that manganese and phosphorus retention were lower for samples with bran present. The no-bran samples had a 9% increase in manganese, whereas samples with added bran had variable losses ranging from 0.8 up to 5.7%. Vohra et al (1965) reported that manganese would form a fairly stable complex with phytate (more stable than calcium-phytate complexes). Thus, it is possible that these losses are primarily in the form of manganese-phytate complexes.

For phosphorus, no-bran samples had a 9.6% loss, which increased to 22.2% loss for the 30% samples. Durum bran contains about 10 times the phytic acid content of seminola (Tabekhia and Donnelly 1982), thus a certain portion of the loss may be accounted for by phytate solubilization in the cooking water. Toma and Tabekhia (1979) found phytic acid content decreased by about 1/3 from uncooked to cooked rice.

The no-bran spaghetti had about a 16% iron loss (Fig. 12), but with the addition of 10% bran, a 5% gain occurred. Other spaghetti samples showed about a 26% increase. Reilly (1979) found iron solubility minimal at pH 7.6, with a 30 to 40% increase in solubility at pH 4.3 for bran and bread. Clydesdale and Camire (1983) reported soy flour at pH 5 bound only about 70% of the iron, whereas 100% was bound at pH 6.8. This may help explain the iron losses in the no-bran spaghetti.

Zinc percentage gains were greatest for the 0 and 10% bran samples. The other samples had 23–30% zinc gains. Clydesdale and Camire (1983) found more zinc bound at pH 5 than at pH 6.8 for soy flour, which agrees with the trend observed for zinc retention in our samples. Rendleman and Grobe (1982) reported similar results for bran, with a gradual increase in solubility up to pH 6.5; above pH 6.5 an abrupt increase in solubility was reported. Vohra et al (1965) reported that at pH 7.4 zinc forms the most stable phytate complex for the mutual minerals studied ($Zn > Mn > Fe^{+3} > Ca$).

Phytic Acid

A typical HPLC chromatogram for phytic acid is shown in Figure 13. Graf and Dintzis (1982) did not detect a negative peak.
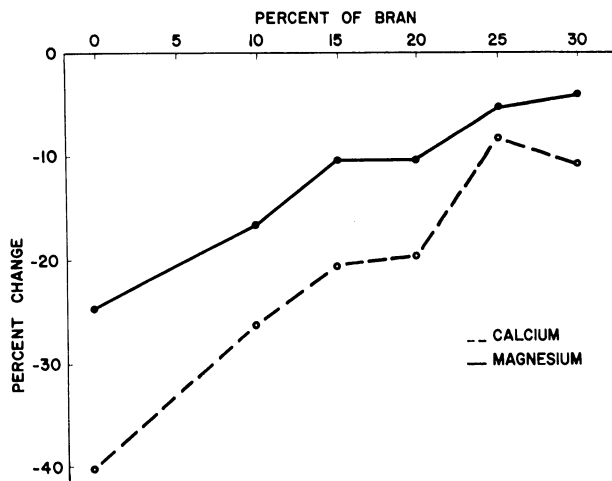

Fig. 10. Calcium and magnesium losses (%) for cooked spaghetti. All losses were significantly different for both minerals ($PR = 0.95$). Root mean square error = 0.01 for calcium and 0.04 for magnesium.
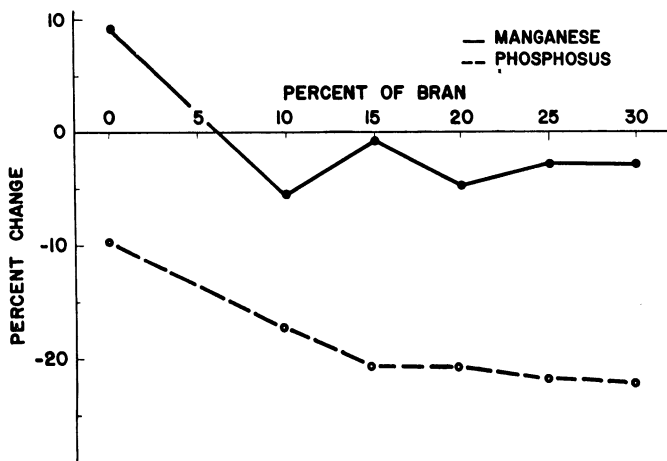

Fig. 11. Manganese and phosphorus changes (%) for cooked spaghetti. All mean changes were significantly different for both minerals ($PR = 0.95$). Root mean square error = 0.02 for manganese and 0.01 for phosphorus.
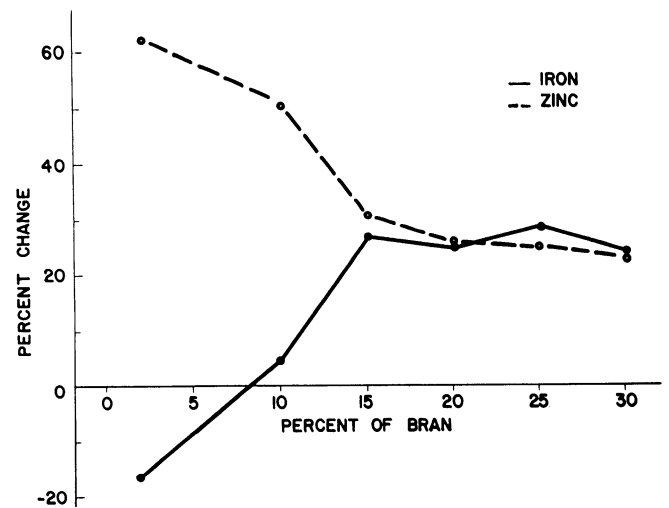

Fig. 12. Iron and zinc overall gains (%) for cooked spaghetti. All mean changes were significantly different for both minerals ($PR = 0.95$). Root mean square error = 0.01 for iron and 0.02 for zinc.
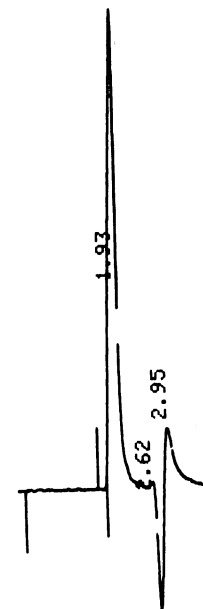

Fig. 13. High performance liquid chromatogram of cooked spaghetti sample. The peak at 1.93 min denotes phytic acid.
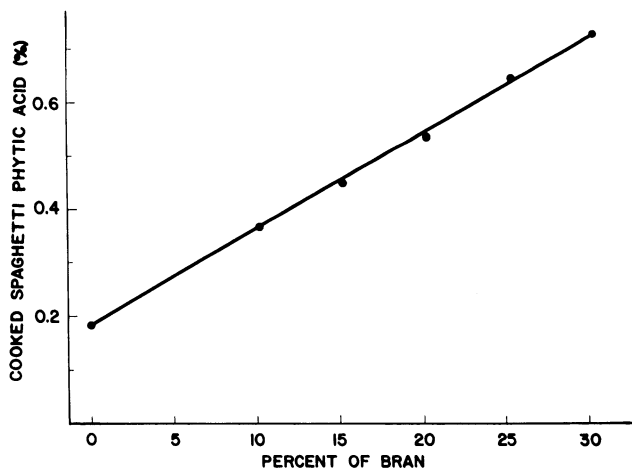
Fig. 14. Means test for mean phytic acid content of cooked spaghetti ($PR = 0.95$). All means were significantly different, and the root mean square error was 0.02.

With an older column, previously used in several other analyses, we obtained chromatograms similar to those of Graf and Dintzis and suggest endcapping (e.g., $-C_{18}$–lipid/protein/etc.) may have prevented detection of the negative peak. The first peak in the chromatogram is phytic acid (1.93 min); the negative peak may be a vacancy or inositol peak, and the final peak is a common salt peak.

Samples containing bran had higher phytic acid levels. Mean phytic acid levels in the cooked spaghetti samples ranged from 0.182% to 0.739% (Fig. 14). All means for phytic acid were significantly different. Phytic acid content decreased from the bran-semolina blends to the cooked spaghetti; losses ranged from 24.6 to 27.7% and were not significantly different. Toma and Tabekhia (1979) reported about 33% phytate solubilization into the cooking water for rice. Phytate may be lost by solubilization into the cooking water, and native phytase may hydrolyze phytate during spaghetti processing.

A 5-oz. serving of cooked spaghetti (calculated from 2 oz. of dry cooked spaghetti) of 10% bran spaghetti would contain about 0.21 g phytic acid. This level is not high enough to cause mineral deficiencies if a serving of 10% bran spaghetti were eaten daily. After four to eight weeks, three human subjects consuming 1.02–1.22 g native phytic acid per day showed positive balances for calcium, magnesium, and iron (Walker et al 1948).

CONCLUSION

Sensory analyses of spaghetti containing bran showed a 10% bran spaghetti was preferred by 1/3 of the panelists; those panelists preferred brown-type breads 2:1 over white bread. The product had acceptable cooking quality, improved nutritional quality, and a phytic acid level low enough to circumvent a health concern for consumers in the United States.

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