Protein-Enriched Spaghetti Fortified with Corn Gluten Meal

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Spaghetti was prepared by replacing either 5 or 10% semolina or farina with corn gluten meal, a high-protein fraction from the wet milling of corn, to increase the protein content of pasta. Spaghetti fortified with corn gluten meal had a similar cooked weight and cooking loss but was less firm compared with the control. The overall flavor quality score of the spaghetti decreased with the increasing additions of either water-washed, water/ethanol-washed or regular corn gluten meal because of the higher intensity of the fermented flavor. Spaghetti with acceptable quality can be prepared with 5% water/ethanol-washed corn gluten meal, thereby improving its nutritional value while providing an additional market for corn gluten meal.

Keywords: *Spaghetti; corn gluten meal; protein; sensory evaluation*

INTRODUCTION

There is an increasing interest among vegetarians and health-conscious people to consume protein-enriched foods from plant sources, which have no cholesterol and low saturated fat content in general. The annual per capita consumption of pasta varies among countries around the world. Italy had the highest consumption of pasta at 28.3 kg/person/year, Ireland had the lowest at 1.0 kg/person/year, and the quantity of pasta sold in the United States was >404 million kg in 1998 (*1*). Although durum wheat is usually the raw material of choice to make pasta, spring wheat, other cereals, or legumes can also be used (*2*). Spaghetti can be supplemented with soy flour or its protein concentrate (*3*−*6*), fish protein concentrate (*7*, *8*), legumes and their protein concentrates (*9*, *10*), and corn distillers dried grains (*11*). In general, the supplementation of pasta with higher protein ingredients increased nutritional properties but had negative effects on the texture, flavor, or acceptability of the resulting products. Corn gluten meal is the high-protein fraction from the wet milling of corn to yield starch, oil, protein, and fiber. The unpleasant taste of corn gluten meal is the main reason it has not been used in food. Processing by supercritical carbon dioxide extraction or hexane/ethanol extraction significantly improved corn gluten meal flavor (*12*). This paper reports the composition, property, and sensory evaluation of protein-enriched spaghetti fortified with corn gluten meal (regular, water-, and water/ethanol-washed to reduce undesirable flavor).

MATERIALS AND METHODS

Corn gluten meal was from Pekin Energy Co. (Pekin, IL). The meal was ground to pass through a sieve with 246 μm square openings. The pH of as-received corn gluten meal was 3.9. A preliminary study indicated that corn gluten meal had a better flavor at pH 7−8 than at pH 4. Also, water-washed corn gluten meal had a less undesirable flavor than regular corn gluten meal. Ethanol washing of water-washed corn gluten meal further improved flavor. Water-washed (W) corn gluten meal was prepared by adjusting the pH from 3.9 to pH 7.2 with 40% sodium hydroxide and then washing in water (1:15 w/v, three times) at room temperature. After the mixture had been magnetically stirred for 20 min and the solids allowed to settle under gravity, the supernatant was removed by aspiration. The wet solids from the last extraction were filtered in a Büchner funnel with Whatman No. 54 filter paper to remove excess water and then dried in a forced air oven overnight at 90 °C. Water/ethanol-washed corn gluten meal (W/E) was prepared by boiling corn gluten meal in water (1:10 w/v) for 90 min, adjusting the pH of the corn gluten meal with 40% sodium hydroxide to 8.0, and washing three times with water. The wet solids after the third washing with water were filtered and dried as before. The dried solids were then washed with absolute ethanol (1:10 w/v) at room temperature for 20 min and then washed again with ethanol (1:5 w/v) and allowed to dry in a hood overnight.

Preparation of Spaghetti. Durakota, a durum semolina from the North Dakota Mill (Grand Forks), was used as a control. Semolina was hydrated to 31% moisture content in a batchwise process. Hydrated semolina was extruded into spaghetti using a DeMaco Laboratory extruder as described by Walsh et al. (*13*). Spaghetti was dried in air for 30 min and then at 40 °C for 18 h at a relative humidity decreasing linearly from 95% to room humidity. The diameter of extruded spaghetti was 1.6 mm. Fortified spaghetti was prepared by replacing either 5 or 10% of the semolina weight with either corn gluten meal, water-washed corn gluten meal, or water/ethanol-washed corn gluten meal. Farina that was milled from spring wheat was substituted for semolina in one experiment. Spaghetti was prepared in duplicate for each formulation. In summary, three separate experiments were conducted in 1998 and 1999 to correspond with the taste panel evaluation.

Elasticity and breakage of uncooked pasta were measured by using a TA.XT2 texture analyzer (Texture Technologies Corp., Scarsdale, NY). A mixograph (National Manufacturing, Lincoln, NE) was used to measure the dough strength of the semolina/corn gluten meal blends. High mixogram ratings

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Table 1. Composition (Percent Dry Basis) and Properties of Semolina (S) and Spaghetti with and without Water-Washed (W) or Regular (R) Corn Gluten Meal (C)[a]

								spaghetti			protein (N × 5.7, %) of freeze-dried samples		
blend, S/C	protein N × 5.7	ash	blend color b	blend color L	mixogram rating	pasta color b	pasta color L	cooked wt, g	cooking loss, %	firmness, g·cm	blend	processed pasta	cooked spaghetti
100/0	13.3 E	0.72 C	31.8 E	81.8 A	5 A	41.4 A	60.6 A	29.9 B	6.6 B	5.7 A	13.0 D	12.8 C	14.1 C
95/5W	16.4 C	0.68 D	32.8 C	75.3 C	4 B	37.3 C	47.9 B	31.2 A	6.6 B	4.7 B	16.0 C	15.3 B	16.8 B
90/10W	19.2 A	0.68 D	33.9 A	71.9 E	3 C	31.3 D	42.0 D	30.5 AB	6.1 B	4.3 BC	18.7 A	17.8 A	19.2 A
95/5R	15.7 D	0.79 B	32.5 D	77.0 B	2 D	40.1 B	48.1 B	31.1 AB	6.6 B	4.0 C	15.4 C	15.4 B	16.8 B
90/10R	18.0 B	0.90 A	33.6 B	74.3 D	1 E	36.3 C	44.1 C	31.7 A	7.3 A	3.3 D	17.8 B	17.3 A	19.1 A

[a] Values followed by different letters in a column are significantly different ($P < 0.05$) for duplicate experiments.

indicate strong dough characteristics, and low ratings indicate weak characteristics.

Cooking Quality. For cooking quality, 10 g of spaghetti was boiled in 300 mL of water for 12 min. The spaghetti was purposely overcooked to express the greatest variation in cooked weight, cooking loss, and firmness. Cooked weight was determined after the cooked spaghetti had been drained. Cooking loss was calculated from the dried residue of the cooking water, expressed as percent of original spaghetti weight. Firmness is the work (g·cm) required to cut a strand of cooked spaghetti and was measured with the TA.XT2 texture analyzer.

Color. The color of semolina, uncooked pasta, and cooked pasta was measured with a Minolta CR310 (Ramsey, NJ) colorimeter. Expression of brightness of the product corresponds to the *L* value (white = *L* value of 100, black = *L* value of 0), expression of red-green corresponds to the *a* value, and expression of yellow-blue corresponds to the *b* value. A positive *a* value indicates greater red chromacity, and a positive *b* value indicates greater yellow chromacity.

Sensory Evaluations. Water was filtered through activated charcoal to remove flavors. Preliminary cooking tests were conducted to determine the amount of time needed to cook spaghetti samples to the desired degree of firmness that is appealing to the consumer. All spaghetti products were cooked for 10 min. Dry spaghetti (50 g) was cooked in 1 L of carbon-filtered boiling water for 10 min, and each panelist was served 10 g of spaghetti without sauce in a 50 mL glass beaker covered with a watch glass. The covered beaker was set in an aluminum block heated to 27 °C and presented to panelists in a randomized order. Eight trained and experienced analytical sensory panelists rated the spaghetti for overall quality on a scale of 1−10, with 1 = poor and 10 = excellent, and for flavor intensities of cereal/grain flavor and fermented flavor on a scale of 0 = none and 10 = strong. A flavor intensity rating of 1−3 is considered to be weak. Panelists were given samples of the corn gluten meal and wheat flour in training sessions for the fermented and cereal/grain attributes. Sensory panels evaluated only the flavor of the spaghetti. Texture and color of spaghetti were measured instrumentally. There are no industry standards for rating the acceptable flavor of spaghetti. Standards for acceptable flavor quality used by our panel include 7−8, good (typical spaghetti flavor, no off-flavors); 5−6, fair (less desirable flavor); and <4, poor (unacceptable flavor) (*14*). Fermented flavor intensity <3 is desired.

Analyses. Nitrogen was determined according to the combustion method with a Leco analyzer (St. Joseph, MI). Protein was calculated from nitrogen × 5.7. Ash was calculated by heating the sample to 600 °C for 2 h and weighing the residue. Moisture was measured by weight loss by heating the sample in a convection oven at 130 °C for 1 h. Details of these procedures for nitrogen, ash, and moisture were described in AACC Approved Methods (*15*).

The samples were hydrolyzed by 6 N HCl for 4 h at 145 °C (*16*), and the amino acids were determined by cation exchange chromatography in a Beckman 6300 amino acid analyzer (Beckman Instruments, Inc., San Ramon, CA). Methionine and cystine were oxidized by performic acid before hydrolysis (*17*). Tryptophan was measured according to a colorimetric method after enzymatic hydrolysis by Pronase (*18*, *19*). Duplicate hydrolyses were carried out for each sample, and amino acids were determined for each hydrolysate.

The data were treated by analysis of variance. Tukey's Studentized range test was used to determine significant differences from duplicate or triplicate experiments ($P < 0.05$; *20*).

RESULTS AND DISCUSSION

Composition and Properties of Spaghetti with Water-Washed Corn Gluten Meal. Regular corn gluten meal contained 3.00% ash and 66.3% protein (N × 5.7), all on a dry basis. Water-washed corn gluten meal contained 0.40% ash and 74.2% protein. Water- and ethanol-washed corn gluten meal had 0.34% ash and 78.5% protein. There was a large decrease in ash content and an increase in protein content after water washing of regular corn gluten meal. An additional increase in protein content resulted when the water-washed corn gluten meal was further washed with ethanol. Table 1 shows that protein content increased 2.3−2.4% with each 5% substitution of regular corn gluten meal for semolina and 2.8−3.1% with each 5% substitution of water-washed corn gluten meal for semolina. Ash content decreased in blends fortified with either 5 or 10% water-washed corn gluten meal but increased in blends with either 5 or 10% regular corn gluten meal.

Semolina blend color and pasta color (Table 1) were darker (lower *L* value) with increasing amounts of corn gluten meal (both regular and water-washed), probably as a result of the darker color of corn gluten meal compared with semolina. There was also a difference in blend color between the regular and water-washed corn gluten meal at the 5 and 10% levels. The intensity of yellow color in pasta decreased (lower *b* value) with increasing amounts of corn gluten meal. This could be attributed to the degradation of yellow pigment during the drying cycle.

The cooked weight of spaghetti increased with substitution of corn gluten meal for semolina, but the increase was not significant ($P > 0.05$) for spaghetti with 10% water-washed corn gluten meal or with 5% regular corn gluten meal (Table 1). Cooking loss of spaghetti was unchanged when corn gluten meal was added except the loss was higher for spaghetti with 10% regular corn gluten meal. Normally, the cooked weight is ∼3 times the dry weight of the spaghetti, and the cooking loss should not exceed 7−8% of the dry weight (*21*). The cooked weight of spaghetti in Table 1 was normal, and the cooking loss was acceptable. The firmness of cooked spaghetti was lower with the addition of corn gluten meal, and the decrease in firmness was more pronounced with regular corn gluten meal than with water-washed corn gluten meal.

Table 2. Composition (Percent Dry Basis) and Property of Semolina (S), Farina (F), and Spaghetti Fortified with Water/Ethanol-Washed Corn Gluten Meal (W/E)[a]

			semolina color			uncooked pasta color		
blend	protein (N × 5.7)	ash	*L*	*a*	*b*	*L*	*a*	*b*
S/W/E								
100/0	14.1 D	0.86 A	81.7 B	−3.8 F	32.8 B	61.6 A	2.1 D	43.0 A
95/5	17.4 C	0.82 B	75.8 D	−2.0 E	33.5 AB	52.6 C	6.1 B	41.8 A
90/10	20.6 B	0.79 B	72.7 F	−1.2 B	34.5 A	46.3 D	8.1 A	36.9 B
F/W/E								
100/0	13.7 E	0.41 C	83.2 A	−1.7 D	13.2 E	56.1 B	2.7 C	26.3 D
95/5	17.7 C	0.39 D	77.6 C	−1.4 C	21.0 D	51.5 C	6.1 B	36.9 B
90/10	22.4 A	0.36 D	74.4 E	−0.7 A	26.8 C	45.7 D	8.2 A	35.2 C

[a] Values followed by different letters in a column are significantly different ($P < 0.05$) for duplicate experiments.

Mixogram ratings (Table 1) indicated that blending with corn gluten meal significantly decreased dough strength, especially with the addition of regular corn gluten meal. Dough strength is important to maintain the structural integrity of the pasta. However, all blends were processed successfully without complication.

The protein content of the freeze-dried samples (Table 1) increased with increasing amounts of corn gluten meal in the blend, processed pasta, and cooked spaghetti. The cooked spaghetti had the highest protein content compared with those of semolina and processed pasta at 0, 5, and 10% of substitution of regular or water-washed corn gluten meal. A higher protein content in the cooked spaghetti relative to protein in the processed pasta would suggest greater loss of starch components during the cooking process.

Composition and Properties of Spaghetti with Water/Ethanol-Washed Corn Gluten Meal. Taste panel evaluation of spaghetti with water-washed corn gluten meal indicated the overall flavor quality score was poor (not shown). Therefore, an additional ethanol wash of water-washed corn gluten meal was attempted to improve the overall flavor. Water/ethanol-washed corn gluten meal had 0.34% ash and 78.5% protein, all on dry basis. Table 2 shows an increase of 3.2−3.3% protein content for semolina with a 5% increase of water/ethanol-washed corn gluten meal and an increase of 4.0−4.7% protein content for farina with a 5% increase of water/ethanol-washed corn gluten meal. There was a decrease in ash content as water/ethanol-washed corn gluten meal was substituted for semolina or farina at the 5 and 10% levels except the decrease in ash content was not significant ($P > 0.05$) for farina with 5% of water/ethanol-washed corn gluten meal.

Semolina color became darker (lower *L* value) and more yellow (higher *b* value) as water/ethanol-washed corn gluten meal was substituted for semolina or farina (Table 2), except the change in *b* value was not significant ($P > 0.05$) between semolina (100%) and 95% semolina plus 5% water/ethanol-washed corn gluten meal. Uncooked pasta color became darker (lower *L* value) as water/ethanol-washed corn gluten meal was substituted for semolina or farina. The uncooked pasta color became less yellow (lower *b* value) when 10% water/ethanol-washed corn gluten meal was substituted for semolina but more yellow when water/ethanol-washed corn gluten meal was substituted for farina. All *a* values in Table 2 were close to zero, although there were significant differences ($P < 0.05$) statistically.

The elasticity and breakage of uncooked pasta were tested with the TA.XT2 texture analyzer (data not shown). Elasticity was unchanged for uncooked pasta with 5 or 10% water/ethanol-washed corn gluten meal in semolina but increased slightly for uncooked pasta with 10% water/ethanol-washed corn gluten meal in farina. Breakage of uncooked pasta was unchanged with 5 or 10% water/ethanol-washed corn gluten meal in semolina or in farina.

Table 3. Property of Cooked Pasta from Semolina (S), Farina (F), and Water/Ethanol Washed-Corn Gluten Meal (W/E)[a]

	cooked pasta color			firmness,	cooked	cooking
blend	*L*	*a*	*b*	g·cm	wt, g	loss, %
S/W/E						
100/0	72.3 A	−3.5 F	18.1 D	8.2 A	31.1 BC	6.8 AB
95/5	66.8 B	−1.4 D	23.9 BC	7.4 B	30.7 C	6.1 C
90/10	64.4 C	−0.4 B	25.5 B	6.4 C	31.2 BC	6.9 A
F/W/E						
100/0	65.1 C	−2.1 E	10.1 E	5.1 D	32.2 A	6.3 BC
95/5	61.8 D	−1.1 C	22.8 C	4.5 E	32.0 AB	6.6 ABC
90/10	60.2 E	0.0 A	27.5 A	4.3 E	31.3 ABC	6.5 ABC

[a] Values followed by different letters in a column are significantly different ($P < 0.05$) for triplicate experiments.

Cooked pasta color became darker (lower *L* value) and more yellow (higher *b* value) as water/ethanol-washed corn gluten meal was substituted for semolina or farina (Table 3). The firmness of cooked pasta was decreased as water/ethanol-washed corn gluten meal was substituted for semolina or farina, and cooked pasta from farina was less firm compared with that from semolina. The cooked weight of pasta was unchanged when water/ethanol-washed corn gluten meal was substituted for semolina or farina, and the cooked weight of pasta made from farina and water/ethanol-washed corn gluten meal was higher than that of pasta made from semolina and water/ethanol-washed corn gluten meal at the 0 and 5% levels. Cooking loss was unchanged when water/ethanol-washed corn gluten meal was substituted for semolina or farina except the cooking loss was lower for pasta made from 5% water/ethanol-washed corn gluten meal and 95% semolina compared with pasta made from 100% semolina. Differences in blends made with semolina and farina reflect differences in yellow pigmentations and differences in protein content and quality.

Table 4 shows the amino acid composition of spaghetti made from 100% semolina and from 95% semolina plus 5% water/ethanol-washed corn gluten meal. There were significant increases ($P < 0.05$) in almost all amino acids when 5% corn gluten meal was added to 95% semolina. In particular, the essential amino acids threonine, cystine, methionine, valine, isoleucine, leucine, lysine, tyrosine, phenylalanine, and histidine were all significantly higher ($P < 0.05$) in spaghetti made from 95% semolina plus 5% water/ethanol-washed corn gluten meal compared with regular spaghetti. Table 2 shows that the protein content increased from 14.1 to 17.4% when 5% water/ethanol-washed corn gluten meal was substituted for 5% semolina in spaghetti. Tables 2 and

Table 4. Amino Acid Composition of Spaghetti from 100% Semolina and 95% Semolina plus 5% Corn Gluten Meal (Water/Ethanol-Washed)[a]

amino acid, % dry basis	spaghetti from 100% semolina	spaghetti from 95% semolina + 5% corn gluten meal
aspartic acid	0.69 B	0.90 A
threonine	0.43 B	0.55 A
serine	0.71 A	0.88 A
glutamic acid	5.46 B	6.84 A
proline	1.86 B	2.14 A
glycine	0.49 B	0.58 A
alanine	0.50 B	0.83 A
half-cystine	0.40 B	0.47 A
valine	0.66 B	0.81 A
methionine	0.29 B	0.39 A
isoleucine	0.56 B	0.67 A
leucine	1.17 B	1.79 A
tyrosine	0.39 B	0.52 A
phenylalanine	0.81 B	1.04 A
histidine	0.37 B	0.43 A
lysine	0.36 B	0.41 A
arginine	0.60 B	0.70 A
tryptophan	0.21 A	0.21 A

[a] Values followed by different letters in a row are significantly different ($P < 0.05$) for duplicate experiments.

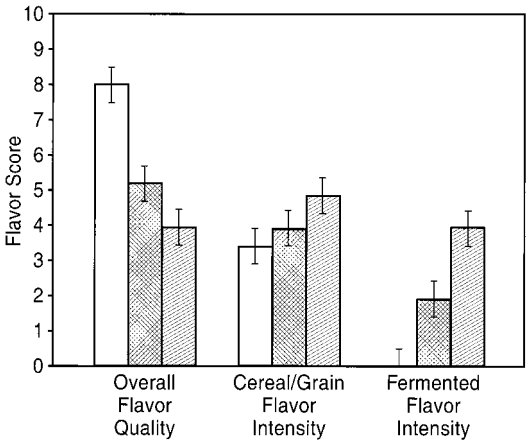

Figure 1. Flavor scores for spaghetti (semolina, 1999) with and without water/ethanol-washed corn gluten meal: (open bars) control; (cross-hatched bars) 5% water/ethanol-washed corn gluten meal; (slashed bars) 5% regular corn gluten meal. There is significant difference when the error bars do not overlap.

4 show that spaghetti fortified with 5% water/ethanol-washed corn gluten meal had both higher protein content and higher essential amino acids content and, therefore, had improved nutritional value compared with regular spaghetti.

Sensory Evaluation of Spaghetti with Corn Gluten Meal. Figure 1 shows there were significant differences in overall quality scores between any two spaghettis prepared with semolina in 1999. The control was rated as highest in quality with quality scores decreasing with the addition of 5% water/ethanol-washed corn gluten meal. Lowest quality was for the spaghetti made with 5% regular corn gluten meal. Intensities of cereal/grain and fermented flavors increased with the additions of 5% water/ethanol-washed or regular corn gluten meal; only the difference between control and 5% regular corn gluten meal was significant. Differences in fermented intensity levels between any two samples were significant.

For spaghetti prepared with semolina in 1998, panelists found significant differences in overall quality scores between any two spaghettis (Figure 2). The control was rated as highest in overall quality with quality scores decreasing with increasing percent of water/ethanol-washed corn gluten meal. No significant difference was found in the cereal/grain flavor intensity between control and 5% water/ethanol-washed corn gluten meal, although there was significant difference between control and 10% water/ethanol-washed corn gluten meal. Significant differences in fermented flavor intensity were found between any two spaghettis. The highest fermented flavor intensity (slightly above 3) was still considered to be weak.

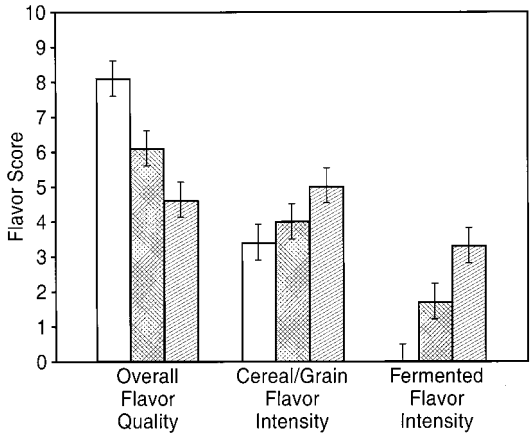

Figure 2. Flavor scores for spaghetti (semolina, 1998) with and without water/ethanol-washed corn gluten meal: (open bars) control; (cross-hatched bars) 5% water/ethanol-washed corn gluten meal; (slashed bars) 10% water/ethanol-washed corn gluten meal. There is significant difference when the error bars do not overlap.

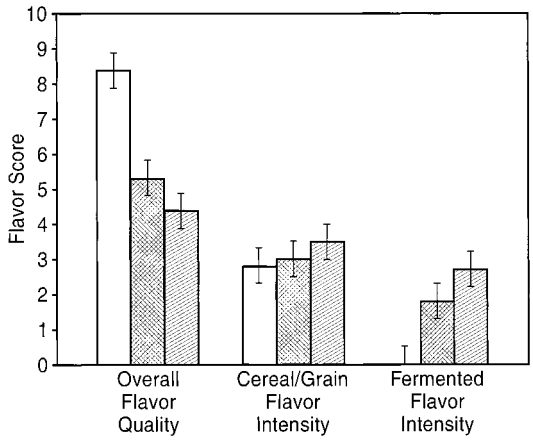

Figure 3. Flavor scores for spaghetti (farina, 1998) with and without water/ethanol-washed corn gluten meal: (open bars) control; (cross-hatched bars) 5% water/ethanol-washed corn gluten meal; (slashed bars) 10% water/ethanol-washed corn gluten meal. There is significant difference when the error bars do not overlap.

For spaghetti prepared with farina in 1998, panelists found significant differences in the overall quality between the control and both samples with water/ethanol-washed corn gluten meal (Figure 3) but not between 5 and 10% water/ethanol-washed samples. The control was rated as highest in quality with quality scores decreasing with higher percentage of water/ethanol-washed corn gluten meal. Significant difference was noted for fermented flavor between control and both samples with 5 and 10% water/ethanol-washed corn gluten meal but not between 5 and 10% water/ethanol-

washed corn gluten meal. However, the highest fermented flavor intensity in Figure 3 was still weak (below 3).

Spaghetti with acceptable overall flavor quality was made with 5% water/ethanol-washed corn gluten meal. The protein content of uncooked spaghetti increased by 23% (from 14.1 to 17.4%) and 29% (from 13.7 to 17.7%), respectively, when semolina and farina were blended with 5% water/ethanol-washed corn gluten meal. Johnsen and Dupree (*22*) reported the trained panelists could discriminate among some flavor attributes but untrained laboratory personnel representing the average consumer were not able to discern differences. Our spaghetti was tasted without any salt or sauce in order not to mask any off-flavor. Because spaghetti is normally served with sauce, masking of at least some fermented flavor by spaghetti sauce is likely to result in an acceptable spaghetti with an even higher percentage of water/ethanol-washed or regular corn gluten meal. The results of this study support the increased utilization of corn gluten meal for food uses.

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LITERATURE CITED

(1) *Pasta J*. **2000**, Feb, 9−11.
(2) Dick, J. W.; Matsuo, R. R. Durum wheat and pasta products. In *Wheat, Chemistry and Technology*; Pomeranz, Y., Ed.; American Association of Cereal Chemists: St. Paul, MN, 1988; Vol. II, pp 507−547.
(3) Paulsen, T. M. A study of macaroni products containing soy flour. *Food Technol*. **1961**, *15*, 118−121.
(4) Clausi, A. S. Cereal grains as dietary protein sources for developing highly acceptable high-protein foods. *Food Technol*. **1971**, *25*, 63−67.
(5) Siegel, A.; Bhumiratana, A.; Lineback, D. R. Development, acceptability, and nutritional evaluation of high-protein soy-supplemented rice noodles for Thai children. *Cereal Chem*. **1975**, *52*, 801−811.
(6) Haber, T. A.; Sayam, A. A.; Banasik, O. J. Functional properties of some high protein products in pasta. *J. Agric. Food Chem*. **1978**, *26*, 1191−1194.
(7) Sidwell, V. D.; Stillings, B. R.; Knobl, G. M., Jr. The fish protein concentrate story 10. U.S. Bureau of Commercial Fisheries FPC's: Nutritional Quality and Use in Foods. *Food Technol*. **1970**, *24*, 876−878, 880, 882.
(8) Kwee, W. H.; Sidwell, V. D.; Wiley, R. C.; Hammerle, O. A. Quality and nutritive value of pasta made from rice, corn, soya, and tapioca enriched with fish protein concentrate. *Cereal Chem*. **1969**, *46*, 78−84.
(9) Bahnassey, Y.; Khan, K.; Harrold, R. Fortification of spaghetti with edible legumes. I. Physicochemical, antinutritional, amino acid, and mineral composition. *Cereal Chem*. **1986**, *63*, 210−215.
(10) Bahnassey, Y.; Khan, K. Fortification of spaghetti with edible legumes. II. Rheological, processing, and quality evaluation studies. *Cereal Chem*. **1986**, *63*, 216−219.
(11) Wu, Y. V.; Youngs, V. L.; Warner, K.; Bookwalter, G. N. Evaluation of spaghetti supplemented with corn distillers' dried grains. *Cereal Chem*. **1987**, *64*, 434−436.
(12) Wu, Y. V.; King, J. W.; Warner, K. Evaluation of corn gluten meal extracted with supercritical carbon dioxide and other solvents: flavor and composition. *Cereal Chem*. **1994**, *71*, 217−219.
(13) Walsh, D. E.; Ebeling, K. A.; Dick, J. W. A linear programming approach to spaghetti processing. *Cereal Sci. Today* **1971**, *16*, 385−389.
(14) Bookwalter, G. N.; Warner, K.; Anderson, R. A.; Mustakas, G. C.; Griffin, E. L., Jr. Fortification of dry soybean-based foods with DL-methionine. *J. Food Sci*. **1975**, *40*, 266−270.
(15) AACC. *Approved Methods of the AACC*, 9th ed.; American Association of Cereal Chemists: St. Paul, MN, 1995; Methods 46-30, 08-16, and 44-15A.
(16) Gehrke, C. W.; Rexroad, P. R.; Schisla, R. M.; Absheer, J. S.; Zumwalt, R. W. Quantitative analysis of cystine, methionine, lysine, and nine other amino acids by a single oxidation−4 h hydrolysis method. *J. Assoc. Off. Anal. Chem*. **1987**, *70*, 171−174.
(17) Moore, S. On the determination of cystine as cysteic acid. *J. Biol. Chem*. **1963**, *238*, 235−237.
(18) Spies, J. R.; Chambers, D. C. Chemical determination of tryptophan in proteins. *Anal. Chem*. **1949**, *21*, 1249−1266.
(19) Holz, F. Automatic determination of tryptophan in proteins and protein-containing plant products with dimethylaminocinnamaldehyde. *Landwirt. Forsch. Sonderh*. **1972**, *27*, 96−109.
(20) SAS Institute, Inc. *SAS/STAT Guide for Personal Computers*, version 6 ed.; Parker, J. C., Ed.; SAS Institute: Cary, NC, 1987; Chapter 20, p 1028, The GLM Procedure.
(21) Dick, J. W.; Youngs, V. L. Evaluation of durum wheat, semolina, and pasta in the United States. In *Durum Wheat: Chemistry and Technology*; Fabriani, G.; Lintas, C., Eds.; American Association of Cereal Chemists: St. Paul, MN, 1988; pp 237−248.
(22) Johnsen, P. B.; Dupree, H. K. Influence of feed ingredients on the flavor quality of farm-raised catfish. *Aquaculture* **1991**, *96*, 139−150.

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