Production of High-Protein Quality Pasta Products Using a Semolina/Corn/Soy Flour Mixture. III. Effect of Cooking on the Protein Nutritive Value of Pasta

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ABSTRACT

Pasta products were prepared from semolina and from semolina replaced at the 20, 40, 60, and 75% levels by whole corn flour processed in a double drum drier at 143°C surface temperature. From these mixtures, spaghetti was prepared with and without either 0.3% L-lysine or 8% defatted soy flour. A test of resistance to disintegration and organoleptic evaluation indicated that quality decreased significantly ($P < 0.05$) when the semolina in the blend was lower than 40 and 32%, respectively. A significant ($P < 0.05$) correlation ($r = -0.93$) was found between solids lost through cooking and organoleptic evaluation score. After cooking, all products showed increased nitrogen content. Cooking decreased significantly ($P < 0.05$) the total and available lysine and the protein quality of the L-lysine-supplemented products, but it caused an increase in the percentage of available lysine in the soy-supplemented and unsupplemented products and therefore improved the protein nutritive value. A significant ($P < 0.01$) positive correlation ($r = 0.98$) was found between the available lysine content and the protein nutritive value of the products.

Pasta products are produced basically from semolina, and none of the Central American countries is a durum wheat producer. The establishment of adequate conditions for the production of pasta products from raw native materials would be of economic significance for the area. In addition, because of their high popularity, these products could be a vehicle to improve the nutritive value of the habitual diets of these countries.

With the above points in mind, Molina et al (1975) reported the beneficial effect that a heat treatment applied to whole corn flour had on the quality of spaghetti prepared from either a 60:40 mixture of semolina/whole corn flour, or a 32:60:8 mixture of semolina/whole corn flour/defatted soy flour. Also, the authors pointed out the significant improvement of the protein nutritive value of the final product when the semolina/whole corn flour mixture was fortified with either 8% defatted soy flour or 0.3% L-lysine.

However, these protein nutritive value estimations were made using uncooked spaghetti. Therefore, a reasonable doubt existed as to whether cooking could affect the protein nutritive value of the product, especially if the protein fortification was made with a highly water-soluble compound such as L-lysine HCl.

The present work was then undertaken to determine the effect of cooking on the protein nutritive value of pasta (spaghetti) and the relationship, if any, between such effect and the quality and/or the organoleptic acceptability of the products. Because Molina et al (1977) showed that highly acceptable pasta products can be produced from a semolina/whole corn/common bean (*Phaseolus vulgaris*) flour mixture when the starch is gelatinized in a double drum drier, such a process was adopted in the present study instead of the dry heating operation used for the corn flour study reported earlier (Molina et al 1975, 1976).

MATERIALS AND METHODS

The corn (*Zea mays*), semolina, and defatted soy flour used in this study were of the same types as those used in earlier studies, and the whole corn flour was prepared in the same manner as that reported earlier (Molina et al 1975, 1976).

A dough was prepared by mixing whole corn flour with an equivalent weight of tap water. This dough was then subjected to a heat treatment by passing it through a double drum drier (General Food Packaging Equipment Corp., G. F. Series, model 215) with an internal steam pressure of 4.08 atm (60 psi), which yielded a drum surface temperature of 143°C, using a drum velocity of 5 rpm and a drum opening of 0.203 mm (0.008 in.). The heat-treated, dry, corn product (flakes) was then ground in a hammer mill equipped with a 30-mesh screen to obtain the heat-treated whole corn flour. A total of 40 kg of this material was prepared. The particle size distribution of the semolina and the heat-treated whole corn flour was determined as described by Molina et al (1975).

Mixtures were prepared by replacing semolina with the heat-treated whole corn flour, at 20, 40, 60, and 75% levels. Similar mixtures were also prepared with the addition of either 8% defatted soy flour or 0.3% L-lysine (using the equivalent of 0.375% of L-lysine HCl obtained from Ajinomoto Co., Inc.). In both cases, these supplements were added at the expense of semolina. Spaghetti products were prepared from these mixtures in a way identical to that described earlier (Molina et al 1975, 1977).

Nitrogen, ash, ether extract, moisture, crude fiber, and starch were determined according to AOAC methods (1975) and reducing and nonreducing sugars by AACC methods (1969). Available lysine was determined following the method described by Conkerton and Frampton (1959). Damaged starch was determined according to Farrand (1964) and amylose according to Williams et al (1970).

Using the AACC method (1969), all pasta products were tested to determine their resistance to disintegration. In this test, the standard cooking time of 30 min was adopted. Organoleptic evaluation of the pasta products was conducted using the consumer preference test described by Kramer and Twigg (1966) and a panel of 10 semitrained individuals. Numerical values of 9, 7, 5, 3, and 1 were assigned to the likeness levels of the hedonic scale. Before testing, all samples were home-cooked for 10 min in boiling water containing 1.0–1.5% NaCl.

The protein efficiency ratio (PER) was determined on uncooked pasta as well as on the cooked product. The latter was prepared essentially the same as for the organoleptic evaluation. All cooked samples were dried in an air convection oven, using an air inlet temperature of 40°C, until they reached a 10% moisture level. These dried samples were used both for the chemical (nitrogen and total and available lysine) and biological (PER) evaluations of cooked pasta. The PER estimations were carried out as described earlier (Molina et al 1975, 1977). Total lysine was determined electrophoretically according to Gómez-Brenes and Bressani (1973).

The statistical analysis of the data was carried out as described by Snedecor and Cochran (1967) and Duncan (1955).

RESULTS AND DISCUSSION

The percent composition (on a dry basis) of the raw flours used in this study is presented in Table I. The high nitrogen and available lysine contents of the defatted soy flour suggest the possible use of

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this material as a protein supplement for food products such as pasta, which are prepared from cereals or cereal mixtures. The available lysine content (expressed as g/16 g of N) was relatively higher in the raw whole corn flour than in the semolina. This finding is in accordance with a previous study (Molina et al 1975) and with the findings reported by other authors (FAO 1970, Orr and Watt 1957). Furthermore, a higher chemical score has generally been reported for whole corn than for wheat flours of different degrees of extraction (FAO 1970). In general, the percent composition of the present raw materials is very similar to that of lots used in the previous studies (Molina et al 1975, 1976). The semolina starch content found here is much lower than that reported previously (Molina et al 1975). This may be due to the fact that in the present case starch was determined by extraction and subsequent enzyme hydrolysis rather than by the direct acid hydrolysis method used previously. The starch content of 3.39% found in this case is quite consistent with that reported for soybeans by another author (Lee 1951). The amylose content of the raw whole corn flour was found to be 21.3 g/100 g of starch.

The damaged starch content of the heat-treated corn flour was 98.8% of the total starch, indicative of the high degree of starch gelatinization achieved with the drum drier under the conditions used. This value is in accordance with previous findings (Molina et al 1977). The utilization of a drum drier to achieve starch gelatinization in corn has already been reported (Anderson et al 1969).

The particle size distribution of the heat-treated (drum-dried) whole corn flour and of the semolina used in this study is presented in Table II. The heat-treated corn flour shows a considerable higher percentage of fine particles than the semolina does. This fact could be due to the high fragility of the drum-dried corn flaky material.

TABLE I
Composition (%) of Semolina, Corn, and Defatted Soy Flour (db)

		Flour	
Component	**Semolina**	**Corn**	**Defatted Soy**
Nitrogen	2.93	1.70	9.24
Ether extract	1.31	4.48	1.76
Crude fiber	0.63	2.17	3.55
Ash	0.69	1.70	5.96
Starch	77.32	78.27	3.39
Reducing sugars[a]	0.43	0.67	1.24
Nonreducing sugars[b]	2.25	1.69	15.91
Available lysine	0.37 (2.02)[c]	0.34 (3.20)	3.26 (5.64)

[a] Expressed as maltose.
[b] Expressed as sucrose.
[c] Figures in parentheses represent grams of available lysine per 16 g of N.

The difference in particle size and shape between the heat-treated corn flour and the semolina can cause the products in the mixture to segregate, and thus can interfere with the cooking and organoleptic characteristics of pasta prepared from such mixtures. To minimize the possible interference of this variable in the present study, the different size fractions of the heat-treated corn flour were mixed in proportions similar to those found for semolina before the flour mixtures were prepared.

The effect of cooking on total nitrogen content of the different products, their solids in cooking water (obtained from the resistance-to-disintegration test and expressed as g/100 g of pasta), and their organoleptic score are presented in Table III. In all cases (including the pasta prepared from 100% semolina), the percent total nitrogen content of the product increased with cooking. This finding suggests that most of the solids lost during cooking are of a nitrogen-free nature. In all cases, the percent total nitrogen of both cooked and uncooked products decreased as the percentage of semolina in the flour mixture decreased. This fact is easily understood because the nitrogen content is relatively lower in corn flour than in semolina (Table I). Comparison of flour mixtures containing the same percentage of corn flour clearly shows that supplementation with defatted soy flour favorably affected the total nitrogen content of both uncooked and cooked products. In all cases, the total solids lost in the cooking water increased and the organoleptic evaluation score decreased as the percentage of semolina in the different flour mixtures decreased. In fact, a significant ($P < 0.05$) negative correlation ($r = -0.937$) was found between the total solids lost through cooking and the organoleptic evaluation score. Analysis of the data using Duncan's multiple range test (1955), however, showed that 60% of the semolina could be replaced by corn flour (both unsupplemented or supplemented with L-lysine) without causing a significant ($P < 0.05$) increase in the total solids lost through cooking. This finding corroborates the efficiency of the drum drier in achieving the high gelatinization of the cornstarch (Anderson et al 1969, Molina et al 1977) needed to obtain an acceptable pasta product from the flour mixture (General Foods Corporation 1972; Molina et al 1975, 1977). It also indicates

TABLE II
Particle Size of Semolina and Heat-Treated Whole Corn Flour

Tyler Mesh	Opening (mm)	Semolina (%)	Heat-Treated Whole Corn Flour (%)
42	0.3531 (0.0139)[a]	28	9
60	0.2489 (0.0098)	41	28
80	0.1778 (0.0070)	18	42
Pan	...	13	21

[a] Figures in parentheses represent the equivalent in inches.

TABLE III
Solids in Cooking Water, Organoleptic Evaluation Score, and Nitrogen Content of Uncooked and Cooked Pasta Products

Flour Mixture				Nitrogen (% db) in Pasta		Solids in Cooking Water (g/100 g)[b]	Organoleptic Score
Semolina (%)	Corn (%)	Soy (%)	L-Lysine[a] (%)	Uncooked	Cooked		
100	...	...	...	2.90	3.11	11.75 y	7.01 y
80	20	...	...	2.63	2.77	11.83 y	6.58 y
60	40	...	...	2.41	2.58	12.31 y	6.45 yz
40	60	...	...	2.17	2.35	12.89 yz	6.48 yz
25	75	...	...	1.96	2.11	13.45 z	5.95 z
		...	...				
80	20	...	0.3	2.64	2.88	11.86 y	6.71 y
60	40	...	0.3	2.41	2.65	12.34 y	6.62 y
40	60	...	0.3	2.18	2.31	12.88 yz	6.40 yz
25	75	...	0.3	1.97	2.14	13.48 z	6.01 z
72	20	8	...	3.15	3.35	12.01 y	6.68 y
52	40	8	...	2.91	3.16	12.83 yz	6.43 yz
32	60	8	...	2.64	2.79	13.46 z	6.21 yz
17	75	8	...	2.48	2.72	13.98 z	5.89 z

[a] Added at the expense of semolina.
[b] Values presented are the mean of six replicates. Duncan's multiple range test: mean values without a letter in common are significantly different ($P < 0.05$).

TABLE IV
Nutritional Characteristics of Uncooked and Cooked Pasta Products from Flour Mixtures Supplemented and Unsupplemented with Lysine or Defatted Soy Flour

Flour Mixture				Available Lysine (g/16 g of N) in Pasta		Protein Efficiency Ratio (PER)[a] in Pasta	
Semolina (%)	Corn (%)	Soy (%)	L-Lysine (%)	Uncooked	Cooked	Uncooked	Cooked
100	...	...	...	2.01	2.12	0.71 x ± 0.14[b]	0.75 x ± 0.15
80	20	...	...	2.23	2.41	0.93 x ± 0.15	0.98 x ± 0.18
60	40	...	...	2.30	2.37	1.00 x ± 0.14	1.05 xy ± 0.23
40	60	...	...	2.31	2.40	0.91 x ± 0.16	0.92 x ± 0.19
25	75	...	...	2.28	2.29	0.95 x ± 0.15	0.91 x ± 0.14
80	20	...	0.3	4.10 (4.62)[c]	2.83 (3.28)	2.35 z ± 0.24	1.56 yz ± 0.23
60	40	...	0.3	4.01 (4.78)	2.94 (3.41)	2.16 yz ± 0.31	1.52 yz ± 0.27
40	60	...	0.3	4.10 (4.88)	2.91 (3.53)	1.99 yz ± 0.28	1.33 y ± 0.26
25	75	...	0.3	3.98 (5.01)	2.85 (3.65)	2.15 yz ± 0.35	1.46 y ± 0.29
72	20	8	...	3.29	3.82	1.84 y ± 0.30	1.99 z ± 0.35
52	40	8	...	3.34	3.47	1.84 y ± 0.28	1.89 z ± 0.28
32	60	8	...	3.36	3.45	1.90 yz ± 0.21	1.95 z ± 0.25
17	75	8	...	3.28	3.69	1.82 y ± 0.22	2.05 z ± 0.30

[a]The casein standard protein showed a PER value of 2.76 ± 0.24. Duncan's multiple range test: mean values without a letter in common are significantly different ($P<0.05$).
[b]Standard deviation of the mean.
[c]Figures in parentheses represent grams of total lysine per 16 g of N.

the relatively higher efficiency of this technological alternative for the production of pasta from a semolina/heat-treated corn flour mixture, as compared to that of the dry heat treatment of the corn flour reported earlier (Molina et al 1975). In the mixtures supplemented with 8% defatted soy flour, 48% of the semolina could be replaced without significantly ($P<0.05$) increasing the total solids lost in the cooking water. These findings indicate that in a product prepared from a corn flour mixture containing a similar (or even lower) semolina concentration, supplementation with 8% defatted soy flour increases the solids lost in the cooking water, compared to the solids lost from the unsupplemented pasta and the pasta supplemented with L-lysine. No significant ($P<0.05$) differences in the organoleptic evaluation scores were found when the semolina was replaced up to a 60% level.

The nutritional characteristics of the uncooked and cooked, supplemented and unsupplemented pasta products are presented in Table IV. The highest available lysine levels and PER values in the uncooked pasta were attained with products prepared from the flour mixtures supplemented with 0.3% L-lysine. These values were followed by those of the products supplemented with 8% defatted soy flour, which in turn were followed by those of the pasta containing the heat-treated whole corn flour; the lowest values were obtained with the pasta prepared from 100% semolina. Cooking increased both the percentage of available lysine and the PER values in all cases except in those products supplemented with L-lysine, which in fact showed a significant ($P<0.05$) drop in available lysine content and in PER after being cooked. To confirm that this drop in available lysine content was due to leaching of the amino acid into the cooking water and not to a thermal effect, total lysine was determined in these products both in the uncooked and the cooked forms. The results clearly indicate a significant ($P<0.05$) drop in total lysine content, which can be explained only through leaching of the amino acid into the cooking water. To attain an effective improvement in protein nutritive value in pasta products if the cooking water is to be discarded (eg, in spaghetti, macaroni, noodles, lasagna, etc.), supplementation of the raw material should not be made with a highly water-soluble compound such as L-lysine HCl but rather with a protein supplement such as soy flour. These findings also put in doubt the effectiveness of supplementing food products of the pasta types with other water-soluble nutrients such as vitamins of the B complex. This is emphasized by the consistent reports of losses of this type of vitamin through leaching into the cooking water in natural products (eg, vegetables) considered good sources of the vitamin B complex (Harris and Karmas 1975).

Neither the increase in the percentage of available lysine nor the increased PER due to cooking of the nonsupplemented and soy-supplemented pasta can be explained by the present data. The possibility exists, however, that nonprotein nitrogen is partially lost in the cooking water, which would cause the above effect. This possibility should be investigated further.

In all the uncooked and cooked pasta products studied, a highly significant ($P<0.01$) positive correlation (r = 0.98) was found between the available lysine content and the PER values. This finding confirms once again the highly beneficial nutritional effect of supplementing cereal proteins, such as semolina or corn or their mixtures, with their most limiting amino acid, either in pure form or by a protein supplement.

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