PRODUCTION OF HIGH-PROTEIN QUALITY PASTA PRODUCTS USING A SEMOLINA-CORN-SOY FLOUR MIXTURE. I. INFLUENCE OF THERMAL PROCESSING OF CORN FLOUR ON PASTA QUALITY

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ABSTRACT

Pasta products were prepared from semolina, with semolina substituted at the 20, 40, and 60% level by whole corn flour, either raw or processed in metal containers at 15 p.s.i. (121°C) for 15 and 30 min. Products from the semolina-corn flour mixtures were used, unsupplemented, or supplemented with either 8% defatted soy flour or 0.3% L-lysine. Both the resistance to disintegration and organoleptic evaluation tests indicated that maximum heat treatment applied to corn flour induced a significant ($P < 0.05$) improvement in the quality of the products. Amino acid analyses and biological studies also revealed a significant ($P < 0.05$) improvement in the protein quality of the pasta product prepared from the mixture containing 60% corn flour, supplemented with either of the supplements used. Improvement in protein quality was highly correlated ($r = 0.98$) with the available lysine content of the samples.

In Central America the pasta and bakery industries represent 41.2% of the total food industry (1). However, pasta products are produced basically from semolina and none of the Central American countries is a hard-wheat producer. It would be of economic significance for the area, therefore, to establish adequate conditions for the processing of pasta products utilizing raw native materials. On the other hand, these products could be considered as a possible vehicle to improve the nutritive value of the habitual diets of these countries. This aspect is of considerable significance since these pasta products are generally included in the diets of infants and children, population groups where malnutrition is more prevalent (2,3).

The possibility of elaborating pasta products with an improved protein quality using soy flour, skim milk, or fish flour as protein supplements has already been reported (4–6). Several authors, however, have indicated that the products obtained from a partially substituted semolina tended to yield a higher solids-in-cooking-water value than commercial pasta, and that their texture or acceptability was compromised (5–7).

The present work was undertaken with the intent of: a) establishing the influence that thermal treatment of corn flour prior to the pasta production could have on the maximum level of substitution to obtain an acceptable product; and b) obtaining a final product with improved protein quality through supplementation with either defatted soy flour or single amino acids.

MATERIALS AND METHODS

The common corn (*Zea mays*) used in this study was an open-pollinated variety (Azotea) from the 1972 crop, grown at INCAP's Experimental Farm

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"San Antonio Pachali", Guatemala, at an altitude of 5,151 ft. above sea level. The semolina was obtained locally. The defatted soy flour was soy fluff, 200 w (supplied by Central Soya, Chicago, Ill.).

Whole corn was ground in a hammer mill, equipped with a 30-mesh screen. The particle size of the semolina and whole corn flours was determined using a set of sieves (U.S. Standard Sieve Series) with a Tyler equivalent to 42, 60, and 80 mesh.

Whole corn flour (3-lb. batches) loosely packed in metal containers (16.5 × 10.0 × 18.0 cm.) was then processed in a still—non-agitating—retort at 15 p.s.i. (121° C.) for 15 and 30 min. The steam was cut off and the pressure released immediately after the time of treatment. At this time containers were removed from the retort and the material was emptied immediately and allowed to cool outside of the containers. Mixtures were prepared substituting semolina by both the raw and processed corn flours, at 20, 40, and 60% levels. Lots of mixtures similar to the above 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 from Ajinomoto Co., Inc.). In both cases these supplements were added at the expense of semolina. The pasta (spaghetti type) products were prepared from the above-mentioned mixtures using a Euro Milan (model TR 5) pasta-making machine. For this purpose, lots of 3 kg. of each flour mixture were added to the mixing bowl of the pasta-making machine. Enough tap water was added stepwise to the flour mixture with constant agitation to obtain the right consistency of the dough. The total amount of water varied between 240 and 270 ml. per kilo of flour. The total mixing time was between 35 and 45 min. After this operation the trap door connecting the mixing bowl with the single screw extruder of the pasta-making machine was opened and the dough passed through the extruder at the single speed available in the machine. All pasta products were air-dried at 40° to 45° C. in a locally built tray dryer (similar to the Schilde Simplicitor dryer, Model SG5/XII) for 12 to 14 hr. The relative humidity of the drying air at such temperatures oscillated between 17 and 20%. The average diameter of the resulting spaghetti was 2.44 mm. (0.096 in.).

Nitrogen, ash, ether extract, moisture, crude fiber, and starch were determined according to AOAC methods (8), and reducing and nonreducing sugars by AACC methods (9). Available lysine was determined following the method described by Conkerton and Frampton (10). The amino acid analyses were carried out in a Technicon amino acid autoanalyzer using a 20-hr. column and a type B resin, applying the general method described by Spackman et al. (11). Determination of the nitrogen solubility index (NSI) of the defatted soy flour was performed according to Smith et al. (12) using 20:1 and 10:1 water:meal ratios with slow paddle-stirring at 30° C. and a pH of 7.2. All determinations were done in duplicate.

Using the methods of the AACC (9), tests were carried out in all pasta products to determine water absorption during cooking, volume increase as the result of cooking, and resistance to disintegration. In the latter test, a standard cooking time of 15 min. was adopted. The organoleptic evaluation of the pasta products was carried out using the consumer preference test described by Kramer and Twigg (13), and a panel of 10 semi-trained individuals. Numerical values of 9, 7, 5, 3, and 1 were assigned to the likeness levels of the hedonic scale. Prior to testing, all samples were home-cooked under equal conditions.

TABLE I
Particle Size of the Semolina and Corn Flours Studied

Tyler mesh	Opening in.	Semolina %	Corn Flour %
42	0.0139	26	27
60	0.0098	38	27
80	0.0070	20	37
Pan	. . .	16	9

TABLE II
Percent Composition of Semolina, Corn and Defatted Soy Flour (as-is basis)

Component	Semolina	Corn Flour	Defatted Soy Flour
Moisture	13.32	13.01	9.77
Nitrogen	2.56	1.50	8.32
Ether extract	1.12	4.83	1.53
Crude fiber	0.54	1.92	3.54
Ash	0.61	1.43	5.43
Starch	67.01	69.14	11.72
Reducing sugars[a]	0.34	0.60	1.14
Nonreducing sugars[b]	1.98	1.50	13.68
Available lysine	0.33 (2.52)[c]	0.28 (3.10)	2.86 (5.47)

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

The protein efficiency ratio (PER) was determined on the raw, uncooked pasta products, essentially by the AOAC method (8). Weanling rats of the Wistar strain from the INCAP animal colony were distributed in groups of 3 males and 3 females each. All diets were supplemented with a 4% salt mixture (14), 5% cottonseed oil, 1% cod liver oil, and enough corn starch to adjust to 100 g., to which 5 ml. of a vitamin B solution (15) was added.

RESULTS AND DISCUSSION

The particle size of the semolina and whole corn flours used in our study is presented in Table I. Efforts were made to use a corn flour with similar particle size to that of semolina, so as to avoid any possible interference of this variable with the cooking and organoleptic characteristics of the final product.

The percent composition (as-is basis) of the flours is shown in Table II. The high nitrogen and available lysine content of the defatted soy flour suggest the possible use of this material as a protein supplement for pasta products prepared from a mixture of semolina and corn flour. In general, the percent composition found for the semolina is in accordance with the values reported in the literature for similar materials (16). The presence of the seed coat in the whole corn and soy flours could explain their relatively higher crude fiber content in comparison to

TABLE III
Percent Water Absorption during Cooking and Volume Increase upon Cooking of the Pasta Products Prepared from Semolina, and from the Semolina-Corn Flour and Semolina-Corn-Soy Flour Mixtures Studied

Mixture Semolina : Corn : Soy Flour	Heat Treatment Given to Corn Flour (min.:p.s.i.) 0:0		15:15		30:15	
	Water absorption	Volume increase	Water absorption	Volume increase	Water absorption	Volume increase
100	108	130	...	...	...	...
80 : 20	114	121	112	141	123	141
60 : 40	130	130	135	141	128	140
40 : 60	130	135	136	141	129	141
72 : 20 : 8	117	130	107	121	108	140
52 : 40 : 8	135	135	124	122	131	135
32 : 60 : 8	147	126	128	141	131	156

TABLE IV
Percent of Solids in the Cooking Water of the Pasta Products Prepared from Semolina and from the Semolina-Corn Flour and Semolina-Corn-Soy Flour Mixtures Studied[a]

Mixture Semolina-Corn-Soy Flour	Heat Treatment Given to Corn Flour (min.:p.s.i.) 0:0	15:15	30:15
100	2.10a ± 0.14[b]	...	...
80 : 20	4.32bc ± 0.21	4.58bc ± 0.17	3.80bc ± 0.11
60 : 40	5.19bc ± 0.18	5.24bc ± 0.21	4.60bc ± 0.15
40 : 60	5.75c ± 0.19	5.53bc ± 0.23	4.90bc ± 0.10
72 : 20 : 8	4.49bc ± 0.17	4.49bc ± 0.15	3.95bc ± 0.09
52 : 40 : 8	5.28bc ± 0.11	5.35bc ± 0.17	4.30bc ± 0.08
32 : 60 : 8	5.67c ± 0.13	5.38bc ± 0.10	4.49bc ± 0.13

[a]Duncan Multiple Range Test: Mean values without a letter in common are significantly different ($P < 0.05$).
[b]Standard error.

that of semolina. However, the presence of the seed coat in the whole corn flour had no effect on the quality of the raw or cooked pasta product; this was possibly due to the low fiber contribution of the corn flour to the final pasta product. As was to be expected, a much higher starch content was found for semolina and corn flour than for soy flour which, at the same time, presented a much higher content of reducing and nonreducing sugars than the former materials. The content of starch and reducing and nonreducing sugars of the corn flour remained unchanged after processing it for 15 or 30 min. at 15 p.s.i. (121°C.). The NSI value found for the soy flour was 84.7%, indicative that a mild-heat treatment had been used during its preparation.

The water absorption during cooking and the volume increase of cooking values determined for the different pasta products prepared are shown in Table III. As the data reveal, the water absorption during cooking tended to increase as the corn flour portion in the mixture was increased. This value appeared to be unaffected by the degree of heat treatment given to the corn flour. On the other hand, the volume increase upon cooking was unaffected by the increase of the corn flour portion in the mixture; nevertheless, it tended to increase with the heat treatment to which corn flour was subjected, thus suggesting a favorable effect of such treatment on this parameter. The addition of 8% soy flour to the mixture did not affect either of the parameters.

The results obtained for the resistance to disintegration test (expressed as solids in cooking water), and the organoleptic evaluation, are presented in Tables IV and V, respectively. As may be observed, both tests show that the maximum heat treatment given to the corn flour prior to the pasta production had a beneficial effect on the quality of the final product. Analysis of variance of the data—eliminating the effect of degree of substitution—indicated that for both tests the beneficial effect obtained through the maximum heat treatment of the corn flour was statistically significant ($P < 0.05$). Analysis of the data using Duncan's test (17) revealed that according to the values attained for both parameters, the pasta products of the poorest quality were those prepared from both the supplemented and unsupplemented mixtures containing 60% of the corn flour. The latter was either unheated or heated in the autoclave for only 15

TABLE V
Organoleptic Evaluation Score Obtained for the Pasta Products Prepared from Semolina and from the Semolina-Corn Flour and Semolina-Corn-Soy Flour Mixtures Studied[a]

Mixture Semolina-Corn-Soy Flour	Heat Treatment Applied to Corn Flour (min.:p.s.i.) 0:0	15:15	30:15
100	7.0a ± 0.5[b]	. . .	. . .
80 : 20	5.2b ± 0.3	6.0ab ± 0.3	6.0ab ± 0.5
60 : 40	4.8bc ± 0.4	5.0bc ± 0.4	5.6ab ± 0.4
40 : 60	3.8c ± 0.6	3.6c ± <0.1	5.2b ± 0.4
72 : 20 : 8	5.7ab ± 0.4	6.2ab ± 0.4	6.2ab ± 0.5
52 : 40 : 8	5.6ab ± 0.4	5.8ab ± 0.4	6.0ab ± 0.5
32 : 60 : 8	4.2c ± 0.5	4.4c ± 0.6	5.6ab ± 0.5

[a]Duncan Multiple Range Test: Mean values without a letter in common are significantly different ($P < 0.05$).
[b]Standard error.

min. Furthermore, only the samples containing 40% (in the case of the semolina-corn flour mixture) or 60% (in the case of the semolina-corn-soy flour mixture) of the 30-min. heat-treated corn flour presented an organoleptic evaluation score statistically significant ($P<0.05$), equal to the standard (100% semolina) pasta product. These results are in accordance with those of the British patent obtained

TABLE VI
Amino Acid Composition and Available Lysine Content of the Pasta Prepared from Semolina-Corn Flour (40:60) and Semolina-Corn-Soy Flour (32:60:8) Mixtures Using Heat-Treated Corn Flour (g. per 16 g. N)

Amino Acid	Pasta from Semolina-Corn Flour	Pasta from Semolina-Corn-Soy Flour
Aspartic acid	6.35	8.15
Threonine	3.51	3.60
Serine	5.98	5.46
Glutamic acid	31.15	27.36
Glycine	4.03	4.16
Alanine	4.52	4.60
Valine	4.24	4.39
Isoleucine	3.97	3.87
Leucine	11.10	10.38
Tyrosine	3.52	3.25
Phenylalanine	6.16	5.76
Lysine	2.62	3.33
Available lysine	2.36	3.21
Histidine	2.66	2.74
Arginine	4.64	5.83
Ammonia	2.20	1.42

TABLE VII
Performance of Rats Fed Commercial Pasta and Pasta Prepared from Semolina-Corn Flour (40:60) and Semolina-Corn-Soy Flour (32:60:8) Mixtures Using Heat-Treated Corn Flour[a]

Type of Pasta	Nitrogen in Diet %	Average weight Gain[b] g./28 days	PER
Commercial pasta[c]	1.50	17d ± 4[d]	0.73d ± 0.14
Semolina-corn (40:60)	1.49	19d ± 3	0.74d ± 0.14
Semolina-corn-soy (32:60:8)	1.50	41c ± 7	1.31c ± 0.24
Semolina-corn (40:60) plus 0.3% L-lysine[c]	1.44	55b ± 7	1.91b ± 0.41
Casein	2.11	137a ± 16	2.79a ± 0.27

[a]Duncan Multiple Range Test: Mean values without a letter in common are significantly different ($P < 0.05$).
[b]Average initial weight, 48 g.
[c]The available lysine content determined for the commercial pasta and the semolina-corn (40:60) plus 0.3% L-lysine pasta was 2.14 and 4.08 g./16 g. N, respectively.
[d]Standard deviation.

by the General Foods Corporation (18) which recommends a gelatinization of the starchy material prior to substitution of semolina intended for preparation of pasta products. This patent was published during the development of the present work.

Based on the above-mentioned results we decided to carry out nutritional studies with those samples containing 60% of the corn flour subjected to the maximum heat treatment—30 min. at 121°C.—prior to the pasta production. The amino acid composition of the unsupplemented and soy flour-supplemented pasta products is given in Table VI. As the data show, a significant increment in the nitrogen and total amino acid content (g. per 16 g. nitrogen) is obtained through the supplementation of the semolina-corn flour pasta with soy flour. Of special interest is the increment obtained through this supplementation both in lysine and in available lysine, since this amino acid has been reported to be the most limiting essential amino acid in corn as well as in wheat proteins (19,20). The high glutamic acid content of both the unsupplemented and supplemented pasta products is in agreement with the high content of this amino acid reported in the literature for either corn, wheat or soy proteins (19–21).

The biological quality of the protein of the two pasta products is shown in Table VII. Data include the results obtained with a local commercial pasta and with the pasta prepared from the same 40-60 mixture of semolina-corn flour (heat-treated for 30 min.), supplemented with 0.3% L-lysine. One can clearly appreciate the beneficial effect of an increased available lysine content in the final product. A high correlation (r=0.98) was found between the PER values and the available lysine content of the protein from the different pasta products evaluated in the present study. These findings clearly indicate that in order to obtain pasta products—either from semolina or from semolina-corn flour mixtures—with an improved protein quality, supplementation with lysine or high lysine-containing proteins is required.

However, since the biological evaluation of the L-lysine HCl fortified product was carried out on the raw, uncooked pasta, the possibility exists that during cooking the added lysine would leach out to the cooking water. This possibility is being investigated. Preliminary data show that 50 to 75% of the added lysine remains in the cooked product in an available form. Such preliminary data would suggest that the raw product should be fortified with about 0.45 to 0.60% L-lysine (in the form of L-lysine HCl) to obtain the equivalent of 0.30% L-lysine in the final cooked product. The effect that different cooking times and other cooking variables could have on the added lysine is being investigated. This, of course, has economic implications, and it is felt that the same favorable nutritional effect could be obtained with protein sources rich in lysine. The results on this problem will be the subject of a further communication.

In summary, pasta products of a higher protein quality and good acceptability can be prepared using high proportions of raw materials available in tropical areas, by applying heat treatments of simple technology to the starchy materials used as semolina substitutes. It is evident, therefore, that implementation of this technology in the Central American area could be not only of nutritional significance but also of economical relevance.

In order to explain the favorable effects that heat treatment of the corn flour had on the quality of the pasta product resulting from either the semolina-corn flour or the semolina-corn-soy flour mixtures, their physicochemical characteristics are now under active investigation. The effect that a more intensive heat treatment of the corn flour could have on the quality of the final product is being investigated as well.

Acknowledgment

This research was carried out with funds from the Research Corporation, New York, N.Y. (grant-in-aid INCAP 740).

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[Received April 23, 1974. Accepted July 10, 1974]