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Use of phaseolus vulgaris in high protein-quality pasta products

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ABSTRACT

A process was developed for the manufacture of pasta products using locally produced raw materials. A mixture of 25-45-30 parts (w/w) of semolina-whole corn-peeled bean flours yielded products of high acceptability and improved protein quality. The particle size of the corn flour and the surface temperature, opening and velocity of the double-drum dryer used to effect the gelatinization of the starch in the mixture proved to be critical in the quality and acceptability of the final product. A statistically higher content of available lysine and PER values were found in the bean-containing pasta (3.8 g/16 g N and 2.02) than in a sample of commercial pasta (1.8 g/16 g N and 0.97).

INTRODUCTION

THE PASTA (spaghetti, macaroni, etc.) industry, together with the bakery industry, represent 41.2 % of the whole Central American food industry (Recinos, 1973). However, pasta products are produced basically from semolina and none of the Central American countries is a hard-wheat producer. Therefore, it would be of economical significance for the area, to establish adequate conditions for the processing of pasta products utilizing raw native materials. Furthermore, 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 pasta products are generally included in the diets of infants and children, population groups where malnutrition is more prevalent (Bressani, 1971; Viteri and Arroyave, 1973).

The possibility of ellaborating pasta products with an improved protein quality using corn and defatted soy flours as substitutes of semolina in relatively large percentages has already been demonstrated (General Foods Corporation, 1972; Molina *et al.*, 1974). The beneficial effect that a heat treatment applied to the starchy material (corn flour) prior to the pasta production has on the quality of the final product has already been shown (Molina *et al.*, 1974).

Bressani *et al.* (1962) have also demonstrated that when the proteins of cereals and common beans (*Phaseolus vulgaris*) are combined in a 1 : 1 ratio —approximately 30 parts of beans and 70 parts of cereal— maximum protein quality of the mixture is obtained. Since soybeans are not currently produced in the Central American area where beans are a common staple, it was decided to examine the possibility of producing high protein-quality pasta products using a semolina-corn-bean mixture, maintaining the proportion of beans at 30 % (w/w).

The present work describes the process developed to prepare pasta products of high acceptability and high protein-quality from a mixture of semolina-corn-bean flours in the proportion of 25-45-30 parts (w/w).

MATERIALS AND METHODS

THE COMMON CORN (*Zea mays*) used in this study was an open-pollinated variety ("Azotea") from the 1973 crop, grown at INCAP's experimental farm, "San Antonio Pachalí", Guatemala, at an altitude of 1,480 m above sea level. The semolina and the common beans (*Phaseolus vulgaris*) were obtained locally.

The beans were hand-peeled, and then ground in a hammer mill equipped with a 40-mesh screen. Whole corn was ground in the same mill.

The whole corn flour, peeled bean flour and semolina were mixed in the proportions specified later in the text using a Patterson-Kelley blender (Model LV-16 qt). An equal weight of tap water was added stepwise to the mixture prepared, in order to obtain a dough. Such dough was hand-fed to a double-drum dryer (General Food Package Equipment Corporation, GF series, Model 215) which was operated under the conditions detailed later on. The pasta products (spaghetti type) were then prepared from the mixtures thus treated, 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-processing machine. Enough tap water —between 240 and 270 ml per kilo of flour— was added stepwise to the flour mixture with constant agitation to obtain the right consistency of the dough. The total mixing time was between 35 to 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° C to 45° C in a locally built tray-dryer (similar to the Schilde Simplicitor dryer, Model SG 5/XII) for 12 to 14 hours. The relative humidity of the drying air at such temperatures oscillated between 17 and 20 %. The average diameter of the resulting sphaghetti was 2.44 mm.

Nitrogen, ash, ether extract, moisture, crude fiber and starch were determined in duplicate according to the AOAC method (1970). Protein was estimated multiplying the nitrogen content by 5.70 in the case of semolina, and by 6.25 in the case of the whole corn and peeled bean flours. Similarly, in the case of the commercial pasta the conversion factor of 5.70 was used, while for the pasta prepared from the semolina-corn-bean (25-45-30) mixture studied, a calculated 6.12 conversion factor was adopted to compensate for the proportion of semolina.

Total sugars were determined using the method described by Pomenta and Burns (1971). The content of available lysine was determined following the method described by Conkerton and Frampton (1959). Damaged starch was established according to Farrand (1964).

Using the methods of the AACC (1969), 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 20 min was adopted. The organoleptic evaluation of the pasta products was carried out using the consumer preference tests described by Kramer and Twigg (1966), 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.

The protein efficiency ratio (PER) was determined on the uncooked pasta product, essentially by the AOAC method (1970). 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 (Hegsted *et al.*, 1941), 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 (Manna and Hauge, 1953) was added.

RESULTS AND DISCUSSION

The chemical composition (on "as is" basis) and available lysine content of the semolina, whole corn and peeled bean flours are presented in Table 1. As was to be expected, a higher protein content was found for the peeled bean flour than for the semolina and whole corn flour. Conversely, the latter materials presented a higher starch content than the former. From a nutritional point of view it is of interest to note the much higher available lysine content presented by the peeled bean flour when compared to that determined in semolina or the whole corn flour. The relatively high protein and available lysine content of the peeled bean flour suggest the possible use of this material as a protein supplement for pasta products prepared from a mixture of semolina and corn flour.

TABLE 1

Percent composition and available lysine content of semolina, and whole corn and peeled bean flours

Component	Semolina	Whole corn flour	Peeled bean flour
Moisture.	13.22	13.11	15.46
Protein.	14.72	9.21	23.10
Ether extract.	1.41	4.27	1.92
Crude fiber.	0.32	1.75	0.48
Ash.	0.71	1.83	3.72
Starch.	68.21	69.31	39.51
Total sugars*.	1.80	1.38	3.35
Available lysine (g/16 g N).	2.48	3.05	7.82

* Expressed as glucose.

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Since Mayorga (1973) and Molina *et al.* (1974) have shown that a heat treatment of the corn flour is necessary to obtain pasta products of an acceptable quality when using a 32-60-8 semolina-whole corn-defatted soy flour mixture, the possibility of using a double-drum dryer to apply such heat treatment with a 25-45-30 semolina-whole corn-peeled bean flour mixture as a basic formula was studied. The degree of gelatinization obtained through the heat treatments was evaluated by measuring the damaged starch content of the.processed samples (Farrand, 1964; Mayorga, 1973).

The relationship between the damaged starch content of the semolina-whole corn-peeled bean flour (25-45-30) mixture subjected to 4 different thermal treatments and the solids in cooking water value obtained for the pasta products prepared from each mixture are shown in Figure 1. The 4 drums' surface temperatures evaluated were 85°, 96°, 130° and 143° C which corresponded to a drum internal steam pressure of 0.70, 1.05, 2.11 and 4.22 kg/cm^2 (10, 15, 30 and 60 psig), respectively. The drums' velocity was 5 rpm and the opening between them

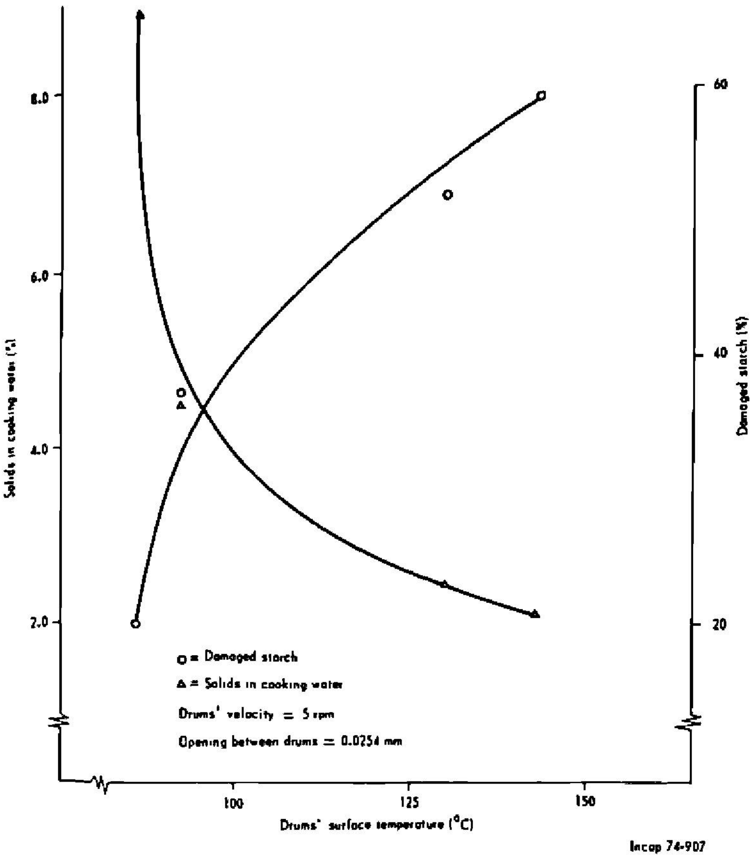

Fig. 1.–Effect of drums' surface temperature on the damaged starch content of the 25-45-30 semolina-whole corn-peeled bean flour mixture, and on the solids in cooking water value from the corresponding pasta products.

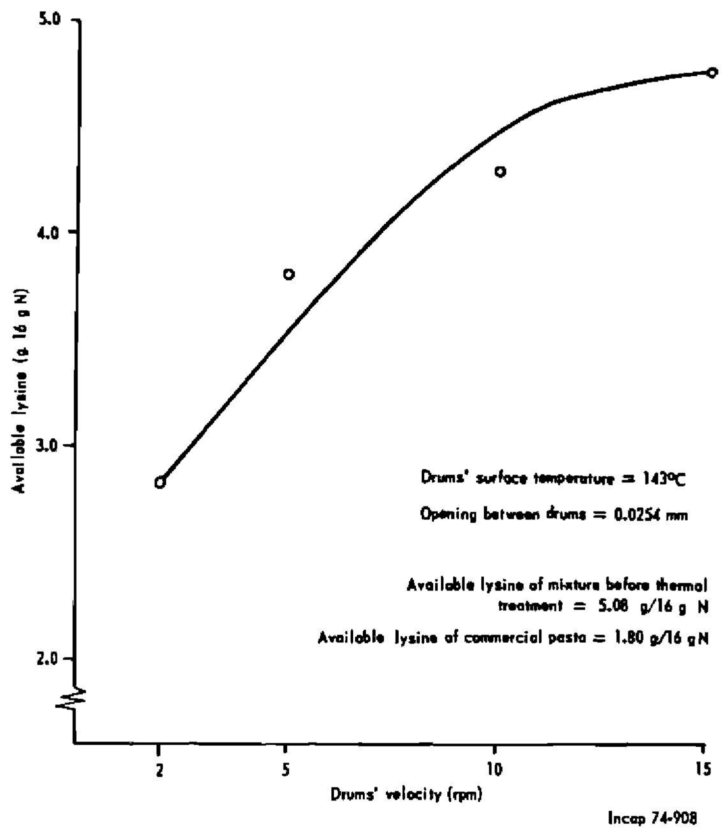

Fig. 2.–Effect of drums' velocity on the available lysine content of pasta prepared from a semolina-whole corn-peeled bean flour mixture (25-45-30).

was 0.0254 mm (0.01 in) to insure a good starch gelatinization (Anderson *et al.*, 1969).

As the Figure reveals, there is an inverse relationship between the damaged starch content of the mixtures and the solids in cooking water value obtained for the pasta products prepared therefrom. The correlation coefficient found for both parameters was -0.91.

Based on the above findings the drums' surface temperature was fixed at 143° C for the following experiments. On the other hand, since varying the drums' velocity from 5 to 15 rpm using the above-mentiones surface temperature (143° C) and drum opening (0.0254 mm) had relatively little effect on the damaged starch content of the mixture, we considered it appropriate to study the effect that the drums' velocity could have on both the protein quality and the acceptability of the final product.

The effect of the drums' velocity on the available lysine content of the pasta product is presented in Figure 2, where the available lysine content of a commercial pasta and of the mixture prior to the heat treatment in the drum dryer, is also shown. As can be observed, decreasing the drums' velocity had a detrimental effect on the available lysine content of the final product. However, in all cases the available lysine content of the pasta product prepared from the mixture studied was higher than that determined in a commercial pasta obtained locally.

Figure 3 illustrates the effect of the drums' velocity on the PER values of the pasta products.

The decrease of the drums' velocity had a detrimental effect on the PER value of the final product, similar to that observed on the available lysine content (Fig. 2). In fact, a correlation coefficient of 0.94 was found between the available lysine content of the samples (Fig. 2) and their corresponding PER values (Fig. 3). In view ot this correlation, a biological trial was carried out with a pasta prepared from a 25-35-40 semolina-whole corn-peeled bean flour mixture processed at a drums' velocity of 5 rpm; the trial revealed a higher available lysine content (4.7 g/16 g N) than the pasta prepared with the 25-45-30 mixture (3.8 g/16 g N) processed under similar conditions (see Fig. 2). Although the PER value obtained for the former product (1.97) was similar to that of the latter one (2.02), the idea of increasing the beans proportion in the mixture was considered of interest since it would increase the total protein content of the final product.

The organoleptic score and the solids in the cooking water value determined for the pasta products containing 3 different levels of peeled bean flour in the mixture with a constant 25 % of semolina and processed at 4 drum velocities are given in Table 2. As may be observed, at any given drum velocity studied, an increase in the beans proportion in the mixture had a detrimental effect both on the organoleptic score and on the solids in the cooking water value obtained in the final product. An increase in the drums' velocity, at any bean flour level in the mixture, also had a detrimental effect on both parameters. Analysis of the data using Duncan's test (Duncan, 1955) revealed that according to the values attained for both parameters, the pasta products statistically equal ($P < 0.05$) to the commercial pasta used as standard, were those prepared from a mixture containing 30 or 35 % bean flour when processed at 2 rpm, and from the mixture containing 30 % bean flour processed at 5 rpm. From the above-mentioned results and from the protein quality findings presented earlier (Figs. 2 and 3) use of the 25-45-30 semolina-whole corn-peeled bean flour mixture processed in the drum dryer at a surface temperature of 143° C, with an opening of 0.0254 mm and a velocity of 5 rpm was agreed upon for any further studies. Increasing the proportion of corn to 55 at the expense of semolina resulted in an organoleptic score of the product (4.3) statistically lower ($P < 0.01$) than that of the standard pasta (7.00).

TABLE 2

*Effect of drums' velocity and percentage of peeled bean flour in the mixture on the organoleptic score and the solids in cooking water value of the pasta products**

	Drums' velocity (rpm)**							
	2		5		10		15	
Mixture***	Organoleptic score	Solids in cooking water (%)	Organoleptic score	Solids in cooking water (%)	Organoleptic score	Solids in cooking water (%)	Organoleptic score	Solids in cooking water (%)
25-45-30. .	7.63	2.24	7.00	2.28	4.26	2.36	–	3.13
25-40-35. .	7.53	2.27	6.05	2.39	2.43	2.53	–	3.26
25-35-40. .	7.31	3.02	5.60	3.59	2.43	3.79	–	5.37

* The standard values obtained for commercial pasta were: organoleptic score = 7.00 and solids in cooking water = 2.01 %.
** Drum's surface temperature = 143° C. Opening between drums = 0.0254 mm.
*** Semolina-whole corn-peeled bean.

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The volume increase and water adsorption during cooking as well as solids in cooking water and protein content determined for the pasta product obtained from the 25-45-30 mixture processed under the above-mentioned conditions, are detailed in Table 3. Values for the commercial pasta used as standard are also included. It is

TABLE 3

Quality characteristics of commercial pasta and the pasta product prepared from the 25-45-30 semolina-whole corn-peeled beans flour mixture

Product evaluated	Volume increase during cooking (%)	Water absorption during cooking (%)	Solids in cooking water (%)	Protein (%)
Pasta from the semolina-corn-bean mixture	80	373	2.28	15.61
Commercial pasta.	151	197	2.01	14.71

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interesting to observe that while the water adsorption during cooking is significantly ($P < 0.01$) greater for the semolina-whole corn-peeled bean product, the standard commercial pasta presents a significantly ($P < 0.01$) higher volume increase during cooking. The solids in cooking water and the protein content, on the other hand, were very similar in both cases.

Evaluation of the effect that the opening between the drums used for processing the mixture could have on the quality of the final product demonstrated that essentially the same results reported in previous paragraphs using an opening of 0.0254 mm were obtained with larger openings up to 0.2032 mm (0.008 in). It was also found that in order to improve the appearance of the uncooked pasta product, eliminating the spots of gelatinized corn starch granule which appeared on the surface of the product, a whole corn flour of 100 mesh or finer had to be used.

The flow diagram of the proposed process and the balance of materials obtained at pilot plant scale presented in Figure 4, was prepared based on the

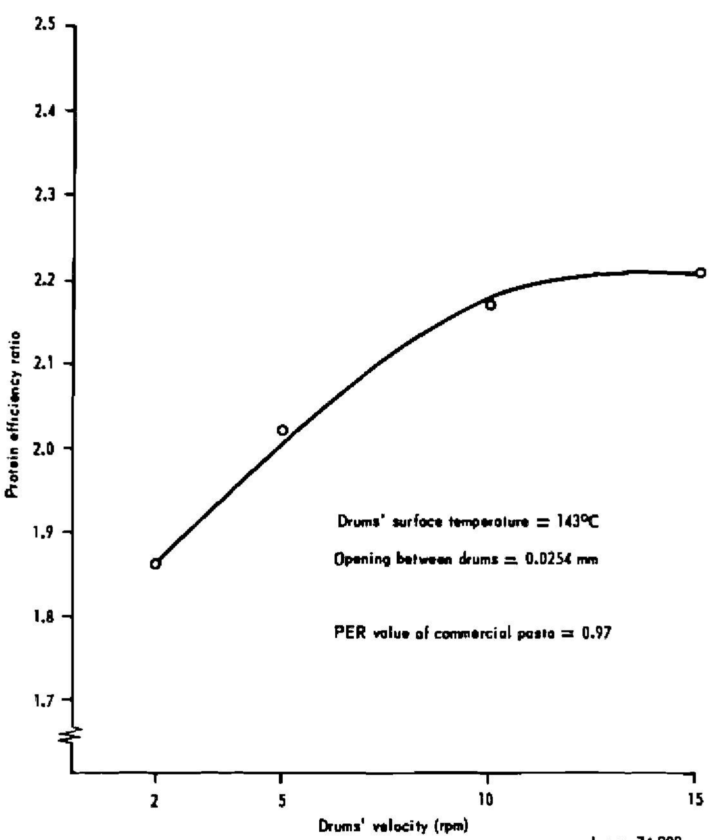

Fig. 3.–Effect of drums' velocity on the protein efficiency ratio (PER) of pasta prepared from a semolina-whole corn-peeled bean flour mixture (25-45-30).

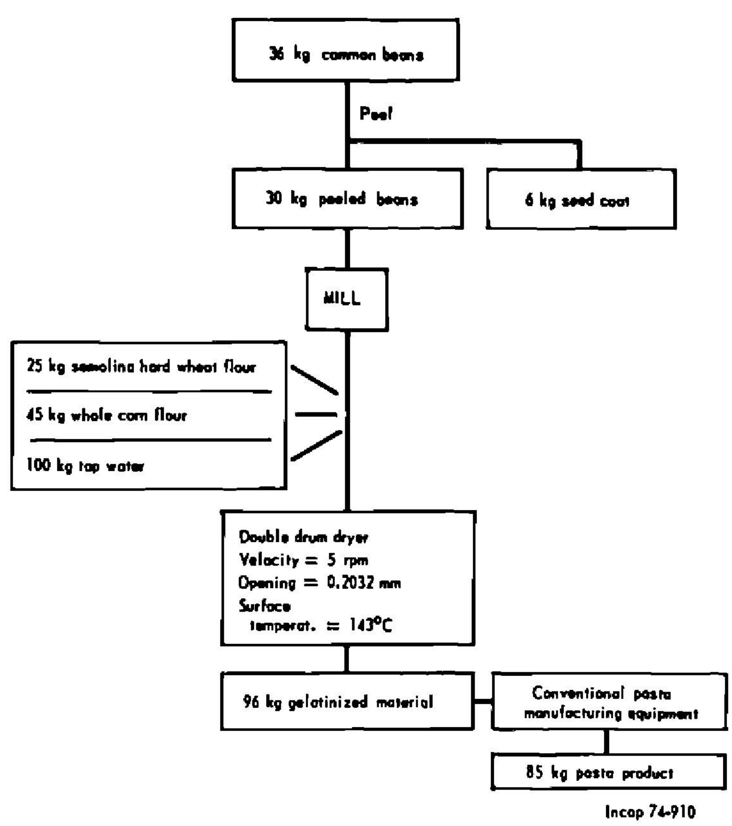

Fig. 4.–Flow diagram and balance of materials for the manufacture of pasta products from a 25-45-30 semolina-whole corn-peeled bean flour mixture.

afore-mentioned findings. The peeling operation is considered necessary since when a whole bean flour was used, the seed coat always separated from the final product during the cooking operation and tended to float in the cooking water, thus impairing the quality of the product. This effect was observed even when a 200-mesh whole bean flour was used. Although the peeling operation in the present study was done by hand, the equipment for such operation is already commercially available (Kon *et al.*, 1973).

Cooking the peeled bean flour (15 min at 15 psig or 121° C) prior to the processing of the mixture had no effect in improving the nutritive value of the final pasta product. This indicates, therefore, that the thermal treatment given to the mixture through the drum dryer was enough to inactivate the growth-inhibiting substances contained in the common bean portion (Liener, 1962).

Preliminary data indicate that the corn variety used in this study ("Azotea") can be substituted by other corn varieties, such as opaque-2 corn or precooked ("nixtamalizadas") corn flours, commercially available, without any detrimental effect on the quality of the final product. The peeled common bean flour can be substituted as well by a peeled black-eyed pea (*Vigna sinensis*) or a peeled chick-pea (*Cajanus cajan*) flour with similar results.

At present we are investigating the possibility of effecting the desired thermal treatment of the mixture by means of other equipment than the drum dryer.

Preliminary cost analysis of the proposed process has proven satisfactory, mainly due to the difference in price between the semolina and the corn and beans. The versatility of the equipment used to effect the thermal treatment also helps to make the present process economically and industrially appealing.

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