Assessment of biological value of a new corn–soy–wheat noodle through recuperation of Brazilian malnourished children[1,2]

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During the last 15 years, the magnitude of the protein problem in the infant and young child has lead to a considerable amount of research on what are called low cost, high protein foods. Incaparina in Guatemala (1) and Pro-Nutro in South Africa (2) can be considered as prototypes of protein-rich foods based on local vegetable products that are markedly less expensive than milk. Extensive experimentation in animals and testing in children established that the biological value of these products is good. Both are commercially successful; sales of Incaparina are rising, and the manufacturer has expanded his production facilities. The fact is, however, that these foods have not contributed to the betterment of nutrition of the vulnerable child to the extent that was expected.

A common feature of these products is that they have the appearance of flour, yet they can be utilized as a gruel. Incaparina owes much of its success to the fact that a corn gruel called "atole" was traditional in Guatemala when the new blend was introduced. Conversely, the introduction of a new flour-like food may be difficult in cultures in which gruels are not commonly consumed. The drawbacks and limitations of the flour then become all too evident, and the need appears for using a product that would be similar to a food already widely consumed. The next logical step then is the research and development of textured products, or what Altschul (3) has called the "third generation" of low cost, high protein foods.

Private industry, particularly in the United States and in Japan, has now put on the market an astounding variety of sausages, pretzels, steaks, hamburgers, et cetera, made from fish protein (4) or oilseed protein (4, 5). Technologically, these are spectacular achievements; practically, their cost puts them out of reach of the poor. If the protein gap (6) is to be filled, widely acceptable foods must become available, i.e., foods which would contain a sizable amount of good protein at a lower cost than conventional sources of protein.

A large international food company[4] developed a new type of pasta, which in theory should meet all the requirements we just discussed: the ingredients are all traditional foods in human nutrition; the appearance and texture are those of a widely consumed food, macaroni; it is high in protein; and the biological value is good when tested in the laboratory.

To Brazil it offers some definite advantages, namely, 90% of the ingredients are produced in large amounts in the country. Although most of the wheat is still imported, national production is rapidly increasing (7). There is only 10% wheat in the new noodle compared with over 95% in traditional pasta products.

Besides our interest in testing the value of this noodle as a food supplement for Brazil, we were also interested in the methodological aspects of testing protein mixtures in pre-

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school children living most of the day in their habitual environment. The methodology we used was based on the earlier experience of one of us under similar circumstances with Incaparina in Cuba (8) and with AK-1000 in Haiti (9). We shall therefore discuss in some detail our methodological observations throughout this report.

The objective of the study was to assess the biological value and the tolerance of the pasta in malnourished children compared with a control group fed a normal balanced diet. More specifically it was to: *a*) investigate whether high doses of the protein under consideration are compatible with normal growth or recuperation from malnutrition, or both, and *b*) explore tolerance and acceptance of the pasta after prolonged administration.

The inference was that if the answer was satisfactory, the pasta could be recommended as a supplement to the diet (10).

Material and methods

Description of the product[5]

The product under study is a short and wide yellowish noodle. Appearance, texture, and color are quite similar to the common egg noodle. It is hard and breakable, but after cooking in boiling water for a few minutes, it becomes elastic, as macaroni does, an obvious advantage in acceptability.

The ingredients are listed in Table 1. The manufacturer uses a defatted soy flour containing 52% protein and a negligible amount of fat. Wheat is either semolina flour or Durham wheat flour. Vitamins and minerals were added for the rat testing, but not for the test in children who received special separate vitamin and mineral mixtures.

Results of the approximate analysis, performed at the Institute according to the Association of Official Agriculture Chemists' (AOAC) procedures, are consistent with the data provided by the manufacturer: the calculated caloric value of 100 g of the noodle is 355 kcal and the protein content is 20.5 g. Moisture content is 8.95%, ash 3.38%, fat 1.35%, and fiber 0.85%.

Biological value of the protein

Amino acid content and biological value were studied by both the manufacturer and the Institute of Nutrition (11, 12). Methionine was found to be the first limiting amino acid. In spite of significant cooking losses, however, the addition of methionine did not improve the biological value of the protein. The addition of lysine had no effect on the biological value of the protein in the rat. The PER adjusted to casein (casein = 2.50) was 2.37 to 2.53. This puts the noodle among products suitable for young children, according to the guideline of the FAO/WHO/UNICEF Protein Advisory Group (13, 14).

TABLE 1

Composition, caloric value, and protein content of the noodle

Ingredients	Amount in percent	Kcal/ 100 g	Protein/ 100 g	Total calories	Total protein
Corn meal	60	363	7.9	217.8	4.74
Defatted soy flour	30	335	52.0[a]	100.5	15.60
Wheat flour	10	364	10.5	36.4	1.05
Total	100			354.7	21.39

[a] Data supplied by the manufacturer. Other figures are based on the values given in (27).

TABLE 2

Comparison between the composition of the noodle and that of selected soybean-based protein mixtures, in percent

Mixture	Corn meal	Defatted soy flour	Wheat flour	Minerals and vitamins	Dried skim milk	Torula yeast
Noodle	60	30	10	(1)[a]		
CSM	68	25		2	5	
Incaparina formula 14	58	38		1		3
Fortifex	49.4	49.4		1.2		

[a] One percent minerals and vitamins added extra.

Quality control and safety of the product

The three ingredients are common foods in human nutrition, and the proportion of each of them in the noodle does not differ substantially from other similar soybean-based mixtures such as Incaparina Formula 14, Fortifex, or CSM (Table 2) (15). Fiber content is 0.85%, which is below the minimum authorized by the FAO/WHO/UNICEF Protein Advisory Group for vegetable mixtures intended for child feeding (13, 14). PER also falls within the acceptable range of the Protein Advisory Group (PAG) guideline, as we have seen. The industrial treatment is simple. Therefore, no toxicity or lack of tolerance was to be expected even during a long period of high dosage. Sanitary conditions were checked prior to shipping the noodle from the United States pilot plant. Storage qualities of the product proved to be remarkable. The noodle

[5] Unless stated otherwise, the data in this section were supplied by the manufacturer of the noodle.

was still in excellent condition after more than 13 months storage under tropical conditions in polyethylene-lined fiber drums.

Test design

The test itself was started after preliminary testing of over 40 recipes using whole or ground noodles. Forty-five pairs of children aged 1 to 4 years with second and third degree malnutrition were taken from a total sample of 604 preschool children from Ilha Sta. Terezinha, a slum area of Recife, and each pair was distributed at random into two groups. To make a pair, the children had to be of the same sex, have the same age ± 0.5 month, and the same weight expressed as percent of standard weight-for-age, ± 5%. Each group was admitted in one of two day-care centers (two houses rented in the middle of the slum) operating as a nutritional rehabilitation center. Such a center has been described elsewhere (16). This design was based on earlier studies as previously mentioned (8, 9, 17).

Great care was taken to follow the recommendations on testing of protein food in children issued by the FAO/WHO/UNICEF Protein Advisory Group (13, 14) and by the Latin American Nutrition Society (18), as well as guidelines proposed by Guzmán (19). No ethical problem interfered with the study: no toxicity or lack of tolerance was to be expected; the subjects were malnourished children deprived of adequate food and medical attention who were put under daily supervision by a qualified pediatrician. In addition, the mothers and the physician were completely free to withdraw any child at any time, a liberty both employed frequently, and which actually complicated our results, as we shall see. Children were checked daily for intercurrent disease and signs or symptoms of toxicity and immediately given medical care when appropriate. Furthermore, at the time the test started in Brazil (September 16, 1969), extensive testing with humans had been completed in the United States.

The centers operated from 7 AM to 5 PM, 6 days a week, under the supervision of nutritionists from the Institute. It is assumed that the food taken at the Center, which was distributed in three meals and two snacks, represented the quasi-totality of the intake of the subjects. The children received supplements for 4 months.

Diets and menus

The control group received a normal balanced diet similar to that used at the Institute's rehabilitation centers (16), but in which 25 to 30% of the protein came from milk. The experimental group received 68.9% of their protein intake from the noodle under study. Diets were calculated to cover 100% of the recommended dietary allowances for Colombia (20), and to provide the same amount of calories, protein, carbohydrate, and fat to each group, i.e., 1,370 kcal, 30, 116, and 35.3 g, respectively, per child per day.

The menus were designed by the nutritionists and constantly readjusted throughout the study in order to keep diets of both groups of equal calorie and protein content. Because it was ethically impossible to reduce the diet in the group who ate more, we only could try to increase intake in the noodle group. Two major menu changes were made. On December 13, 1969, calories were increased in both groups, and on January 10, 1970, milk was added to the diet of the nine children of the experimental group who had not yet completed the 4 months of observation.

The noodle was served to the experimental group either as such, or as a dish made of fine or gross flour, after at least 10 min cooking in boiling water. The noodle was introduced progressively over a 2-week period, but it was actually well accepted from the beginning.

A vitamin supplement (prepared by Merck & Co., Inc., Rahway, New Jersey) covering 100% of the NAS–NRC recommended dietary allowances (21), and a mineral supplement covering 50% of the same recommendations were given to both groups every day. The mineral supplement, a syrup, was prepared at Lafepe, the official pharmaceutical laboratory of the State of Pernambuco.

Collection of data and statistical analysis

The children were weighed every week. Height, head circumference, arm circumference, tricipital skin-fold thickness, and clinical signs of malnutrition were measured every month. Blood was collected at the start, and after 2, 3, and 4 months for determination of total protein, vitamin A, hemoglobin, and hematocrit according to the ICNND *Manual for Nutrition Surveys* (22). Protein fractions were determined by micro-electrophoresis on cellulose-acetate using a Beckmann R 100 apparatus.

Food intake data were collected daily and computed weekly. Attendance and possible symptoms of disease or lack of tolerance were also collected every day. Children who did not attend at least 80% of the total time were not included in the final evaluation.

The rate of dropouts from both groups was high during the first weeks. Hence, the number of pairs who remained in the study until the end did not allow us, as expected, to perform a statistical analysis using a t test for matched pairs between the groups. The t test for matched pairs was used only to compare initial and final data within the same group. A regular t test or a chi-square test was applied as appropriate between groups. Differences were considered significant when P was less than 5%.

Results

Intake

Attendance was computed every week, and the children who did not come regularly to the centers were eliminated from the study. This seldom happened, with the exception of the withdrawals at the beginning and at the end of the study, which we mentioned earlier. As a result, the average attendance rate was above 95% in each group (Table 3), which means that our data refer to children under close supervision.

Acceptance of meals, which was recorded daily, was the same in both groups: 95.6% and 92.2%, respectively, for the control and the experimental group. Meals rejected were only 0.7% among the controls and 3.2% among the experimental children. But the latter small proportion of rejections almost all occurred in the experimental group during the 3rd week, i.e., during the week the full ration of macaroni was served for the first time.

The diets had been calculated to provide 1,370 kcal per child per day; the observed average intake was 1,533 kcal in the control group and 1,357 in the experimental group (Table 4). Calorie consumption increased markedly as recuperation proceeded, but it was consistently lower in the experimental group. The mean for the first 3 weeks was 1,227 kcal/day in the control group; it rose to 1,984 kcal in the last 3 weeks. Corresponding figures for the experimental group are 1,067 and 1,837, respectively. Calorie intake, expressed per kilogram of actual body weight, increased substantially in both groups (Fig. 1): control group 121 kcal/kg in the first 3 weeks, 175 kcal in the last 3 weeks, average 147; experimental group 109, 146, and 131 kcal/kg, respectively. The average intake was thus above the 100 kcal/kg recommended by Waterlow (23) for normal growth of each group from the start. It is likely, however, that the intake in the experimental group was still not high enough to insure full recuperation. Protein intake was to be 30 g/child per day; actual intake was 41.1 g in the control group and 36.1 g in the experimental. There was no difference in the proportion of calories from protein origin: 10.7% and 10.6%, respectively. A slight increase in consumption was observed as recuperation proceeded, but it was not as marked for protein as for calories. In the beginning, protein accounted for approximately 12.2% of total calories. We then increased the calories and at the end of the study, protein and calories were approximately 9.8%, a more satisfactory figure which, under the conditions of the experiment, was associated with the highest growth rate. Protein intake per kilogram of body weight was 3.9 g in the control group and 3.5 g in the experimental group (Fig. 1), a reflection of a slightly higher intake in the control children. It seems that the lower food intake in the experimental group is the main phenomenon or major fact observed during this study, and that it is responsible for the lower weight gain which, as we shall see, was observed among the experimental children.

The noodle itself was extremely well accepted. The average intake was 121.35 g/child per day for 4 months, and it was steady

TABLE 3

Attendance rate and acceptance of meals, given in weekly averages (percentages)

	September			October				November				December					January				February	Mean %	Median %
	16	22	29	6	13	20	27	3	10	17	24	2	9	15	22	29	5	12	19	26	2		
Control group																							
Acceptance	100	93	96	95	96	94	94	96	94	94	95	97	96	97	93	86	97	98	97	99	100	95.6	96
Refusal		0.1	0.3	0.2	0.3	1.5	1	1	2	3	2	0.5	0.1			3	1			0.3		0.7	0.3
Absence		7	4	5	4	4	5	3	4	3	3	3	4	3	7	11	2	2	3			3.7	3
Experimental group																							
Acceptance	97	97	82	89	93	90	88	94	91	88	97	93	89	95	86	94	99	91	90	95	100	92.2	93
Refusal	2	2.5	<u>12</u>	3	4	4	3	2	1	1	2	5	5	4	7	4	0.5	1	3	0.3		3.2	3
Absence	1	1	6	8	2	6	9	4	8	10	1	2	6	1	7	2	1.5	8	7	5		4.6	5

Period of maximum incidence is underlined.

TABLE 4
Observed daily intake, per child, based on weekly averages

	Calories		Protein, g		Protein–calories, %		Noodle, g
	Control	Experimental	Control	Experimental	Control	Experimental	Experimental
16–20 September	1,126	1,116	33.3	34.4	11.8	12.3	113.49
22–27 September	1,194	1,069	37.3	32.7	12.5	12.2	109.90
29 September–4 October	1,361	1,017	41.4	31.2	12.2	12.3	114.35
6–11 October	1,002	1,006	36.1	31.9	14.4	12.7	114.46
13–18 October	1,052	1,058	39.2	34.1	14.9	12.9	122.02
20–25 October	1,233	1,012	38.8	30.0	12.6	11.8	101.39
27 October–1 November	1,323	1,205	40.9	36.1	12.4	12.0	127.71
3–8 November	1,298	1,076	40.0	32.3	12.3	12.0	121.00
10–15 November	1,335	1,134	38.0	33.0	11.4	11.6	117.74
17–22 November	1,261	1,318	33.3	36.0	10.6	10.9	138.46
24–29 November	1,260	1,468	34.1	38.4	10.8	10.5	150.41
1–6 December	1,358	1,403	35.5	34.2	10.4	9.8	127.29
8–13 December	1,661	1,557	40.7	34.7	9.8	8.9	132.10
15–20 December	2,004	1,503	46.8	32.0	9.3	8.5	118.89
22–27 December	2,100	1,539	51.2	34.9	9.8	9.1	127.35
29 December–3 January	2,101	1,634	47.6	32.3	9.1	7.9	123.82
5–10 January	1,762	1,710	47.9	41.2	10.9	9.6	111.94
12–17 January	1,802	1,153	43.1	42.7	9.5	14.8	118.07
19–24 January	1,934	1,827	46.7	44.7	9.6	9.8	120.78
26–31 January	1,889	1,880	46.9	46.3	9.9	9.8	120.32
2–7 February	2,219	1,804	46.3	44.8	8.7	9.9	116.89
Mean	1,533	1,357	41.1	36.1	10.7	10.6	121.35

throughout the period; only 1 week was it below 110 g. This is a high amount, if one remembers that the children initially weighed approximately 10 kg, on the average. This amount represents 24.9 g protein, or 68.9% of the total protein intake of the experimental group, which was 36.1 g. Figure 2 illustrates the trend in consumption. There was no indication of fatigue at any time during the 4-month test period.

The experimental noodle was well tolerated at high doses over an extended period of time, during which it accounted for more than two-thirds of all protein intake. This exceptionally good acceptance is the most positive fact of the whole study.

Pathological manifestations; intercurrent diseases

As we already mentioned, all pathological symptoms or signs of disease were noted. We did not anticipate, however, that our subjects, who live in an extremely unhealthy environment, would constantly suffer from infectious diseases, as was the case. This situation created a daily problem and involved much more medical attention than had been expected, as all symptoms and diseases were given immediate attention.

Diarrhea was more frequent in the experimental group during the first 4 weeks (Table 5). A certain degree of initial intolerance to the noodle cannot be excluded. There is no doubt in the mind of the two physicians who took care of the children that the diarrheas were infectious, as was revealed clinically and epidemiologically. For the rest of the period, diarrhea was equally frequent in both groups. The children seldom vomited, but when they did, it was associated with diarrhea. Nausea and stomach pains were not significant, nor was constipation. Skin manifestations were frequently presented and were almost exclusively either contagious pyodermitis or impetigo; they were more commonly seen in the experimental group. This may reflect the fact that their health situation was less bright when we first saw them. No allergic manifestations were observed whatsoever. Other diseases, as we already mentioned, were exceedingly common: upper respiratory infections, bronchitis, and childhood diseases such as measles, chickenpox, mumps, and whooping cough. In November, an epidemic of flu and bronchitis equally affected both groups. These diseases were consistently accompanied by weight loss, a fact that in part explains the difficulty we had in getting satisfactory recuperation. All diagnoses were made by the same physicians, and no difference was observed between groups.

In addition to this heavy toll paid to common acute infections, the children were also heavily loaded with intestinal parasites. Sixty-one stool examinations revealed 97% *Trichuris trichiura,* 75% *Ascaris,* 44% hookworm, 30% *Strongyloides stercoralis,* in addition to over one-third infestations with protozoa. More than one-half the children had at least three different worms! This is a reflection of the extremely bad environmental conditions in the area under study. *Schistosoma mansoni* was present in only one child. Deparasitization was performed twice in both groups, with little success, probably because of immediate recontamination.

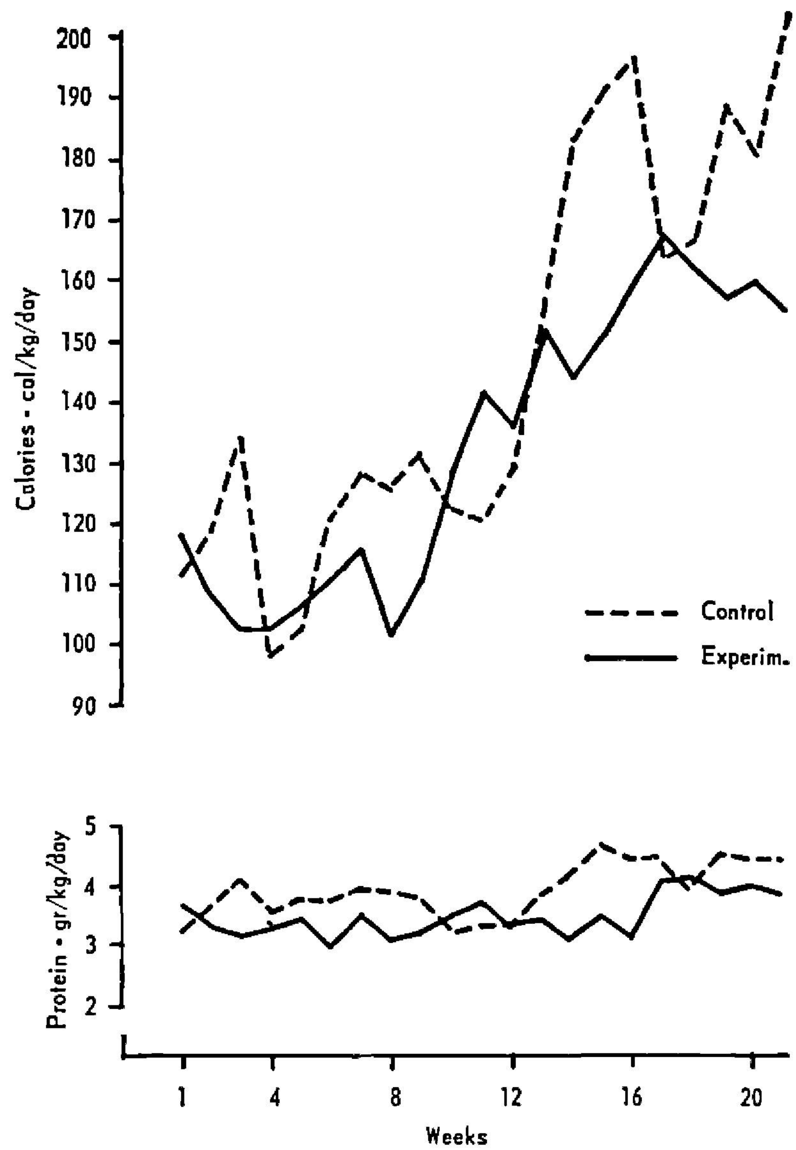

FIG. 1. Intake of calories and protein per kilogram of body weight per day (weekly averages).

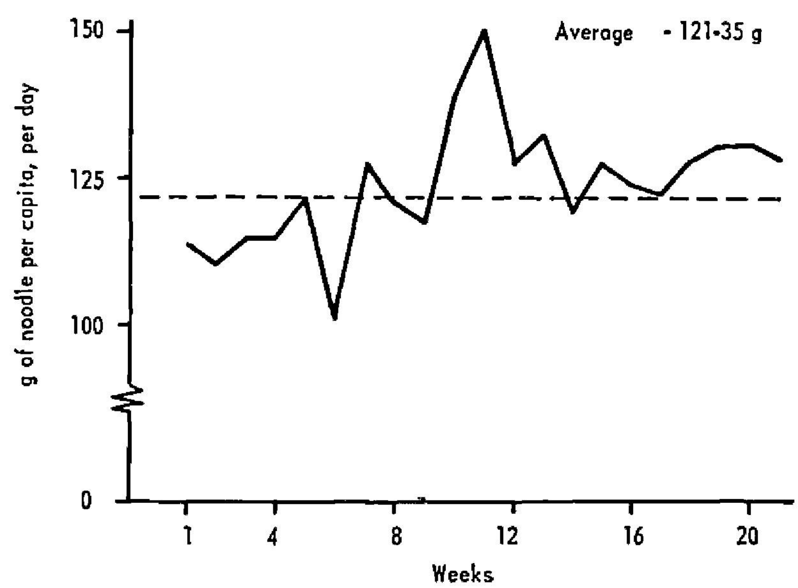

FIG. 2. Observed daily intake of noodle, based on weekly averages.

Changes in anthropometrical measurements

Changes in anthropometrical measurements are summarized in Table 6. The last column indicates the change expected from children of that age during 4 months of normal growth, as calculated from tables and data presented by Jelliffe (24).

Observed height was much below the normal height for age: the deficit was 16.5 cm, indicating a marked cumulative growth retardation among those children. Head circumference was 3.0 cm below normal. Both measurements reflect the poor nutritional history and health conditions of the children, and also point to the fact that malnutrition among this group comes as much from caloric deficiency as from lack of protein. The initial difference in height between the groups remained unchanged. The height increase was highly significant in both groups, and it was in the range of expected gain, indicating that normal growth was resumed, in contrast to the previous retardation. The same happened to head circumference. No difference was observed between groups.

Midarm circumference increased somewhat, and tricipital skin-fold thickness decreased slightly, observations consistent with earlier experience in Haiti (9, 17) and in Brazil (16), although in this series the differ-

TABLE 5
Pathological manifestations given in sick child-days, per week

	September			October				November				December					January				February	Mean per week	Median per week
	16	22	29	6	13	20	27	3	10	17	24	2	9	15	22	29	5	12	19	26	2		
Control group																							
Diarrhea	4	14	5	4	1	3	20	18	15	1	1	12	44	3		10	20	6	5	3	2	9.1	5
Vomiting			2						8		1	2								1		0.7	0
Nausea																							
Skin disease	4			4	8	26	22	36	22	12	16	1	3	3	4	6	18	21	12	9	15	12.0	9
Others	22	11	19	22	11	15	13	7	134	219	153	54	31	50	26	44	41	24	16	13	5	44.3	22
Experimental group																							
Diarrhea	16	29	40	51	29	12	15	19	24	27	22	38	27	19	15	12	4	2				19.1	19
Vomiting		1	3	3	2	1		1	2		1	5	4	3	7	4	1					1.8	1
Nausea														6	1	2						0.4	0
Skin disease				9	14	29	23	22	27	30	20	42	26	25	43	25	36	26	8	8	23	20.7	23
Others		5	6	10	24	106	180	184	142	173	172	20	21	16	2	8		12	3	6		51.9	12
Total	46	60	75	103	89	190	273	287	374	460	396	174	156	125	98	112	120	91	44	40	45	66	36

Periods of maximum incidence are underlined.

TABLE 6
Changes in anthropometrical measurements

Measurement	Control group n = 26			*P*	Experimental group n = 22			*P*	Expected change[a]
	Before	After	Change		Before	After	Change		
Age, months	36	40	4		34	38	4		
Weight, g	9,923	10,922	999	**	10,006	10,449	443	*	432[b]
Height, cm	80.79	83.67	2.88	**	78.39	81.39	3.00	**	2.6
Head circumference, cm	46.25	47.00	0.75	**	46.64	47.68	1.04	**	1.0
Arm circumference, cm	13.56	14.04	0.48	NS	13.68	14.01	0.33	NS	None
Skin-fold thickness, mm	8.63	8.38	−0.25	NS	8.77	7.66	−1.11	NS	None
Midarm muscle circumference, cm	10.84	11.40	0.56	**	10.90	11.59	0.69	**	None

NS = not significant. * = $P < 0.05$. ** = $P < 0.01$.
[a] From (24). [b] For maintenance of growth only.

ences were not statistically significant. Again, there was no difference between the groups. These measurements, however, are interesting, as they allow calculating the muscle arm circumference. The increase in the latter in both groups was highly significant without differences between the groups. Because at this age, muscle arm circumference is not supposed to increase significantly in 4 months, these findings can be interpreted as reflecting an increase in muscle mass, indicating an improvement in the protein nutriture of the subjects. Once again, the muscle arm circumference was found to be a sensitive index of nutritional recovery (25).

On the average, the weight was approximately 68% of the expected weight-for-age initially, and 90% of expected weight-for-height, according to the standards proposed by Jelliffe (24). The weight gain, 443 g, of the children fed the noodle was slightly below that expected for age and initial weight.

Growth was therefore resumed, but frank recuperation in terms of weight was achieved only in the control group in whom the weight gain was 999 g. The difference between groups is significant at the 5% level.

The analysis and interpretation of the anthropometric data suggest the following conclusions: *1*) longitudinal growth was resumed in both groups; *2*) there was a highly significant improvement in protein nutrition in both groups; and *3*) there was a frank recuperation of the weight deficit among the controls, but barely a resumption of normal growth in the experimental group. The major cause of difference in weight gain appears to be the lower caloric intake, probably due to the high amount of noodle offered in the daily diet. The most likely explanation is that satiety preceded high dosage. Longitudinal growth and increase in muscle mass were the same in both groups, as far as we can judge from the data. The difference in weight gain may be due to a lower deposit in fat in the experimental group, associated with their lower caloric intake. Skin-fold thickness data would support such a view, but the wide individual variation in adipose tissue does not allow significant conclusions. On the other hand, as we shall see below, biochemical data suggest that part of the difference might be attributed to a lesser biological value of the protein under study.

A similar analysis was performed on the data from the 30 experimental children and the 34 control children who completed 3 months in the study. The conclusions are identical.

Changes in clinical signs

All subjects had a marked deficit in weight and height initially, but there were remarkably few specific signs of malnutrition among them (Table 7). A good illustration of the predominance of the marasmic type of protein–calorie malnutrition is the observation that only 1 child in 48 had edema. All signs disappeared except in one child whose hair remained discolored. Angular lesions appeared in one child in each group. Although these observations are of minor significance, they certainly point to improvement in both groups.

TABLE 7
Changes in clinical signs of malnutrition

Clinical signs	Control group		Experimental group	
	Before	After	Before	After
Discoloration of hair	2	1		
Easily pluckable hair	1		2	1
Angular lesions (mouth)		1[a]	1	1[a]
Follicular hyperkeratosis	1		1	
Bilateral edema			1	
Loss of adipose tissue	1		1	
Total signs	5	2	6	2
Children with one or more signs	5	2	4	2
Children without any signs	21	24	18	20
Total children	26	26	22	22

Note: All children were checked for presence of Bitot spots, conjunctival xerosis, and dyspigmentation of skin, but symptoms were present in none of them.

[a] Sign not present initially in the same child.

The disappearance of apathy and hostility, the psychomotor recuperation, and the progress in language were striking. A number of children who did not walk, or even sit, started doing so. Stimulation and the care given to the children undoubtedly played a role. However, in the experimental group as in the control group, the diet was, if not the cause, at least closely related to such a recovery. As in our earlier experience with rehabilitation centers (16, 17), it is the progress in motor development and language that most amazed the parents and the auxiliary personnel in charge of the children.

Biochemical data

With the children being prone to malnutrition caused by marasmus, it is not surprising to find that biochemical evidence of malnutrition is scarce.

Total serum protein was high at the beginning of testing in both the control group (7.81 g/100 ml) and the experimental group (7.96 g/100 ml). The differences observed between the means or the distribution, either between groups or between periods in the same group were not significant. The rather

TABLE 8
Serum protein

	Control group		Experimental group	
	Initial (19)	Final (19)	Initial (19)	Final (19)
Total protein, g/100 ml				
Deficient[a] <6.0			1	1
Low 6.0–6.4				
Acceptable 6.5–6.9	3	4	2	1
High ≥7.0	16	15	16	17
Mean	7.81	7.63	7.96	7.81
Serum albumin, g/100 ml				
Deficient[a] <2.80		1	1	1
Low 2.80–3.51	11	13	7	14
Acceptable 3.52–4.24	7	5	11	4
High ≥4.25	1			
Mean	3.49	3.25	3.57	3.27
Below 3.0	1	3	1	2
≥3.0	18	16	18	17
Gamma globulin, %				
≤20	5	5	5	1
21–24	7	11	9	9
≥25	7	3	5	9
Mean	22.9	21.9	23.1	24.4
Albumin–globulin ratio	0.81	0.74	0.81	0.72

Numbers in parentheses refer to number of subjects.
[a] According to (22).

high figures are accounted for by generally normal albumin levels accompanied by extremely high gamma globulin values (Table 8). Albumin was above 3.0% in almost all children. The albumin–globulin ratio dropped somewhat during the study, but did so equally in both groups. The high gamma globulin pattern undoubtedly reflects the frequency and severity of infectious or parasitic infestations, or both, to which those children are submitted. The normal or high total protein and albumin levels confirm the previous data on the essentially marasmic nature of malnutrition in our subjects.

Mean plasma retinol was satisfactory initially and it did not change significantly in time in either group (Table 9). The average level, however, was significantly higher ($P < 0.05$) in the control group at the beginning, and this difference persisted unchanged throughout the observation period. When the children were distributed by levels of plasma retinol according to the ICNND classification (22), a slight drop was observed in the experimental group but it was not significant.

Initially average hemoglobin levels were borderline to normal, although distribution of the subjects shows that approximately one-half of them were anemic, that is, they had less than 11 g hemoglobin/100 ml blood (26) (Table 10). In the control group, which had a slightly lower initial value, hemoglobin improved; there was no change in the experimental group. Anemia was diagnosed in approximately the same number as the controls at the end of the 4-month period, in spite of the daily administration of a supplement containing iron, folic acid, and vitamin B_{12}. This illustrates the difficulties one faces when trying to rehabilitate malnourished children in a

TABLE 9
Plasma retinol, micrograms/100 ml[a]

	Control group		Experimental group	
	Initial	Final	Initial	Final
	(20)	(20)	(19)	(19)
	Distribution			
Deficient[b] <10				1
Low 10–19		1		5
Acceptable 20–49	15	15	18	13
High ≥50	5	4	1	
Mean plasma retinol	43.42 ± 13.2	41.62 ± 13.3	32.75 ± 12.6	26.33 ± 9.0

Numbers in parentheses refer to number of subjects.
[a] Mean ± SD. [b] According to (22).

heavily contaminated environment. Hematocrit was high initially, and it increased slightly but not significantly.

The biochemical data are rather disappointing: few changes were observed, and they seldom were statistically significant. When putting all the data together, however, one cannot escape the conviction that, on the whole, the performance of the experimental group was not as good as that of the control group; however, the difference was small. The poorer nutritional status of the experimental group and their higher rate of diseases can explain this in part, but it is also possible that the experimental diet was not quite as good as the control diet.

TABLE 10
Hemoglobin and hematocrit

		Control group		Experimental group	
		Initial (24)	Final (24)	Initial (22)	Final (22)
Hemoglobin, g/100 ml					
Deficient[a]	<10.0	9	3	4	2
Low	10.0–10.9	6	7	7	7
Acceptable	11.0–11.9	7	7	8	10
High	≥12.0	2	7	3	3
Mean		10.6	11.3	11.0	11.1
Hematocrit, %					
Deficient[a]	<30				
Low	30–33	5	1		
Acceptable	34–36	8	5	8	3
High	≥37	11	18	14	19
Mean		36	39	37	39

Numbers in parentheses refer to number of subjects.
[a] According to (22).

Discussion and conclusions

The obvious drawback of these data is that because the children were the victims of so many diseases, they were not adequate subjects for a study of the biological value of an experimental protein. There is no doubt that one of the usual prerequisites for such a study was unmet (14). The planning and the site selection were based on considerable experience gained in the rural area by the Institute: it was a surprise to us, however, to discover how much poorer and how deprived of elementary sanitation and health care the children in the slum were. On the other hand, to conduct such a test on malnourished children free from infectious and parasitic diseases would be totally unrealistic. Such healthy children do not exist in this area. The conditions of the present test reflect those of a sizable proportion of the population of Recife, itself over a million, and the conclusions therefore apply to a real situation. The bias, and there is a real one, may not be larger than to select a malnourished child, cure him from his infections, give him good protein, and then bind him to a metabolic bed for a few days, deprived of maternal care, the daily stimuli of life, and even, quite often, of affection. The bias here is of a different, and maybe less usual, nature, but it is not necessarily larger. Both methods are necessary: a test with children under normal conditions of life complements the metabolic unit study, it does not replace it. Midway between these extremes are the conditions of the Haitian study already mentioned (7).

Another bias comes from the withdrawal rate, particularly at the beginning and at the end of the study. Reasons for irregular attendance or withdrawal were carefully screened. They were related, in the beginning, to the attitude of the community toward a new program. This is usual when rehabilitation centers are created, but it was found here to be more frequent than anticipated. Withdrawals in the late period were due to the removal of families by the town authorities during slum-clearance operations. In neither case was there any discrimination against any one center. But the number of subjects were reduced, and the original matched-pairs distribution had to be abandoned in the final tabulation.

Although the children were distributed in the two groups in a completely random fashion, those in the experimental group had a somewhat poorer nutrition and health status initially, as evidenced by some anthropometric, clinical, and biochemical observations. They also suffered more from infectious diseases, at least in the earliest part of the study. These facts introduce in our conclusions another systematic bias that we can not ignore.

This bias, however, plays against the null hypothesis, that is, against a good protein value for the product under study. The biological value of the noodle is therefore at least as good as shown by this study, and probably better.

In spite of the limitations, what can we then conclude from this study?

In the first place, the analysis of the anthropometric measurements shows that the administration of the high protein macaroni as the major source of protein for 4 months is compatible with the maintenance or resumption of a growth rate at least equal to normal. Whereas no difference is observed with reference to a control group in the measurement of the children's length, there was no true recovery of the weight deficit. One of the factors involved certainly is that the calorie intake of the experimental group was almost constantly below that of the control children, in spite of the attempt of the nutritionists to vary the diet by adding sweets, sugar, fruit juices, et cetera. The presence of the macaroni seems to have brought about a check on appetite, at least above a certain dose (actually a high dose).

Clinical observation showed a reduction of clinical signs of malnutrition, and a marked improvement in psychological and motor behavior, as well as progress in language. In both groups there was some recuperation. A few children did not recover satisfactorily, but in all recuperation centers, there is an average of approximately 20 to 30% of the children who do not improve (16, 17). The observations here, for both groups, fit our earlier experience.

Laboratory data provide less useful data, as the clinical findings varied only slightly, or not at all. On the whole, the data are compatible with a certain degree of recuperation. Notwithstanding, a detailed examination of our anthropometrical and biochemical data suggest that, even when changes were not found to be statistically significant, most point to a lower response in the experimental group. This study points once again to a contrast between the expectation from rat studies and the findings from actual conditions in humans.

Tolerance of the macaroni was remarkably high. Those children, with a mean weight of approximately 10 kg absorbed on the average nearly 121 g of the noodle, that is, two-thirds of their protein intake, in a sustained way, during 4 months, without showing evidence of intolerance or refusal. This is a high figure by any standard.

We may conclude that the protein under study is a fairly adequate one, although not as good, under the conditions of the experiment, as a diversified diet containing a sizable proportion of animal protein. The noodle is safe and wholesome, stores well, and it is extremely well tolerated. If the present estimates that the cost to the consumer would be well below that of standard wheat macaroni are confirmed, then it definitely represents a valuable additional source of protein to the diet of poor people, and it can be recommended for use as a supplement.

As for the methodology used, and taking into account the restrictions made above, we believe this study brings an original contribution to the testing of protein products in real population groups.

Summary

A new macaroni, containing 60% corn (maize), 30% defatted soy flour, and 10% wheat germ (protein = 20.5%), was used in an experiment with Brazilian malnourished children who were treated and fed daily in a nutritional rehabilitation center. The children were served five meals covering their recommended daily allowance for all nutrients for 4 months. One group received 69% of their protein from the macaroni. A control group, in a separate center, received a regular diet containing animal protein, and calculated to provide the same amount of calories, protein, carbohydrate, and fat.

Nutritional recuperation was observed in both groups, although anthropometrical and biochemical data indicate a better response in the control group. Acceptability was excellent: the average noodle consumption per child per day was 121 g for 4 months. The authors conclude that the macaroni can be recommended as a supplement.

Methodological aspects of the study are

discussed, with particular reference to experimental design and interference of infectious processes.

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