APPENDIX V-j

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Prolonged Consumption of Wheat-Based Diets by Infants,
With and Without Casein or Lysine Supplementation

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ABSTRACT

Earlier short-term studies had demonstrated that recovering malnourished infants and small children could consume 75% of calorie requirements as 82% extraction wheat flour without deterioration in high digestibility of protein and energy of wheat. Nitrogen (N) balances indicated that at this level protein needs of the children, represented by N retentions from an isonitrogenous casein diet, probably were not satisfied. Additional long-term (3+ months) studies in four similar infants and children have shown that a diet with 50% calories and 80% protein from wheat (casein added so protein calories = 8% of total) was consumed and digested efficiently and supported wt gain and linear growth in excess of expected for age or "height age". Prolonged feeding of 75% calories and 100% protein from wheat was attempted in three infants and small children. In the oldest (age 15.5, height age 12.3 mos.) digestibility and growth were satisfactory. In one infant, despite good digestibility, wt gain and linear growth were inadequate and serum albumin fell to deficiency levels until 0.2% lysine was added to wheat flour. In the third infant wt gain was satisfactory but serum albumin fell to borderline (3.25 g/dl) levels and linear growth was inadequate. In 6 additional infants and children, lysine addition during the second of three months was associated with a significant increase in N retention and wt gain and stabilization of falling serum albumin levels. Withdrawal of lysine resulted in a significant decrease in rate of wt gain, no effect on N retention or serum albumin. Linear growth was barely adequate during 3-month study. Previously noted fall in serum cholesterol with wheat diets was seen only when dietary protein was inadequate. It is practically impossible for unsupplemented wheat to satisfy protein needs of infants and most small children.

Wheat, rice and maize are the principal sources of energy and protein in the diets of millions of less-privileged people. Adults and older children almost invariably consume these staples with complementary sources of protein, notably the legumes, but mothers commonly withhold the legumes from infants and young children because of concerns about their appropriateness for this age group (1). During the past few years world food policies have been strongly influenced by a series of published opinions to the effect that the major staples, if consumed in amounts adequate to satisfy energy needs of children, would automatically satisfy their protein needs (2). At least three major doubts should be clarified before the above assumption is made into policy: whether the bulkiness of most such diets would allow for sufficient consumption by small children, whether the digestive capacities of small children would remain adequate over long periods of time to handle such large amounts, and if the nitrogen and essential amino acid requirements would indeed be satisfied.

Although the carbohydrate component of properly cooked common varieties of rice is very well assimilated by infants and small children, the low energy density of rice makes it difficult to consume in amounts sufficient to meet calorie needs and the poor digestibility of its protein, already present in low concentration, makes it impossible for common rice to satisfy nitrogen and essential amino acid needs of this age group (3). The inferior digestibility of the carbohydrate and protein components of maize and its severe deficiencies of lysine and tryptophan make it absolutely impossible for infants and small children to satisfy their protein needs from this cereal alone. Even when the opaque-2 gene has been introduced to increase the contents of the limiting amino acids, maize still falls short for nearly all small children (4).

The higher protein content of wheat and its decreased bulkiness when processed into pasta make it an attractive source of energy and protein for small children. An earlier study demonstrated that the digestibility of the carbohydrate and protein components remained high despite consumption of as much as 75% of total calories as 82% extraction flour (5). When wheat provided 25% of calories and 50% of 6.6% protein calories (the remaining 50% from casein) apparent nitrogen retentions were indistinguishable from those of preceding and following casein-based control diets. When wheat provided 50% of total calories and all the protein in similar 6.6% protein calorie diets, the apparent nitrogen retentions averaged 50% of those from the same casein control diets. This suggested that even if the infants and children under study had consumed all of their energy needs as wheat, if digestibility had remained equally high, and if no other nutritional deficiencies had supervened, only 50% of the children would have satisfied protein needs, as defined by the retentions from the casein control diets. When wheat provided 75% of calories and all of 9.8% protein calories for nine small children, apparent nitrogen retentions were inferior to those from a casein-based 9.8% protein calorie diet in five children, equal in three, and higher in one who had an aberrantly low retention from casein during one diet period. Although the higher protein content of these diets blunted the sensitivity of the balance technique, the results suggested that even this high an intake of wheat did not meet the protein needs of the children.

Additional studies were carried out for two purposes: (a) to determine if the digestibility of wheat could be maintained over long periods of time and (b) to determine if a diet providing 75% of calories

and 100% of protein as wheat could support satisfactory growth in recovering malnourished infants and children without protein or lysine supplementation. Studies carried out some years ago had indicated that a diet based on a high-protein white wheat flour which provided all of 8% protein calories could support satisfactory growth when adequately supplemented with lysine (6). No attempt was made to prolong the feeding of unsupplemented flour, as it was assumed that protein needs would not be satisfied.

MATERIALS AND METHODS

Subjects. Thirteen infants and children (9 female, 4 male) participated in the studies (Table 1). Ages ranged from 6.4 to 24.5 months. All had been admitted to the Instituto de Investigacion Nutricional for treatment of malnutrition and its complications, were well along in recovery, and were in the hospital to consolidate their rehabilitation and prevent relapse[1]. They were free of apparent infections and gaining weight steadily when studied. Serum albumin concentration had reached or remained steady at >3.4 g/dl (range 3.44 to 4.75, mean 4.07) while consuming a diet adequate in high quality protein. Their height ages ranged from 3.0 to 18.4 months and their weight ages from 2.3 to 11.4 months at the beginning of the studies, with most children still demonstrating significant weight-for-height deficits. Instead of the 50th percentile of the Boston reference data to calculate height and weight ages, the present study made use of the 50th percentile of the growth data of infants from the same racial and socio-economic background growing in a protected environment for the first one to two years of life. This data base is considerably expanded over the one already

published (7). It was also used to judge the adequacy of subsequent linear and ponderal growth. The 50th percentile of these data corresponds approximately to the 25th of the Boston reference (8).

Diets. The study was carried out in three distinct phases. During the first (A), 50% of diet calories and 77 to 80% of protein were provided by 100% wheat semolina noodles (82% extraction flour, hard winter Argentine wheat), with enough casein (as Casec, Mead Johnson) added to bring protein calories to 8%. With the exception of the small amount of sugar displaced by casein, this diet was essentially identical to the 50% pasta diet of the previous study: soybean-cottonseed oils (80:20) provided 25% of calories, sucrose made up the remaining 23+% of calories, and the same mineral and vitamin supplements were added (5).

In the second (B) and third (C) phases of the study 75% of calories and 100% of protein in the diets were provided by the wheat noodles, the balance of calories provided by the soybean-cottonseed oil blend, as in the previous 75% pasta diet (5). In phase B one of the three subjects had lysine added to the diet (0.2% of the wheat) during the last two months. This resulted in a small increase in dietary nitrogen. In phase C all six subjects received the same diet with and without supplementary lysine, an isonitrogenous amount of urea being added during the unsupplemented periods to maintain nitrogen intakes constant.

All diets were prepared as in the previous study and blenderized for bottle- or spoon-feeding.

Study Design and Analysis. In phase A the diets were fed for a minimum of three months to determine if satisfactory tolerance and digestibility could be sustained and if satisfactory rates of "catch-up"

growth would be supported.

In phase B it was planned to feed 75% of calories as wheat, without protein supplementation, to determine if satisfactory tolerance and digestibility could be maintained and if the inferiority to isonitrogenous casein diets suggested by the previous nitrogen balance studies (5) had a demonstrable effect on growth, the ultimate test of dietary protein adequacy. In the first child it was decided after four weeks that weight gain was unsatisfactory despite a level of calories that had previously proven adequate. An increase in caloric intake (with a parallel increase in protein) resulted in a prompt acceleration of weight gain. To determine if the previous inadequacy was due to insufficient calories or inadequate lysine, the diet was reduced after 15 days to the previous level. Rate of weight gain during the next 11 days was 25% lower, but higher than the original low one; lysine was then added for 61 days. Two children completed the three months of consumption of the unsupplemented 75% wheat diet.

In phase C it was planned to feed the same 75% wheat diet for three months, with 0.2% lysine added during the second month only. In each of two subjects one of the dietary periods was prolonged because of intercurrent illness. In another, the least malnourished, the study was discontinued midway through the second month. In the last three the study was completed as planned.

The children received 100 to 160 Kcal/kg/day, recalculated weekly, with the level based on that previously shown to maintain each child's rate of weight gain in an acceptable range of 3-7 g/kg body weight/day. In two of the children in phase C the level had to be increased during the initial period.

In phases A and B two consecutive three-day balance studies were carried out at the end of each month. One child in phase B had an additional six-day study in the second month, just after the addition of lysine to the diet. In phase C, six-day balances were carried out at the end of the initial wheat period, at the beginning and end of the wheat plus lysine period, and at the beginning and end of the final wheat period. In three children an additional balance study was carried out while consuming an isoenergetic isonitrogenous casein-based diet after the termination of the last wheat period. In girls no attempt was made to separate urine and stool, preventing observations on nitrogen absorption or stool wet weight. It was assumed that the urine was fat-free and that its contribution to energy content and dry weight was too low to affect results. Methods for total nitrogen, fat, and calorimetry were the same as in previous studies (5). Serum total protein (Biuret), albumin (acetate gel electrophoresis) and total cholesterol were determined at least once a month, more often when diet changes or concerns about protein adequacy indicated.

Weight gains were expressed in g/day and, for periods of at least 10 days, as percentages of the expected for age and for height age in the local reference data. No attempt was made to interpret linear growth during periods of less than 50 days. For periods of at least that duration it was expressed as mm/day and as percentages of the expected for age and for height age. A stunted child growing at the rate expected for age will maintain the same deficit in grams of weight or mm of height. Over time, because of slowing of growth, this would lead to an increasing deficit in weight or height "ages". The same child, growing at the faster rate corresponding to his or her considerably younger

height age, would reduce gram or mm deficits and would cross percentile lines in a growth chart, but would keep the same deficit in weight or height age. This would steadily become less and less significant. If growing at a rate in excess of that expected for height age, the child would tend to correct all deficits. Student's "t" test for paired values was used to compare rates of weight gain (as percentages of expected) in the third phase of the study.

RESULTS

Tolerance and Digestibility. With the exception of one child whose study was discontinued because of incomplete consumption, the diets were well consumed in the form and amount offered. There were no signs of intolerance such as nausea, vomiting, or abdominal distress. This cannot be construed as a proper test of acceptability.

None of the four children in phase A gave evidence of poor digestibility. In the only male, stool wet weight, 96±42 g/day, was very similar to the 95±33 g/day found for 50% wheat diets in the earlier study. Apparent nitrogen absorption (84.5, 85.4 and 89.3% of intake) was also comparable. Stool (or stool + urine) dry weights of the four children were 15.0±2.7, 11.0±2.2, 15.8±4.1 and 16.2±1.9 g/day, similar to the stool only dry weights of 13.3±2.5 g/day of the previous study. Stool fat, in g/day, as % of dry weight, or as % of intake (Table 2) was normal in all four subjects, with a slight decrease over time. Stool calories, as % of intake (Table 2) were also low.

Stool plus urine dry weights of the three girls in phase B were 15.3±2.6, 22.2±3.4 and 17.4±3.5 g/day, similar to the stool only dry weights of 17.0±4.0 g/day of the previous study for children consuming a similar

diet for nine days. There was no tendency for dry weight to increase over time. Stool fat was within the presumed normal range (15% of intake) in the three girls (Table 2) in almost all studies. In #556F it was lower after the addition of lysine. In #564F it had increased at the end of the second month but decreased appreciably at the end of the third month. In #566F stool fat was on the high side of normal at the end of the first month, just above normal after two months, and just within normal at the end of three months. Although many of the values in these three girls were above the mean (5.7±4.1% of intake) found in the previous study (5), the subjects were not comparable in age, stage of recovery, or duration of feeding the diets. Infant #566F, the one with the highest values, was the youngest and smallest of the seven subjects in phases A and B.

The findings in phase C were different. Stool wet weights of the three boys were 274±86, 178±31 and 232±36 g/day, more than the 124±43 g/day of the previous study. Stool or stool + urine dry weights were 35.8±6.7, 28.6±4.6, 29.1±3.1, 54.4±12.2, 44.9±12.6 and 36.0±12.1 g/day in the six subjects, significantly higher than in the previous study and with a tendency in some of the children to increase over time. Stool fat and calories (Table 2) in one subject, #582M, were within the published range and that found in the first two phases. In #585M, who did not complete the whole study, stool fat and calories were moderately higher but still within the expected range. In subject #578M, the one with the lowest height and weight ages and the most severe degree of malnutrition, stool fat was already high after one month, improved slightly during lysine addition, increased again after its withdrawal,

and finally improved again after recovery from an intercurrent infection with diarrhea (to 19.1% of intake, still high). Stool calories generally paralleled stool fat. In the remaining three subjects, two of them with very young height ages, stool fats and calories were high and did not improve with lysine supplementation. In #588F and #591F fat and energy absorption deteriorated over time. In all four children in whom elevated stool fats and energy were already found at the end of one month, these represented a distinct deterioration from values prior to this study while consuming milk diets. The wheat studies in these children, however, were begun at an earlier age and stage of recovery (Table 1). The apparent absorptions of nitrogen for the three boys were 76.0±5.0, 87.2±2.8 and 79.5±2.2% of intake. Only in the youngest subject, #578, were these suggestively lower than the 84.7± 3.5% found in the previous study for comparable diets (5). The casein-based diets which followed the wheat diets in the last three subjects were invariably associated with the expected decrease in stool dry weight and with a striking decrease in stool fat and energy.

Apparent Nitrogen Retentions. During phase A of the study all four subjects demonstrated progressively increasing apparent retentions of nitrogen (Table 3).

The initial apparent retentions of nitrogen in phase B, with a 22.5% higher nitrogen intake, seemed as high or higher than those of phase A, but did not increase over time. The progressively greater errors in the balance technique with larger intakes (9) cast doubt on the apparent initial superiority. In subject #556F lysine supplementation was associated with an apparent increase in retentions.

The addition of lysine was associated, in all seven children (six from phase C), with a modest increase in apparent retention (Table 3) which was statistically ($P<0.02$) significant. Return to a non-supplemented wheat diet in five children, however, was not associated with a consistent decrease. Nitrogen retentions during the final casein periods in the last three children were considerably higher than during the last wheat periods.

Growth. In phase A all four children gained weight (Table 4) at accelerated rates, much greater than those expected for age or for height age. Linear growth rate was greater than expected for age or as great or greater than expected for height age. All four advanced more in height age and weight age (Table 1) than in chronologic age. At the end of the study three of the four had weight ages well in excess of their height ages and were visibly obese.

Subject #556F in phase B gained weight very slowly during the first 27 days (Table 4). When total calorie (and protein) intake was increased, the rate of weight gain exceeded the expected for height age; when calorie intake was again reduced the rate of weight gain fell off moderately but still exceeded the expected. During the total of 53 days linear growth did not reach the expected rate for age. When lysine was added, rates of weight gain increased to the level previously achieved with a greater calorie and protein (and lysine) intake and linear growth considerably exceeded the expected for height age. During the 3.8 months of study the gains in height age exceeded those in chronologic age but weight age still lagged behind (Table 1).

Subject #564F gained in weight at a rate in excess of the expected for height age. Linear growth just equalled the expected for height age (Table 4). The height age of 15.4 months at 18.5 months of age might well have represented complete catch-up. The results in the third child in phase B were not satisfactory. Although rate of weight gain was 48% higher than expected for height age, linear growth did not match the expected for age.

Because of the short duration of each of the three diet periods in phase C, no attempt was made to calculate or assess linear growth rates other than for the entire duration of the study (Table 4).

For subject #578M the rate of weight gain during the first month did not equal the expected for height age. When lysine was added this rate was exceeded by 46%, and when lysine was withdrawn, weight gain fell to the previous rate. During the combined 2.5 months linear growth was minimally greater than expected for height age. During the following 38 days of illness and recovery the diet was varied, at times containing milk protein. During the final 16 days on the unsupplemented wheat diet, weight gain matched that of the lysine-supplemented period. This might have been due to a carry-over effect from the immediately preceding period, to further recovery of weight lost during the illness, or to decreasing protein (and lysine) requirements with advancing age. For the entire 4.3 months, the gain in weight age exceeded the time elapsed, that in height age, 3.4 months, fell short (Table 1).

In the second subject in phase C, #582M, the 11-day interruption occurred after 21 days of the lysine-supplemented period. Following recovery, the lysine-supplemented diet was given for another 27 days.

Weight gain during the first lysine period was greater than that of the preceding unsupplemented period, although this had already been high. During the final unsupplemented period, though still high, rate of weight gain was less than during the resumption of the lysine-enriched diet.

When rates of weight gain, as percentages of expected for height age, of the initial wheat periods were compared with those of the immediately following lysine period, they were significantly lower, with "t" = 3.96 and $P<0.01$. When those of the final wheat period were compared with those of the preceding lysine period, they were significantly lower, with "t" = 2.84 and $P<0.05$. No such comparison could be made for linear growth rates but for the overall study, most of it without lysine added, they did not reach the expected for height age in 5 of the 6 children. The lower expected rate for age was approximately equalled or exceeded in all of the children.

Serum Albumin and Cholesterol. Figure 1 summarizes the evolution of serum albumin and cholesterol in the 13 children. For those consuming wheat plus casein both remained essentially unchanged. For the two receiving unsupplemented wheat throughout, there was a fall in both albumin and cholesterol, most striking in #566F, whose growth was considered unsatisfactory. Much of this fall may have been due to initially high levels of both, probably the result of an immediately preceding milk diet. In #556F serum albumin was quite low after 30 and 53 days of the unsupplemented diet and recovered rapidly after the lysine addition; serum cholesterol did not change to the same degree. In subject #585 both albumin and cholesterol fell from initial high levels during the unsupplemented wheat period. In the remaining five subjects

of phase C there was a similar initial fall in both, with a relative stabilization of albumin and a moderate increase in cholesterol during lysine supplementation. When lysine was withdrawn albumin remained stable and cholesterol fell again, although the change was not statistically significant.

DISCUSSION

A diet in which wheat supplied 50% of total calories and approximately 80% of protein (balance as casein) was easily consumed and digested by infants and young children for at least three months. It supported rates of weight gain and linear growth which led to rapid correction of existing deficits. Serum albumin levels were not indicative of protein deficiency. Contrary to a previous experience with wheat diets without a supplementary source of protein or lysine (10), there was no significant fall in serum cholesterol levels. This suggests that the previously observed decline was more the result of protein inadequacy than of dietary fiber.

When wheat supplied 75% of total calories and 100% of protein, the results were different. Low stool dry weight, energy and fat, indicative of satisfactory digestion and intestinal absorption, were found in five of nine subjects during at least three months of consumption. These included three children who were 15.5, 24.5 and 19.4 months of age and had height ages of 12.3, 17.7 and 18.4 months, respectively. One was 8.9 months of age and had a height age of 5.8 months. The youngest, whose stool fats were borderline normal, was 8.5 months old and had a height age of 5.5 months. Four of the children had stool dry weight, stool energy, and stool fat values which were indicative of less than

adequate starch digestion and of significant steatorrhea, progressive in two of the four. They were 10.4, 9.7, 9.2 and 6.4 months of age and had height ages of 3.0, 8.0, 4.6 and 4.0 months, respectively. It is apparent that age or "biologic age" was a factor in determining whether the gastrointestinal tract of an infant could handle such large amounts of 82% extraction wheat flour over a prolonged period of time with continued high efficiency.

In the first child receiving a 75% wheat diet, despite satisfactory digestion, growth was not adequate and an increase in calorie and protein intakes, or the addition of lysine alone was necessary to produce accelerated growth and to correct hypoalbuminemia. The addition of lysine may also have improved digestive function. The second child grew well without the addition of lysine and maintained serum albumin at satisfactory levels. Whether lysine would have improved performance was not tested. She was 15.5 months of age, had a minimal "deficit" in height age and a moderate weight deficit indicative of recent malnutrition. The third child, though gaining weight satisfactorily, did not grow adequately in length and had a gradual fall in serum albumin. After three months, however, this was still 3.25 g/dl. She was 8.5 months old and had a height age of 5.5 months. Lysine supplementation was not tried.

In the remaining six children lysine supplementation produced a significant increase in apparent nitrogen retention and a significant increase in weight gain. Because of the short periods involved, an effect on linear growth could not be ascertained. The withdrawal of the supplemental lysine in 5 children resulted in a decreased rate of weight gain, but no measurable effect on nitrogen retention. During

the entire study, most of it without supplemental lysine, linear growth was inadequate or just barely adequate. The addition of lysine had an apparently favorable effect on falling serum albumin levels.

The effects of the 75% wheat diet on serum cholesterol, though not statistically significant, were suggestive of a positive effect of lysine supplementation. They support the hypothesis that the previously reported cholesterol-lowering effect of wheat diets in infants was the result of dietary protein inadequacy rather than of fiber in the diet. The steatorrhea seen in the younger subjects of this study would also seem to be the result of protein deficiency.

A diet in which wheat provided 75% of calories, and which should have satisfied the energy requirement of infants, did not satisfy their requirements for essential amino acids. In children with "biologic" ages of over 12 months, a supplementary effect of lysine could still be demonstrated. If such a diet were consumed in excess of energy needs it might meet essential amino acid requirements of small children but at the cost of decreased efficiency of energy utilization, the risk of manifestations of protein deficiency, or both. In the younger age group there was evident a deteriorating digestive and absorptive capacity which may have been the result of protein deficiency. When casein was added to a diet providing 50% of calories as wheat there was excellent growth, continued high digestibility, and no evidence of protein deficiency.

Premature weaning from the breast, for whatever reason, represents a life-threatening problem to millions of infants whose families do not have the hygienic or economic resources for artificial feeding with

cow milk formulas. For many who are being breast-fed but whose rate of growth falls off significantly, adequate and safe supplementation is also a serious nutritional problem. Wheat flour of 82% extraction, or possibly higher, can easily provide 50% of energy requirements and be a rich source of protein, with its lysine deficiency corrected by the relative excess of all essential amino acids in breast milk. For the infant who has been weaned another source of high quality protein or of lysine in particular needs to be consumed with wheat so that it can satisfy protein needs with less than 75% of diet calories. Without such supplementation wheat cannot successfully be the only source of protein in the diet of infants or most young children. During infancy the excellent digestibility of wheat is not maintained if dietary protein is not adequate, particularly so in those under six months of age.

FOOTNOTE

The protocols for these studies were approved by the Joint Committee on Clinical Investigation of the School of Medicine, The Johns Hopkins University and by the corresponding committee of the Instituto de Investigacion Nutricional. All children were admitted and participated in the studies with the informed consent of their parents.

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Table 1

Initial chronologic age (CA), height (length), height age (HA)*, weight, and weight age (WA)* of the 13 recovering malnourished infants participating in the three phases of the study. Total duration of study (including interruptions due to illness) and final HA and WA also listed.

Subject Number and Sex	Initial Ages and Measurements					Total dur'n mos.	Final	
	CA mos.	Height cm	Weight kg	HA mos.	WA mos.		HA mos.	WA mos.
				Phase A (W50+Casein)				
529F	13.0	66.5	7.01	8.6	6.9	3.2	14.5	18.5
533M	8.6	67.8	6.58	7.2	5.0	3.2	11.5	11.2
535F	20.2	71.0	8.60	12.3	11.4	3.6	18.1	25.8
540F	18.9	72.3	8.05	13.6	9.8	3.2	17.5	24.9
				Phase B (W75)				
556F	8.9	62.8	4.35	5.8	2.5	3.8	10.3	6.1
564F	15.5	71.0	7.17	12.3	7.4	3.0	15.4	13.8
566F	8.5	62.2	4.52	5.5	2.7	3.2	7.6	5.9
				Phase C (W75±Lysine)				
573M	10.4	59.0	4.55	3.0	2.3	4.3	6.4	7.8
582M	24.5	78.1	8.24	17.7	8.0	3.9	19.9	17.1
585M	19.4	78.8	9.19	18.4	11.1	1.5	20.6	15.7
583F	9.7	65.5	6.10	8.0	5.3	3.3	10.4	8.5
590F	9.2	60.1	5.27	4.6	4.2	3.0	6.9	8.2
591F	6.4	58.4	4.93	4.0	3.4	3.0	5.5	6.6

* Height and weight "ages" derived from 50th percentile for children from same original environments but under protected conditions for first 1-2 years of life.

Table 2

Effect of prolonged consumption of wheat flour as 50 or 75% of diet calories on 6-day stool fat and stool calories of recovering malnourished infants

Subject Number and Sex	One Month % of Intake		Two Months % of Intake		Three Months % of Intake	
	Fat	Kcal	Fat	Kcal	Fat	Kcal
			Phase A (W50+Casein)			
529F	5.1	5.7	5.4	5.1	3.7	4.5
533M	5.1	4.5	3.4	5.0	4.1	3.7
535F	11.2	7.1	--	--	4.2	3.4
540F	7.0	5.1	7.8	5.4	4.9	4.0
			Phase B (W75)			
556F	8.7	8.8	10.1, 4.1*	8.5, 6.3*	3.9	6.7
564F	7.8	9.4	14.7	9.0	7.0	6.9
566F	12.7	7.1	15.3	9.3	14.5	12.5
			Phase C (W75±Lysine)			
578M	32.2, 27.4	20.8, 22.9	22.5, 29.3	17.5, 21.3	19.1	13.4
582M	3.9, 4.9	8.9, 9.5	--	--	3.6, 5.6	8.9, 8.2
585M	12.7, 10.1	11.8, 11.3	11.7	9.0	--	--
588F	17.7, 19.1	22.5, 19.7	20.1, 20.7	21.9, 20.5	33.0	30.0
590F	24.7, 20.8	16.1, 18.3	27.8, 24.7	25.3, 23.6	25.2	20.4
591F	15.5, 14.4	11.3, 11.7	21.3, 28.4	16.4, 23.3	43.1	24.4

* Two sets of values under same column heading represent two separate 6-day collections in the time period. Underlined values are during 0.2% lysine enrichment of wheat flour.

Table 3

Apparent nitrogen retentions, as % of intake, of recovering malnourished infants consuming 50 or 75% of diet calories as wheat flour. Casein added to 50% diets to bring protein calories to 8%. Lysine, 0.2%, added to flour in 75% diets when indicated. Protein (g) and Kcal intakes/kg body weight/day are listed.

Subject Number and Sex	Daily/kg Intake Prot/Kcal	Apparent N Retention, % of Intake in 6-day collections after approximately		
		One Month	Two Months	Three Months
		Phase A (W50+Casein)		
529F	2.5/125	29.9	48.2	61.6
533M	2.5/125	29.4	33.9	47.3
535F	2.0/100	24.7	--	40.0
540F	2.2/110	36.9	38.8	53.8
		Phase B (W75)		
556F	3.5/125	(46.9)*	24.0,35.3**	32.1,43.5
564F	3.1/110	24.7	36.4	30.4
566F	3.5/125	30.0	30.7	35.2
		Phase C (W75±Lysine)		
578M	4.3/160	27.0,31.5	29.0,30.3	32.0
582M	3.0/110	18.0,24.5	--	19.0,22.0
585M	3.0/110	22.5,26.0	25.5	--
588F	4.0/140	41.7,42.0	31.0,37.0	33.0
590F	3.9/150	38.0,42.0	42.5,34.5	40.0
591F	3.9/150	34.5,44.0	40.5,39.5	38.5

* During this collection diet intake had been increased to 4.0 g protein and 140 Kcal/kg/day

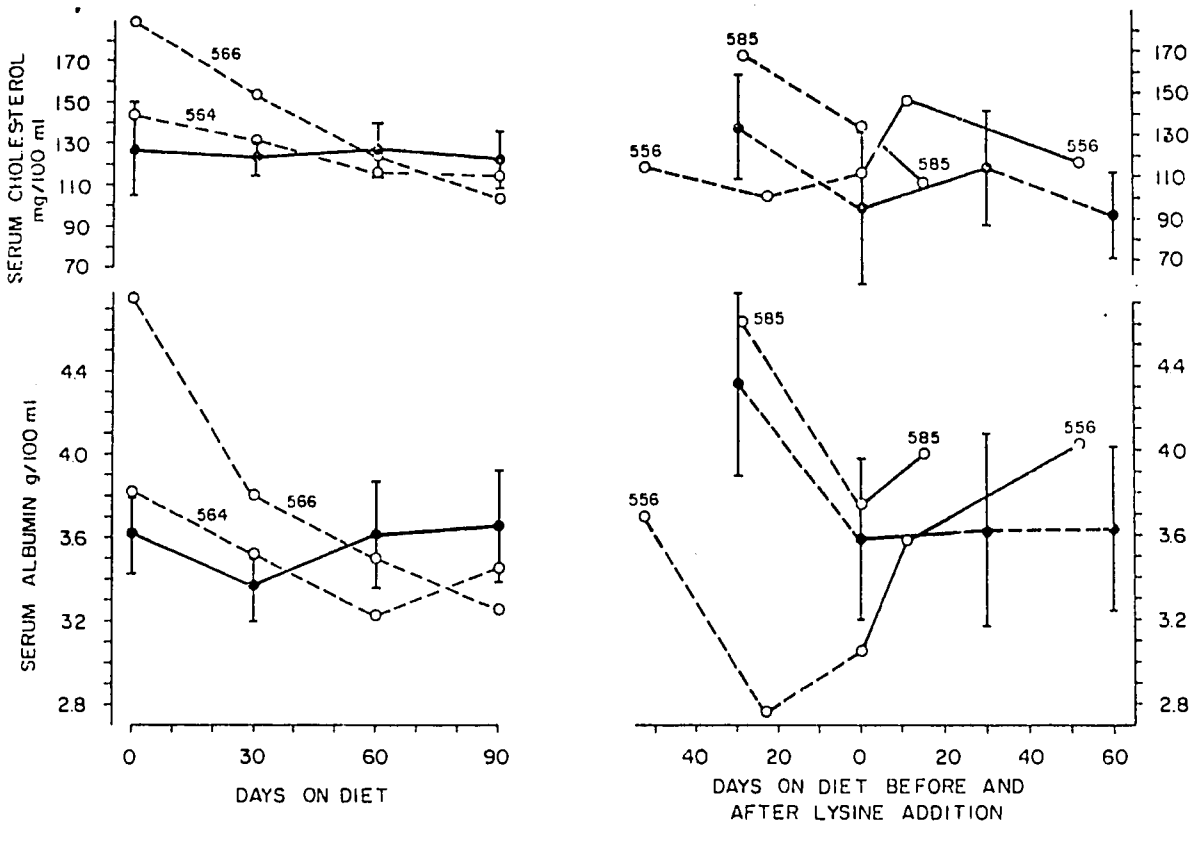
** All underlined results are during 0.2% lysine enrichment of wheat flour.

Table 4

Growth rates of infants in the three phases of the study in mm/day and g/day, and as percentages of the 50th percentile rates for Peruvian children of the same age or height age who grew for 1-2 years in a protected environment. Daily protein (g) and calorie intakes/kg body weight are also listed.

Subject # & Sex	Intake/kg/d Prot/Kcal	No. of Days	Linear Growth Rate mm/day	% age	% HA	Rate of Weight Gain g/day	% age	% HA
			Phase A (W50+Casein)					
529F	2.5/125	96	0.73	218	191	35.4	590	290
533M	2.5/125	96	0.55	137	137	28.8	232	218
535F	2.0/100	107	0.58	270	208	23.4	532	433
540F	2.2/110	96	0.33	156	100	36.5	830	608
			Phase B (W75)					
556F	3.5/125	27	0.30	64	60	2.6	22	17
	4.0/140	15	↓	↓	↓	24.0	202	158
	3.5/125	11				18.2	153	120
	3.5/125*	61	0.77	166	157	25.1	211	165
564F	3.1/110	90	0.34	146	103	26.0	743	433
566F	3.5/125	96	0.38	89	78	23.2	180	148
			Phase C (W75±Lysine)					
578M	4.3/160	31	0.74	292	108	20.0	123	79
	4.3/160*	30	↓	↓	↓	36.7	284	146
	4.3/160	15				20.0	177	79
	varied	38	--	--	--	Illness and Recovery		
	4.3/160	16	--	--	--	36.3	321	144
582M	3.0/110	30	0.30	180	78	34.7	913	457
	3.0/110*	21	↓	↓	↓	46.2	1216	608
	varied	11				Illness and Recovery		
	3.0/110*	27				54.1	1424	712
	3.0/110	20				29.0	763	382
585M	2.7/100	15	0.28	164	96	9.3	129	129
	3.0/110	15	↓	↓	↓	41.3	574	574
	3.0/110*	14				58.6	814	814
588F	3.8/140	10	0.26	97	81	-0.5	-5	-4
	4.0/150	29	↓	↓	↓	9.3	96	74
	4.0/150*	30				30.7	316	246
	4.0/150	30				7.7	79	62
590F	3.9/150	31	0.37	117	58	22.3	181	88
	3.9/150*	30	↓	↓	↓	33.7	274	133
	3.9/150	30				20.3	165	80
591F	3.9/150	30	0.42	93	53	17.7	143	70
	3.9/150*	30	↓	↓	↓	35.7	288	141
	3.9/150	31				11.3	91	45

* 0.2% lysine (as mono-hydrochloride) added to wheat flour.

FIGURE

Evolution of serum albumin and cholesterol of infants and children consuming wheat diets. Solid lines on left correspond to means (± S.D.) of 4 infants consuming 50% wheat + casein diets, broken lines to two infants consuming 75% unsupplemented wheat. Lines on right correspond to means (± S.D.) of 5 infants consuming 75% wheat with (solid line) and without (broken line) supplemental lysine. Two additional infants are plotted individually.