APPENDIX V-i

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Prolonged Consumption of Potato-Based Diets
by Infants and Small Children

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Abstract

A previous short-term study demonstrated that infants and children could consume diets in which 75% of energy and all protein was provided by the white potato. Nitrogen balance was inferior to casein control at this level of protein intake. Potato intake was limited by the bulk of the diets and the poor digestibility of carbohydrates. In the present study 10 children were offered diets containing 50%, 75% and 84.2% of total energy as potato during a period of 3 months. Casein was added to the 50% and 75% diets to complete 8% of energy as protein (N x 6.25). Acceptability, tolerance, digestibiligy and growth of the children were analyzed. The 84.2% potato studies were absorbed shortly after the beginning because of the excessively large volume. Acceptability and tolerance to the 50% potato diets were excellent but with the 75% potato diets were noted to decrease during the last days of the studies. Six of the 8 children who completed the studies showed satisfactory weight gain and catch-up growth while maintaining normal serum albumin concentrations. In one other, weight gain was adequate but did not achieve catch-up growth, and in the youngest child weight gain and linear growth were inadequate. Metabolic balances did not show improvement or deterioration of digestibility throughout the study. Infants can consume up to 50-75% of energy and as much as 80% of their nitrogen requirements as potato if the remaining energy and nitrogen is provided by a non-bulky, easily digestable food.

Key Words: infant nutrition, potato, infant growth

Introduction

Vegetable foods are the primary source of energy and protein for most humans throughout the world; wheat, rice, maize, and the potato being the four leading world food crops. These staples acquire special importance in developing countries, where they account for the largest proportion of the diets. It is estimated that in some countries wheat provides as much as 50% of the dietary energy while in others, rice and maize may account for more than 70% of the energy intake (1). In spite of the importance of the potato in the diet of many developing countries there is little information in the literature with respect to its nutritional value for human consumption, especially in infants and children, the age groups most vulnerable to suffer from malnutrition.

In a previous short-term study carried out to evaluate the utilization of the protein and energy of the white potato by human infants (2) we found that infants and children recovering from malnutrition could consume up to 75% of energy and most of their nitrogen requirements as white potato. The limiting factors for the consumption of these diets were the bulk of the diets and the relatively poor digestibility of carbohydrates. The result of the latter was that a considerable part of the energy content of the diets was lost in the stool with a secondary increase of the stool volume. The effect correlated linearly with the total amount of potato in the diet and led to the conclusion that 75% of the energy as potato in the diet was close to the maximum

amount that could be tolerated by infants and children.

The present study was designed to evaluate whether diets with considerable amounts of potato can provide most of the energy and protein requirements of infants and small children when consumed during a prolonged period of time.

Material and Methods

Patients: Ten children (9 female, 1 male) admitted to the Instituto de Investigacion Nutricional for treatment of acute complications and nutritional rehabilitation of severe malnutrition participated in the study. Their mean age at the beginning of the study was 13.1 mos with a range from 6.2 mos to 24.6 mos. All patients had passed the acute phase of treatment and remained in the unit to consolidate their nutritional rehabilitation. The following criteria were used to admit the children into the study: free of infections and diarrhea, no evidence of malabsorption in previous metabolic balances, steady rate of weight gain while consuming varied diets and serum albumin concentration level above 3.3 g/dl[1].

Diets: A single batch of cooked, oven-dried potatoes processed and provided by the Centro Internacional de la Papa (International Potato Center) in Lima, Peru was used. The potato variety and processing methods utilized were as previously described (2). Nitrogen content of the dehydrated material was 1331.5 mg/100 g.

Three potato diets with increasing amounts of potato to provide 50%, 75% and 84.2% of total energy were prepared (Table 1). Nitrogen content of the 50% and 75% potato diets

was adjusted to 320.0 mg per 100 Kcal (8% protein energy) by the addition of casein. In the 84.2% potato diet all nitrogen was provided by potato. A blend (50:50) of soybean-cottonseed oil was used to provide 24.1% of total energy as fat in the 50% and 75% diets and to complete the energy content in the 84.2% potato diet (15.8% fat-energy). Sucrose was added to the 50% diet to complete total energy content. All three diets were supplemented with vitamins and minerals to meet or exceed Recommended Dietary Allowances (3). Na content of the diets was adjusted to 2 mEq/kg body weight/day. K content, all provided by potato, varied from 6 to 10 mEq/kg body weight/day.

Dry potato material was rehydrated and mixed with the other components of the diet in a blender. Total volume of the diets was adjusted, depending on the age and preference of the patients to produce a liquid or a more dense (mashed potatoes) diet. Energy density varied from 0.6 to 1.0 Kcal/ml.

Study design: Based on the results obtained in a previous study (2) the first four patients to participate in the study (No. 555, 556, 557, 566) were offered the 50% potato diet. After the completion of these studies the next two children admitted into the study (No. 525, 569) received the 84.2% potato diets but these studies were aborted shortly after the beginning because of poor acceptibility and the clear difficulty of consuming the volume of the diets. Several attempts to decrease the volume by increasing the density were made but palatability became the limiting factor.

The last four children enrolled in the study (No. 597, 600, 607, 612) received the 75% potato diet and completed the studies.

Diets were offered as the complete source of energy and protein during a 3 month period. The initial intake was estimated on the basis of the energy intake required during the previous 2 weeks to promote a weight gain of 2-4 g/kg body weight/day while consuming a formula diet adequate in animal protein. This intake (per kg body weight) was not changed during the study unless a gross difference in the rate of weight gain was noted. Energy and nitrogen intakes were recalculated weekly.

All children were weighed daily (8 am). Throughout the day, information concerning the time to consume the diets, presence of nausea or vomiting, abdominal distention and characteristics of the feces were recorded. At the beginning of the study and every 30 days thereafter children were measured anthropometrically and a blood sample was obtained for determination of hematocrit, hemoglobin concentration, serum total protein (Biuret) and albumin (acetate gel electrophoresis) concentrations, and serum levels of triglycerides and cholesterol.

During the last six days of each month 2 metabolic collections of 3 days each were carried out using methods standard for the unit (4). Apparent nitrogen retentions, stool wet and dry weight, fecal fat and total energy content of stool were determined.

Data were analyzed as follows: linear growth and weight gain were expressed as a percentage of the height and weight increments expected of children of the same chronologic age, sex, race and socio-economic status growing in a protected environment for the first one to two years of life (5). This data base has been increased considerably since publication. Height age (HA) was derived from the 50th percentile of these reference data, which corresponds approximately to the 25th percentile of the Boston reference (6), and its changes were compared to the advance in chronologic age (CA).

Results

Acceptability of and tolerance to the 50% potato diet were excellent. The time to consume the diet varied little throughout the study and no adverse reactions such as vomiting, diarrhea or abdominal distention were noted. With the 75% potato diets two children (No. 597, 600) increased the time to consume the diet during the last month of the study. In the last days the diet had to be divided into smaller but more frequent feedings so that they could consume the total volume. In spite of the poorer acceptability that these two patients showed during the last month their appetites seemed to be preserved judging by the avidity that they showed during the first minutes of each feeding. The other two patients that received the 75% diet did not show changes in acceptability but in one of them (No. 607) the time to consume the diet

increased during the last two weeks of the study. The 84% potato studies were discontinued within 48 hours of the beginning because of the large volumes they entailed. Four of the 8 patients who completed the study accepted the diets better and decreased time for feeding within a few days of beginning of the study.

Initial age, height, weight and height age values and their changes during the study are presented in Table 2. Mean gains of height and weight were 139%±53 and 297%±116 respectively of those expected for age; the mean advance in HA was greater than the advance in CA. Five children (No. 555, 556, 566, 600, 612) showed rapid catch-up growth and satisfactory increases in body weight. Mean ΔHA in these 5 children was 4.7±0.9 mos during the 3 month period and their mean weight gain was 298% of the expected weight gain for age as defined by the reference data. Three children (No. 557, 597, 607) failed to achieve an increase in HA equal or superior to their advance in CA. Nevertheless patient No. 607 still showed increments in height and weight greater than expected for age. Linear growth in patient No. 597 was inadequate for her age but her weight gain was 440% of the reference data. Patient No. 557 did not achieve an adequate increase in height or weight.

Results of metabolic balances and changes in serum albumin, triglycerides and cholesterol concentrations during the study are presented in Table 3. Statistical analysis to compare monthly changes of each parameter was not carried out

because of the small number of cases in each group. No attempt to compare results between diets was made because of the different proportion of energy and protein supplied by potato. The results of the metabolic balances were similar to those obtained in the previous study (2) and did not show changes of biological significance in nitrogen retention or overall digestibility that could be attributed to the long-term consumption of the potato diets. Changes in serum albumin, triglyceride and cholesterol concentrations were seemingly unrelated to diets. A trend toward increasing serum cholesterol levels during the consumption of the 75% potato diet was seen in only one of the four children.

Discussion

Results of these studies show that infants and small children can sustain an adequate rate of growth and maintain normal serum albumin concentrations consuming diets in which potato supplies a substantial part of both protein and energy requirements for extended periods of time. Acceptability of and tolerance to the 50% potato diets were excellent. Diets containing 75% of energy as potato are probably close to the maximum amount of potato that can be accepted in this form over a prolonged period of time, mainly because of the bulk and the monotony of the diet. Nevertheless these results may not be able to be generalized to normal infants in whom monotony of the diet probably might manifest much earlier than in infants recovering from malnutrition with increased appetite.

Estimation of growth during a prolonged period of time is the best indicator of the adequacy of a diet in children, especially in rapidly growing infants or in children recovering from malnutrition, with high nutrient requirements for catch-up growth. It was difficult to assess the adequacy of growth of the children in this study because their genetic potential is not known with certainty. For this reason we have compared the growth rates with those of children of the same age, sex, race and socio-economic population presumably growing at their genetic potential in a protected environment.

For a malnourished child an increment in height of 100% of the reference data for age indicates that the child is growing along or on the 50th percentile of this population, but it does not represent catch-up growth. An increase in HA of 3 mos during a 3 mos period indicates that the child is growing at the same rate as a younger (normal) child of the same height following the 50th percentile. This growth rate is above that expected for age and represents catch-up growth. By this more strict criterion the growth of 5 of the children was quite satisfactory. The 3 patients (No. 557, 597, 607) who did not achieve increments in HA superior to their advance CA were the ones with lower HA at the beginning of the study ("biologically" younger) and with larger discrepancies between their HA and CA, indicating the severity and chronicity of the malnutrition process. Patient No. 607 showed catch-up growth (147% ΔHt expected for age) and satisfactory weight gain (356% ΔWt for age). Her HA did

not advance as much as her CA, most likely because of the severe deficit in height at the beginning of the study. It is also possible that she was genetically smaller than the median of the Peruvian reference. Patient No. 597 experienced satisfactory weight gain but did not show catch-up growth. This phenomenon is seen in many children recovering from malnutrition; only after a period of an adequate energy and protein intake that produces a satisfactory rate of weight gain does a spurt in height begin. Patient No. 557, the youngest, did not achieve adequate gains in height or weight. This child showed a steady rate of weight gain, food acceptability and tolerance to the diet and no exaggerated losses of energy in stools. Only after the study was completed and the data were analyzed was it realized that this child could probably have experienced better rates of weight and height gains with a higher intake.

Based on prolonged feeding studies carried out with beans based diets Graham et al. (1979) suggested the possibility of adaptative improvement in digestion over time (7). Metabolic balance results in the present study did not suggest any consistent pattern of improvement or deterioration in digestibility throughout the study.

In our previous study (2) consumption of increasing amounts of potato was associated with a linear increase of stool wet weight, stool dry weight and losses of carbohydrates and energy in stools due to the indigestibility of carbohydrates. This phenomenon was also seen in the present study and explains the differences in stool dry weight and total energy content

of feces between the 50% and 75% potato diets. Protein status of the children was maintained during the study reflecting the adequacy of the dietary protein. The small variations in serum albumin concentration observed are within the normal range.

After the completion of these two studies with the white potato we believe that infants of weaning age can consume 50-75% of their energy and as much as 80% of their nitrogen requirements as potato. Since potato is scarcely ever the sole source of nitrogen in the diet of children, the remaining protein should preferably be provided by a less bulky food that is a source of high quality protein. This is desirable less because of the need to improve the quality of the potato protein than to decrease the bulk and volume of the diet. Potato varieties with higher protein content, similar protein quality and better carbohydrate digestibility could be very beneficial for the prevention of malnutrition in developing countries in which potato is a major staple.

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Footnotes

[1]Protocols for these studies were approved by the Joint Committee on Human Investigation, The Johns Hopkins Medical Institutions and the corresponding committee of the Instituto de Investigacion Nutricional, Lima, Peru. Informed consent was obtained from the parent of all children participating in the studies.

Table 1. Composition of study diets (per 100 Kcal)[1,2]

		50% Potato	75% Potato	84% Potato
Potato	g	14.3	21.3	24.0
N	mg	190.3	284.1	320.0
Energy	Kcal	50.0	75.0	84.2
Ca Casinate [3]	g	0.94	0.26	-
N	mg	129.7	35.9	-
Energy	Kcal	3.5	1.0	-
Sucrose	g	5.6	-	-
Energy	Kcal	22.4	-	-
Soybean-Cottonseed (50:50) Oil	ml	3.1	3.0	2.0
Energy	Kcal	24.1	24.1	15.8
TOTALS				
N		320.0	320.0	320.0
Protein (N x 6.25)% energy		8.0	8.0	8.0
Potato Protein (N x 6.25)% tot. prot.		59.5	88.9	100.0
Energy Kcal		100.0	100.0	100.0

[1]Minerals were supplemented in all diets to provide intakes of 2 mEq Na/kg body weight/day using a mineral mixture without potassium of the following composition (w/w): NaCl, 30.701%; $MgSo_4 \cdot 7H_2O$, 22.804%; $CaHPO_4$, 41.615%; $FeC_6H_5O_4 \cdot 3H_2O$, 3.549%; $CuSO_4 \cdot 5H_2O$, 0.625%; $ZnSO_4 \cdot 7H_2O$, 0.355%; $MnSO_4 \cdot H_2O$, 0.277%; KI, 0.025% and NaF, 0.50%. [2]Vitamins were supplemented by a single daily dose of 0.6-1.2 ml of Poly-Vi-Sol (Mead Johnson, Evansville, IN). The composition (per ml) of this preparation is as follows: retinyl palmitate, 1,500 IU; ergocalciferol, 400 IU; Vitamin E, 5 IU; ascorbic acid, 35 mg; thiamin, 0.5 mg; riboflavin, 0.6 mg; niacin, 8 mg; vitamin B-6, 0.4 mg, and vitamin B-12, 1 μg. Patients also received a single dose of 191 mg choline, 180 mg myo-inositol 200 μg folic acid and 500 mg PABA. [3]Casec, Mead Johnson, Evansville, IN., 1.88 g Casec was used to provide 1.5 g casein.

Table 2. Potato intake (% total energy), energy intake, initial chronologic age (CA), height (Ht), weight (Wt), and height-age (HA) and their changes during the study.

Patient No.	Potato Intake % total energy	Energy Kcal/kg/d	Initial CA mos	Initial Ht cm	Initial Wt g	Initial HA[a] mos	Final Δ Ht cm	Final Δ Ht %[b]	Final Δ Wt g	Final Δ Wt %[b]	Final Δ HA[a] mos
555	50	125	9.4	65.0	5510	7.58	6.4	154.6	2930	273.6	5.12
556	50	125	14.4	68.9	6840	10.33	4.2	142.4	2220	207.5	4.07
557	50	135	6.2	54.5	3150	2.50	3.8	76.4	1580	88.9	1.42
566	50	109	12.1	65.1	7080	7.67	7.4	248.5	2600	240.3	6.13
597	75	133	14.8	63.7	5570	6.45	3.3	91.2	2850	440.3	2.43
600	75	125	15.4	70.7	7580	12.00	3.9	102.9	2720	405.0	3.87
607	75	133	14.4	59.6	5380	4.44	4.5	147.1	1940	356.3	2.38
612	75	125	9.6	65.1	5820	7.67	5.7	150.0	3140	360.9	4.43

[a] Derived from the 50th percentile of Peruvian reference data

[b] Percentages of expected for age of Peruvian reference data

Table 3. Apparent N retention, digestibility parameters, serum triglyceride and cholesterol concentrations and changes in serum albumin concentration during the study.

Potato Diet %	Days of Study	Apparent N Ret % int	Stool: Dry Wt g/d	Stool: Fat % int	Stool: Energy Kcal	Stool: Energy % int	Serum: Triglycerides g/dl	Serum: Cholesterol g/dl	Δ [Alb] g/dl
50	1	-	-	-	-	-	59.5 ±13.1	127.7 ±36.2	-
50	25-30	35.3 ±7.0	20.8 ±5.4	8.3 ±3.8	73.5 ±25.6	9.2 ±1.9	65.5 ±28.0	119.5 ±21.1	-0.03
50	55-60	45.1 ±1.3	21.0 ±6.6	5.5 ±1.6	69.8 ±20.4	7.8 ±0.5	83.0 ±9.5	122.3 ±27.0	-0.04
50	85-90	42.4 ±6.0	24.0 ±6.3	5.9 ±2.4	85.6 ±20.0	8.5 ±0.1	88.0 ±47.8	131.5 ±25.9	-0.02
75	1	-	-	-	-	-	88.8 ±34.9	118.3 ±25.2	-
75	25-30	43.5 ±7.1	34.3 ±3.8	8.5 ±4.3	117.3 ±11.6	12.7 ±1.4	115.7 ±72.1	125.0 ±24.0	-0.64
75	55-60	42.0 ±5.8	38.4 ±4.4	8.7 ±2.8	133.4 ±11.8	13.7 ±1.7	83.5 ±19.8	136.3 ±9.2	+0.10
75	85-90	42.8 ±2.0	39.6 ±4.3	8.5 ±0.3	135.3 ±13.8	12.7 ±1.3	90.3 ±20.8	140.5 ±12.0	+0.20
$\bar{X}$ 50		43.9	21.9	6.6	76.3	8.5	74.0	125.3	-0.03
SD(±)		9.5	1.8	1.5	8.3	0.7	13.7	5.4	0.01
$\bar{X}$ 75		42.8	37.4	8.6	128.7	13.0	94.6	130.0	-0.11
SD(±)		0.8	2.8	0.1	9.9	0.6	14.4	10.2	0.45

13