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AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D.C. 20523

DATE: 8/18/88

MEMORANDUM

TO: AID/PPC/CDIE/DI, room 209 SA-18

FROM: AID/SCI, Victoria Ose VU

SUBJECT: Transmittal of AID/SCI Progress Report(s)

Attached for permanent retention/proper disposition is the following:

AID/SCI Progress Report No. 3.M-04
FINAL

Attachment

3. M-04

CASSAVA: Consumption and Digestibility by Small Children

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Final Report to:

Program in Science and Technology Cooperation
Office of the Science Advisor
Agency for International Development
Room 720 SA-18
Washington, D.C. 20523

Date:

August 15, 1988

All correspondence to:

Dr. George G. Graham
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Baltimore, Maryland 21205

Rec'd by SCI AUG 1 9 1988

TO: John A. Daly, Ph.D.
Irwin M. Asher, Ph.D. and
Miloslav Rechcigl, Ph.D.
Office of the Science Advisor
Agency for International Development

FROM: George G. Graham, M.D.
Guillermo Lopez de Romaña, M.D.
Enrique Morales, M.D.

Subject: Final Report on 3.N04:
Cassava: Consumption and Digestibility by Small Children

During the duration of this study (1983-1985) reports on its progress were sent regularly by Dr. Enrique Morales through the offices of AID-PERU.

For this "final-final" report we have waited until the last of three major publications, with the results of the proposed studies, were available for inclusion. Ten copies of each of the first two publications were sent to your attention as soon as they were received. Ten copies of the last of the three are being mailed today to the attention of Dr. Rechcigl.

The research to be carried out under this proposal consisted of one preliminary study and two major studies.

The preliminary study was designed to determine if there was any difference between the digestibility of cassava when it was boiled and the same when it was oven-dried and stored for short periods of time. None was found and the results were reported in the Journal of Nutrition, volume 117:pages 129-132, 1987. This is the most prestigious refereed journal in the field of Nutrition and the time frame for submission, review and publication is around one year. The publication emphasized the excellent digestibility found for cassava

energy, the high fecal wet weights being associated with considerably lower fecal energy concentrations than with most cereal-based diets.

The first part of the major study was designed to determine whether increasing the proportion of cassava in the total diet resulted in a progressive deterioration of its digestibility. The results were also reported in the Journal of Nutrition, volume 117: pages 2116-2120, 1987. Although there was some increase in the percentage of energy lost in the feces as the proportion of cassava was increased from 25 to 75% of total calories, this was not severe and did not of itself preclude the consumption of such a large proportion, assuming protein and micronutrient needs were met. These studies were carried out with freeze-dried cassava: its hydrocyanic acid content (prior to cooking) was found to be considerably higher than that of the oven-dried product used previously. Although this content was within the limits reported as safe in the literature, subsequent consultation with Dr. Hans Rosling of Uppsala University in Sweden suggests that it is not. In the last publication we have urged against the use of freeze-drying unless other processes first release the hydrocyanic acid.

The second part of the major study, carried out with important collaboration from IITA in Nigeria, was designed to assess the effects of varietal and processing variables on digestibility. No differences were found for two varieties and two processes and the results were also reported in the Journal of Nutrition, volume 118:pages 877-882, 1988 (July).

In addition to the results reported in the literature, we carried out studies of breath hydrogen excretion, as a measure of carbohydrate digestion in the large bowel, during all three of the above studies.

Although the results all suggest that relatively little carbohydrate is salvaged by the calonic flora, it was not clear just why this was so. Further studies, carried out after the completion of the grant, suggest that almost 100% of cassava fiber is insoluble and resistant to microbial fermentation: almost 100% of the fiber measured in the diet was insoluble and recovered in the feces. We assume that whatever hydrogen was produced came from starch which escaped digestion in the small bowel. The lack of caloric salvage was presumably not due to inadequate bacterial mass, at least as this was estimated by measurements of diaminopimelic acid contents of the feces. These studies will be the subject of later publications.

Following are copies of the three publications described above.

Effect of Amounts Consumed on the Digestion of Cassava by Young Children[1]

ENRIQUE MORALES AND GEORGE G. GRAHAM

Instituto de Investigacion Nutricional, Miraflores (Lima), Peru

ABSTRACT To determine whether increasing proportions of cassava could be consumed and satisfactorily digested, eight recovering malnourished children (20–38 mo old) received 25, 50 and 75% of their diet energy as freeze-dried cassava flour during 9-d periods, with intervening casein control diets. Enough casein was added to all cassava diets to bring protein energy to 8% of the total. When compared to the control diet, the 25% diet had no significant effect on consumption time or measures of protein and energy digestion. With the 50% diet, fecal wet and dry weights were moderately higher than with the 25% diet (196 ± 44 and 24 ± 4 vs. 121 ± 36 and 16 ± 3 g/d, respectively), as were fecal energy (89 ± 16 vs. 63 ± 16 kcal/d) and calculated carbohydrate (11 ± 2 vs. 5 ± 1 g/d); apparent nitrogen absorption (mostly from casein) was slightly lower (79 ± 5 vs. 83 ± 6%) and consumption time slightly higher (5–25, median 10, vs. 4–18, median 6 min/feeding). When energy from cassava was increased to 75%, fecal weights (240 ± 49 and 31 ± 5 g/d), energy (124 ± 27 kcal/d) and carbohydrate (16 ± 4 g/d) were all higher than when cassava provided 50 or 25% of energy. Consumption required 8–34, median 17 min/feeding and apparent nitrogen absorption was 76 ± 6% of intake. Assuming proper detoxification, appropriate protein supplementation and no untoward effects on micronutrient absorption, 25% of energy in the diets of young children can be supplied with impunity as cassava flour, 50% with modest energy and nitrogen wastage and 75% with moderately lower energy and apparent protein digestibilities but greater consumption times. *J. Nutr.* 117: 2116–2120, 1987.

INDEXING KEY WORDS:

• *cassava flour* • *digestibility* • *young children*

In an earlier study, when 50% of the energy in the diet of convalescent malnourished infants and children was provided as boiled or oven-dried cassava and nearly all the diet protein as casein, higher than usual fecal wet weights but only minor excess losses of energy and nitrogen were observed; fat absorption was seemingly not affected (1). Oven-drying of the boiled fresh cassava seemed to have had an untoward effect on digestibility, but the nature of those studies, with the oven-dried product always following the boiled and with no intervening control periods, suggested an order effect instead. The time required to spoon-feed both cassava diets was approximately twice that usually taken to consume bottle feedings: this was attributed to bulkiness and to a spoon vs. bottle difference.

The above results stimulated further assessment of the value of cassava as the major source of energy in weaning diets. The previous studies were carried out with a constant proportion (50%) of total energy as cassava: it was decided to also study lesser (25%) and greater (75%) proportions of energy as cassava and to introduce preceding, intervening and following control periods that would facilitate interpretation of the results and minimize carryover effects. These proportions were arbitrarily chosen to represent situations in the developing world in which cassava might be just one highly acceptable source of diet energy for young children (25%), in which it might be the most important and cheapest source of energy (50%) and in which it might be virtually the only abundant source of energy (75%). Cassava's contribution to the protein needs of such children is so meager that there must always be a good supplementary source of protein in the diet. Casein was chosen for these studies because of its well-documented high digestibility and excellent protein quality, thus avoiding confounding variables in the interpretation of the results. Consumption of such large amounts of cassava is a real-life situation for millions of young children in tropical Africa and Latin America (2).

MATERIALS AND METHODS

A large batch of fresh cassava (*Manihot esculenta*, Crantz) was obtained from the jungle area, as its availability on the coast was limited at the time of this

[1]This study was supported by a grant from the Program in Science and Technology Cooperation, Office of the Science Advisor, Agency for International Development, U.S. Department of State.

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study. It was flown to Lima, boiled immediately on receipt and dried into a flour. Instead of oven-drying, as in the preliminary study (1) and in earlier studies with the potato (3), it was found more expedient to use commercially available freeze-drying. The potato studies had shown no difference in digestibility between oven-dried and freeze-dried potatoes. The results with 50% of energy as freeze-dried cassava in this study and those with 50% fresh or oven-dried cassava in the earlier study proved to be quite similar. The hydrocyanic acid content of the freeze-dried cassava was determined (4) and found to be a safe 47 mg/kg (5).

In the 75% diets, cassava flour provided 75% of total energy, with enough calcium caseinate (Casec, registered trademark of Mead Johnson, Evansville, IN) added to make a total of 8% protein energy. Of this 8%, only 12.9% (approximately 1% of total energy) was provided by cassava protein. A 1:1 blend of soybean and cottonseed oils supplied the remaining energy. As in all diets in this study (**Table 1**), the resulting distribution of energy was 8% protein, 20% fat and 72% carbohydrate (CHO).

In the 50% diets, cassava supplied 50% of total energy and 8.5% of the 8% protein energy, the remainder of protein coming from calcium caseinate. Oil brought energy from fat to 20% of the total, and sucrose provided the remaining 23% of energy.

In the 25% diets, cassava provided 25% of total energy and only 4.5% of the 8% protein, the bulk of protein coming from calcium caseinate. Oil brought fat to 20% and isoenergetic amounts of sugar and corn syrup solids supplied the final 47% of energy.

In the control diets calcium caseinate supplied all 8% protein energy, oil blend all 20% fat energy and isoenergetic amounts of sugar, corn syrup solids and cornstarch the 72% CHO energy. These carbohydrates, all of known very high digestibility, were chosen to complete the CHO energy in the control, 25% and 50% diets so that differences in fecal energy and calculated CHO could reasonably be attributed to the cassava carbohydrates. The corn syrup solids and starch were used to keep osmolalities of all diets below 500 and close to the 350 mOsm/kg water of the 75% diet and to prevent these from being a factor in consumption times.

Diets were supplemented with minerals and vitamins as in the previous study (1), to satisfy the recommended dietary allowances of the National Research Council and to provide 2.0 meq of sodium and 3.0 meq of potassium per kilogram body weight per day. Table 1 lists the major components of the four diets.

Eight recovering malnourished young boys participated in the studies (**Table 2**) with the informed written consent of their parents. Protocols were approved by the Ethics Committee of the Instituto de Investigacion Nutricional. The children were between 20.0 and 37.8 mo of age, but height ages of 7.25–16.5 and weight ages of 4.10–12.75 mo made them physiologically less mature. Although still markedly undernourished on a weight-for-age or height-for-age basis, all had reached the 10th percentile of the NCHS weight-for-height reference data (6). All had serum albumin levels of at least 3.5 g/dl, were free of apparent infection, had intestinal absorptive functions (for protein and fat) that had been shown to be in the normal range while consuming milk protein-based diets and were gaining weight steadily.

Each child received all three cassava diets for periods of 9 d each, in one of six possible sequences (two were repeated). Six-day control diet periods preceded and followed each cassava period, the one exception being a 9-d control period before the first cassava diet for each child. Feces and urine were collected separately during the last 6 d of the cassava periods and of the initial 9-d control period and during the last 3 d of the other 6-d control periods. Diets and feces were analyzed for total energy by bomb calorimetry, for total fat by the van de Kamer method, for total nitrogen by the micro-Kjeldahl method and for total CHO by difference. Methods used were as in previous studies (3). Serum albumin determinations were made at the beginning and end of each diet period by acetate gel electrophoresis. Body weight was determined daily. Time to consume each feeding was recorded by the aides who regularly fed the children. All the control feedings, six of the eight 25% feedings and five of the eight 50% feedings could be given by bottle; all the rest were given by spoon as semisolid "porridges."

Analysis of variance for repeated observations was used to assess the significance of the effects of amounts of cassava consumed on the various measures of digestibility. Polynomial regression analysis was used to determine if there was a quadratic (or higher order) component of significance in these relationships. Paired *t*-tests were used to determine the statistical significance of the differences between levels of cassava intake, both in absolute amounts and as percentages of the preceding and following control periods.

TABLE 1

Composition of casein control diet and of diets providing 25, 50 and 75% of energy as freeze-fried casssava with casein added to make 8% protein energy[1]

Ingredient	Casein control	25% cassava	50% cassava	75% cassava
		per 100 kcal		
Cassava, *g*	—	6.71	13.41	20.11
(*% of protein*)	—	(4.5)	(8.5)	(12.9)
Ca caseinate, *g*	2.32	2.23	2.13	2.03
Vegetable oil, *ml*	2.39	2.43	2.39	2.23
Cane sugar, *g*	6.08	5.96	5.83	—
Corn syrup solids, *g*	6.27	6.14	—	—
Starch, *g*	6.79	—	—	—

[1]Vitamin and mineral mixtures (1) added to all diets in amounts sufficient to satisfy recommended dietary allowances.

6

TABLE 2

Age, anthropometric measurements and serum albumin concentrations of eight young boys who participated in these studies

Subject no.	Age	Height	Height age	Weight	Weight age	Serum albumin
	mo	*cm*	*mo*	*kg*	*mo*	*g/dl*
827	20.0	71.4	8.25	7.60	5.60	3.62
825	26.4	78.2	13.75	9.60	10.25	3.79
842	21.0	70.0	7.25	6.98	4.40	3.85
849	35.9	74.7	10.75	6.78	4.10	3.59
848	20.1	79.1	14.75	10.38	12.75	3.83
868	28.5	81.0	16.50	8.83	8.00	3.50
872	20.5	72.8	9.25	8.60	7.50	4.24
891	37.8	79.7	15.25	9.66	10.25	4.17
Mean ± SD	26.3 ± 6.8	75.9 ± 3.9	12.0 ± 3.3	8.55 ± 1.24	7.9 ± 2.9	3.82 ± 0.25

RESULTS

Median time to consume the control feedings was 6 (range 4–16) min/feeding; median time to consume the 25% feedings was 6 (4–18) min, the 50% feedings 10 (5–25) min and the 75% feedings 17 (8–34) min. Only the last value was significantly ($P < 0.05$) longer than the preceding and following control periods.

By analysis of variance there was a significant effect of amounts of cassava consumed on apparent nitrogen (mostly from casein) absorption ($P < 0.01$), fecal wet and dry weights ($P < 0.01$ for both), and fecal energy and CHO ($P < 0.01$). All of these significant relationships were linear only. Apparent nitrogen retentions and fecal fat excretions were not significantly affected.

During the 25% diet periods (**Table 3**) fecal wet weights (121 ± 36 g/d) were significantly higher than during the preceding (85 ± 28 g/d) but not the following (101 ± 14 g/d) control periods. Fecal dry weights, energy (kcal/d), fat (g/d or % of intake) and CHO (g/d) were not significantly higher than those of the preceding control periods. During the following control periods, fecal fat was slightly higher ($P < 0.05$) and fecal CHO was lower ($P < 0.05$) than during the study period. Apparent nitrogen absorptions were indistinguishable from those of the control diets; apparent retentions tended to be slightly, but not significantly, lower than those of the preceding control periods but significantly ($P < 0.05$) lower than those of the following control periods (33 ± 8 vs. 45 ± 11% of intake). Rates of weight gain (not entirely reliable during short periods) in grams per day or grams per kilogram per day mirrored those of apparent N retention without being significantly different. Changes in serum albumin levels were very small and of no statistical or biologic significance.

When cassava flour supplied 50% of diet energy (Table 3), fecal wet weights were almost double those of the preceding and following control periods ($P < 0.01$) and dry weights were only moderately, but still significantly ($P < 0.05$), higher, as were fecal energy losses. Fecal fat, by contrast, was significantly lower, while fecal CHO (calculated by difference) was much higher

TABLE 3

Energy and protein digestibility and utilization in eight infants consuming cassava as 25, 50 and 75% of diet energy, with casein added to make 8% energy from protein, or preceding, intervening and following casein control diets[1]

	Casein pre	Cassava 25%	Casein post	Casein pre	Cassava 50%	Casein post	Casein pre	Cassava 75%	Casein post
Intake, *kcal/d*	1053 ± 152	1061 ± 134	1103 ± 175	1042 ± 129	1056 ± 122	1144 ± 136	1143 ± 172	1114 ± 187	1135 ± 178
Fecal wet wt, *g/d*	85 ± 28[2]	121 ± 36	101 ± 14	101 ± 53[3]	196 ± 44	118 ± 41[3]	94 ± 23[3]	240 ± 49	132 ± 61[3]
dry wt, *g/d*	17 ± 4	16 ± 3	19 ± 3	19 ± 4[2]	24 ± 4	21 ± 3[2]	17 ± 4[3]	31 ± 5	21 ± 7[3]
kcal/d	56 ± 18	63 ± 16	62 ± 13	70 ± 22[2]	89 ± 16	67 ± 15[3]	61 ± 16[3]	124 ± 27	73 ± 38[2]
fat, *g/d*	2 ± 2	2 ± 1	3 ± 2[2]	4 ± 2[3]	2 ± 1	3 ± 2[3]	3 ± 1[2]	2 ± 1	3 ± 2[3]
% intake	10 ± 5	9 ± 5	12 ± 5[2]	17 ± 8[3]	8 ± 4	14 ± 7[3]	13 ± 5[2]	11 ± 5	14 ± 10[2]
CHO, *g/d*	4 ± 2	5 ± 1	3 ± 2[2]	3 ± 1[3]	11 ± 2	4 ± 2[3]	3 ± 2[3]	16 ± 4	3 ± 1[3]
N intake, *mg/d*	3287 ± 451	3340 ± 424	3475 ± 490	3320 ± 365	3380 ± 416	3518 ± 461	3405 ± 561	3458 ± 557	3579 ± 595
Absorption, %	83 ± 4	83 ± 6	82 ± 7	81 ± 7[2]	79 ± 5	82 ± 4[2]	83 ± 4[3]	76 ± 6	81 ± 5[3]
Retention, %	35 ± 6	33 ± 8	45 ± 11[2]	39 ± 13[2]	31 ± 8	39 ± 10[2]	38 ± 9[2]	29 ± 9	37 ± 11[2]
Δ body wt, *g/d*	37 ± 15	35 ± 18	50 ± 21	34 ± 25	28 ± 20	47 ± 44	44 ± 26	34 ± 22	37 ± 21

[1]Values are means ± SD, $n = 8$.
[2]Significantly different from corresponding cassava period, $P < 0.05$.
[3]Significantly different from corresponding cassava period, $P < 0.01$.

($P < 0.01$), accounting for some 50% of fecal energy losses. Apparent absorptions of nitrogen were only slightly lower (79 vs. 81 and 82% of intake) than those from the control diet and significantly ($P < 0.05$) lower than those from the 25% diet. Apparent retention of nitrogen (31 ± 8% of intake) from the 50% diet was significantly less than from either control diet and was lower, but not significantly so, than from the 25% diet. Changes in body weight again paralleled those in nitrogen retention but without being significantly different. Mean serum albumin increased slightly (0.2 g/dl), but was not significantly different from baseline values.

When cassava flour supplied 75% of diet energy, fecal wet and dry weights and fecal energy were high, all double the values seen with the 25% diet. Fecal fat remained very low but fecal CHO was more than five times the control values and three times the values calculated for the 25% diet. Apparent absorption and retention of nitrogen tended to be lower than from the 50% diet. The lower nitrogen retention was almost entirely due to the lower absorption, with no change in the percentage of absorbed nitrogen that was retained. Mean serum albumin change (0.3 g/dl) was not significantly different from baseline.

DISCUSSION

Tapioca, gelatinized cassava starch, is a component of children's diets in many parts of the world. De Vizia et al. (7) showed that newborn infants could efficiently digest amounts of tapioca equivalent to 10% of their energy requirements. Reports from India showed that tapioca "macaroni" enriched with various sources of protein could be used to nutritional advantage as supplements to otherwise marginal rice-based diets for children (8, 9). The relatively small amounts of tapioca starch (15–20% of energy intake) represented by the "macaroni" do not permit any judgment of its digestibility. In our earlier studies it was shown that 50% of energy in a highly nutritious purified diet for young children could be replaced by cassava flour with only modest losses of energy and nitrogen (1). Fecal energy was some 10% higher than that found with casein control, rice or white wheat flour diets in children of the same size. It was very similar to that of potato diets and lower than that seen with other cereal or legume diets. Fecal nitrogen was similarly low when compared with that from other diets (10).

The current set of studies was designed to determine whether a greater proportion of diet energy could be fed as cassava flour without paying too large a penalty in fecal losses of energy and nitrogen and in time required to consume the greater bulk involved. It was not possible at this time to study the effect on micronutrient, particularly trace mineral, absorption.

When only 25% of diet energy was provided as cassava flour, it was still possible to feed most of the children by bottle in no more time than that required for the control diets. Although fecal wet weights were measurably higher, this was of a minor degree, not likely to cause concern. Slightly higher fecal CHO was balanced by lower fecal fat. Slightly lower apparent nitrogen retention during the study period was followed by a significantly higher, presumably compensatory, retention in the following control period. These modest nutritional effects suggest that cassava flour can readily replace 25% of energy in the diet of young children if the levels of protein and other essential nutrients are high enough to permit some dilution.

When 50% of energy was supplied as cassava flour, three of the eight children were fed by spoon instead of bottle and the mean time required was modestly but not significantly increased. In some cases fecal wet weight was high enough to possibly cause concern in mothers of infants who habitually consume fiber-free diets associated with low fecal outputs. Energy losses, practically all due to CHO, were significantly higher than those from the control or 25% diets, but still modest. The higher fecal nitrogen resulting in a lower absorption rate, could in theory be due to an absorption rate for cassava protein some 30% lower than that for casein. The even higher excretion when 75% cassava was fed would fit this assumption, which is in line with the apparent nitrogen absorption from white potatoes (3). It is also likely that this represents greater bacterial proliferation and nitrogen associated with undigested fiber (11).

If the fecal energy and CHO losses of the appropriate control periods are subtracted from those measured during the three different cassava periods and only the differences are attributed to complex CHOs of cassava, it seems that these are almost completely digested when cassava represents 25% of diet energy, but there is a seeming increase in the percentage not digested when first 50 and then 75% of diet energy comes from cassava. Polynomial regression analysis did not support this impression. If fecal nitrogen and water are looked at in the same way, the increases with increasing cassava intake are more clearly linear, suggesting a constant proportion of undigested matter.

In a previous report we compared the digestibility of white potato energy and protein with that of various cereals (10). When the present results are included in the comparison, cassava flour seems to be as good a source of energy as the potato and as maize, but not as efficient as wheat or rice. Its protein content is so low that it could not be studied alone; it can be surmised that protein digestibility is on the low side. The quality of cassava protein cannot be judged. Because its content is so low, little amino acid complementation of any usefulness can be expected when it is fed to young children. If the diet is supplemented with an adequate amount of a well-balanced protein, cassava can be used as the major source of energy with relatively minor limitations, most notably its bulkiness and the con

sequent long time required to feed it to children of this age group.

Assuming that protein and other essential nutrients are provided and absorbed in adequate amounts, cassava can readily supply 25 or even 50% of diet energy for healthy infants and young children. The time required to consume such diets is only slightly longer than that required for milk feedings and the very modest excess losses of energy in the feces could be made up by feeding 5%, or even less, additional energy. The most important problem associated with increasing the cassava content to 75% of total diet energy is the tripling of the time required to consume the much bulkier diet; to a harried mother in a poor society this can be a serious constraint, probably more than the additional diet energy needed to compensate the fecal losses, and can be expected to result in seriously inadequate energy intakes. The processing used, whether traditional or industrial, must lower HCN content to safe levels. Of particular concern among the poor is the ability of small children who are recovering from diarrhea, or who are malnourished, to digest cassava flour; without actual study, one can do no more than speculate.

ACKNOWLEDGMENT

The assistance of Birthe Pedersen of the Department of Animal Physiology and Biochemistry, National Institute of Animal Science of Denmark, is gratefully acknowledged.

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Effects of Cassava Variety and Processing on Energy and Protein Digestibility and Utilization by Young Children[1]

GEORGE G. GRAHAM, JORGE LEMBCKE AND ENRIQUE MORALES

Instituto de Investigación Nutricional, Lima, Peru

ABSTRACT Two varieties of cassava, processed as Nigerian fermented flour (gari) or as Brazilian flour (farinha), were fed to two groups of eight infants and young children, each group receiving both forms of one variety, with preceding, intervening and following casein control diets. The flours provided 50% of diet energy, with casein added to make 8% energy as protein, vegetable oils to make 20% as fat and corn syrup solids and sugar to make 72% carbohydrate (CHO) energy. Fecal wet weight increased ($P < 0.05$) from approximately 100 g/d (casein diets) to means (± SD) of 202 ± 72, 171 ± 58, 154 ± 46 and 190 ± 67 g/d; dry weights from means of 14.7–18.3 g/d to means of 22.9–24.4 g/d ($P < 0.05$); fecal energy from means of 50–60 kcal/d to means of 89–94 kcal/d ($P < 0.01$); fecal fat was generally not affected; and fecal CHO nearly tripled ($P < 0.01$) from approximately 4 to 12 g/d. Apparent nitrogen absorptions and retentions from the cassava + casein diets were modestly lower than from casein diets. Rates of weight gain were very variable and not significantly different by diet; serum albumin levels were essentially unchanged. The results with these flours were indistinguishable from each other and from those previously found with freeze-dried cassava flour in otherwise identical diets. Variety and processing method had no effect on the digestibility of cassava starch and oligosaccharides and on the great resistance to digestion and the water-holding capacity of cassava fiber. *J. Nutr.* 118: 877–882, 1988.

INDEXING KEY WORDS:

• *cassava* • *digestibility* • *protein* • *energy*

Infants and young children recovering from malnutrition readily consumed, with relatively minor fecal wastage of energy and protein, diets in which 50% of energy was provided by either fresh, boiled or oven-dried cassava (1). When only 25% of energy came from freeze-dried cassava, there was no significant effect on consumption times and digestibility, compared with a casein-based formula (2). When cassava was increased to 50%, there was a significant effect on energy and protein digestibility and a minor effect on consumption times, although many of the feedings could not be given by bottle and had to be spoon-fed. A further increase to 75% of energy markedly increased consumption times (nearly all spoon-fed) and fecal losses of energy and protein (2). This does not rule out the practical use of such large amounts of cassava as the major source of energy in the diets of infants and young children, provided that its potential toxicity is neutralized in processing, a satisfactory source of protein and micronutrients is fed simultaneously and the extra time required for feeding is available to the mother or caretaker.

The above studies were carried out with two batches of Peruvian cassava, one from the coast (1) and one from the jungle (2) (both *Manihot esculenta* Crantz), which were processed in the laboratory (1) or in a commercial freeze-drying facility (2). The purpose of the present study was to determine if varietal differences and traditional processing affect digestibility and utilization.

Cassava was transplanted from Brazil to Africa by the Portuguese nearly three centuries ago (3). They were undoubtedly struck by cassava's very high per-acre energy yields in the wet tropics, by the fact that it did not have to be harvested at once and did not present storage problems and by its general acceptability as a source of energy. They did not realize that its extremely low protein content (less than 1% of energy) would contribute to the etiology of protein malnutrition (4), as it does despite the claims that protein does not count all that much (5).

The two most widely known forms of processed cassava are gari, a fermented flour consumed in Nigeria and farinha, the flour consumed in Brazil. Two varieties of cassava from Nigeria were each processed into both forms at the International Institute for Tropical Agriculture (IITA) in Ibadan and shipped to Peru for study.

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MATERIALS AND METHODS

Variety TMS 60142 was described by the IITA as "moderate yielding, not very resistant to diseases but resistant to insect pests, low in cyanide (37.4 ± 14.0 mg/kg wet wt), relatively good in gari and fufu quality." Variety TMS 4(2)1425 was described by the IITA as "high yielding, disease and insect pest resistant, low in cyanide (33.2 ± 12.9 mg/kg), poundable and mealy in texture, good in gari and fufu quality, low in maximum paste viscosity." Gari processing consisted of peeling, shredding, fermenting and dehydrating (light roasting) in sacks for 3–4 d, sifting, gelatinizing and roasting. Farinha processing was the same without the fermentation. In our laboratory, cyanide content of the TMS 60142 was 2.6 mg/kg as gari and 3.4 mg/kg as farinha. For TMS 4(2)1425 the respective values were 3.0 and 1.8 mg/kg (6). Our values for these four flours are approximately one-tenth of those we found for freeze-dried flour from a Peruvian variety (2).

Four experimental diets were prepared by adding vegetable oil (equal parts of soybean and cottonseed), sucrose, corn syrup solids (CSS) and casein to each flour so that it contributed only 50% of total diet energy (**Table 1**). Enough casein was added for a safe 8% of diet energy as protein: Only 6% of this was from cassava and the remaining 94% (of much higher quality) was from casein. Oil provided 20% of energy as fat, and isoenergetic amounts of sucrose and CSS raised the carbohydrate (CHO) content to 72% of diet energy, two-thirds from cassava. The flours were mixed with water and boiled for 10 min before blending in the oil, CSS, sucrose and vitamin and mineral mixes.

The casein control diets had 8% protein, 20% fat and 72% CHO energy, this last from isoenergetic amounts of sucrose, CSS and cornstarch (Table 1). Vitamin and mineral mixes were added to all diets in amounts sufficient to satisfy recommended intakes, as in previous studies (1).

Eight recovering malnourished male infants and young children (**Table 2**) received TMS 60142 as gari and as farinha during 9-d periods, in alternating sequence, with preceding (9-d), intervening (6-d) and following (6-d) casein control periods.

The eight subjects had been treated for 20–97 d and had a mean age of 14.8 mo, but mean length age was only 7.3 mo, which indicates severe chronic undernutrition (or in part genetic short stature). Mean weight age was an even lower 5.7 mo, indicative of ongoing undernutrition. This was borne out by weights, as a percentage of those expected for length (7) of 80.5–95.7 (mean 90.0%). Two children were still below the third percentile of expected weight-for-length, with the remainder between the fifth and thirtieth percentiles. Their Z-scores (weight-for-length) ranged between −2.1 and −0.4 (mean −1.1). Their mean serum albumin level was 3.92 g/dl, suggestive of no current protein malnutrition. None had evidence of active infection and all had been shown to absorb nitrogen (N), fat and CHO from cow milk-based formulas normally. During the study each child's weight gain was projected to reach the fiftieth percentile of weight-for-length in 3 mo, and total energy intake was adjusted accordingly at the beginning of each diet period. Daily intake was kept constant during each diet period.

The eight children who received TMS 4(2)1425 as gari and farinha had been treated for 29–100 d, were slightly older (mean 16.1 mo), had a greater mean length age of 9.5 mo, a greater mean weight age of 7.8 mo, a similar mean weight-for-length (90.3) and mean Z-score of −1.1; six of the eight were at or below the fifth weight-for-length percentile.

Most of the feedings were given by bottle, with spoon-feeding for older children. Metabolic balances were carried out during the last 6 d of the initial casein and both cassava periods and the last 3 d of the other two casein periods. Diets and feces were analyzed for energy (bomb calorimetry), fat (van de Kamer), N (micro-Kjeldahl) and CHO (by difference); urine was analyzed for N only. Serum albumin was determined by acetate gel

TABLE 1

Composition of four cassava-based diets and casein control diet[1]

Ingredient	TMS 60142 cassava as		TMS 4(2)1425 cassava as		Casein control diet
	Gari	Farinha	Gari	Farinha	
Cassava, *g/100 kcal*	14.05	14.24	14.25	14.88	—
Casein,[2] *g/100 kcal*	2.18	2.18	2.10	2.18	2.32
Vegetable oil,[3] *ml/100 kcal*	2.44	2.43	2.43	2.43	2.40
Sucrose, *g/100 kcal*	2.85	2.83	2.90	2.89	6.05
Corn syrup solids, *g/100 kcal*	2.93	2.93	2.98	2.98	6.24
Cornstarch, *g/100 kcal*	—	—	—	—	6.83

[1]Vitamin and mineral mixes (1) added to satisfy National Research Council recommended intakes, Na to make 2.4 mEq and K to make 3.0 mEq/(kg body wt·d).

[2]Casec, Mead Johnson, Evansville, IN.

[3]Equal parts of soybean and cottonseed oils.

TABLE 2

Nutritional status of 16 recovering malnourished male children participating in studies of cassava digestibility and utilization

Type of cassava fed	IIN no.	Age	Weight	Weight age	Height	Height age	Weight-for-height[1] Percent	Percentile	Z-score	Initial Serum albumin
		mo	*kg*	*mo*	*cm*	*mo*				*g/dl*
TMS 60142 as gari and farinha	904	12.3	7.63	5.6	69.2	6.8	93.3	20	−0.9	3.34
	907	10.3	5.83	2.7	65.8	4.9	80.5	<3	−2.0	4.33
	908	10.0	7.23	4.8	66.5	5.3	97.3	30	−0.5	4.04
	913	14.6	6.93	4.3	65.8	4.9	95.7	30	−0.4	4.22
	931	12.6	6.14	3.2	67.1	5.6	80.8	<3	−2.1	3.77
	932	18.5	9.02	8.5	74.4	10.5	92.9	20	−0.7	3.89
	955	26.5	10.57	13.5	80.5	16.0	94.5	30	−0.5	3.78
	960	13.2	6.00	3.0	65.0	4.6	85.0	5	−1.6	3.98
TMS 4(2)1425 as gari and farinha	922	13.0	9.19	8.8	73.4	9.8	97.5	40	−0.2	3.98
	938	9.3	5.60	2.5	64.1	4.2	82.1	3	−1.7	3.85
	924	17.2	8.81	8.6	78.0	13.8	82.9	<3	−2.0	3.07
	945	10.9	5.85	2.8	64.0	4.1	86.5	5	−1.5	4.24
	814	27.0	11.85	20.2	77.4	13.0	114.0	95	1.7	4.04
	951	21.0	9.32	9.3	78.9	14.5	86.3	5	−1.5	3.82
	949	8.6	6.85	4.2	67.5	5.8	89.0	5	−1.4	3.84
	956	22.4	8.17	6.5	74.4	10.5	84.2	3	−1.8	3.25

[1]Data from reference 7.

electrophoresis at the beginning and end of each diet period. Weight was determined daily. Time taken to consume each feeding was recorded.

For purposes of statistical analysis, the results from each experimental diet were compared, by paired *t*-tests, with those of the casein control periods that preceded and followed them (**Tables 3 and 4**). The results with the two different processes of the same variety fed to the same children were compared directly and as percentages of their preceding and following controls (combined). The results for the same process with two different varieties were also compared. Finally, the results for all four flours were compared with each other and with the published results from identical diets with

TABLE 3

Digestibility and utilization of gari and farinha energy and protein from cassava TMS 60142 compared with casein control diets

Measure	Diet: Casein	Gari	Casein	Diet: Casein	Farinha	Casein
Minutes/feeding	3.4	5.2	4.8	4.8	8.0	5.8
(SD)	(0.8)	(2.9)	(3.6)	(3.5)	(8.4)	(5.0)
Fecal						
Wet wt, *g/d*	87.1[1]**	201.6	105.9**	87.8*	171.4	114.2*
(SD)	(31.6)	(72.3)	(45.8)	(55.3)	(58.4)	(41.2)
Dry wt, *g/d*	15.6**	24.3	18.0*	14.7**	23.4	18.3
(SD)	(3.3)	(4.0)	(8.1)	(3.5)	(5.3)	(1.6)
Energy, *kcal/d*	51.1**	94.4	53.9**	46.6**	89.0	64.2
(SD)	(12.0)	(18.4)	(19.5)	(13.1)	(17.1)	(14.8)
Fat, *g/d*	2.0	1.9	1.8	1.8	1.8	2.3
(SD)	(1.0)	(0.6)	(1.0)	(1.2)	(0.8)	(1.7)
CHO, *g/d*	3.4**	12.6	4.1**	4.0**	11.4	4.4**
(SD)	(1.4)	(3.1)	(2.2)	(2.2)	(2.6)	(1.3)
Nitrogen balance						
Absorption, %	82.2	77.1	81.8	83.9**	77.6	81.8
(SD)	(3.1)	(3.9)	(5.3)	(4.2)	(3.4)	(2.1)
Retention, %	34.0	29.8	38.4**	34.5	30.4	35.8
(SD)	(6.1)	(5.3)	(7.3)	(4.5)	(5.4)	(8.5)
Change in body weight, *g/d*	23.2	30.1	37.0	39.4	36.5	20.9
(SD)	(22.2)	(23.8)	(20.1)	(19.9)	(13.1)	(26.5)
Change in serum albumin, *g/al*	−0.07	−0.14	0.01	−0.14	−0.11	0.20
(SD)	(0.36)	(0.27)	(0.30)	(0.19)	(0.31)	(0.28)

[1]Significantly different (*$P < 0.05$ or **$P < 0.01$) from corresponding cassava (gari or farinha) period.

TABLE 4

Digestibility and utilization of gari and farinha energy and protein from cassava TMS 4(2)1425 compared with casein control diets

Measure	Diet			Diet		
	Casein	Gari	Casein	Casein	Farinha	Casein
Minutes/feeding	3.1	4.5	3.2	3.1	6.6	3.8
(SD)	(0.4)	(2.1)	(0.2)	(0.3)	(4.4)	(1.6)
Fecal						
Wet wt, *g/d*	105.0[1]**	153.9	104.4**	96.4**	190.1	105.6*
(SD)	(48.7)	(46.2)	(37.4)	(32.5)	(67.0)	(48.8)
Dry wt, *g/d*	16.4**	22.9	16.9**	17.4**	24.4	16.8**
(SD)	(4.4)	(5.1)	(3.6)	(3.7)	(5.3)	(4.2)
Energy, *kcal/d*	58.6**	89.4	51.7**	59.2**	92.4	60.4**
(SD)	(22.3)	(19.1)	(11.0)	(13.0)	(18.0)	(21.0)
Fat, *g/d*	2.3	1.5	2.0	2.8*	1.9	2.3
(SD)	(1.2)	(0.6)	(0.6)	(1.3)	(0.6)	(1.3)
CHO, *g/d*	4.1**	12.2	3.4**	3.3**	12.0	4.4**
(SD)	(2.2)	(3.1)	(1.8)	(1.2)	(3.2)	(2.5)
Nitrogen balance						
Absorption, %	83.0**	79.0	83.9**	82.9**	77.0	82.8*
(SD)	(2.8)	(1.3)	(2.1)	(1.9)	(4.3)	(3.7)
Retention,	33.2	31.0	41.1**	33.6	28.9	34.1
(SD)	(5.3)	(3.3)	(4.9)	(8.2)	(6.1)	(7.9)
Change in body weight, *g/d*	36.1	43.2	34.1	33.9	38.9	40.3
(SD)	(16.6)	(14.8)	(25.7)	(16.6)	(13.6)	(14.0)
Change in serum albumin, *g/dl*	−0.27	−0.02	0.24	0.19	−0.17	−0.09
(SD)	(0.21)	(0.38)	(0.21)	(0.34)	(0.24)	(0.29)

[1]Significantly different (*$P < 0.05$ or **$P < 0.01$) from corresponding cassava (gari or farinha) period.

a freeze-dried Peruvian variety (2) by analysis of variance (**Table 5**). The protocols for these studies were approved by the Ethics Committee of the Instituto de Investigación Nutricional (IIN) and all children participated with the informed consent of their parents.

RESULTS

Table 3 summarizes the results for TMS 60142 as gari and as farinha, compared with preceding and following casein controls in the same children. Mean times

TABLE 5

Comparison of TMS 60142 and TMS 4(2)1425 as gari and farinha with a lyophilized Peruvian variety of cassava[1]

Measure	TMS 60142		TMS 4(2)1425		Peruvian lyophilized[2]
	Gari	Farinha	Gari	Farinha	
Minutes/feeding	5.2 ± 2.9	8.0 ± 8.4	4.5 ± 2.1	6.6 ± 4.4	9.6 ± 8.1
Fecal					
Wet wt, *g/d*	202 ± 72	171 ± 58	154 ± 46	190 ± 67	196 ± 44
Dry wt, *g/d*	24 ± 4	23 ± 5	23 ± 5	24 ± 5	24 ± 4
Energy, *kcal/d*	94 ± 18	89 ± 17	89 ± 19	92 ± 18	89 ± 16
% of intake	10 ± 2	9 ± 1	8 ± 1	9 ± 1	10 ± 3
Fat, *g/d*	2 ± 1	2 ± 1	2 ± 1	2 ± 1	2 ± 1
% of intake	9 ± 3	9 ± 4	7 ± 2	8 ± 2	8 ± 4
CHO, *g/d*	13 ± 3	11 ± 3	12 ± 3	12 ± 3	11 ± 2
% of intake	7 ± 2	7 ± 1	7 ± 1	6 ± 1	6 ± 1
Nitrogen balance					
Absorption, %	77 ± 4	78 ± 3	79 ± 1	77 ± 4	79 ± 5
Retention, %	30 ± 5	30 ± 5	31 ± 3	29 ± 6	31 ± 8
Change in body weight, *g/d*	30 ± 24	37 ± 13	43 ± 15	39 ± 14	28 ± 20
g/(kg body wt·d)	3.4 ± 2.5	4.5 ± 1.6	5.0 ± 2.0	4.5 ± 1.8	3.0 ± 1.9
Change in serum albumin, *g/dl*	−0.14 ± 0.27	−0.11 ± 0.31	−0.02 ± 0.38	−0.17 ± 0.24	0.22 ± 0.19
Final, *g/dl*	3.51 ± 0.27	3.47 ± 0.29	3.63 ± 0.27	3.72 ± 0.22	3.72 ± 0.40

[1]All values are means ± SD. By analysis of variance there was no significant effect of cassava variety or process on any of the reported parameters.

[2]Data from ref. 2.

taken to consume the cassava diets tended to be greater than those taken to consume casein diets.

For both processes fecal wet weights were twice as high as with casein diets but dry weights were only 50% higher. Differences in fecal energy contents were similar. Energy concentrations per unit of fecal dry weight during cassava diets were higher than during casein diets, despite the lower percentage of fat. Water contents of feces during cassava diets were higher, 86–88 versus 82–84% ($P < 0.05$). There was no effect of cassava consumption on fecal fat. Fecal CHO (by difference) was much higher during the cassava diets and accounted for nearly all the differences in energy content. This and the similar ash contents explain the higher energy density. Apparent absorptions of N were lower, but not always significantly so, than during the casein control periods. The same was true for apparent retentions. Rates of weight gain were extremely variable, with no clear trends apparent. Changes in serum albumin levels were no greater than might be expected from variability of the method but might have been affected by rapid weight gains (8).

Table 4 summarizes the results for TMS 4(2)1425. Consumption times were similar to those in Table 3, as were fecal weights, fecal energy, fecal fat and fecal carbohydrate. Differences in rates of apparent N absorption between the cassava and the casein periods were also similar, as were those for apparent N retentions, rates of weight gain and changes in serum albumin.

When the results of the current studies (two varieties × two processes) were compared among themselves and with the previously published results with a Peruvian freeze-dried cassava, the similarities were quite remarkable, whether in absolute amounts (Table 5), or as percentages of the respective control periods (not shown). The slightly lower rate of weight gain during the earlier studies was probably due to slightly lower energy intakes.

DISCUSSION

The fermentation of cassava used in the production of gari in Nigeria did not convey any advantage in digestibility and utilization of cassava energy and protein over those of the Brazilian flour, farinha, made without fermentation, nor did either of these have any advantage over the freeze-drying of the Peruvian cassava used in our earlier studies (2). The results in those studies, when freeze-dried cassava provided 50% of diet energy, as in the current studies, were not different from those obtained earlier with oven-dried or simply boiled fresh cassava (1). This lack of effect from various forms of processing is quite different from that found for cereals such as wheat (9) and sorgnum (10) or a cereal legume such as *Chenopodium quinoa* (11).

The modest decrease in apparent N absorption from the cassava + casein diets, when compared with the casein diets, can be explained on the basis of differences between the digestibility of casein and cassava proteins only if we postulate that the latter was not digested at all. It is more reasonable to assume that the digestibility of casein was slightly but adversely affected by the cassava or that the increased fecal N was the result of microbial proliferation favored by cassava carbohydrates not digested in the small bowel. The differences in apparent N retention are almost certainly the result of the lesser amounts of N absorbed, an inferior biological value of cassava proteins and the adverse effect on N retention of the inferior amounts of energy absorbed.

In attempting to summarize the results obtained with cassava in the various studies, it seems that part of its CHO is in a form of fiber that is highly resistant to all forms of reasonable digestion, that has a high water-holding capacity resulting in increased consumption times and in bulky feces, that has no untoward effects on the absorption of added fat, that has a modest effect on the absorption of added high quality protein and that probably does not favor microbial proliferation in the lower gut. The greater part of its CHO is in the form of starch or oligosaccharides and seems to be completely digested in the small bowel.

The marked differences in cyanogenic glucoside content between the flours from Africa and those from Peru may be the result of genetic or processing differences or of environmental factors such as drought, but they had no apparent effect on respective digestibilities. One must conclude that cassava is an excellent source of highly digestible CHO on one side and of unfermentable dietary fiber on the other. It is preferable that the processing of cassava liberate the glucosides as hydrocyanic acid prior to consumption and to potential conversion in the intestine. An adequate complement of high quality protein is essential to supply the sufficient N and essential amino acids, particularly a surplus of methionine, needed for the conversion of residual cyanide to thiocyanate (12). An adequate iodine intake is then essential to counteract the goitrogenic effect of the thiocyanate formed (3).

The decision as to the most desirable form for processing cassava into a flour may not have to be based on nutritional considerations alone but rather on economic terms and acceptability, taking into account the time that must be spent on home processing, which is usually carried out by housewives for whom this is a most important consideration. Because freeze-drying does not reduce cyanogen content, it is not a desirable process unless previous steps have accomplished the reduction.

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Digestibility of Boiled and Oven-Dried Cassava in Infants and Small Children[1]

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ABSTRACT Boiled fresh cassava or oven-dried cassava flour provided 50% of the energy and less than 10% of the protein in diets of convalescent mainourished infants; casein was added to complete 8% of energy as protein, and vegetable oil (soybean-cottonseed) was added to make 20% of energy as fat. Despite high wet weights of feces (172 ± 42 and 214 ± 41 g/d), their dry weights (20 ± 3 and 22 ± 2 g/d) and their energy (6.9 ± 0.7 and 7.6 ± 0.5% of intake) and nitrogen (17 ± 3 and 20 ± 3% of intake) contents were low, and their fat content (4.4 ± 1.3 and 5.2 ± 1.2% of intake) was very low. Cassava is a surprisingly effective source of energy which interferes little or not at all with digestion of added protein and fat in weaning diets. For its safe use, it is important that home or industrial processing almost completely eliminate its potential hydrocyanic acid content, and that a good quality protein supplement be consumed regularly in nutritionally adequate amounts. *J. Nutr.* 117: 129–132, 1987.

INDEXING KEY WORDS:

• *weaning foods* • *cassava* • *digestibility*

The historical association of cassava consumption with kwashiorkor in weaned infants of tropical Africa and Brazil rests on the very low protein content of this root and on the frequently simultaneous absence from the diet of satisfactory sources of supplementary protein (1). Reliance on one of the cereals, or on a higher protein tuber such as the white potato, is considered nutritionally more sound because supplementation with a good source of protein, though almost always desirable, may not be absolutely essential to prevent protein malnutrition or poor growth rates (2). The "bad name" that cassava has earned should not obscure the fact that it has a very high energy yield, that it does not have many of the storage problems of cereals, and that it is the only major source of diet energy readily available to millions of inhabitants of the wet tropics (3).

The low energy density and the bulkiness of cassava-based weaning foods suggest that infants and small children might have considerable difficulty in satisfying most of their energy needs from them. Our limited experience (unpublished) with diets based on a cassava flour (farinha de mandioca) from Brazil was not encouraging; only the larger children (2–3 yr old) were able to consume the programmed amounts (50–75% of energy) with relative ease, and all of them passed amounts of feces (over 200 g wet wt per day) which were considerably larger than the usual and suggested nutritionally important losses of diet energy.

On the other hand, European investigators have reported digestibilities of cassava starch, as industrially produced tapioca flour, in infants, that were essentially complete and not different from those of wheat, rice and potato starches (4, 5). In those studies the starch never represented more than 20% of total energy. Reports from India indicate satisfactory digestibility and utilization of comparable amounts of tapioca flour (as "macaroni") in older children (6, 7).

Despite the real or presumed drawbacks of cassava as a staple for infants and small children, its obvious importance in the developing world prompted a study in some detail of its utilization as a major source of energy, beginning with the effect of simple processing on the digestibility of the energy and protein components of the total diet.

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MATERIALS AND METHODS

Diets. Cassava is commonly consumed, or fed to small children, as the fresh, boiled root, a form not easy to study by the usual methods. It was thus considered necessary first to document the fact that oven-drying (or freeze-drying) the boiled root did not alter its digestibility. Because storage of the root results in the release of potentially dangerous amounts of hydrocyanic acid (HCN) (8), it was necessary to identify a nearby source of the fresh root.

The study consisted of two 9-d periods, the first with boiled, fresh cassava and the second, immediately following, with corresponding amounts of the same cassava, which had subsequently been oven-dried.

In order to prepare the two diets, cassava (*Manihot esculenta* Crantz, *negra*) from one of the nearby coastal valleys was purchased daily in amounts sufficient for 2 d of consumption by each of the children under study on that day. The root was peeled and cooked in boiling water for 30 to 45 min. Half of this boiled cassava was used during that day, and the remainder was kept frozen to be oven-dried and made into flour for use during the corresponding day of the second diet period. On d 7 of the first diet period, enough cassava was boiled for the last 3 d of both diet periods. On the same day all the boiled cassava that had been kept frozen for the preparation of flour, as well as half the cassava boiled on that day, was cut into pieces, oven-dried at 45°C for 20 h and ground into flour at the nearby Instituto de Desarrollo Agroindustrial of Peru (INDDA-Agroindustrial Development Institute).

During the second 9-d diet period the cassava flour was prepared daily by boiling in water for 5 min. During both diet periods the complete diets for each child were prepared by blending enough cooked cassava to provide 50% of total diet energy with enough calcium caseinate (Casec, registered trademark of Mead Johnson, Evansville, IN) to raise the percentage of energy as protein from less than 1% to 8%, enough vegetable oil (equal parts of cottonseed and soybean oils) to bring the percentage of energy as fat to 20%, and enough dextrimaltose (Mead Johnson) and cane sugar, in energetically equal amounts, to complete 72% of energy as carbohydrate. Vitamin and mineral mixtures (**Table 1**) were added in amounts sufficient to satisfy the Recommended Dietary Allowances of the Food and Nutrition Board of the U.S. National Research Council.

Energy intake, per kilogram body weight, was that which had been documented to support accelerated weight gain and was kept constant during the 9 d of each study period. For the smallest child in the studies, the above ingredients were brought with water to a volume of 1320 mL in order to be fed by bottle in six feedings per day. For the remaining children the volumes were 1450 to 1600 mL divided into five cup-and-spoon feedings.

The amounts of cassava fed to the first two children (Table 1) were based on Peruvian tables of composition, whereas those for the last four children were based on the analyses carried out on the material from the first two studies. All balance calculations, however, were based on the analyzed values for each day's batch of fresh or oven-dried cassava and total diet.

During the last 6 d of each diet period, each child's urine and feces were collected in a metabolic bed or "stroller."

Laboratory determinations. Hydrocyanic acid was determined daily on each day's supply of raw, boiled and oven-dried cassava (9). Boiled cassava, oven-dried

TABLE 1

Calculated compositions of diets based on boiled or boiled, oven-dried cassava. Energy and protein contents of cassava, as consumed, differed by up to 10% from these assumed values

Diet	Boiled[1]				Boiled, Oven-dried[2]			
	Amt	Energy	Prot	Fat	Amt	Energy	Prot	Fat
	g	*kcal*	*g*	*g*	*g*	*kcal*	*g*	*g*
Cassava	33.34	50.0	0.17	0.07	14.17	50.0	0.21	0.25
Ca caseinate	2.13	7.7	1.84	0.04	2.08	7.6	1.79	0.04
Vegetable oil	2.41	19.1	–	2.12	2.21	17.5	–	1.94
Cane sugar	2.90	11.6	–	–	3.12	12.5	–	–
Dextri-maltose	2.99	11.6	–	–	3.22	12.5	–	–
Total[3]	–	100.0	2.01	2.23	–	100.1	2.00	2.23

[1]Cassava values for first two studies from "Composicion de los Alimentos Peruanos' Lima, Instituto de Nutricion, 1969; remaining values from analyses of earlier batches.

[2]Oven-dried cassava values for first two studies from Instituto Nacional de Desarrollo Agroindustrial, La Molina, Peru; remainder as above.

[3]Mineral mixture was added to all diets with the following composition (% wt/wt): NaCl, 30.701; $MgSO_4 \cdot 7H_2O$, 22.804; $CaHPO_4$, 41.615; $FeC_6H_5O_7 \cdot 3H_2O$, 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. Vitamins were supplemented by a single daily dose of 0.6–1.2 mL of Poly-Vi-Sol (Mead Johnson, Evansville, IN) and a single dose of 101 mg choline, 180 mg *myo*-inositol, 200 μg folic acid and 500 mg *p*-aminobenzoic acid. The Poly-Vi-Sol contains (per mL): retinyl palmitate, 1500 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.

flour, aliquots of each day's diet, and the 3-d fecal samples were analyzed for total energy (bomb calorimetry), total nitrogen (micro-Kieldahl), total fat (van de Kamer) and carbohydrates (by difference). Nitrogen concentration in urine was also determined.

Serum total protein (Biuret) and albumin (acetate gel electrophoresis) and packed red cell volumes were estimated at the beginning and end of each diet period.

Subjects. Six male infants and small children, all far advanced in their recovery from malnutrition (**Table 2**), participated in these studies with the consent of their parents. In each case, weight age had begun to approximate height age, and serum albumins were all in the normal range, above 3.60 g/dL. There was no evidence of infection or of intestinal malabsorption. The protocols used in these studies were approved by the Ethics Committee of the Instituto de Investigacion Nutricional.

RESULTS AND DISCUSSION

The results of the studies in the six subjects are summarized in Table 3. All the parameters of digestibility are suggestive of a slight superiority of the boiled cassava over the same that had been subsequently oven-dried. Some of the differences are statistically significant ($P < 0.05$ by paired t-tests) but the statistical analyses have intentionally not been reported because the periods during which the oven-dried cassava was fed invariably followed those in which the boiled product was fed, without an intervening control period. The differences might thus be due to an order effect, in which there might have been deterioration in digestive function as cassava consumption continued. Intervening control periods would have been expected to restore digestive functions to the "normal" for each child and to prevent a carry-over effect.

Fecal wet weights were high, two or more times those seen in children of comparable ages with casein, white wheat flour or rice diets, and higher than those seen with maize, whole wheat or potato diets (10). Fecal dry weights and energy were only slightly higher, suggesting that the undigested residues of cassava have considerable water-holding powers, as does the root or its flour, but that this does not represent an important nutritional handicap, at least when no more than 50% of diet energy is fed as cassava to older infants and children. These results are similar to those obtained with the white potato (11). Apparent absorptions of nitrogen were not lower than those seen with casein diets, suggesting that this amount of cassava does not adversely affect the digestion and absorption of high quality proteins fed with it, an important consideration in the preparation of weaning foods. Fat absorption (apparent) was not affected by the cassava in the diet, remaining in the high normal range of 95% of intake. These results are consistent with those reported from India for tapioca starch (7).

Apparent retentions of nitrogen and rates of weight gain, although seemingly high, cannot be interpreted without control diet periods for comparison. Serum albumin levels did not change appreciably (Table 3), and packed red cell volumes (not shown) were not altered. No studies were made that might permit any conjectures about the effects of cassava consumption on mineral and vitamin absorptions.

In no case were HCN concentrations in the boiled cassava or in the oven-dried flour higher than 5 mg/kg. This is well below the 50 mg/kg considered innocuous. The release of HCN by the action of linamarase on linamarin (both present in the tubers) begins shortly after harvest, but can be prevented by a variety of phys-

TABLE 2

Age, anthropometric measurements and initial serum albumin concentrations of six male infants consuming boiled cassava and then boiled, oven-dried cassava as 50% of diet energy in consecutive 9-d periods

Subject	Age	Height	Ht age	Weight	Wt age	S. Alb[1]
#	*mo*	*cm*	*mo*	*kg*	*mo*	*g/dL*
780	22.6	76.0	11.8	9.20	9.0	4.16
781	12.7	68.5	6.3	7.12	4.8	4.14
779	11.9	72.3	9.0	8.50	7.3	3.59
791	21.0	78.5	14.0	10.08	11.5	3.86
800	33.6	82.5	18.0	11.40	17.5	3.84
806	27.0	76.7	12.5	9.53	10.0	3.60

[1]S. Alb, serum albumin.

TABLE 3

Energy and protein digestibility and utilization in six male infants consuming boiled fresh cassava and then boiled, oven-dried, cassava as 50% of diet energy, with casein added to bring protein to 8% of calories[1]

Cassava	Boiled	Boiled, oven-dried
Energy intake, *kcal/d*	1046 ± 173	1097 ± 140
kcal/(kg · d)	112 ± 10	112 ± 10
Fecal measure		
Wet wt, *g/d*	172 ± 42	214 ± 41
Dry wt, *g/d*	20 ± 3	22 ± 2
Energy, *kcal/d*	72 ± 14	83 ± 8
% intake	6.9 ± 0.7	7.6 ± 0.5
Fat, *g/d*	1.0 ± 0.3	1.2 ± 0.2
% intake	4.4 ± 1.3	5.2 ± 1.2
CHO (calculated), *g/d*	10.4 ± 3.2	12.2 ± 3.3
% intake	5.5 ± 1.3	5.9 ± 0.8
Nitrogen intake, *mg/d*	3222 ± 342	3363 ± 385
Absorption, % *intake*	83 ± 3	80 ± 3
Retention, % *intake*	33 ± 7	38 ± 10
Minutes/feeding	11 ± 5	14 ± 9
Δ Body weight, *g/d*	47 ± 16	32 ± 16
Δ Serum albumin, *g/dL*	0.1 ± 0.2	−0.2 ± 0.4

[1]Values are means ± SD.

ical or chemical actions when cassava is appropriately processed (8).

The times required to consume the cassava-based diets (Table 3) are 5–9 min more per feeding than those of similar children consuming liquid bottle feedings. In that this represents 25–45 min a day of an almost certainly overburdened mother's time, it cannot be dismissed easily. Most of the excess time is almost certainly due to the spoon-versus-bottle difference, but the greater hygiene of the spoon than that of an improperly washed bottle may well outweigh the lost time.

These limited studies suggest that, although cassava's bulkiness, low energy density, and very low protein content are distinct nutritional handicaps, the elevated fecal weights seen during its consumption are probably of minor concern. The energy in cassava is highly digestible, and its consumption does not interfere appreciably with the digestion of added protein or at all with that of added fat, overall making it a satisfactory source of most of the energy in a small child's diet. For its safe use, it is important that home or industrial processing almost completely eliminate its potential hydrocyanic acid content, and that a good quality protein supplement be consumed regularly in nutritionally adequate amounts. Oven-drying of boiled cassava does not interfere significantly with its digestibility. The experience with the white potato suggests that freeze-drying would also not interfere (11).

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