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REHABILITATION OF UNDERNOURISHED CHILDREN IN TANZANIA USING LOCALLY AVAILABLE FOOD

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The rehabilitative effects of a long-term feeding trial in Tanzania with moderately undernourished children are reported. It lasted 88 weeks and involved 49 children. Food consisted of locally available cereals (maize), legumes (beans), and vegetables for 74 weeks, supplemented by animal protein for 14 weeks. Children stayed in a day-care center for 6 days of the week, and were medically supervised and treated, if necessary. In addition to anthropometric measurements, biochemical tests were carried out at regular intervals, and previous diseases and vaccinations were ascertained.

Forty-one children grew faster than, and 6 about parallel to, the Baganda standard for the first 74 weeks. While for the former no growth acceleration was observed in the meat diet period (weeks 75–88), the latter group grew faster than the Baganda standard during that period. Methionine supplementation of the diet did not seem to produce any noticeable growth improvements.

BACKGROUND

In order to study nutritional patterns of populations in Tanzania, the Max Planck Nutrition Research Unit (MPNRU) was established in 1964 in Bumbuli, Lushoto District (Usambara mountains), Tanzania†. Efforts of the MPNRU were directed at four major problems: study of local food consumption pattern; assessment of the nutritional status of the population; examination of the relationships between nutrition and growth development in the population; and investigation of rehabilitation and preventive methods with regard to malnutrition, based on the use of locally available foods.

Previous MPNRU studies (Kraut and Cremer, 1969) had shown that maize is the staple food in the Usambara mountains. Cassava (*Manikot esculenta*), green leaves, bananas, and beans are common, and animal products are limited. Even though, on the average, adults do not appear to be undernourished, they are shorter than corresponding population groups in Western developed countries. Infants develop normally within the first few months of their lives, but as soon as breast milk (almost the only food in the first 24 months of life) becomes insufficient, the growth process slows down, often resulting, for the two-year old child, in body length corresponding to that of an one-year old, and in body weight corresponding to that of a nine-month old child in Western developed countries. Major reasons for the observed retardation of growth are insufficient protein intake due to bad weaning practices and poor environmental conditions. Deficits in body development persists until adolescence, when the ratio of weight/height approaches the Harvard standard range, with both components, however, stabilizing at a lower level as compared to adults of Western developed countries.

The Lushoto District is a mountainous area (1000–2000 m in altitude) with rather poor soil (50 percent is arable). Few tropical diseases are prevalent. More than half of the population is below 15 years of age and 18 percent are younger than four. Most adults are engaged in agriculture, the majority living close to subsistence levels due to hereditary customs (partition of land resu .ing in

† It operated under an agreement with the government of Tanzania and was supported financially by the Fritz Thyssen and the Robert Bosch Foundations (Federal Republic of Germany). In 1969, the MPNRU was integrated into the Lushoto Integrated Development Project (LIDEP), Lushoto District, Tanzania, which was jointly administered by the Tanzania Community Development Trust Fund in Dar-es-Salaam, and the Kübel Foundation, Bensheim (FRG), with the latter funding the project.

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small, scattered plots), overgrazing (excessive number of cattle), and lack of fertilizers. But the number of families selling vegetables is increasing. The average annual income in the district is 1000–2000 East African shillings. (U.S. $ 0.12 as of 1969)

LITERATURE REVIEW AND PILOT STUDIES

It has been suggested by WHO and FAO that nutrition rehabilitation centers be started for protein-energy malnourished (PEM) children and that children be kept in such centers for the duration of the rehabilitation period, estimated to be 3–5 months (Bengoa, 1955). In addition, FAO/WHO (1971) recommend a daily intake of 100–200 kcal (420–840 kJ) and 4 g protein per kg body weight for such children. However, many of these experiments have neither been evaluated nor have their long-term effects been reported in the literature. Beaudry-Darismé and Latham (1973) and Beghin and Viteri (1973) review a few of these trials. For example, 131 Haitian school children, after a median stay in rehabilitation centers of 4.9 months, and 111 Guatemalan children, after a median stay of 7.3 months, showed significantly higher weight-age gains than the corresponding control groups in the village. However, neither of the experimental groups improved their weight for age during the year following discharge, the major reason probably being poor nutritional education of the mother (Beaudry-Darismé and Latham, 1973). In a four-month experiment among about 500 rural Haitian children, the children substantially improved their anthropometric and blood value measurements. However, two years after discharge, differences between these children and a control group could not be detected (King *et al.*, 1966).

In summary, while such FAO/WHO recommendations seem to show short-term nutritional results, long-term effects of short-term trials seem to be minimal. The reasons for this may be manifold, among them that the rehabilitative period is not long enough and rehabilitation itself not optimal; the educational effect on mother and child is small; there is insufficient health education, and poor hygienic conditions persist after trial termination; and such trials often involve food compositions not locally available, so that the continuation of experimental feeding patterns after the trial is almost impossible.

Following FAO/WHO recommendations on increasing legume consumption (Aykroyd and Doughty, 1964), many feeding trials based on

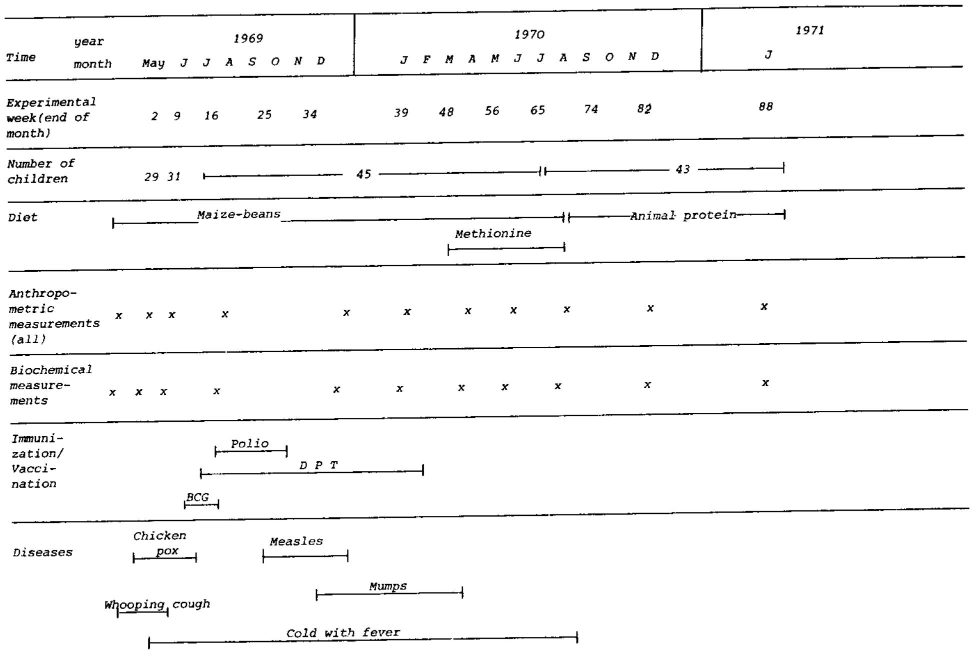

FIGURE 1 Schedule of the feeding trial, showing intervals at which anthropometric and biochemical measurements were taken, immunizations, and periods of disease incidence.

cereals and legumes were carried out (Hansen, 1961; Scrimshaw *et al.*, 1961; Venkatachalam and Srikantia, 1961; Devadas and Bai, 1966; Dutra de Oliveira and de Souza, 1967; Ghai and Chaudhuri, 1971), including some with maize-bean diets (King *et al.*, 1966; Cerný and Addy, 1973). All of them reported immediate weight gains. However, the study period was usually short (about one month) or the children were in a hospital environment. In contrast to these trials, our study attempted to examine the rehabilitative effects of a long-term feeding trial involving children in a day-care center.

METHODS

Organization of the Trial

The trial started in May 1969 and lasted for 88 weeks, until January 1971. The MPNRU was responsible for its scientific supervision. Weekly medical checkups and weighing of the children were supplemented by biochemical and clinical examinations (11 times). Diseases and parasitic infestations were treated and all children were vaccinated (see Figure 1 for trial schedule).

A female kindergarten teacher was in charge of the day-care center established in Soni, assisted by seven girls from participating villages who also served as communication links between parents and center. In the course of their stay, they were trained in nutrition and particularly in the running of child-care centers. The children came from the Shaskwi, Mbuzzi, Kigulunde, Zwandai, and Kisiwani villages in the Soni area, Lushoto District (Kreysler and Mndeme, 1975). A landrover was used for transportation of the children. As good cooperation with the parents was considered essential for the success of this long-term experiment, extensive discussions between parents, village elders, leaders of the ruling political party (TANU), and the center staff took place in order to explain the rationale of the research project.

The trial group consisted of 49 children aged 2–6 years whose exact ages were known and whose parents had agreed to cooperate. All children except one (Figure 2 No. 33) had a weight/age ratio of 70–80 percent of Harvard standard (Jelliffe, 1966). Twenty-seven children started the trial in the first week, 15 in the 15th week, and seven entered between weeks 7 and 21 (Table I). There were 26 female and 23 male children. Children normally spent Monday through Saturday in the center.

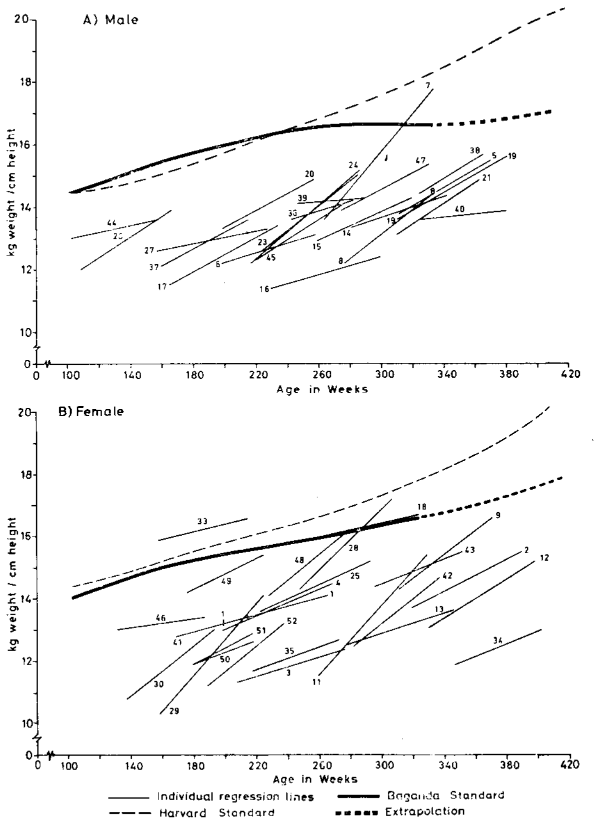

FIGURE 2 Slopes of weight/height by sex for all children in a Tanzania feeding trial (Child 31 was excluded because of insufficient data).

Absences were recorded and reasons noted, the major reason being sickness. Days of attendance varied from 63–90 percent for all children, with a median of 79 percent (see Table I).

Description of Feeding Trial

Choice of diet and number of meals were determined on the basis of earlier investigations in the area (Poeplau, Schlage, and Keller, 1969). As it had been decided to offer a locally available food composition, local food combinations were screened to see if they provided full dietary coverage. Among foods produced locally are garden beans (*Phaseolus vulgaris*), maize, carrots, potatoes, tomatoes, green beans, onions, green maize, green leaves, bananas, papaya (pawpaw) and plums, of which beans are by far the most important protein supplier. Foods not grown in the area but normally available to the population are rice, sugar, and palm oil.

In their study of the biological value of maize

TABLE I

Distribution of selected demographic, administrative, biochemical, and anthropometric characteristics among children in a Tanzanian feeding trial

1. Demographic Characteristics		No. of Children	
Age at entry (years)			
2–4		31	
5–6		18	
Total Children		49	
Sex			
Male		23	
Female		26	
2. Administrative Characteristics			
Total weeks in trial			
27–50		2	
51–70		7	
71–88		40	
Week of entry			
1		27	
7–9		2	
15		15	
16–21		5	
Attendance[a]			
63–75%		13	
76–80%		14	
81–87%		19	
Received milk		4	
Received methionine supplement (17 weeks)		25	
3. Biochemical and anthropometric symptoms of malnutrition	*At entry*	*In week 71*	*In week 44*
Hemoglobin <11.0 g/100 ml blood	12	2	1
Hematocrit <32%	3	2	0
Albumin <2.8 g/100 ml serum	12	6	4
<80% of Harvard standard for weight/age (Jelliffe, 1966)	47	41	35
<90% of Harvard standard for height/age (Jelliffe, 1966)	47	39	21
<90% of Baganda standard for weight/height (Rutishauser, 1965)	43	29	25
Head/chest ratio over 1.00	21	3	0
Arm circumference <80% of standard (Jelliffe, 1966)	42	4	0

[a] (days present/days at risk) × 100.

bean mixtures, Kofrányi, Jekat and Müller-Wecker (1970) found a mixture of one part bean protein and one part maize protein, each individually of low biological value, to have the highest biological value achievable with these two foods, equaling that of whole egg protein. Thus, a mixture of $\frac{1}{3}$ garden beans and $\frac{2}{3}$ maize was fed daily as the basic food. Both products were ground, mixed, boiled, and offered as porridge soup (*uji*), as a stiff porridge (*ugali*), or whole as part of a stew. Dishes containing beans were to be cooked for 30 minutes in order to destroy toxins (Aykroyd and Doughty, 1964; Jaffé, 1973). In order to meet daily vitamin and mineral requirements, the mixture was supplemented by vegetables and fruits. After the initial four weeks, the oil content of the di etwas increased by about 50 percent in order to raise the energy intake to the level recommended by FAO/WHO. Several children did not tolerate this diet and vomited. Reasons for this may have been diseases and vaccinations. The diet was better tolerated after reducing the fat content for a while, and then increasing it slowly to the former level. The children received this menu during the first 74 weeks of the trial, which is referred to as the maize-bean period.

In comparison with the FAO-reference protein (F.A.O. 1957), methionine at that time appeared to be the most limiting aminoacid (Table II). Therefore, the food of 25 children (Figure 2, No.

TABLE II

Amino acid composition of maize-bean diet given to Tanzanian children (g/100 g crude protein)

Amino acid	Maize-bean diet[a]	*FAO-reference protein* 1957[b]	1973[c]
Valine	6.2	4.2	4.7
Leucine	13.0	4.8	4.8
Isoleucine	5.5	4.2	3.5
Threonine	4.6	2.8	4.4
Phenylalanine and tyrosine	7.4	2.8	6.3
Lysine	5.9	4.2	5.2
Methionine and cysteine	2.8	4.2	2.9
Tryptophan	1.1[d]	1.4	0.85

[a]Analyzed for week 30.
[b]According to FAO (1957).
[c]According to FAO (1973).
[d]Calculated according to FAO (1970).

1–9, 20, 23, 26, 28, 31–41, 50, 51) was supplemented from weeks 54 to 71 with 0.5 g of D,L-methionine per child and day. The last 14 trial weeks were used for an experiment based on food containing milk, eggs, meat, and fish, as fed in hospitals for undernourished children, to study whether better growth could be achieved with a diet based on animal proteins (animal protein period).

The daily feeding schedule started with porridge (*uji*) in the morning, followed by a midmorning snack of fruit, the main meal at midday (*ugali* or stew), an afternoon snack of porridge, an occasional piece of fruit, and an evening meal (not given on Saturday) which resembled the morning dish. It was ascertained by interview that, during the week, children usually did not receive any additional food at home. Information about food consumption on Sunday and during times of absence from the center is not available. Fruit was given out in individual pieces. Green vegetables and bean-maize flour were cooked and served separately. Food was dished out in individual bowls in ample quantities. Each bowl was weighed (using a Salter spring balance) before being given to the child. After completion of the meal, any food remaining in the bowls was weighed, the difference between before-and-after measurements being the actual food consumption. Computations of nutrient composition of foods were based on two references (Platt, 1962; FAO, 1968). Food samples were analyzed at regular intervals at the MPNRU for control purposes.

Data Collection

Nutritional status was assessed periodically in agreement with Jelliffe's recommendations (1966). A medical assistant made the clinical diagnoses, while the survey team took anthropometric measurements. Blood and urine specimens were collected for biochemical tests, stool samples in order to check for parasites, and blood slides in order to check for malaria. Initially, Heaf tests and X-ray examinations (at Bumbuli Hospital) of chest and wrist were obtained. All diseases and infections were treated; some serious cases of whooping cough were referred to Bumbuli Hospital, with children returning to the center after recovery. Case sheets were kept for each child in order to record observations of interest, for example, diseases and absences.

Anthropometric measurements are the major dependent variables in the trial. Weight was measured every week and the remaining measurements were taken 11 times in the course of the 88 trial weeks, namely, weeks 1, 5, 15, 22, 37, 43, 54, 60, 71, 81, 88. Six types of measurements were taken: weight (Salter beam balance), height, circumference of head, chest and mid-arm, and skinfold over biceps and triceps (Harpenden caliper). Two types of standards were used for references, one (the Harvard standard) published by Stuart and Stevenson (1959) and the other (the Baganda standard) by Rutishauser (1965). The former was established for white North American children and has been found to be valid for corresponding European age-sex groups (Tanner, 1962). The latter standard describes well-nourished Baganda children up to age 6 and was extrapolated to ages beyond (Figure 2). Both standards report length and weight by sex at half-year age intervals. Among the eight signs of underdevelopment shown in Table I, five are anthropometric: weight, heigth, weight/height ratio, head/chest circumference ratio, and arm circumference, each for the particular age. Deficiencies are defined as follows: Weight <80 percent of Harvard standard, height <90 percent of Harvard standard, weight/height <90 percent of Baganda standard, head/chest circumference >1.00 arm circumference <80 percent both according to Jelliffe (1966), for the particular age and sex groups, respectively.

Biochemical data were likewise collected 11 times during the trial. Blood samples were taken from the finger tip and analyzed in the MPNRU laboratory. Only 4 of about 20 biochemical measurements are presented, i.e., hemoglobin (measured as cyanmethemoglobin using Drabkin's solution), hematocrit (Hawksley microfuge), and albumin in serum (Beckman cellulose acetate electrophoresis) and total protein (Biuret reagent). Urinary total nitrogen was determined with Kjeldahl's method, and urinary urea after conversion with urease with phenol-hypochlorite reagent (Fawcett and Scott, 1960). Biochemical data were also used to identify specific deficiencies, such as anemia. Deficiencies for the reported four measurements were defined as follows: <11 g per 100 ml of blood for hemoglobin; <32 percent hematocrit; <6 g per 100 ml of blood for total protein and <2.8 g per 100 ml of plasma for albumin. Each deficient value was counted as one sign of malnutrition or underdevelopment in Table I.

Data Handling and Analysis

Weekly readings were obtained for each child on food intake, body weight, attendance, and reasons for absence. Anthropometric and biochemical data were ascertained 11 times during the trial and physician reports about communicable and parasitic diseases recorded at time of onset. Data were processed and analyzed at the Max-Planck-Institute of Nutrition Physiology and the University of Dortmund Computer Center.

Plots of the original time series for each child of anthropometric, biochemical, and nutrient intake data show that there were six experimental periods, the last three of which were planned as such. The first three periods (about 29 weeks in length) consisted of four weeks of initial feeding, 19 weeks of oil-rich food, one week of reduced oil content, and five weeks of gradual increase of oil content to the former level, which was maintained after week 30. The shapes of the individual growth curves (weight/height) show a general upward trend with substantial irregular variation (noise) around it. The noise was eliminated by piecewise polynomial approximation (cubic spline functions, Greville 1969). Examples of the resulting growth curves are shown in Figure 3. Analysis of the spline-fitted curves showed that distinct depressions of the curves (local minima mainly due to disease) were in most cases compensated by subsequent increases (see dotted lines in Figure 3). Therefore, individual trend curves of weight/height were approximated by using beginning and end points (data up to week 74) of weight/height curves only. Nine children each, with the highest and lowest slopes, were studied further.

RESULTS

As shown in Table I for the 49 children in the trial, signs of underdevelopment decreased sub-

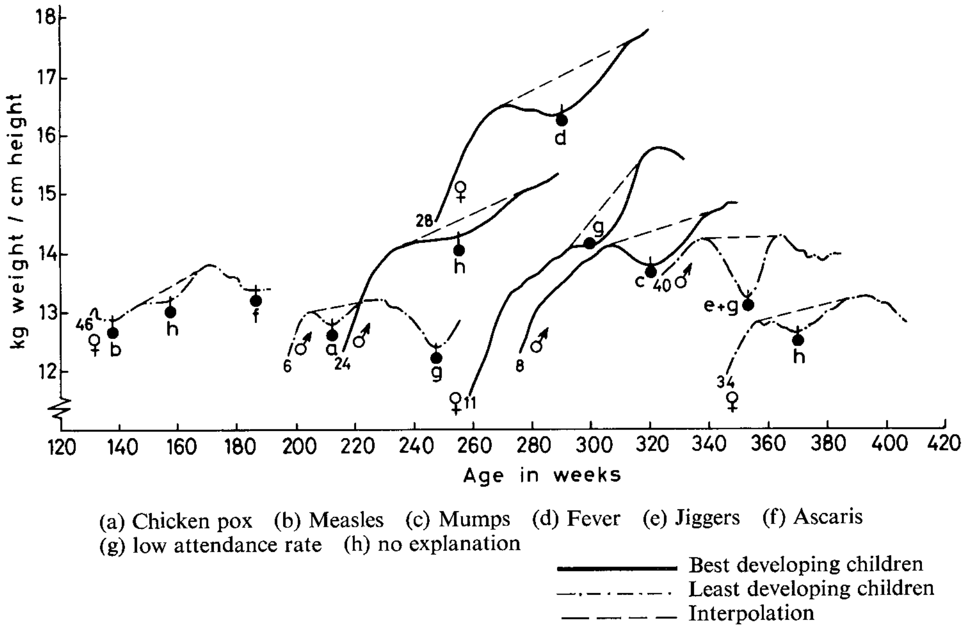

FIGURE 3. Growth curves of selected children in a Tanzania feeding trial (♂-males, ♀-females).

stantially, but did not disappear entirely after 88 weeks. While the number of children with a head/chest ratio > 1.00 was reduced from 21 to 3 in the maize-bean period, no children showed this deficiency at the end of the animal protein period. For weight, the reduction in numbers of underweight was 47 to 41 for height 47 to 39, weight/height 43 to 29 and arm circumference 42 to 4. A substantial reduction was observed for children with deficient values according to the Harvard standard during the maize-bean period. For all these measures, the number of deficiencies was further reduced in the subsequent animal protein period: from 41 to 35 for weight, from 39 to 21 for height, from 29 to 25 for weight/height, and from 4 to 0 for arm circumference.

Numbers of children with deficiencies in biochemical values were also substantially reduced in the maize-bean period. For example, for blood values of hemoglobin < 11 g/100 ml from 12 to 2 children, for hematocrit < 32 percent from 3 to 2 children, and for albumin < 2.8 g/100 ml serum from 12 to 6 children. Such deficiencies were almost nonexistent by the end of the animal protein period.

Food and Nutrient Intake

Table III gives the mean daily food intake per child in the maize-bean and the animal protein periods. During the former, maize and beans provided 70 percent of the daily protein intake and 42.5 percent of the daily energy intake. Actual average daily intakes of energy and protein in the different experimental periods are given in Table IV. The energy intake did increase during the trial from 280–368 kJ(67 to 88 Kcals)/kg body weight/day. Protein intake ranged around 1.7 g/kg body weight during the maize-bean period and was subsequently increased to 2.3 g/kg body weight daily in the animal protein period.

Table V shows that the mean daily nutrient intake per child in the maize-bean period and the animal protein period was sufficient in comparison with recommended values (Passmore *et al.*, 1974), with the exception of calcium and vitamin B2 in the maize-bean period. However, none of the two is considered to be a limiting factor for development. While the niacin intake was low as well, no signs of deficiency of calcium, vitamine B2 and niacin could

TABLE III

Daily food intake per child in feeding trial in Tanzania

	Maize-bean period (74 weeks, n = 49)				Animal-protein period (14 weeks, n = 42)			
Foods	Mean (g)	Energy (kcal)	Energy (kJ)	Protein (g)	Mean (g)	Energy (kcal)	Energy (kJ)	Protein (g)
Maize	107	214	895	9.6	121	418	1750	10.1
Beans	54	166	695	10.5	7	23	96	1.4
Rice	15	53	220	1.2	31	109	454	2.6
Potatoes	10	8	31	0.2	18	14	56	0.4
Sugar	28	112	468	0	31	124	519	0
Oil	37	330	1381	0	42	375	1567	0
Green beans	14	20	82	1.3	—	—	—	—
Carrots	40	15	62	0.4	29	11	45	0
Onions	2	1	4	0	5	2	10	0.1
Tomatoes	2	0	2	0	11	2	9	0.1
Green maize	47	58	242	1.9	—	—	—	—
Green peas	8	8	32	0.6	—	—	—	—
Green leaves	31	15	62	1.2	24	12	48	1.0
Bananas	32	32	135	0.4	—	—	—	—
Mangoes	32	20	82	0.2	26	16	66	0.1
Pawpaw	99	35	145	0.5	53	19	78	0.3
Oranges	61	31	128	0.5	28	14	59	0.2
Plums, Sambia	20	8	33	0.1	9	4	15	0.1
Milk, dried, skimmed	—	—	—	0.7	18	67	279	6
Meat, lean	—	—	—	—	27	43	178	5
Eggs	—	—	—	—	4	6	26	0.5
Fish, dried	—	—	—	—	4	12	52	2.5
Total		1306	5460	29.3		1269	5293	29.9

TABLE IV

Energy and protein intake of Tanzanian children by age and trial period

Age at entry (years)	n	Trial weeks	Average daily intake per kg body weight: Energy (kcal)	Energy (kJ)	Protein (g)	Percent of total energy: From Protein	From Fats
2–<4	8	1–4	63	264	1.76	11.2	21.2
	20	5–24	85	356	1.67	8.6	33.8
	20	25–29	72	301	1.58	9.2	24.5
	20	30–59	84	351	1.74	8.6	31.2
	19	60–74	79	330	1.68	8.6	32.0
	16	75–88	84	356	2.24	11.2	34.0
4–6	18	1–4	74	310	2.04	10.9	20.9
	29	5–24	89	373	1.76	8.2	32.0
	29	25–29	75	314	1.91	9.6	24.0
	29	30–59	91	381	2.03	9.1	30.7
	28	60–74	88	368	2.06	9.5	31.2
	26	75–88	94	393	2.48	10.4	31.7
All ages	26	1–4	67	280	1.85	11.1	21.1
	49	5–24	87	364	1.71	8.5	33.1
	49	25–29	73	305	1.71	9.4	24.3
	49	30–59	87	364	1.85	8.8	31.0
	47	60–74	83	347	1.84	9.0	31.7
	42	75–88	88	368	2.33	10.9	33.1

TABLE V

Actual and recommended daily nutrient intake of Tanzanian children in maize-bean and animal protein periods

Daily nutrient intake per kg body weight		Maize-bean period	Animal protein period	Recommended[a]
Energy	kcal	82	85	92
	kJ	343	356	384
Protein	g	1.7	2.2	1.0
Fat	g	3.3	3.4	
Carbohydrate	g	11.8	11.8	
Calcium	mg	12.5	29.2	20–25
Iron	mg	0.67	0.47	0.25–0.50
Phosphorus	mg	33	48	
Vitamin A	mg	0.024	0.016	0.005
Vitamin B1	mg	0.060	0.046	0.035
Vitamin B2	mg	0.030	0.046	0.055
Niacin	mg	0.30	0.36	0.60
Vitamin C	mg	6.5	5.0	1.0

[a] According to Passmore *et al.* Handbook on Human Nutritional Requirements (1974)

be observed. Overall, average nutrient intake was higher than that observed in some Usambara villages (Poeplau, Schlage and Keller, 1969).

Body Development

Table VI shows means and standard deviations for anthropometric measurements taken at three points during the trial and their product-moment correlations with weight/height as taken at week 71. All single measures as well as weight/height increased within the maize-bean feeding period, even though some of the increases may not be statistically significant. Correlations of weight/height were high with arm and chest circumference and weight, medium with height and head circumference, and low with skinfold measurements. On the basis of these results, it was decided to use weight/height as the major dependent variable in the analysis. A further reason for this decision was that normal

TABLE VI

Anthropometric measurements of children in Tanzanian feeding trial expressed as means and standard deviations (s.d.), and correlations with weight/height

Measure		Maize-bean period				Animal protein period		Correlation with weight/height
		week 5 (n = 23)		week 71 (n = 34)		week 88 (n = 41)		week 71 (n = 34)
		Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	
Weight	kg	12.2	(1.7)	14.3	(2.2)	15.4	(2.5)	−.93
Height	cm	91.6	(7.0)	98.4	(8.0)	104.1	(8.2)	−.66
Weight/height	kg/cm	0.13	(.01)	0.15	(.01)	0.15	(.02)	1.00
Head circumference	cm	49.1	(1.7)	49.1	(1.6)	49.8	(1.9)	−.53
Chest circumference	cm	51.6	(3.1)	52.4	(2.6)	53.5	(2.5)	−.84
Midarm circumference	cm	13.9	(.8)	15.2	(.9)	16.2	(.9)	−.81
Biceps, skinfold	mm	3.3	(.9)	4.0	(1.1)	4.3	(1.6)	−.08
Triceps, skinfold	mm	7.5	(1.7)	8.2	(2.3)	8.2	(1.8)	−.12

TABLE VII

Diseases and weight loss among Tanzanian children in feeding trial

Disease	n	Time of Occurrence (week)	Cases with weight loss	Cases without weight loss
Communicable				
Mumps	24	33–44, 52[b]	14	10
Measles	12	24–34	2	10
Whooping cough[a]	5	5–12	—	—
Cold with fever	20	4–44, 50[b], 51[b], 57[b], 71[b]	13	7
Chicken pox	7	12–14	1	6
Subtotal	68		30	33
Infestation[c]				
Ascaris	23		6	17
Hookworm	9		2	7
Subtotal	32		8	24
Total	100		38	62

[a]Not epidemic at the time; children received treatment in Bumbuli hospital. Weight development was not followed.
[b]One case each.
[c]Only severe cases are included. Light infestations were frequent throughout the trial.

African adults reach approximately similar weight/height ratios as individuals in Western developed countries, despite the fact that their average weights and heights are lower than those of the latter group. Thus, weight/height may provide a yardstick for the amount of rehabilitation achievable under existing conditions. While weight/height increased in general, this increase did not show a continuous upward trend (see Figure 3). Analysis of minima of these curves for possible explanatory factors showed that among the 35 definite minima, 21 could be explained by disease, seven by nonattendance, and the remaining seven could not be attributed to any of the factors analyzed (Table VII).

Slopes for weight/height for all children (Figure 2) show that 39 children grew faster than and six about parallel to the Baganda standard. Four children (Figure 2 No. 11, 30, 50, 51) in the former group had received some milk supplement. Six children had reached 95 percent or more of weight/height for age, which may be classified as complete rehabilitation. Average weight/height of the children increased from 77.5 percent to 81.0 percent of Harvard standard or from 80.8 percent to 88.2 percent of Baganda Standard during the maize-bean period. During weeks 54 to 71 no differences in body development could be detected regardless of food supplementation by methionine. This result is in agreement with the 1973 FAO-reference protein (FAO, 1973 and Table II), and supports their figure for methionine plus cysteine of 2.9 g per 100 g crude protein. The same holds for tryptophan, which seemed to be the second limiting amino acid, compared to the 1957 FAO-reference protein (FAO, 1957).

During the animal protein period, the weight/height ratio was only slightly improved (see Table VI). Contrary to expectations, neither age at entry or sex, nor the initial nutritional status seemed to be important determinants of future growth (see Figure 2). Consistent with this was the finding that the nine best and the nine least developing children differed neither with respect to those characteristics nor with respect to recorded types and bouts of diseases. Not even food consumption differed among the two groups. However, while the nine best developing children grew parallel to the Baganda standard during the animal protein period (weeks 75–88), the nine least developing children grew faster than the standard during that period. The nine best developing children (Figure 2 No. 7, 8, 9, 17, 19, 24, 28, 29, 42) started at 78 percent of Baganda standard for weight/height and reached 93 percent during the maize-bean period. There was no change during the animal protein period, and maximum rehabilitation in this group was probably achieved with 1.73 g protein/kg body weight of the maize-bean diet. In contrast, the 9 least developing children (Figure 3 No. 3, 6, 16, 18, 34, 35, 40, 43, 46) started at 81 percent of the Baganda standard for weight/height, reached 84 percent at the end of the maize-bean period, and 86 percent at the end of the animal protein period.

Biochemical Data

While individual biochemical values varied somewhat in the course of the trial, overall improvement could be detected. Most of the children started without noticeable deficiencies (37 or more children, see Table I). This confirms the fact that children were only moderately malnourished initially. Overall, however, biochemical measurements turned out to be poor indicators of nutritional improvement but were sensitive to diseases. These findings agree with experience in other out-of-hospital investigations (Beghin and Viteri, 1973). Therefore, only a few measurements were used in further analyses. Mean values for selected determinants at entry, at the end of the maize-bean feeding period, and at the end of the animal protein period are shown in Table VIII. During the feeding trial, the numbers of children with biochemical deficiencies decreased as the average values increased.

Clinical Observations and Diseases

At the beginning of the trial, few clinical signs of protein energy malnutrition were observed, due to the selection criteria. Some children had ulcerations of the extremities and conjunctivitis. Almost all children carried intestinal parasites and had colds and respiratory infections. All children appeared apathetic, certainly not only due to malnourishment but also to psychological reactions to the unfamiliar environment and to the novelty of center life. All diseases were treated. Ulcerations and conjunctivitis disappeared soon. After approximately two weeks, the children had become fully acquainted with the center, were lively, more active and participated in center activities. As it had been intended to allow children to return home in the evening, frequent reinfections occurred and, despite treatment, infestations with intestinal parasites persisted. However, center children had fewer and

TABLE VIII

Biochemical measurements of selected indicators during maize-bean and animal protein periods for Tanzanian children

		Maize-bean period				Animal protein period	
		week 5 (n = 23)		week 71 (n = 34)		week 85 (n = 42)	
		Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)
Hemoglobin	g per 100 ml	12.8	(1.3)	13.3	(1.4)	12.0	(1.8)
Hematocrit	%	35.4	(3.2)	37.7	(3.8)	36.5	(8.7)
Albumin	g per 100 ml	3.0	(0.5)	3.1	(0.3)	3.0	(0.94)
Urea nitrogen/ total nitrogen in urine		0.35	(0.3)	0.76	(0.17)	0.66	(0.17)

less severe bouts of disease than children confined entirely to the villages. Of a total of 100 severe cases of disease (see Table VII), 68 were attributable to communicable diseases and 32 to infestations. In 57 cases, no weight loss occurred, and in the remaining 43 cases it was made up rather quickly following recovery. Severe infestations with intestinal parasites were evenly distributed over the whole experimental period, but the incidence rates decreased, from about 50–80 percent of all children in the beginning to 20–30 percent at the end of the trial. Communicable diseases occurred mainly in the first part of the experiment, and only five cases were recorded after week 44 (see Figure 1 and Table VII). On the average, diseases had no appreciable negative effect on rehabilitation.

DISCUSSION AND IMPLICATIONS

Rehabilitation of moderately undernourished children can be achieved by a diet of maize, beans, vegetables, and fruit in optimal composition. This diet is available to people living in a subsistence economy in the Usambaras of Tanzania. The diet supplies 330–380 kJ (80–90 Kcals) energy and 1.7–2.0 g protein/kg body weight and day. This is still far below the recommendations of the FAO/WHO Expert Committee on Nutrition (1971) for rehabilitation of protein energy malnutrition, namely 420–840 kJ (100–200 Kcals) energy and 4 g protein/kg body weight and day, and rehabilitation therefore proceeds slowly.

Starting out at a mean of 80 percent of the Baganda standard of weight/height, children reached a mean of 88 percent in the course of 18 months. These results agree with those reported by other investigators (Beaudry-Darismé and Latham, 1973; Beghin and Viteri, 1973). While the number of children showing deficient blood values was reduced drastically in the maize-bean period, more than half still had deficient anthropometric measures as compared to the Harvard and Baganda standards. An ensuing experimental period, with a diet supplemented by animal protein, verified, that for most of the children rehabilitation terminated during the maize-bean period and only the few least developing children made further progress. Individual differences in rehabilitation rates cannot be explained satisfactorily by the variables measured and analyzed during the investigation, (age, sex, initial degree of malnourishment, disease incidence and severity, and quantity of food consumed). While it is noted that these diets are not sufficient for rehabilitating children with severe protein energy deficiency (Ashworth, 1969, 1974), we conclude from this trial that children can be protected from malnutrition with food locally available in the Usambaras, provided that people are trained to give the proposed diet after weaning. This implies an increase of bean production, which seems feasible (Attems, 1969).

As moderate malnourishment is more prevalent than its severe form and conditions in day-care center experiments cannot be as well controlled as those in hospital, conclusions from this trial can be expected to be more realistic for field applications. Thus recommendations derived from such trials are more relevant for improving the nutritional status of populations.

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