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Activating the community for nutritional improvement

Rajammal P. Devadas

Abstract

This presentation provides information on community-oriented action research conducted under the leadership of Dr. Rajammal P. Devadas, the recipient of the IUNS International Nutrition Award for 2001. Educating, activating, and energizing the community with empowerment have been the focus of the action-oriented research. In the four decades of work presented, massive efforts have been made in the areas of infant and preschool child nutrition; nutritious noon meal programs for children; integration of nutrition, health, and sanitation concepts in the primary school curriculum; use of local foods to eradicate malnutrition; introduction of novel and underexploited foods; food-based approaches to overcome micronutrient malnutrition; equipping women for food and nutrition security; and nutrition education. These efforts have been activated through development of relevant food and educational materials, their introduction to the community, impact evaluation, follow-up, and implementation of the concepts in relevant national programs with massive training efforts. Many of the efforts outlined have formed the basis for regional and nationwide nutrition intervention strategies. The experiences gained and training efforts developed have gone beyond the country-level exposure to training and equipping nutrition workers in other countries.

Key words: India, community nutrition, intervention, nutrition education, women's empowerment, overcoming micronutrient malnutrition

The author (deceased, March 17, 2002; see obituary page 230) was the Chancellor and Chairperson of the Avinashilingam Trust and Institute for Home Science and Higher Education for Women in Coimbatore, Tamil Nadu, India.

This paper was presented at the IUNS Nutrition Awards Ceremony on 29 August 2001 during the 17th International Congress of Nutrition in Vienna, Austria. The award is given every four years by the Council of the International Union of Nutritional Sciences.

Introduction

Inspired by the founder of the Avinashilingam Trust and Institute for Home Science and Higher Education for Women, Dr. T. S. Avinashilingam, who dreamed about a hunger- and malnutrition-free India, all the programs of the institute have been geared to meet the needs of the community. The well-being and improvement of the community were the major goals in the programs undertaken. This massive community effort involved building rapport for motivating the people, eliciting their cooperation, accomplishing the actual work, and studying the impact through evaluation at various stages. All these efforts involved many trials, tribulations, and deep commitment of workers in the field. The main aim was to make the communities realize their need for self-help and self-reliance. Because the ultimate goal was sustainability of action plans, the whole approach involved participation from the community for the benefit of the community. In this paper, our action-oriented research is summarized according to activities at the national and international levels.

Infant and pre-schoolchild nutrition

Development of ready-to-consume supplements

In the early 1960s, concepts regarding weaning and supplementary foods were lacking, and there was a need to develop supplementary foods using indigenous ingredients for local familiarity, sustainability, and cost-effectiveness. At that time, the Indian Council of Medical Research (ICMR), under the leadership of Dr. C. Gopalan, who was then the Director of the National Institute of Nutrition, instituted a research program to develop region-specific, ready-to-consume (RTC) foods. Accordingly, our institute developed six RTCs for our region, with three different cereals and two different pulses as the basic ingredients, to provide 300 calories and 10 g of protein per child per day in a single 80-g serving at a cost of Ps. 10 (US1$ = 46 rupees; 1 rupee = 100 paise). The compositions of the developed mixes are shown in table 1.

Feeding trials with 100 infants for 12 months using the developed RTC showed significant increments in weight and height (fig. 1).

Activation of the community for infant and child nutrition

Activation of the community for infant and child nutritional improvement was achieved through various programs. In one significant program in 100 anganwadis (preschools), children were offered total development through varied inputs, including nutritious food, nutrition education, and establishing nutrition gardens, through guidance given to over one hundred thousand children through preschools. This was facilitated by membership in the State Planning Commission for child survival, health, and development and through the state nutrition policy and its action plans.

Training of personnel

Training of personnel, with the emphasis on nutrition and health, provision of nutritious supplements, safe drinking water, hygiene, and environmental sanitation, in a large measure helped empower the community for child development. Table 2 gives the statistics on training conducted.

TABLE 1. Compositions of ready-to-consume foods[a]

Food	Weight(g)	Calories	Protein(g)
Jowar[b]/maize[c]/ragi[d]	30	98–105	2.19–3.33
Bengal gram[e]/ green gram[f]	20	70–74	4.50–4.90
Roasted groundnuts	10	56	3.15
Jaggery	20	76	0.08
Total	80	300–311	9.92–11.46

a. Prices in Coimbatore in September 1970: Rs. 0.10–0.11 (US$0.002). Price in August 2001: Rs. 1.16 (US$.03).
b. Sorghum vulgare.
c. Zea mays.
d. Eleusine coracana.
e. Cicer arietinum.
f. Phaseolus aureus Rox.

Community nutrition camps

Community nutrition camps covering more than 10,000 women were another means to educate women on infant and early childhood nutrition. Giving due consideration to extraneous factors, positive improvement in breastfeeding practices over the last 35 years has been achieved, as can be seen from table 3. Growth trends over the past 35 years reflect the empowerment women have had toward infant and child nutrition (tables 4 and 5).

Applied nutrition program

Another significant program through which community empowerment was achieved was the Applied Nutrition Program (ANP) sponsored by UNICEF, the Food and Agriculture Organization (FAO), and the World Health Organization (WHO). At a regional training center from 1960 to 1965, training was provided to over 4,781 health workers, grassroots-level workers, members of women's organizations, extension

TABLE 2. Beneficiaries trained for the child development program

Beneficiaries	No.
Anganwadi workers	> 4,445
Job training for community nutrition supervisors	515
Refresher course training for preschool and primary-school teachers	2,023
Adolescents	1,140
Young parents	> 3,750
Child-care workers in Malaysia	20

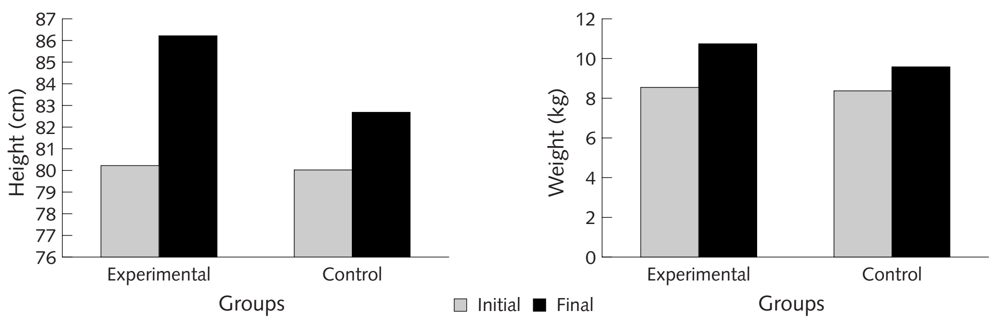

FIG. 1. Mean increases in height and weight of infants given ready-to-consume foods for 12 months

TABLE 3. Reported practices with regard to feeding infants colostrum and reasons given for the practices (based on a total of more than 10,000 rural and urban women studied in the 1960s and in 2001)

Practice	Rural		Urban		Reasons	Rural		Urban	
	1960s	2001	1960s	2001		1960s	2001	1960s	2001
	% of women					% of women			
Colostrum fed	10	45	40	88	Colostrum has protective action	5	50	40	90
					Colostrum is the first food for the baby	2	60	22	98
Colostrum not fed	52	5	1	—	Colostrum causes diarrhea	5	—	—	—
					Colostrum is curdled milk	2	—	—	—
					Colostrum is hard to digest	3	—	1	—
					Colostrum was not fed earlier	50	—	1	—

workers, teachers, local leaders, and district officials. Reorganization of the ANP in a village to strengthen the intervention strategy was also carried out, and the outcomes (table 6) served as a model. Certain components, such as nutrition gardens, can be seen as a part of their lifestyle even today.

Tamil Nadu Integrated Nutrition Program (TINP)

A more recent World Bank-assisted program, the Tamil Nadu Integrated Nutrition Program (TINP), is another scheme through which empowerment for early childhood nutrition has been achieved. The objective of TINP is to reduce the infant mortality rate and malnutrition of children under six years old. Our institute has trained personnel for TINP in skills such as the use of nutritious supplements, measuring weight, the use of audiovisual aids, record-keeping, and assessing nutritional grades. The numbers trained can be seen in table 7.

TABLE 4. Trends in birthweight and length of the newborn

Period	Weight (kg)	Length (cm)
1960s	2.0–2.2	45.0–46.1
2001	2.6–3.2	51.0–52.0

Nutritious noon meal program for children in Tamil Nadu

Our varied and applied research for the successful implementation of the noon meal scheme since 1962 provided the foundation for launching the statewide nutritious noon meal program. In July 1982, the extensive Chief Minister's Nutritious Noon Meal Program (CMNNMP) was launched for children 2 to 10 years of age. It was later extended to children up to 14 years of age, and the program today covers more than 8.5 million children. Our involvement in this program can be summed up as follows:

1. Basic concept, expertise to draw meal plans, menu (cyclic)

TABLE 5. Trends in mean height and weight of preschool children

Age (yr)	Year	Weight (kg)	Height (cm)
2	1965	7.5	82.0
	2001	8.8	85.0
3	1965	9.3	86.0
	2001	10.2	88.9
4	1965	9.9	89.0
	2001	11.3	92.1
5	1965	11.6	93.0
	2001	13.2	95.8

TABLE 6. Impact of implementation of the applied nutrition program (ANP) for six months on the nutritional status of the beneficiaries: mean increases in weight, hemoglobin (Hb), and length

Area	Pregnant women		Newborns		Lactating women	Infants		Preschool children	
	Weight (kg)	Hb (g%)	Weight (kg)	Length (cm)	Weight (kg)	Weight (kg)	Length (cm)	Weight (kg)	Length (cm)
Reorganized ANP	4.6	76.70	3.15	50.0	0.92	1.70	4.50	1.37	3.50
Original ANP	2.1	66.60	2.51	47.0	0.04	1.22	3.11	0.76	3.06
No ANP	2.0	60.03	2.50	46.1	–1.88	1.38	4.74	0.48	1.88

2. Training of personnel B multiplier system
   - Village level 11,795
   - Block level 5,468
   - District level 850
3. Impact evaluation
   - School enrollment
   - Employment generation
   - Nutritional outcome

The nutritional outcomes of these programs were systematically evaluated over a period of 12 months on 3,857 children, and tables 8 and 9 give an idea of the growth achieved.

Improvements in other measures of nutritional assessment, school performance, nutrition knowledge, food habits, and cognition have also been obtained. Improvements in the knowledge, attitudes, and practices (KAP) of both children and mothers and involvement of women from the community in the programs were also positive indicators of community activation. Table 10 gives an idea of the nutritional knowledge of mothers of children who participated in the noon meal program, and table 11 shows the extent of participation recorded by members of the rural women's clubs in the CMNNMP.

The planners and the policy makers can take advantage of such joint collaborative actions between the preschools and the women's clubs and gear their action plans and projects in this direction.

TABLE 7. Personnel trained for the Tamil Nadu Integrated Nutrition Program (TINP)

Type of personnel	No.
Nutrition officers (3 weeks)	43
Community nutrition instructors (4 weeks)	91
Community nutrition supervisors (8 weeks)	921
Orientation training for in-service candidates (3 weeks)	96

Integration of nutrition, health, and sanitation education in the primary-school curriculum

Based on our research on the feasibility of integration of nutrition and health concepts in the primary-school curriculum, a curriculum was developed to national standards, and the proposal to test its efficacy was funded by UNICEF through the National Council for Education Research and Training (NCERT) in five regional centers. In our region, Tamil Nadu, our institute was involved in training personnel at various levels for implementation, preparation of the guidebooks, teaching aids, and training of teachers.

Ten thousand primary-school teachers were provided training through skill orientation, which equipped them to implement the scheme in all the primary schools of the state. Changes effected in the school lunch program, dietary practices and habits at home, food habits of the children, and nutrition knowledge of parents are all notable outcomes of this mode of empowerment.

TABLE 8. Mean change in height (cm)

	Boys			Girls		
Age (yr)	Initial	Final	Increase	Initial	Final	Increase
2	87.3	93.3	6.0	85.6	91.0	5.4
3	92.0	96.9	4.9	88.8	93.0	4.2
4	97.6	102.4	4.8	95.7	100.7	5.0
5	105.1	109.1	4.0	104.9	109.2	4.3
6	111.0	117.2	6.2	108.9	113.4	4.5

TABLE 9. Mean change in weight (kg)

	Boys			Girls		
Age (yr)	Initial	Final	Increase	Initial	Final	Increase
2	9.77	11.82	2.05	9.46	12.21	2.75
3	11.74	14.37	2.63	11.68	13.92	2.24
4	13.83	15.87	2.04	13.50	15.53	2.03
5	15.34	16.99	1.65	15.11	17.69	2.58
6	16.89	18.51	1.62	17.38	19.90	2.58

Evaluation of trained teachers

The outcome of training for teachers in different zones of Tamil Nadu—rural (Coimbatore), urban (Coimbatore), coastal (Kanyakumari), and tribal (Nilgiris)—on the effective implementation of the nutrition and health concepts in the schools is shown in table 12.

Evaluation among children

The cognitive, effective, and psychomotor impacts on children were assessed. The cognitive impact included awareness of nutrition and health concepts and gain in nutrition and health knowledge; the effective impact covered the changes in attitudes; and the psychomotor impact included the nutrition and health practices adopted by children. Table 13 gives an idea of the changes in practices of children. In general, the nutrition, health, and sanitary practices followed by children showed good improvement.

Table 14 shows the remarkable improvement in certain observable deficiency symptoms in children, which bears testimony to the KAP adopted by the community at large.

TABLE 10. Nutritional knowledge of mothers before and after participation of their children in the noon meal program

Knowledge	No. of marks allotted	Mean no. of marks: Experimental ($n = 400$) Initial	Experimental ($n = 400$) Final	Control ($n = 100$) Initial	Control ($n = 100$) Final
Meaning of nutritious food	2	0.59	0.63	0.60	0.57
Names of 5 nutritious foods	5	3.09	3.40	2.70	2.60
Advantages of greens	5	2.83	3.16	2.50	2.55
Desirable methods of cooking	3	1.12	1.45	1.36	1.42
Ways of conserving nutrients in cooking	5	2.06	2.28	1.72	1.80
Total	20	9.69	10.92	8.88	8.94

TABLE 11. Percentage of women's club members participating in the noon meal program in the five villages ($n = 100$ per village)

Activity	Village 1	2	3	4	5
Checking vegetables bought by the organizer	85	80	75	80	84
Helping in menu planning	91	52	90	67	92
Helping in cooking and serving	91	87	90	60	92
Supplying drinking water	79	80	80	67	85
Looking after the kitchen garden	76	80	85	60	92
Supplying firewood	50	80	80	30	87
Supplying vegetables from own garden	75	54	90	67	92

TABLE 12. Percentage of schools effectively implementing integrated nutrition and health education program

Evidence of effective implementation	Coimbatore (rural)	Coimbatore (urban)	Kanyakumari (coastal)	Nilgiris (tribal)
Including nutrition and health concepts in lesson notes	80	70	45	60
Composing stories and songs about nutrition	90	75	80	85
Presence of visual aids in nutrition and health education	50	60	75	80
Nutrition and health concepts written in children's notebooks	30	35	25	30
Maintaining health card for children	25	20	30	50

Experience gained from all the regional centers gave NCERT (the leading body to bring such changes in curriculum) the conviction to incorporate nutrition, health, and environmental sanitation concepts in the curriculum and textbooks of the primary schools.

TABLE 13. Percentage of children showing nutritional health and environmental sanitation practices before and after intervention ($n = 25{,}000$)

Practice	Before	After
Including raw vegetables and seasonal fruits in the diet	11	44
Eating all foods without waste	20	56
Brushing teeth every day	60	95
Washing fruits and vegetables before eating	15	54
Keeping nails trimmed and clean	18	75
Keeping surroundings clean	10	69
Buying food exposed to flies, dust clarify	75	15

TABLE 14. Disappearance of observable deficiency symptoms in children over six months ($n = 25{,}000$)

		Recovered	
Symptom	No. affected	No.	%
Angular stomatitis	1,960	475	24.2
Bleeding gums	2,455	746	30.4
Dry, scaly skin	2,500	1,540	61.6
Bitot's spots	1,800	950	52.8

Use of local foods for eradication of malnutrition

Formulation and evaluation of improved diet combinations

In a long-term effort in the community, diet combinations based on the local pattern were developed and the best two—one ragi-based (finger millet) and one rice-based—were evaluated through longitudinal human feeding trials. Menus were planned to meet two-thirds of the daily requirement. Twenty-five pregnant women received the rice-based diet as a supplement, 25 received the ragi-based diet, and 25 served as nonsupplemented control subjects. These women were followed through pregnancy, delivery, and 18 months of lactation. The infants were monitored for their growth from birth, given weaning foods developed from the same diet as their mothers received from the fourth month onwards, slowly shifted to a normal diet by the age of one year, and given the intervention up to preschool age; they were followed to adolescence. Figure 2 shows an improving trend in growth patterns of these children given early nutrition intervention as compared with their control counterparts.

For the multigenerational study, 35 young women who had been among the children given interventions in the earlier study were followed up during their first pregnancy, and their data were compared with those from their own mothers. Remarkable improvements in birthweight and other measures were evident in the second generation of infants (tables 15 and 16). These are indicative of the beneficial effect of early nutritional interventions, coupled with empowerment of mothers through nutrition education and participation in the scheme itself, in activating them for better nutrition for future generations.

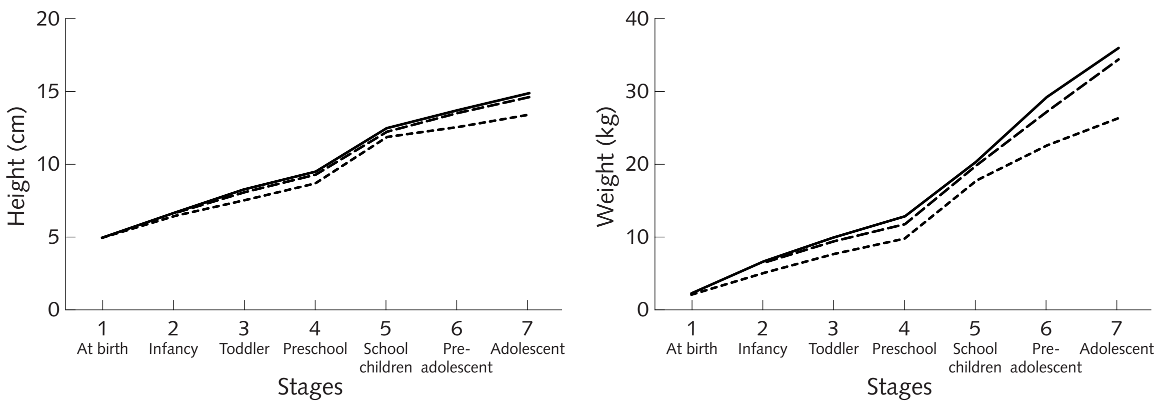

FIG. 2. Growth patterns from birth to adolescence of children given early nutrition intervention

Female literacy and family improvement

Female education has a positive impact on family nutrition. In a study in the four southern states and the Union Territory of Pondicherry, 15,000 women of different levels of literacy were surveyed to determine the effect of level of education on family size, birth-rate, infant mortality rate, health status, and nutritional status. It was found that all these factors had a direct association with female literacy (table 17). In general, as the level of education among the mothers increased, the infant mortality rate decreased, and this association was significant at the 1% level.

The percentage of healthy children, the morbidity pattern of children, and the prevalence of nutritional disorders were also studied in the population surveyed. The percentage of healthy children was greater among those whose mothers were highly literate than among those whose mothers were moderately literate or illiterate (table 18). Children of illiterate mothers had a greater occurrence of diseases than children of moderately literate or highly literate mothers. In general, children whose birth order was below three had a lower incidence of morbidity than children whose birth order was three or above.

These findings bring out the impact of women's literacy level on the nutritional status of their infants and children and suggest the need for concerted efforts to eradicate illiteracy in order to bring up a strong future generation.

Introduction of novel foods and underexploited foods

In this effort we worked with leaf protein concentrate under the guidance of the late Dr. N. W. Pirie, popularized the use of wheat and wheat products in non-wheat-consuming areas, explored the use of soy and soy protein in specific intervention strategies, and studied

TABLE 15. Anthropometric measurements of two generations of pregnant women

Measurement	Intervention group 1st generation	Intervention group 2nd generation	Control group 1st generation	Control group 2nd generation
Weight gain (kg)	7.9	10.5	6.0	6.5
Hemoglobin (g/dl)	8.5	13.8	8.3	10.0

TABLE 16. Anthropometric measurements of two generations of neonates

Measurement	Intervention group 1st generation	Intervention group 2nd generation	Control group 1st generation	Control group 2nd generation
Crown-heel length (cm)	50.0	53.0	49.9	50.0
Birthweight (kg)	2.8	3.3	2.4	2.5
Arm circumference (cm)	9.3	10.2	9.1	9.3
Chest circumference (cm)	34.0	35.0	33.0	33.4
Head circumference (cm)	34.2	35.8	34.0	34.5

TABLE 17. Birth rates and infant mortality rates in low- and high-literacy districts according to maternal educational level ($n = 500$/group)

District literacy level	Maternal educational level	Birth rate	Infant mortality rate	$\chi 2$ Birth rate	$\chi 2$ Infant mortality rate
Low	Illiterate	35.9	118.4	4.35 NS	20.26**
	Medium	29.0	81.9		
	High	25.1	62.5		
High	Illiterate	32.3	100.8	2.04 NS	18.35**
	Medium	24.2	61.9		
	High	17.6	49.5		

NS, Not significant.
** $p < .01$.

TABLE 18. Percentage distribution of healthy children in low- and high-literacy districts ($n = 500$/group)

District literacy level	Maternal educational level	% healthy children	χ2
Low	Illiterate	50.6	8.84*
	Medium	67.8	
	High	85.2	
High	Illiterate	58.4	8.21*
	Medium	71.0	
	High	90.6	

* $p < .05$.

the feasibility of incorporating certain underexploited small millets in common dietary and intervention programs.

Efforts to popularize wheat in non-wheat-eating areas

In our effort to popularize wheat in non-wheat-eating areas, we standardized over 1,000 recipes. Table 19 presents the wide array of wheat-based items that have begun to adorn the south Indian cuisine over the last two decades, as compared with the scarcity of wheat foods that existed during the initial stages of the popularization period.

Today wheat and wheat products are included in the daily meal pattern of south Indian (Tamil Nadu) families, as items in the noon meal program, and as weaning and supplementary foods. They are served in several south Indian dishes in all eating places and as popular fast-food items. This transformation has not only helped increase the sale of wheat and wheat products from Fair Price shops, but it also has helped to replace rice, the production of which is still not enough to feed the entire population, thus filling the existing food and calorie gap by eradication of hunger.

Efforts to introduce soy in the noon meal scheme

At the request of the Government of Tamil Nadu, our institute undertook a study on the feasibility of incorporating defatted soy flour as a substitute for dal in the single meal recipe of the noon meal scheme. The soy flour was substituted at 50%, 75%, and 100% levels in place of red gram dal in 12 preschools of Coimbatore for 12 months. The impact of this substitution on the 400 children who took part in this study in terms of their nutritional status is shown in figure 3.

Increments in the levels of substitutions of soy flour gave corresponding higher increments in the nutritional status of the children studied. These results motivated the state government to replace red gram dal with soy flour at a 25% level initially, and later the substitution level was raised to 50%.

Studies with soy protein isolate

In collaboration with Protein Technologies International and the American Soybean Association, a study was conducted over a 12-month period on 1,200 children one to two years old with grade II malnutrition. The children were given a soy protein isolate (SPI)–based food mix as a weaning supplement in the form of porridge. The results showed a most promising shift in the malnutrition grades (fig 4).

These children also showed significant improvement in other anthropometric measurements, hemoglobin status, clinical picture, morbidity pattern, and cognitive development as assessed by certain developmental criteria. Eighty children one to two years of age in the same community with grade III malnutrition were available. These children were also given 62 g of

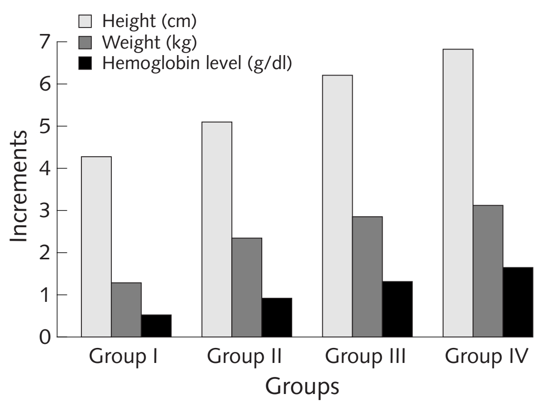

FIG. 3. Mean increases in height, weight, and hemoglobin of preschool children given noon meals in which red gram dal was replaced by defatted soy flour at levels of 50% (group II), 75% (group III), and 100% (group IV) for 12 months; group I is control

TABLE 19. Wheat-based items prepared according to year

1980	1990	2000
Uppuma, dosai, poori, kali, kanji	Chapati, idli, phulkas, adai, pittu, mixed bhath varieties, pongal, malted wheat, weaning foods	Cakes, puddings, biscuits, and a variety of sweets and savories, such as omapodi, murukku, laddu, pakodas, modagam vadai + Jumbo meal, mixed vegetable rice, germinated green gram pittu, and amylase-rich weaning foods

SPI-based food as a humanitarian consideration, and their growth was monitored over the 12-month period. At the end of the study period, 65 of the 80 had shifted to grade II malnutrition. Based on these results, efforts are under way to commercialize these SPI-based weaning and supplementary foods. The product, under the name of Soy Poshak, is on the shelves of several pharmacies connected with pediatric centers in Coimbatore and also in two hospital pharmacies in Erode. Many parents also benefit directly from our production unit in the institute on a regular basis. Popularization efforts for community involvement are under way.

Food-based approaches to overcome micronutrient malnutrition

Vitamin A deficiency

Development of a seasonal calendar

After surveying over 500 households and the local market, we developed a seasonal calendar for locally available vitamin A–rich foods (table 20). This calendar is being used in all education programs.

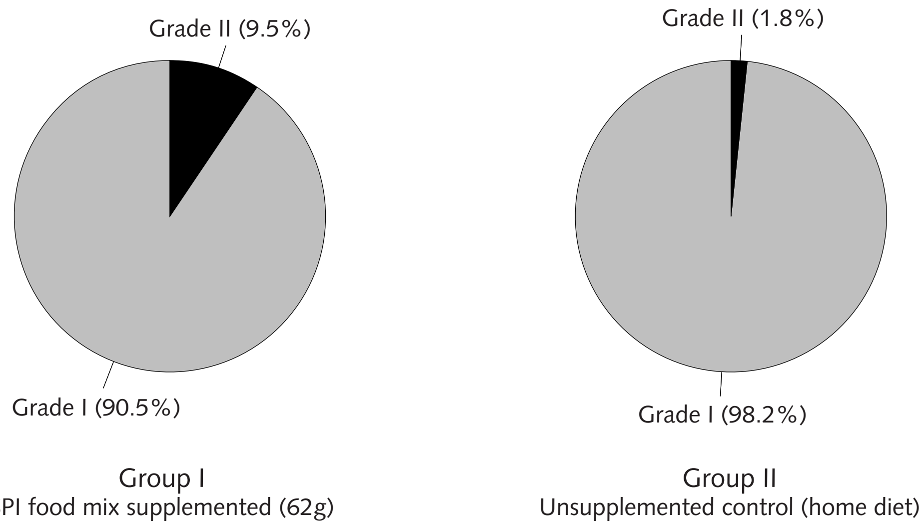

FIG. 4. Shift in malnutrition grades among children receiving supplements of 62 g of soy protein isolate (SPI) daily for 12 months (group I) as compared with control children receiving unsupplemented home diets (group II)

TABLE 20. Seasonal calendar of β-carotene-rich foods

Food	Amount required to meet RDA (g)	Cost (Rs) per portion to meet 2,400 μg			
		Summer	Southwest monsoon	Northeast monsoon	Winter
Green leafy vegetables					
Agathi	15.58	0.13	0.04	0.04	0.04
Amaranth, tender	28.78	0.14	0.10	0.10	0.08
Coriander leaves	50.00	1.78	1.59	1.75	2.25
Curry leaves	33.75	0.43	0.29	0.35	0.73
Drumstick leaves	12.19	0.13	0.90	0.09	0.12
Mint leaves	43.79	0.99	0.95	0.85	0.55
Ponnanganni	44.44	1.78	1.30	0.48	0.50
Other foods					
Carrot	37.15	0.43	0.48	0.32	0.26
Mango, ripe	120.60	3.75	2.49	5.18	5.69
Papaya	272.73	0.80	0.97	1.09	0.98
Tomato	406.78	2.43	3.24	4.06	4.67

Feasibility of using red palm oil as a source of vitamin A

The possibility of using crude red palm oil as a source of vitamin A was investigated in a study on 2,425 preschool children from the International Child Development Services (ICDS) centers. The prevalence of clinical signs of vitamin A deficiency was markedly reduced as compared with the control group of 2,237 children (table 21).

Nutrition education and nutrition garden: A means to improve vitamin A nutrition

Development of vitamin A gardens and nutrition education was another strategy studied. Four groups of 25 ICDS centers each were identified and given the following treatments:

Group A: greens (amaranth 30 g/child/day) only
Group B: amaranth and nutrition education plus a nutrition garden
Group C: massive oral dose of vitamin A only
Group D: massive oral dose of vitamin A and nutrition education

The results over a period of 18 months indicated that children in group A who were given nutrition education and interventions showed the highest increments in growth parameters, hemoglobin levels, clinical picture, serum vitamin A level, and KAP of mothers, which in turn resulted in the development of home gardens and greater intake of vitamin A–rich foods by the end of the two-year study. Improvements in the serum vitamin A levels of the children can be seen in figure 5.

The results of KAP surveys of mothers (fig. 6) indicate that nutrition education had a significant take-home effect, which was evident from the backyard gardens raised by these women and from the quantity of β-carotene–rich foods consumed by the families before and after implementation of the scheme (fig. 7).

Anemia

The availability of iron from food sources, tonic, and tablets was studied in the school lunch program. The results indicated a clear role of food sources in terms of improvements in hemoglobin levels, hematocrit, and red blood cell counts of children over an eight-month period (table 22).

Equipping women for food and nutrition security

Empowerment for postharvest technology

Empowering women to use simple postharvest technologies (PHTs) could help minimize food losses considerably and aid toward food and nutrition security. Realizing this need, the institute implemented a three-phase project, sponsored by the Food and Agriculture Organization (FAO) through the Government of India (fig. 8).

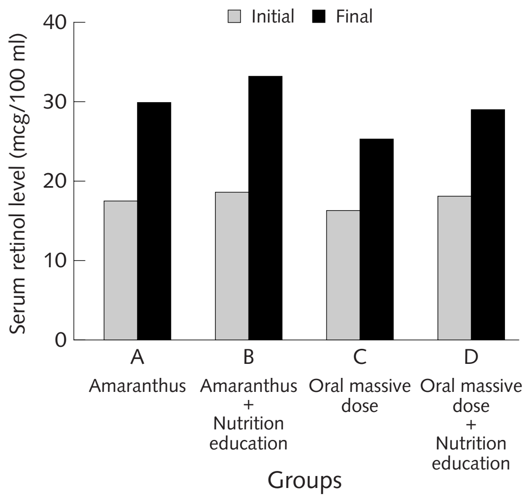

FIG. 5. Mean serum retinol levels of target children. Group A received amaranth; group B received amaranth plus nutrition education; group C received a massive oral dose of vitamin A; group D received a massive oral dose of vitamin A plus nutrition education

TABLE 21. Prevalence of clinical signs of vitamin A deficiency among 2,425 children receiving red palm oil for 14 months and 2,237 control children

		Initial		6 mo		Final	
Sign	Group	no.	%	no.	%	no.	%
Bitot's spots	Red palm oil	7	0.29	3 (+1[a])	0.12	—	—
	Control	12	0.54	9 (+3[a])	0.40	6 (+3[a])	0.27
Conjunctival xerosis	Red palm oil	4	0.16	2 (+3[b])	0.21	—	—
	Control	7	0.31	5 (+2[a])	0.22	3 (+2[a])	0.13
Total prevalence	Red palm oil	11	0.45	8	0.33	—	—
	Control	19	0.85	14	0.62	9	0.40

a. Numbers in parentheses indicate children who left the program during the study period.
b. Number in parentheses indicates children who shifted from Bitot's spot stage to conjunctival xerosis stage.

The action plans under the three phases were the following:

- » Identification of storage conditions, problems, and causes of losses
- » Observation of existing storage practices and preservation methods
- » Estimation of losses of food grains and other foods in farm and household
- » Awareness campaigns and dissemination of improved technology; adoption of technology
- » Inclusion of PHT component in the job chart of grassroots-level workers
- » Establishment of self-sustaining preservation units

The outcomes of this empowerment were the following:

- » Sensitization of farm families and authorities
- » Improvement of traditional storage structures and practices
- » Adoption and construction of scientific storage structures and zero-energy chambers
- » Women's participation in control of rodents and pests, reducing grain losses
- » Saving of 20 million quintals of food grains worth Rs. 30 millions (46Rs. = US$1)
- » Four self-sustaining fruit and vegetable preservation units established
- » PHT: an integral part of extension activities of grassroots-level functionaries
- » Empowerment and activation of women and farmers for better food and nutrition security.

Sustainable technologies for empowering women and reducing drudgery

Training in the use of viable food-preservation techniques, reduction of drudgery through the use of sus-

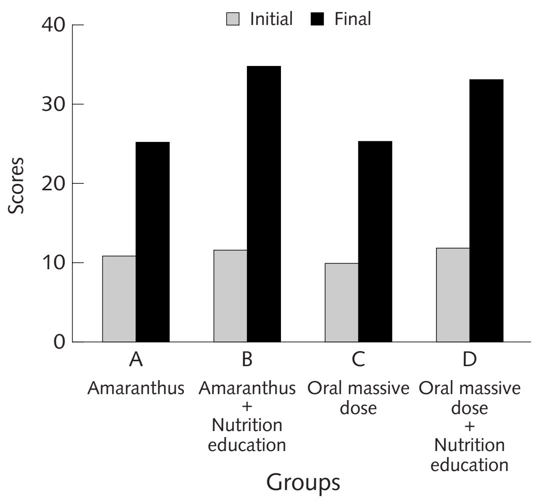

FIG. 6. KAP survey scores of mothers. Group A received amaranth; group B received amaranth plus nutrition education; group C received a massive oral dose of vitamin A; group D received a massive oral dose of vitamin A plus nutrition education

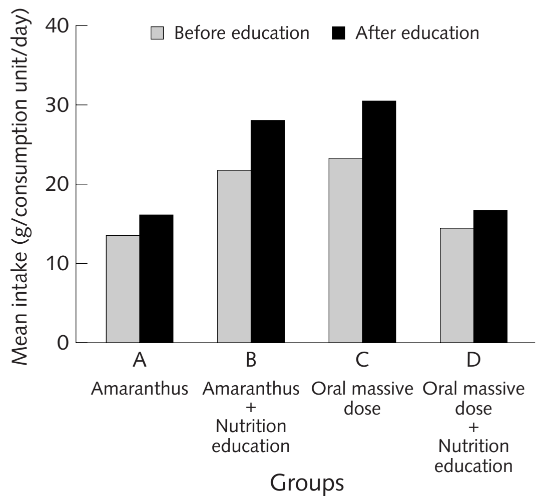

FIG. 7. Quantities of vitamin A–rich foods consumed by the families. A, Green leafy vegetables; B, roots and tubers (carrots, yams, etc.); C, other vegetables; D, fruits (ripe mangoes, papayas, etc.)

TABLE 22. Mean increase in hemoglobin level, hematocrit, and red blood cell count of children over 8 months (n = 100 per treatment group)

Treatment group	Iron intake (mg)	Hemoglobin (g%)	Hematocrit (%)	Red blood cell count (million/ cu.mm)
School lunch	11.7	1.46	0.8	0.26
School lunch + amaranth	28.7–29.2	2.04	1.8	0.23
School lunch + iron tonic		1.82	1.7	0.27
School lunch + iron tablet		1.63	1.4	0.33
No school lunch	9.7	1.19	0.3	0.17

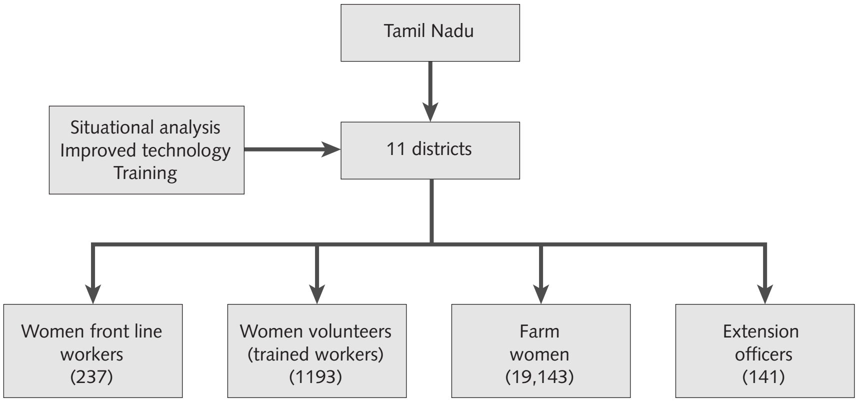

FIG. 8. Empowerment of women for postharvest technology (three phases, three years each)

tainable technologies, creation of consumer awareness, self-employment and entrepreneurship development, and eradication of illiteracy were some of the other empowerment action plans that have had a significant impact on the community. Table 23 gives an idea of the extent to which rural women have adopted technology to reduce drudgery.

In addition, 26,000 women have become literate, 115 self-employment groups have been organized, and most of the entrepreneurship activities are food and nutrition related, such as food-preservation units and masala powder-preparation units. Thus, both formal and informal activities to empower women are under way.

Nutrition education and nutrition information dissemination

Nutrition education by both formal and informal means is given from preschool through school and university stages. Nutrition is an integral part of all outreach activities. Various methods are used to convey the message. Apart from the formal setup in our institute, there are several other channels for the dissemination of nutrition information:

» Nutrition education through research, extension, and training programs
» Nutrition training for grassroots-level women workers
» Development of course content for nurses
» Program for mass media personnel of All India Radio
» Publications in scientific journals in local languages
» Nutrition networking for Tamil Nadu and Kerala

Figure 9 shows the effect of community nutrition education on the nutrient intake of different age groups over a decade.

TABLE 23. Use of technology by rural women to eliminate drudgery

Device	No. of women using
Smokeless chula	2,500
Biogas	530
Haybox	400
KVIC biogas plant	750
Fixed dome biogas plant	1,250
Box type solar cooker	250
Solar cookit	1,722
Solar water heater	500
Solar dryer	100

Activities at the international level

Training childcare workers from Malaysia

At the request of the National Land Finance Cooperative Society, Malaysia, 16 groups of child welfare organizers and preschool teachers were trained for three months on organization of preschools, play equipment, supplementary feeding, and nutrition and health education for children. These teachers subsequently went to different schools in Malaysia for placement and are still in contact with follow-up on childcare activities.

Empowering health workers in Cambodia

As a nutrition consultant to UNICEF, the author had the opportunity to develop a curriculum for training the health personnel of the Government of Cambodia for two weeks on the rudiments of nutrition, with particular reference to assessment of the nutritional status of vulnerable groups, their nutritional needs, and nutrition education as a sustainable means of improving the community's nutritional status. During the first

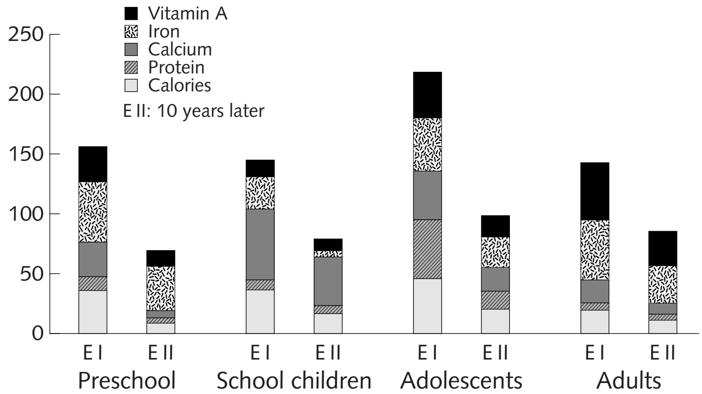

FIG. 9. Percent deficit in mean nutrient intake of different age groups before and after 10 years of community nutrition education

visit to the program areas, plans were made to empower health workers by training, and detailed course contents were worked out and approved by the concerned authorities through discussions. During the second visit, actual training commenced. After the training, nutritional assessment, with particular reference to children and their mothers, was conducted in the six deficient provinces and the city of Phnom Penh with the help of trained health personnel. The assessment study covered 3,283 children and their 2,454 mothers. Younger children were healthier than older children, particularly among those zero to five months old. The highest incidence of malnutrition, according to height, weight, and weight-for-age, was among the older age groups (72 to 144 months). This clearly indicated that at any stage after the age of zero to five months, there is the possibility of reverting to malnutrition, which may be attributed to improper weaning and supplementary feeding practices. Computation of several indices, particularly Quetelet's index (weight/height^2 $\times$ 100), showed a higher incidence of malnutrition among older children, indicating that the nutritional requirements of the growing children are not being adequately met. Other causes, such as worm infestation, morbidity, and lack of knowledge on the part of mothers, could not be ruled out. Thus, the nutritional status picture of the children in Cambodia was grim, as can be seen from table 24.

Therefore, plans were made to conduct nutrition education by various methods using the local language, weaning foods for use in Cambodia were developed, and plans were developed to improve the nutritional status of the community for the Cambodian Government.

Other international training courses sponsored by FAO, UNICEF, and UNESCO for candidates from abroad

Short- and long-term training courses in nutrition have been organized by the author on campus through specific rural-based syllabi of the country and by giving special field experiences to candidates from Brazil, Ethiopia, Malawi, Mauritius, the Netherlands, Sweden, the United Kingdom, and the United States.

Conclusions

The action schemes undertaken show how to spread the message of good nutrition among the community, to activate, enthuse, and empower people for sustainable nutritional development, self-reliance, and security.

TABLE 24. Comparison of nutritional status of Cambodian children as assessed by different criteria (percent of 3,283 children)

	Nutritional grade			
Criterion	I Good/very good	II Fair	III Poor	IV Very poor
Weight-for-age	17.85	23.65	19.85	38.65
Height-for-age	52.22	38.08	7.02	2.68
Mid-upper-arm circumference for age	22.70	50.00	23.35	3.95
Weight-for-height	48.85	36.00	11.15	4.00
Clinical	42.60	38.59	18.81	—

These are worthy of trying out in different communities in developing countries.

Acknowledgments

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Control of vitamin A deficiency in Vietnam: Achievements and future orientation

Nguyen Cong Khan, Ha Huy Khoi, Tu Giay, Nguyen Trong Nhan, Nguyen Thu Nhan, Nguyen Chi Dung , Hoang Viet Thang, Dao Ngoc Dien, and Hoang Thi Luy

Abstract

Vitamin A deficiency is one of the major nutritional deficiencies in Vietnam. The first survey, conducted in 1985–1988 showed that the prevalence of severe xerophthalmia was seven times higher than the cutoff point established by the World Health Organization (WHO) to define vitamin A deficiency as a public health problem. The result of this survey strongly convinced the government to launch a program to control vitamin A deficiency, which started in 1988. The program strategies included nutrition education, universal distribution of high-dose vitamin A capsules to children aged 6 to 36 months in combination with national immunization days, and promotion of production and consumption of vitamin A–rich foods at the family level. The implementation network was set up based on the existing preventive health structure at all administrative levels. Organizations such as the women's union and other social sectors have participated actively in the program. Surveys conducted in 1994 and 1998 showed that the prevalence of clinical xerophthalmia was significantly lower than that identified in the baseline survey and below the WHO criteria for a public health problem. The achievements of our program have demonstrated that an effective vitamin A supplementation program can be implemented successfully by the preventive health network with active community participation. In the coming years, it will be important for our program to develop approaches other than vitamin A supplementation in order to maintain the past achievements.

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Key words: Vietnam, vitamin A, supplementation, fortification, community nutrition

Introduction

Vitamin A deficiency has long been recognized as a serious public health problem in many developing countries. It affects large numbers of preschool children and women of childbearing age. Over 78 million children under five years of age are affected by vitamin A deficiency, putting them at risk in terms of health and survival [1, 2]. Vitamin A deficiency appears to be a major risk factor for both child and maternal mortality [3, 4]. There is strong evidence that vitamin A deficiency increases mortality among children from six months to six years of age, and that improving the vitamin A status of children with deficiency dramatically increases their chance of survival [4, 5].

The World Summit for Children, held in 1990, set the goal of virtual elimination of vitamin A deficiency and its consequences, including blindness, by the year 2000. In 1992 the World Declaration and Plan of Action for Nutrition of the International Conference on Nutrition also called for efforts toward eliminating vitamin A deficiency and xerophthalmia before the end of the 1990s [6].

In 1958, vitamin A deficiency among children was recorded, with hospitalized cases of keratomalacia in the northern region of Vietnam [7]. For many years, keratomalacia has been reported in eye hospitals throughout the country [8–10]. However, there were no national data on the nature and magnitude of this problem until the first survey was conducted in 1985–1988 [11]. The finding from this survey of a high rate of blindness due to xerophthalmia convinced the government to launch a program to control vitamin A deficiency, which started in 1988. The program has been implemented by the existing preventive health sector. The vitamin A supplementation program was integrated with the national immunization days (NIDs). The achievements of our program have demonstrated that an effective vitamin A supplementation approach can be successfully implemented by the preventive health network with active community participation.

This paper reviews the progress of the vitamin A program in Vietnam during the past 10 years, its achievements, and lessons learned. The paper also discusses strategies to eliminate vitamin A deficiency in children and women in Vietnam in the coming years.

Program design and activities

In 1996 and 1997, the National Institute of Nutrition organized two national workshops to address the problems of vitamin A deficiency and xerophthalmia and their control. The government was convinced by the fact that many preschool children go blind every day, although the problem can be prevented. With joint work between the National Institute of Nutrition, the National Institute of Ophthalmology, and the National Institute of Pediatrics, the program to control vitamin A deficiency was developed and was soon approved by the Ministry of Health. The general objectives of the program were to reduce the prevalence of xerophthalmia, especially active forms with corneal lesions leading to blindness, and to virtually eliminate this disease by the year 2000; to improve dietary intake of vitamin A and fat, especially among young children and mothers; and to spread awareness among health professionals and people in general about the prevention and control of vitamin A deficiency and xerophthalmia. From the beginning, we have received support from UNICEF for this program.

Universal vitamin A supplementation

As shown in figure 1, the program network was established with intensive involvement of both the curative and the preventive health systems. At the community level, the program was implemented by the commune health center, which serves more than 95% of all communes throughout the country. Two distribution campaigns were undertaken in June and one in December (integrated with NIDs). The schedule of administration of vitamin A capsules is shown in table 1. One month before the vitamin A distribution campaigns took place, the commune health centers received vitamin A capsules, guidelines, booklets, and recording notebooks from the district health center, which were provided by the provincial center for preventive medicine. The staff of the commune health centers organized training for village collaborators and worked with them on activities prior to the campaign. Members of the women's union, village health workers, and kindergarten teachers collaborated in a commune nutrition network based on the existing village health network. The lists of children 6 to 36 months old living in each village were obtained from village collaborators and made available about two weeks before the campaign began. The communication, education, and promotional activities began about one week before each vitamin A campaign.

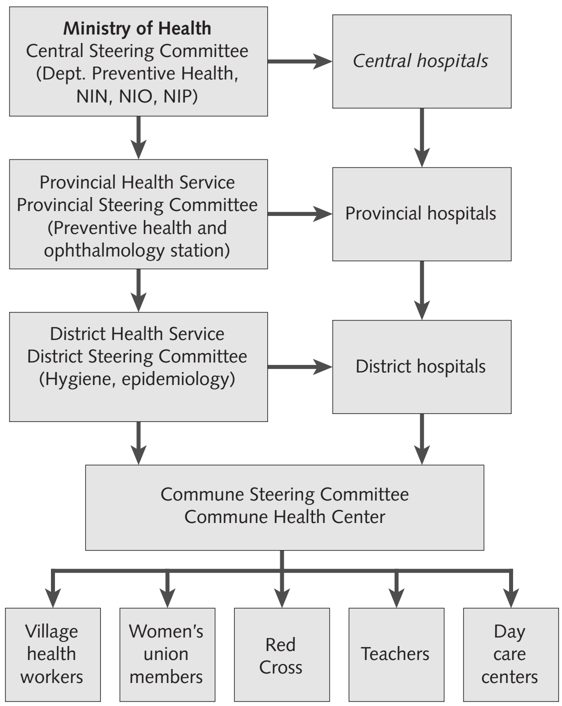

FIG. 1. Diagram of program networking. NIN, Institute of Nutrition; NIO, National Institute of Ophthalmology; NIP, National Institute of Pediatrics

TABLE 1. Schedules of administration of vitamin A capsules (100,000 IU)

Purpose	Target group	Dose
Universal protection for prevention	Infants 6–12 mo	1 capsule once a year
	Children 1–3 yr	2 capsules twice a year
	Lactating women	2 capsules within 1 mo after delivery
Disease-targeted prevention	Children 1–5 yr	2 capsules for each episode of illness
	Infants 6–12 mo	1 capsule for each episode of illness

During the campaign, children were brought by their parents to receive vitamin A capsules at a central point in each village. One or two collaborators were responsible for the distribution of vitamin A capsules in each location. The names of the children who received the capsules were recorded, as were their weights, which were plotted on individual growth charts. If a child did not come to the central point, the village collaborators went to the child's home to give the capsules. The vitamin A capsules were provided by UNICEF and were given free of charge. After the campaign, the village collaborators sent reports to the community health center. About three or four days after the campaign was completed, the community health center prepared a report combining all the records submitted by the village collaborators and forwarded it to the district health center. However, for communes in mountainous regions or difficult areas, the vitamin A campaigns took longer to complete, sometimes one week to 10 days. On each working day of the vitamin A campaign, the commune health staff and collaborators either received an incentive from the local government or were given lunch or dinner. Vitamin A capsules were available at community health centers as well as during the campaigns. Children with measles, diarrhea, or acute respiratory infections were given a prophylactic dose of vitamin A at the commune health center. A single 200,000-IU dose of vitamin A was given to each mother after she gave birth at the commune health center or the hospital.

Vitamin A supplements were also given to high-risk children hospitalized with measles, diarrhea, acute respiratory infections, and severe malnutrition. The vitamin A capsules were provided to the hospital system by the provincial station for ophthalmology. Since 1992, vitamin A capsules (100,000 IU) have been locally produced according to the World Health Organization (WHO) standards for medicines and supplements.

The program was implemented in close cooperation with both the preventive and the curative systems under the guidance of the provincial and district health services. For this purpose, one program secretary working at the provincial center for preventive medicine was appointed in each province.

The national program was under the direct guidance of the Ministry of Health. The National Institute of Nutrition in Hanoi was appointed as the focus point for the program and was responsible for community-based activities, while the Institutes of Ophthalmology and Pediatrics in Hanoi and the Eye Center in Ho Chi Minh City were responsible for hospital-based activities. The community-based activities also involved regional institutions, including the Institute of Public Health in Ho Chi Minh City, the Pasteur Institute in Nha Trang, and the Institute of Epidemiology and Hygiene in Tay Nguyen.

To test the feasibility of program networking and activities, we began with seven pilot districts in 1988. One year after the pilot program was tested, we implemented the program in 27 provinces, and in 1990 this number rose to 31. Since 1993, the program has expanded to a national scale and is closely integrated with NIDs.

Training activities for nutritionists, health workers, and medical staff are an important part of our program. The National Institute of Nutrition has organized 286 training courses for 17,100 health workers at the provincial and district levels. The provincial or district staff was responsible for training the commune health workers. The National Institute of Ophthalmology conducted training courses for almost all the health staff working at provincial hospitals and provincial ophthalmology stations.

Dietary improvement through promotion of food production and consumption at the family level

Horticultural intervention combined with extensive nutrition education is recommended as a long-term measure to eliminate micronutrient malnutrition. Adequate production and consumption of vitamin A–rich food play an important role [12]. Vegetable and fruit gardens, ponds for fish culture, and cattle sheds for animal husbandry were the common home-based agricultural practices of many Vietnamese families [13]. However, the term "VAC" has been known in Vietnam since the early 1980s. VAC, an acronym for garden (V), pond (A), and cattle shed (C) in Vietnamese, was suggested by Professor Tu Giay, the founder and first director of the Vietnam National Institute of Nutrition [13, 14]. Different species of plants, including vegetables, beans, legumes, roots, tubers, and fruits, are grown in multilayered cultivation, mixed cropping, and intercropping cultivation systems. People may use their ponds for cultivating various types of fish, shrimp, and crabs. Animal husbandry with poultry and livestock cultivation can be linked with the garden and fishpond culture. Thus, the VAC might contribute to variety in the people's diet [14–16], and it was considered as a means to solve the problem of household food insecurity in Vietnam [15].

The association of Vietnam VAC (so-called VACVINA) was established in 1986. In promoting VAC, the VACVINA has provided technical training and education for its members in order to transfer knowledge and experience to the farmers. Several projects on vitamin A nutritional improvement through promotion of VAC food production and consumption at the family level have been implemented [16]

Development of community nutrition educational activities

Nutrition education aims to spread awareness of vitamin A deficiency among the people and to specifically address feeding problems related to vitamin A deficiency [17]. The following points were highlighted: promotion of breastfeeding and appropriate weaning practices; educating mothers to feed children vegetables, fruits, and fats regularly; improving the dietary intake of vitamin A–rich foods by pregnant and lactating women; and introduction of locally available vitamin A–rich foods (combined with VAC activities).

Nutrition education activities have been implemented in different ways. Mass education and communication campaigns were organized twice a year, with the involvement of mass media agencies such as television, radio, and newspapers at the central and provincial levels. The government has funded such campaigns within the framework of the national plan of action for nutrition 1996–2000. The main emphasis from 1996 onwards has been to provide information about all micronutrients (vitamin A, iron, and iodine) during a “micronutrient days campaign” in June. The preventive health sector provided communes with booklets, posters, and leaflets before each vitamin A distribution campaign. Families were encouraged to bring their children to the distribution point for vitamin A supplementation, weighing, and immunization. At the community level, health workers, nutrition collaborators, and the information staff of the commune people’s committee were responsible for communication activities.

Monitoring and evaluation

A few days after the vitamin A distribution campaigns, reports, in a standard form, were sent from the communities to the central level. Reports from the hospitals were sent to the Institute of Ophthalmology every six months, with information on the prophylaxis activities carried out in hospitals and eye stations. Progress was monitored at all levels through the established reporting system and through post-campaign spot checking to validate the reported results. National evaluations were conducted in 1994 and 1998 with the technical assistance of international experts and the financial support of UNICEF.

Program outcome

Every six months, vitamin A distribution has served about nine million children under five years old (1993–1996) and about five million children aged 6 to 36 months (from 1997) in all communes throughout the country. As shown in figure 2, the coverage rate of vitamin A supplementation in children 6 to 36 months old was 70% to 80% in almost all regions in the country. However, in some remote regions the coverage rates were lower. Special attention should be given to improving the coverage of such localities. During some initial years, the coverage of vitamin A supplementation for lactating mothers after delivery was quite low. One reason was that the capsules were not always available at the commune health center. Since 1998, vitamin A capsules have been packed in the blister form, which can be kept at the community health center. The national coverage rate for lactating mothers in 1998 was 52.2%, but there was a large variation among ecological zones (fig. 3). Since that time, our program has addressed the hard-to-reach localities in order to increase the coverage rates of vitamin A capsules for children and lactating mothers by integrating them with the child malnutrition control program.

The integration of vitamin A distribution and the expanded program of immunization (EPI) in some countries has been reviewed by UNICEF [18]. The integration and close operational cooperation of vitamin A

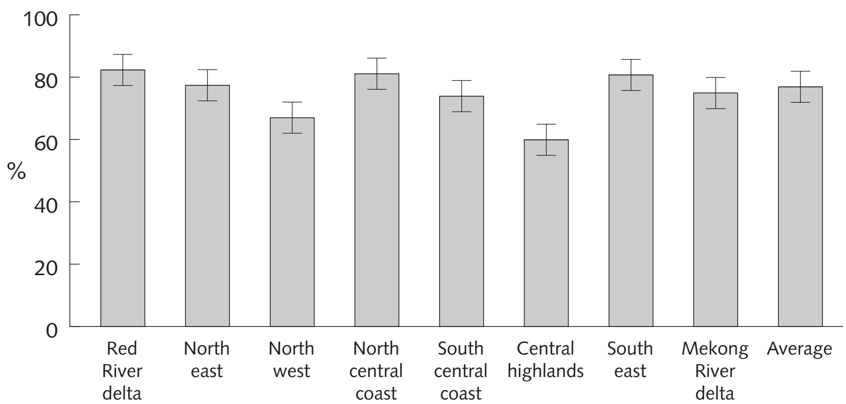

FIG. 2. Percentage of children aged 6–36 months receiving vitamin A capsules in different regions

supplementation and EPI/NIDs programs has proven to be a powerful way to enhance and sustain both programs. Micronutrient days have involved several civil society organizations, such as the women's union, the Red Cross, and education sectors. The preventive health sector in Vietnam has implemented several health-care programs and health-promotion campaigns. This was an advantage for the implementation of the nutrition program. Thus, the program moved ahead in the integration process of health-care activities based on strengthening the implementation capacity of the existing preventive health network. The health workers of all communes have learned to detect, treat, and prevent vitamin A deficiency early, while people, in general, have learned how to prevent vitamin A deficiency in children.

Along with the supplementation approach, food production and consumption by families through the VAC has contributed to their vitamin A intake. A nutrition improvement project conducted in four communes of Vietnam that included 5,588 households with 3,716 young children showed a significant increase in production of fruit, vegetables, and other food from family gardens [16]. An increased intake of nutrients, including carotene, iron, vitamin C, and protein, among households with young children was observed. Other evaluations showed that well-developed VAC production by families could contribute from 50% to more than 70% of family income [14–16]. Promotion of family food production through the VAC ecosystem has become government policy in improving people's diet and nutritional status [13].

Nutrition education and social mobilization have a positive influence on attitudes and practices of different groups concerning micronutrient deficiency control, including community leaders at all levels, which in turn, contributes greatly to the success of a vitamin A supplementation program. The evaluation surveys revealed that 60% to 70% of the mothers knew how to prevent night-blindness and the purpose of vitamin A supplementation for their children. A large proportion of mothers knew how to wean their children correctly. There were improvements in feeding practices of young children, with more frequent consumption of vitamin A–rich foods and fats as compared with the past, when these foods were commonly restricted out of habit (table 2) [11, 19, 20].

Program impact

The clinical assessment of vitamin A deficiency and xerophthalmia in the first survey in 1985–1988 is shown in table 3. The total prevalence of vitamin A deficiency was 0.72%, the prevalence of corneal lesions was 0.07%, and the prevalence of inactive corneal scars

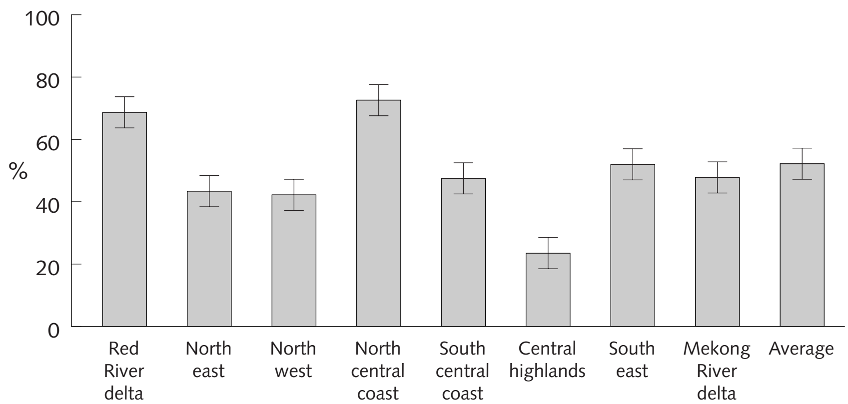

FIG. 3. Percentage of mothers receiving vitamin A capsules after delivery in different regions

TABLE 2. Frequency of consumption of vitamin A– and carotene-rich foods by children without clinical xerophthalmia during the last two months

	% of children consuming							
	Never		Monthly		Weekly		Daily	
Food	1985–88 survey	Year 2000	1985–88 survey	Year 2000	1985–88 survey	Year 2000	1985–88 survey	Year 2000
Eggs	36.8	14.4	19.0	21.6	33.9	53.9	10.3	10.1
Green vegetables	24.2	8.6	0.5	4.3	12.5	28.8	62.8	58.3
Fats and oils	27.0	7.2	4.7	8.6	18.0	25.2	50.3	59.0

Source: refs. 11, 20.

TABLE 3. Clinical assessment of vitamin A deficiency and xerophthalmia during the first survey, 1985–1988 (n = 34,214)

Clinical forms	Prevalence (%)	WHO criteria [1]
Night-blindness (XN)	0.37	> 1%
Bitot's spots (X1B)	0.16	> 0.5%
Corneal ulceration/keratomalacia (X2/X3A/X3B)[a]	0.07	> 0.01%
Corneal scars (XS)	0.12	> 0.05%

a. X2, corneal xerosis; X3A, corneal xerosis and ulceration < ⅓ surface of cornea (keratomalacia); X3B, corneal xerosis and ulceration > ⅓ surface of cornea (keratomalacia).
Source: ref. 11.

was 0.12%. Two criteria that exceeded the WHO threshold for a public health problem [1]—xerophthalmia with corneal lesions and xerophthalmic scars—were prevalent in all ecological regions (fig. 4), whereas the rates of night-blindness (XN) and Bitot's spots (X1B) were below the WHO cutoff criteria. Xerophthalmia occurs in the population with a very high prevalence of protein–energy malnutrition. Many cases of marasmus or marasmic-kwashiorkor with clinical signs of vitamin A deficiency were found in the field. In these cases, corneal xerosis and ulceration developed quickly after the child had acute diarrhea, even skipping the period of night-blindness or Bitot's spots. The rate of blindness in hospitalized children was very high, which clearly indicated the severe clinical manifestations of vitamin A deficiency (table 4).

Many countries, such as Indonesia and India, have reported high prevalences of XN and X1B [7]. However, a study by Cohen et al. [21] reported that in rural and very poor urban areas, the prevalence of Bitot's spots was 0.09% and 0.16%, respectively. Another study in northern mountainous areas of Vietnam, where the rate of severe malnutrition in children is very high, reported that the rate of X1B was 0.13% [22].

Children 12 to 36 months of age had the highest prevalence of xerophthalmia and severe clinical forms of vitamin A deficiency. The vitamin A intake of children with xerophthalmia was significantly lower than that of controls. In many regions, people believed that they should not feed fats, fruits, vegetables, and animal foods to their young children when they suffered from measles, diarrhea, and respiratory infections [19, 23].

The 1994 and 1998 surveys showed that the prevalence of clinical xerophthalmia was lower than the WHO criteria for a significant public health problem in preschool children and significantly lower than those identified in the baseline survey (table 5) [11, 24, 25]. The prevalence of active cases of xerophthalmia (X3A–X3B) did not exceed any of the WHO cutoff points in any of the ecological zones in Vietnam [24]. The prevalence of night-blindness among children under five years of age who did not receive vitamin A capsules was similar to the prevalence noted during the first survey, which indicates the effectiveness of the vitamin A capsule supplementation program. The prevalence of maternal night-blindness was 0.58% in 1994 and 0.90% in 1998. The surveys in 1994 and 1998 pointed out that low vitamin A intake is associated with maternal night-blindness. Mothers with a low intake of vitamin A are particularly at risk when they are pregnant or lactating [6]. Although the coverage of vitamin A supplementation for children was maintained at a

TABLE 4. Reported patients with xerophthalmia admitted to central hospitals of Vietnam

	% of patients	
Condition	Institute of Ophthalmology 1979–83 (n = 104)	Institute of Pediatrics 1984–86 (n = 275)
Visual impairment	26.9	3.6
Monocular blindness	26.9	8.7
Binocular blindness	13.5	8.0

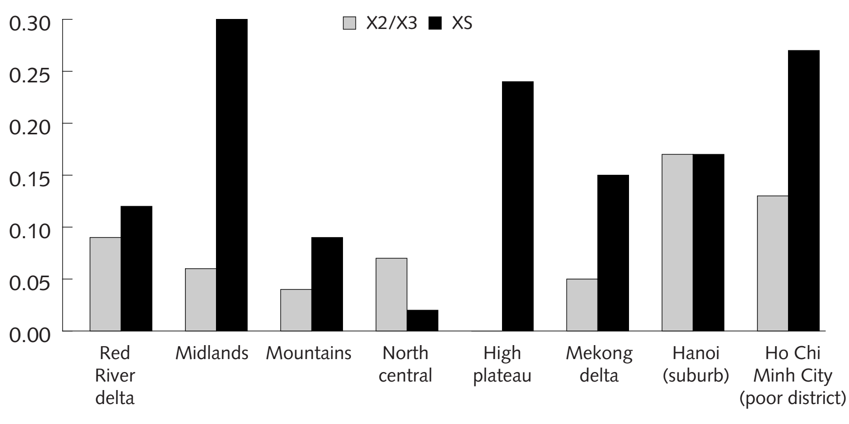

FIG. 4. Distribution of active xerophthalmia with corneal lesions and xerophthalmic scar by ecological regions (the first prevalence survey, 1985-88 [11])

high rate for many years, the coverage rate of vitamin A capsules for lactating women has been rather low, in some regions reaching only about 20%. In controlling vitamin A deficiency, efforts must be focused on mothers as well as children.

The numbers of children with xerophthalmia admitted to the main hospitals in Vietnam over 10 years (1990–1999) are shown in table 6. The data show that the number of patients with xerophthalmia (corneal xerosis/ulceration forms) admitted to the main hospitals throughout the country has been dramatically reduced. Although the hospital data are not representative of the community, this figure shows a significant achievement of the program in preventing nutritional blindness in Vietnam.

The prevalence of subclinical vitamin A deficiency (serum concentration of retinol < 0.70 μmol/L) in children under five years old was 10.8% (fig. 5). No case with very low serum retinol (< 0.35 μmol/L) was detected in the survey sample. Subclinical vitamin A deficiency was found to be higher in children under one year of age (fig. 6). The prevalence of lactating women with low breastmilk retinol concentration (< 1.05 μmol/L) was 48.5% in 1997 (fig. 7) and went up to 58.3% in 1998. It may reflect a large variation in the vitamin A status of women.

More attention should be given to improving maternal vitamin A nutritional status in future programs. It is suggested that although there were important improvements in the diet during the last decade, the intakes of micronutrients of Vietnamese people are still poor, especially among those living in rural and remote areas [26]. On the other hand, some carotene-rich crops have been underutilized, such as gac fruit

TABLE 5. Clinical assessment of vitamin A deficiency in Vietnam (percent prevalence)

Clinical signs	1988[a]		1994[b]		1998[c]	
	Total sample (n = 34,214)[d]	Non-VAC recipients (n = 2,953)[d]	Total sample (n = 37,920)[d]	Women (n = 27,803)[e]	Total sample (n = 12,900)[d]	Women (n = 10,650)[e]
Night-blindness (XN)						
Children under 5 yr	0.37	0.37	0.05		0.20	
Reproductive-age women				0.58		0.90
Bitot's spots (X1B)	0.16	0.23	0.045	ND[f]	ND	ND
X2/X3A/X3B	0.07	ND	0.005	ND	ND	ND
Corneal scars (XS)	0.12	ND	0.048	ND	ND	ND

a. National Survey on Vitamin A deficiency, National Institute of Nutrition, 1988 [11].
b. National Vitamin A Deficiency/Protein-Energy Malnutrition Survey, 1994, National Institute of Nutrition /Helen Keller International/ UNICEF [24].
c. National PEM/VAD Survey, 1998, National Institute of Nutrition/UNICEF [25].
d. Sample for children under five years of age.
e. Sample for reproductive-age women (mothers of children under five years of age examined).
f. Not detectable.

TABLE 6. Number of children with xerophthalmia admitted to main hospitals in Vietnam, 1990–99[a]

Hospital	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
North										
Hanoi, Institute of Ophthalmology	6	12	20	18	0	0	1	1	1	0
Hanoi, Institute of Pediatrics	48	42	48	36	11	6	7	8	4	3
Haiphong, Children's hospital	64	42	38	27	5	0	1	0	0	0
Namha, provincial hospitals	71	51	55	34	21	7	8	1	5	0
Hatay, provincial hospitals	307	36	92	92	51	11	7	2	0	0
South										
Ho Chi Minh City, Eye Center	45	41	38	17	9	0	0	0	0	0
Cantho, Children's Hospital	NA[b]	NA	NA	NA	16	3	3	2	1	1
Central										
Danang, provincial hospitals	NA	15	12	10	5	1	1	0	0	0
Hue, Central Hospital	NA	19	13	19	2	4	1	1	0	1
Total	541	258	316	253	120	32	29	15	11	5

a. Patients with corneal lesions (X2/X3A/X3B).
b. Not available.

(*Momordica cochinchinesis* Spreng) [27]. The goal is to identify local plant foods rich in provitamin A carotenoids, encourage their use, and develop methods to improve their production, preservation, and preparation for family consumption [28, 29].

Future directions

During the last decade, supplementation has played the key role in achieving the program goal of eliminating clinical xerophthalmia in children, whereas other approaches have not been established yet or are not easy to evaluate on a large scale. Subclinical vitamin A deficiency is prevalent in Vietnam and may contribute to high mortality and morbidity rates and growth retardation among young children. Continuing efforts to achieve further sustainable results to end micronutrient malnutrition are critical to our nutrition agenda.

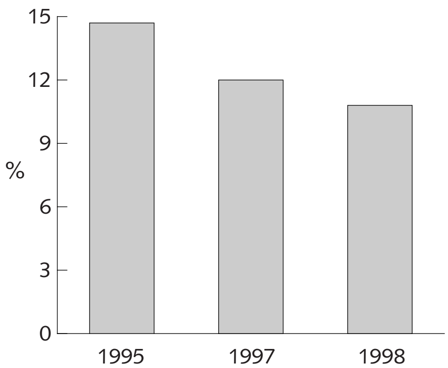

FIG. 5. Percentage of children under five years of age with low serum retinol concentrations (< 0.70 μmol/L). 1995 and 1997 data are from a small sample survey. 1998 data are from a national protein-energy malnutrition/vitamin A deficiency survey [25]

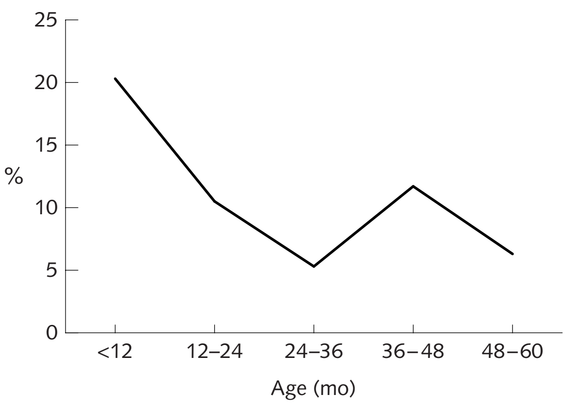

FIG. 6. Prevalence of children under five years of age with low serum retinol concentrations (< 0.70 μmol/L) according to age group (1998 survey)[25])

Dietary diversification

Although there has been a tendency for some years to improve dietary quality with more protein-rich food and less staple food [19], the staple-based diet places the Vietnamese population at risk for micronutrient deficiencies. The epidemiology of vitamin A deficiency associates the problem with diets consisting predominantly of vitamin A–poor staples, such as cereals, grains, and tubers, with little diversity, and with low and infrequent consumption of animal sources [28]. The main issue here is to address the people of lower economic groups and inhabitants of rural areas, because animal products, which can be the best sources of vitamin A, are not affordable by everyone. More efforts are needed to promote the production, preservation, preparation, and consumption of micronutrient-rich crops and animal products. The concept of "home-based fortification," which assumes local availability of naturally rich food sources of vitamin A that are underutilized in the diet of high-risk groups, may be more practical for Vietnam, where centralized fortification is not currently developed [27, 28]. The agricultural strategies may help to alter the content of absorption modifiers in plant-based staple foods [29]. Appropriate agricultural technologies may need to be applied to large-scale agricultural production and family VAC production.

Vitamin A supplementation

This approach provides supplements to the population through the health-care system. Because the prevalence of malnutrition and vitamin A deficiency in children is high, and other approaches are not adequately developed, the supplementation program will be needed for years to come. Nevertheless, it requires close supervision by health-care workers and high compliance by the community to be successful [24]. More attention should be given to supplementation programs in remote regions and to lactating mothers in clinics and in the community.

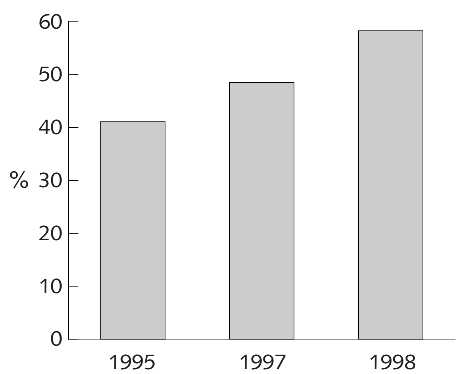

FIG. 7. Percentage of breastfeeding mothers with low breastmilk retinol concentrations (< 1.05 μmol/L)

Food fortification

Fortifying commonly consumed staple foods with micronutrients has proved to be the most cost-effective and sustainable solution to eliminate micronutrient malnutrition. The most successful fortification experience worldwide, including Vietnam, has been fortification of salt with iodine. Currently 87.5% of the Vietnamese population consumes iodated salt. Universal use of iodated salt was approved by the Government of Vietnam, and it is expected to be achieved soon. Recently, fortification of other staple foods with other minerals and vitamins has been considered. The National Institute of Nutrition and the International Life Sciences Institute are experimenting with fortification of fish sauce with iron [30]. Fortification of sugar with vitamin A is in a stage of pilot production by the Bien Hoa sugar company, with the technical support of La Roche [31]. Some research on fortification of biscuits with iron and vitamin A has been carried out [26]. In recent years, Vietnam has experienced rapid economic growth, including the food industry sector. People can access good-quality foods not only by production at the household level, but also through food distribution via the free marketing mechanism. According to current food-consumption data, sugar is widely consumed, with a daily per capita mean consumption of 15 grams [26]. Cooking oil is also considered a potential vehicle for fortification with vitamin A in Vietnam.

However, for this food fortification approach to be successful, there must be a multisectoral partnership among government sectors, industry (food producers, processors, and distributors), international agencies, and others, which is currently still weak. New communication channels need to be opened among those involved.

Conclusions

Universal vitamin A supplementation for children has been achieved through the strong implementation support structure based on the preventive health network. Linking the vitamin A program with the national immunization days (NIDs) is a good approach, and we can make use of this system. This is a positive development, indicating that the vitamin A program has close integration with health-care services, effective social mobilization, and community participation.

Close cooperation among implementing institutions is also a key element in the program's success. We have paid much attention to promoting dietary vitamin A intake through the VAC ecosystem combined with nutrition education. The government at all levels is highly committed to the program. Furthermore, the program has received great support from international agencies and from all the communes in the country.

In the years to come, the supplementation program should continue but become more targeted. Together with promotion of dietary diversification, the food fortification program will begin soon, and it is considered an important strategy in our future program.

Acknowledgments

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Empowering a tea-plantation community to improve its micronutrient health

Tara Gopaldas and Sunder Gujral

Editorial introduction

It has almost become a mantra in international nutrition circles that there is an urgent need for success stories. The Bulletin *is pleased to have published a number of these and encourages their submission. The article that follows describes an intervention on a tea plantation in India and presents convincing evidence that it proved to be "simple, effective, and sustainable." Although micronutrient supplementation may be easier to implement with captive populations such as those on agricultural plantations, it is worth pursuing with these populations because of the large number of individuals involved and the importance of their health and productivity.*

In the 1979 study of Basta et al. cited by the authors, there was a 19.8% increase in the take-home pay of anemic rubber tappers paid by the amount collected when they were given an iron supplement. Some years later, when I returned to help set up another study in the region, it was impossible to find a rubber plantation in which the owners were not providing an iron supplement. The thesis of the authors of the following article that every effort should be made to extend their experience to other plantations in India can be generalized to plantations in other countries. However, it should be noted that their success is likely to depend on a participatory approach involving owners, managers, and workers in the planning and implementation process.

Editor

Abstract

*This project was designed to convince and empower management and plantation workers to improve their own nutritional health status and productivity. Plantations are generally bypassed by the government's primary health-care system. A nine-month intervention with iron (60 mg of elemental iron) and vitamin A supplementation and iodized salt was performed on the Balanoor Plantations in India. Of the women tea pickers, 99% (*n *= 334) received the supplements and bought the iodized salt from the plantation ration shop. Their mean hemoglobin level rose significantly from 11.0 to 11.9 g/dl. The women pickers gave the supplements to their families as well as themselves. The results were the same whether iron was given once or twice a week. The mean hemoglobin level of the women pickers rose significantly from 11.1 to 12.0 g/dl with the twice-weekly dose and from 10.9 to 11.8 g/dl with the weekly dose. The prevalence of clinical signs of vitamin A deficiency in the entire plantation population (about 2,500) was reduced significantly (from 19% to 4%), as was iodine deficiency (from 17% to 7%). Common health problems decreased from 88% to 54%. The number of patients referred to larger hospitals decreased significantly from 116 to 86. Absenteeism was not affected.*

Key words: India, micronutrient supplementation, micronutrient intervention, iron, iodine, vitamin A, iron-deficiency anemia, women's empowerment

Introduction

The focus of this research project was to provide a multinutrient package in the workplace to improve the health, productivity, and profitability of tea-plantation workers. Plantations are generally bypassed by the government's primary health-care system. The design

The authors are affiliated with Tara Consultancy Services in Bangalore, India.

Mention of the names of firms and commercial products does not imply endorsement by the United Nations University.

called for working with the management of the tea estate as an equal partner and demonstrating the simplicity and cost-effectiveness of the intervention. The multinutrient package consisted of iron plus vitamin A supplements and iodized salt.

India produces nearly 30% of the world's tea. India is also the largest consumer of tea in the world, and domestic demand for tea has outstripped production, despite phenomenal technological advances in increasing tea-crop yield or its productivity. Unfortunately, a similar effort has not been extended to increasing human health and productivity although picking is a high-cost, labor-intensive step in tea production and accounts for most of the employee costs [1].

The concentration of tea, coffee, rubber, and spice plantations is greatest in South India, and the Northeast has the second highest concentration of tea plantations. Plantations are distinct entities, managed by large companies, corporations, or single owners, with management practices of decreasing efficiency in that order [2]. The health and welfare of the plantation workers are generally the responsibility of its management. The plantation sector employs about a million workers, who support about another five million dependents. The tea industry is unique in that 40% to 50% of its workers are women. The permanent work force lives on the plantations. Thus, there is great potential to design continuous, large-scale micronutrient and related health interventions for these large, accessible worker groups.

The United Planters Association of South India (UPASI) is a highly respected and powerful association of plantation managers and owners of all types of produce. They are worker and welfare oriented and are amenable to suggestions to improve the well-being and productivity of their workers. In the 1980s, UPASI supported a research project in the tea plantations of Kerala, where Rahamatullah [3] demonstrated by the Sahli method that the hemoglobin levels of female plantation workers (mostly of childbearing age) were very low (6.1 g/dl). Daily iron supplementation with ferrous sulfate tablets containing 65 mg of elemental iron significantly increased the hemoglobin levels and the average picking yield of tea leaves per supplemented worker. The intervention did not include other micronutrients.

The classical studies of Basta et al. [4] clearly demonstrated the relationship between iron-deficiency anemia and productivity of adult male workers on rubber plantations in Indonesia. The hemoglobin concentrations of these workers were 11.0 to 11.9 g/dl. Gardner et al. [5] also established the interrelationship between physical work capacity and work performance among female tea-plantation workers 26 to 62 years of age. A wide variation in hemoglobin concentrations, from 6.1 to 15.9 g/dl, was reported. In another Sri Lankan study of tea-plantation workers, Edgerton et al. [6, 7] reported very low hemoglobin levels of 6.0 to 9.0 g/dl, with substantial improvement in picking performance after iron supplementation. Kalita [2] also reported low hemoglobin levels among male and female tea-plantation workers of Assam. A combination of an anthelmintic, iron, and vitamin C had the greatest impact in raising hemoglobin levels (M. C. Kalita, personal communication, 1993).

The intervention package of iron plus vitamin A and iodine was selected for this study based on its epidemiological need on the plantations [8], its cost-effectiveness, and its excellent success in improving the health and nutritional status of schoolchildren in Gujarat, Western India [9].

Methods

Baseline and resurvey for the impact evaluation

A comprehensive baseline survey of approximately 2,500 subjects was conducted just prior to the implementation of the micronutrient-package intervention to record the existing health, nutritional status, and micronutrient status of 617 workers and their available family members. The resurvey was conducted after the completion of the two rounds of dosing. The total intervention period was nine months.

Family socioeconomic and other characteristics

Socioeconomic data included monthly family income, age, literacy, number of children, use of the ration shop, use of iodized salt, visits to the plantation hospital, referral to larger hospitals, attendance, and long absenteeism.

Dietary survey

The 24-hour-recall method was employed on a subsample of women tea pickers only (89 at baseline and 94 at resurvey). Monthly purchases of raw food commodities (rice, lentils, oil, salt, sugar, etc.), weekly purchases (usually of fish), and daily purchases of perishables (vegetables and milk) were recorded. The nutritive value of the raw foods [10] and the recommended daily allowance (RDA) of nutrients [11] were calculated according to the methods of the Indian Council of Medical Research.

Anthropometry

While wearing normal clothing, the subjects were weighed to the nearest 0.5 kg with a Krup's weighing scale [12]. Height was measured to the nearest 0.1 cm with a nonstretchable measuring tape fixed to a smooth-surfaced wall. Waterlow's classification [13] was employed for nutritional categorization based on body-mass index (BMI), which is calculated as the weight in kilograms divided by the square of the height in meters. A BMI of 18.5 or higher was indicative of a normal nutritional status in adults, and a BMI of 16.5 or less was considered to indicate and undernourished status.

Clinical examination

All subjects were examined for eye signs of vitamin A deficiency [14]. The signs were classified as night-blindness (XN), conjunctival xerosis (XIA), Bitot's spots (XIB), and corneal xerosis (X_2).

Hemoglobin measurements

The cyanmethemoglobin method as described by Oser [15] was employed. The physician and head nurse were trained to draw fingertip blood and estimate the hemoglobin value by using a digital colorimeter. Hemoglobin levels of less than 12 g/dl in nonpregnant adult women and children 6 to 14 years old, less than 13 g/dl in adult men, and less than 11 g/dl in children under 5 years of age were taken to be indicative of anemia [16].

Survey procedure

Survey teams

As an empowerment strategy, we considered it essential to build capacity and confidence in the plantation hospital staff by having them conduct all aspects of the survey with us. Two teams were set up containing equal numbers of members from the plantation hospital and from Tara Consultancy Services. This greatly helped in capacity and confidence building in the plantation hospital staff. The trainers were the two authors of this paper. After all the tests had been conducted on the subjects, each subject was given a plastic screw-topped container containing a five-month supply of the iron tablets (60 mg of elemental iron) and the vitamin A capsules. The subject was told to dose herself or himself and all family members above three years of age with one iron tablet each, after the evening meal, on Tuesday and Friday. The red capsule (vitamin A) was to be taken on Friday only. The subject was further given a 1-kg packet of iodated salt of a brand known to contain adequate iodide. Thereafter the iodated salt was to be bought from the plantation ration shop. Adverse effects, if any, were to be reported to the plantation hospital as soon as possible. The same procedure was repeated 4½ months later (second dosing).

Further procurement of the medicinal supplies and the iodized salt

As a part of the equal partnership arrangement, the cost of the total micronutrient package was shared equally by the plantation management and Tara Consultancy Services. The yearly cost of the micronutrient intervention per worker and family was only Rs. 61.50 (about US$2) in 1996–1998, the period of our study. The cost of the screw-topped container was about Rs. 15 (50 US cents).

Results

Nutrient intake of a subsample of women pickers at baseline and the end of the study

Table 1 shows that the intakes of all the macronutrients and micronutrients had increased significantly at the end of the study period. The ongoing informal nutrition education given by the hospital staff and research team also had some beneficial effect. However, at the resurvey the intake of iron still remained at a low 38% of the RDA, and that of vitamin A remained at only 27% of the RDA. Hence, it would appear that the only feasible way at the present time to improve the iron and vitamin A status of plantation workers, especially the women pickers, is by supplementation or food fortification.

TABLE 1. Nutrient intake of the subsample of the women pickers in the baseline and resurvey

	Baseline (n = 89)			Resurvey (n = 94)		
Nutrient	Mean	SD	% RDA[a]	Mean	SD	% RDA
Energy (kcal)	1,847	298	88	1,950*	250	93
Protein (g)	38	7	76	42*	8	84
Iron (mg)	1	1.9	3	21.3*	2.3	38
Vitamin A (μg)	129	65	21	165*	38	27

a. The RDAs (recommended dietary allowances) for a moderate worker are 2,100 kcal, 50 g of protein, 30 mg of iron, and 600 μg of vitamin A (retinol β-carotene × 0.25)[10].
*$p < .05$ for the comparison between baseline and resurvey.

Impact of the micronutrient intervention on perceived improvements in health according to regularity of use of the supplements

There was a clear and significant increase in the percentage of twice-weekly users of the iron and vitamin A supplements (72%) who reported "feeling better" (table 2). Overall, 54% claimed to feel better, 9% said their appetite had improved, and 44% perceived no change in their state of health. However, 6% of those who had stopped taking the supplements after one or two months also said they felt better.

Body-mass index

A larger percentage of both female and male pickers had a BMI of 18.5 or more at resurvey than at baseline (table 3). Women who did not work as tea pickers ("nonpickers") did not have to expend as much energy as those who worked as pickers, and these nonpickers showed a highly significant improvement: 69% at resurvey, as compared with 42% at baseline. Overall, the BMI in the total worker population improved significantly: 40% at baseline and 48% at resurvey had a BMI of 18.5 or more. This was possibly due to a combination of better appetite and the general nutrition education given by the research team. The management stated that more subsidized rice was being purchased from the ration shop.

Clinical signs of iron deficiency

The prevalence of pale conjunctiva, the most reliable clinical sign of iron deficiency, was significantly reduced in the picker population (women) from 45% to 9% (table 4). In the nonpicker population (predominantly men), the prevalence was reduced from 42% to 8%.

Clinical signs of vitamin A deficiency

The prevalence of preclinical and clinical signs of vitamin A deficiency (night-blindness, conjunctival xerosis, and Bitot's spots) was reduced from 19% at baseline to 4% at resurvey (table 5). In the pickers (almost all women), the prevalences of all the signs were significantly reduced: night-blindness from 9% to 2%, conjunctival xerosis from 8% to 2%, and Bitot's spots from

TABLE 2. Relationship between frequency of taking iron tablets and perceived improvement in health of pickers and nonpickers[a]

	No. of tablets taken weekly							
	2 (n = 345)		1 or "off and on" (n = 218)		Stopped after 1–2 mo (n = 50)		Total (n = 613)	
Perception	no.	%	no.	%	no.	%	no.	%
Feel better	248	72	80	37	3	6	331	54
Improved appetite	41	12	16	7	1	2	58	9
No change	94	27	128	59	47	94	269	44

a. The relationship is significant at $p < .05$.

TABLE 3. Impact of the micronutrient intervention on body-mass index (BMI) of pickers and nonpickers

	Baseline				Resurvey			
	BMI ≥ 18.5		BMI < 18.5		BMI ≥ 18.5		BMI < 18.5	
Subjects	no.	%	no.	%	no.	%	no.	%
Pickers								
Women	122	37	212	63	140	42	195	58
Men	7	50	7	50	10	71	4	29
Total	129	37	219	63	150	43	199	57
Nonpickers								
Women	22	42	30	58	37	69**	17	31
Men	97	45	120	55	107	51	103	49
Total	119	44	150	56	144	54	120	46
Total	248	40	369	60	294	48	319	52

**$p < .01$ for the comparison between baseline and resurvey.

2% to less than 1%. In the nonpickers (mostly men), the prevalences of all the signs were also significantly reduced: night-blindness from 10% to 2%, conjunctival xerosis from 9% to 1%, and Bitot's spots from 3% to 1%. Among children there was a nonsignificant reduction from 6% to 3% in the percentage with any signs of vitamin A deficiency. The nutrient intake data of the women pickers reflected their very poor vitamin A status (table 1). At baseline their intake of vitamin A was just 21% of the RDA. The research team noted that the meals were monotonous and consisted of large servings of rice and lentil curry. Very little milk, vegetables, or fruits was consumed. Fish was eaten only occasionally. However, due to nutrition education and improved appetite, the average retinol intake increased to 27% of the RDA. The vitamin A supplement of 1,600 IU, if taken weekly, would have added 230 IU or 69 µg of retinol to the meager 165 µg of retinol obtained from the diet, bringing it up to 239 µg, or about 40% of the RDA. All those identified as vitamin A deficient had acute signs of deficiency.

Clinical signs of iodine deficiency

Overall, 17% of the participants manifested signs of mild iodine deficiency (small swelling at the base of the neck) at baseline, which was significantly reduced to 7% at resurvey (table 6). The reduction was significant in both pickers (from 18% to 10%) and nonpickers (from 20% to 5%). No child manifested clinical signs of iodine deficiency at baseline, but one did at resurvey.

TABLE 4. Impact of the micronutrient intervention on clinical signs of iron deficiency in pickers, nonpickers, and children

	Baseline		Resurvey	
Sign	no.	%	no.	%
Pickers				
No sign	190	55	312	89***
Any sign	158	45	37	11
Pale conjunctiva	156	45	33	9***
Pale nails	78	22	10	3***
Nonpickers				
No sign	141	52	242	92***
Any sign	128	48	22	8
Pale conjunctiva	112	42	21	8***
Pale nails	80	30	2	1***
Children				
No sign	29	35	55	80***
Any sign	55	65	14	20
Total				
No sign	360	51	609	89***
Any sign	341	49	73	11

***$p < .001$ for the comparison between baseline and resurvey.

Overall, the use of a reliable source of iodated salt by the whole family had beneficial effects on its iodine-deficiency disorder status.

Hemoglobin status

The mean hemoglobin levels in the women significantly rose from 11.0 g/dl at baseline to 11.9 g/dl at resurvey (table 7). The change was more impressive in

TABLE 5. Impact of the micronutrient intervention on clinical signs of vitamin A deficiency in pickers, nonpickers, and children

	Baseline		Resurvey	
Subjects	no.	%	no.	%
Pickers				
No sign	281	81	335	96***
Any sign	67	19	14	4
Night-blindness	32	9	8	2***
Conjunctival xerosis	29	8	8	2***
Bitot's spots	6	2	3	1 NS
Nonpickers				
No sign	208	77	255	97***
Any sign	61	23	9	3
Night-blindness	27	10	5	2***
Conjunctival xerosis	25	9	3	1***
Bitot's spots	9	3	2	1**
Children				
No sign	79	94	67	97 NS
Any sign	5	6	2	3
Total				
No sign	568	81	657	96***
Any sign	133	19	25	10

**$p < .01$, ***$p < .0001$ for the comparison between baseline and resurvey. NS, not significant

TABLE 6. Impact of the micronutrient intervention on clinical signs of iodine deficiency in pickers, nonpickers, and children

		Baseline		Resurvey	
Subjects	Clinical signs present	no.	%	no.	%
Pickers	Yes	63	18	36	10***
	No	285	82	313	90
Nonpickers	Yes	55	20	12	5***
	No	214	80	252	95
Children	Yes	0	0	1	1***
	No	84	100	68	99
Total	Yes	118	17	49	7***
	No	583	83	633	93

***$p < .001$ for the comparison between baseline and resurvey.

the men, in whom there was a significant rise from 12.1 to 14.0 g/dl. Among the children, there was a nonsignificant rise from 10.8 to 11.6 g/dl.

Hemoglobin levels rose significantly among women pickers and nonpickers (table 8). Among women pickers who consumed the supplement twice a week, the mean hemoglobin level rose significantly from 11.1 to 12.0 g/dl. The level rose from 10.9 to 11.8 g/dl among the women pickers who took the supplement only once a week or "off-and-on." We, therefore, concluded that it did not make an appreciable difference whether the subject dosed herself once or twice a week. Among the few who stopped taking the supplements, there was a nonsignificant rise in hemoglobin from 11.0 to 11.3 g/dl.

TABLE 7. Impact of the micronutrient intervention on hemoglobin (Hb) status of pickers, nonpickers, and children

	Baseline		Resurvey	
Subjects	*n*	Mean ± SD Hb (g/dl)	*n*	Mean ± SD Hb (g/dl)
Pickers				
Women	334	11.0 ± 0.9	334	11.9 ± 1.1***
Men	13	12.0 ± 0.6	14	13.5 ± 1.3***
Nonpickers				
Women	51	10.7 ± 1.3	51	11.6 ± 1.8**
Men	213	12.1 ± 0.9	209	14.0 ± 1.2***
Children	83	10.8 ± 1.0	69	11.6 ± 0.9
All adults				
Women	385	11.0 ± 0.9	385	11.9 ± 1.2**
Men	226	12.1 ± 0.9	223	14.0 ± 1.2***

$^{**}p < .01$, $^{***}p < .001$ for the comparison between baseline and resurvey

Morbidity and absenteeism

On the whole, the workers perceived that their common health problems decreased from baseline to resurvey (table 9). This decrease was found to be highly significant. The prevalence of general weakness decreased from 17% to 7%; the prevalence of all aches (body, head, neck, limbs, joints, and shoulders) decreased from 65% to 13%; the prevalence of bronchitis, upper respiratory tract infection, cough, etc. decreased from 11% to 1%; and the prevalence of obstetrical and gynecological problems decreased from 13% to 3%. How-

TABLE 8. Relationship between frequency of taking iron tablets and hemoglobin (Hb) status

		No. of tablets taken weekly					
		2	1 or "off and on"	Stopped after 1–2 mo	2	1 or "off and on"	Stopped after 1–2 mo
Subjects	Value	Baseline Hb (g/dl)			Resurvey Hb (g/dl)		
Pickers							
Women	*n*	174	135	8	174	135	8
	Mean	11.1	10.9	11.0	12.0*	11.8*	11.3
	SD	0.8	1.0	1.4	1.1	1.1	1.3
Men	*n*	9	4		9	4	
	Mean	11.6	1.2	—	13.6	14.0	—
	SD	1.3	0.2		0.9	1.3	
Nonpickers							
Women	*n*	18	10	1	18	10	1
	Mean	11.1	10.8	11.0	12.1	10.9	11.1
	SD	1.0	0.9		1.2	2.4	2.0
Men	*n*	118	44	4	118	44	4
	Mean	12.1	12.2	12.3	14.0	14.2	14.2
	SD	0.9	0.9	0.6	1.2	1.1	0.5
Pickers and nonpickers							
Women	*n*	192	145	9	192	145	9
	Mean	11.9	1.09	11.0	12.0**	11.7**	11.4
	SD	0.8	0.9	1.4	1.0	1.3	1.3
Men	*n*	127	48	4	127	48	4
	Mean	12.1	12.2	12.3	14.0	14.2	14.2
	SD	0.9	0.8	0.6	1.2	1.1	0.5

$^{*}p < .05$, $^{**}p < .01$ for comparisons within baseline and resurvey: 2 tablets per week vs. 1 tablet per week or "off and on," 2 tablets per week vs. stopped after 1–2 mo, 1 tablet per week or "off and on" vs. stopped after 1–2 mo ever, the prevalence of abdominal pain, giddiness, and gastritis rose significantly from 7% to 32%, a change that we cannot explain.

Table 10 sets out the relationship between monthly attendance and hemoglobin status. The hypothesis was that a better hemoglobin status would lead to better attendance. Although there was a distinct trend to support this hypothesis, the relationship missed statistical significance. Absenteeism was not health related (table 11). The overall absenteeism rate over the nine-month intervention study was 27%. The maximum absenteeism was in the months of January, February, and March, which correspond to the marriage season. They are also the lean tea-picking months.

TABLE 9. Impact of the micronutrient intervention on common health problems in pickers and nonpickers as perceived by them

Health problems	Baseline		Resurvey	
	no.	%	no.	%
Present	543	88	333	54***
Not present	74	12	280	46
General weakness	104	17	44	7***
All aches or pains (body, head, neck, limbs, joint, shoulder)	400	65	85	13***
Bronchitis, upper respiratory infection, cough, congestion	66	11	8	1***
Abdominal pain, giddiness, gastritis	43	7	195	32***
Obstetrical and gynecological problems (women)	81	13	20	3***

****p* <.001 for the comparison between baseline and resurvey.

Reduction in iron-deficiency anemia

There was a highly significant reduction in iron-deficiency anemia among the women, men, and children (fig. 1) [17]. All of the children were anemic at baseline, although the mean hemoglobin value appeared to be fairly adequate at a mean of 11 and 10.8 g/dl, respectively for boys and girls (WHO cutoff ≥ 12 g/dl). Iron-deficiency anemia was widely prevalent at baseline among men as well (WHO cutoff ≥ 13 g/dl).

Discussion

The success of this study is to be judged at least as much by the success of its participatory plan of action as by the impact achieved as a result of the micronutrient intervention. Plantations have some unique characteristics, which can be capitalized upon in the delivery of a micronutrient package to workers and their families. In India the tea pickers are almost always women, and skilled pickers are becoming rare. Forty to fifty percent

TABLE 10. Impact of the micronutrient intervention on attendance of women pickers in relation to their hemoglobin status[a]

Hemoglobin (g/dl)	Attendance ≤ 20 days		Attendance > 20 days	
	no.	%	no.	%
< 10	8	57	6	43
10–11.9	58	52	53	48
≥ 12	80	44	100	56

a. Relationship not significant at $p < .05$ for the comparison within attendance

TABLE 11. Monthly absenteeism among pickers before and during intervention

Month	Before intervention				During intervention			
	Work days	Days present	Days absent		Work days	Days present	Days absent	
			no.	%			no.	%
Aug	27	20	7	26	27	20	7	26
Sep	26	21	5	19	25	19	6	24
Oct	26	19	7	27	27	22	5	19
Nov	26	21	5	19	26	19	7	27
Dec	26	20	6	23	27	20	7	26
Jan	27	17	10	37	27	17	10	37
Feb	25	17	8	32	24	16	8	33
Mar	26	19	7	27	26	18	8	31
Apr	26	18	8	31	26	20	6	23
Overall	26	19	7	27	26	19	7	27

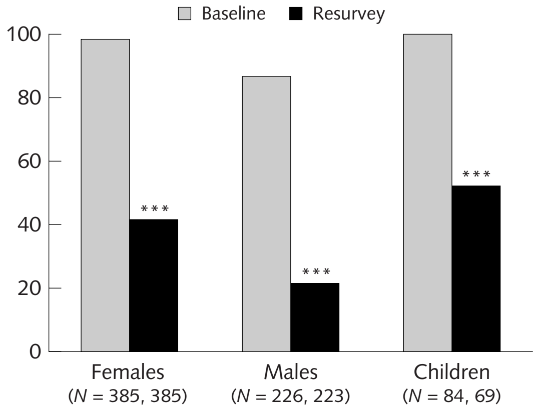

FIG. 1. Impact of the micronutrient intervention as indicated by the reduction of anemia in men and women pickers and nonpickers and their children at baseline and resurvey. The numbers of subjects are given under the bars. Cutoff points for anemia are hemoglobin levels < 12 g/dl in women and children and <13 g/dl in men [17]. *** $p < .001$ for the comparison between baseline and resurvey

of the operational field costs of tea production are for picking the leaves. Therefore, it makes good sense to devise and assess an intervention or strategy that is simple, acceptable, and sustainable [18–20].

Was the micronutrient intervention acceptable and sustainable?

Iodine-deficiency disorders are endemic in Chickmagalur District. Most low-income groups manifest a high prevalence of iron-deficiency anemia and vitamin A deficiency as well. A recent Karnataka nutrition profile of women, adolescent girls, and children confirmed that hidden hunger for iron, iodine, and vitamin A was widely prevalent in Chickmagalur District, where our study estate was located [8]. Our previous experience in advising the Government of Gujarat Western India had shown that it was possible for the government to successfully procure and distribute the above micronutrients along with albendazole (an anthelmintic) for nearly three million schoolchildren in every district of Gujarat on a continuing basis [9]. Hence, we knew that it would be not be difficult to devise a similar and much-needed intervention for the plantation workforce. An uninterrupted supply line is essential for any intervention.

Fortunately, ferrous sulfate and iodated salt were in abundant supply, although vitamin A was not. Salt doubly fortified with iron and iodine was our first choice, but no supplier was found. In Gujarat the cost of albendazole plus iron and vitamin A came to Rs. 10.50 per schoolchild per year (about 30 US cents in 1994–1996). In this intervention, the cost of the three micronutrients was about Rs. 12 per person per year (about 35 US cents in 1996–1998). Provided there is a well-established source, such as the plantation hospital for the medicinal supplements and the plantation ration shop for iodated salt, this combination of supplementation and fortification is by far the most easily managed, cheapest, and most accountable nutrition intervention [21].

The purpose of this project was to design and implement a joint intervention that was fully acceptable to both the plantation management and the workforce. Many well-intentioned national and international projects do not give sufficient importance to the community and its leaders in project design. As a result, the project ends when the research team leaves [22]. In this project, maximum emphasis was put on evolving a strategy or intervention that this study plantation now, and other surrounding ones in the near future, could and would adopt willingly.

The director of the study plantation and his management continued with the micronutrient intervention, even after the research team left in April 1997. We believe that this was possible because of the simplicity of the intervention, its high acceptability to both the management and the workforce, and its sustainability, since it was cost effective and the micronutrients were easily available in the market.

Was the intervention effective in improving the health of the workers?

Very significant micronutrient-specific improvements in the health of the workforce (pickers and nonpickers) and their dependents were observed. The clinical signs of iron, iodine, and vitamin A deficiencies declined. At the baseline survey, the workforce as a whole either had no iron-deficiency anemia or suffered from mild iron-deficiency anemia. The mean hemoglobin level of the women pickers was 11 g/dl, and this went up by a gram due to the intervention. In the men workers, there was a significant mean rise of 2 g/dl. Hence, the intervention did improve the iron status of the workforce. Referral to big hospitals for nutrition and micronutrient-related health problems decreased significantly, from 116 to 86 patients. The majority of the workforce stated that they “felt better,” “ate more,” and “felt less tired.” Perception is almost as potent as objectively measured change. The intervention created a reservoir of good will and a feeling of being cared for. The improved health of the workforce permeated to the management as well. Many workers told the research team that this was the first time they and their families had been given a health checkup in the plantation hospital.

Multinutrient interventions can be comfortably and cost-effectively included in ongoing programs, and it makes good sense to deliver a “three-in-one” package of iron, iodine, and vitamin A. There is also good evidence that mass deworming of entire plantation populations not only controls intestinal helminthic infections, but also brings about better utilization of the micronutrients [23–25]. This was begun on the study plantation in April 1997 and still continues.

This study showed that iron supplementation two times a week or once a week works just as well. A strategy that advocates weekly iron supplementation, particularly in institutions, is likely to be well received [26–29]. The study showed that the workers were responsible about taking the supplements themselves and giving them to their children. We conclude that the micronutrient intervention jointly evolved with the study estate proved to be simple, effective, and sustainable.

Recommendations

The following recommendations are based on the findings of this project, which demonstrated that the iron, iodine, and vitamin A status and the health of the plantation workforce improved significantly:

» Encourage partnerships among the management of plantations, academia, researchers, and the pharmaceutical and food-processing industries to design and deliver simple, cost-effective, and sustainable micronutrient interventions of iron, iodine, and vitamin A for the workforce on plantations.

» Build confidence and capacity among the management and staff of plantations to manage micronutrient interventions on their own.

» Demonstrate how combined multinutrient interventions can be easily integrated into the ongoing health programs or activities on the plantation.

» Encourage the management and plantation ration shops to procure and store only reputable brands of iodated salt and to sell it at subsidized rates. Fortification of common foods is the cheapest and simplest way to ensure that the entire workforce and their families consume the three micronutrients, iron, iodine, and vitamin A. Plantation managers should seriously explore procuring double-fortified salt (iron and iodine) and selling it to their workforce at reduced cost. Cooking oil likewise could be fortified with vitamins A, D, and E.

» Promote a movement in the plantation industry to replicate this study's success story by convincing the managers that the improvement of the health and well-being of their workforce through micronutrient interventions will result not only in better worker productivity but also in more cordial relations between the management and workforce.

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The monetary value of human milk in Francophone West Africa: A PROFILES analysis for nutrition policy communication

Víctor M. Aguayo and Jay Ross

Abstract

Using a simple and conservative methodology, we estimated the volume and monetary value of the human milk produced by lactating women in Francophone West Africa. In that region, children zero to 35.9 months old consume over 1.1 billion liters of human milk per year. However, suboptimal breastfeeding practices account for the loss of 175 million liters of human milk annually. If the human milk consumed by children zero to 35.9 months old were to be adequately replaced using commercial breastmilk substitutes, an annual expenditure of about 2 billion US dollars would be needed. At the household level, the annual replacement cost of human milk would amount to US$412 per infant. This is beyond the reach of most families in West Africa, where as many as 61% of families in some countries live on less than one US dollar per day. Appropriate policies to foster breastfeeding need to be developed and adequately implemented. Such policy action is more likely to occur if decision makers fully appreciate the monetary value of human milk.

Key words: West Africa, breastmilk, breastfeeding practices, nutrition policy, communication, monetary value of breastmilk

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Mention of the names of firms and commercial products does not imply endorsement by the United Nations University.

Introduction and objectives

Breastfeeding protects infants against disease and death [1], provides optimal nutrition for children's physical growth [2] and development [3], delays the return of menses [4], and enhances child spacing [5]. Breastfeeding also provides immediate economic benefits. Direct economic benefits result from the lower cost of human milk relative to commercial breastmilk substitutes. Indirect economic benefits result from the lower morbidity-related costs in breastfed children and from the lower costs in family planning services resulting from the fertility reduction associated with lactation.

The health and fertility benefits of breastfeeding have been at the forefront of breastfeeding advocacy efforts. However, awareness of the immediate economic benefits of breastfeeding is crucial from a policy perspective. Such benefits can now be quantified with some precision. The purpose of this analysis is twofold: to estimate the volume of human milk consumed by children zero to 35.9 months old in the eight Francophone countries of the Economic Community of West African States, and to estimate the potential monetary cost of safe breastmilk replacement with commercial breastmilk substitutes to households and governments.

Methods

The estimation of the volume of human milk currently consumed by children zero to 35.9 months old was based on the distribution of children by age group (0–5.9, 6–11.9, 12–23.9, and 24–35.9 months), the distribution of current breastfeeding practices (exclusive breastfeeding, partial breastfeeding, and no breastfeeding) by age group, and the average daily intake of human milk by breastfed children of a given age group and breastfeeding practice. The total daily volume of breastmilk consumed by children zero to 35.9 months old in a given country ($TM_{0-35.9}$) was calculated by the following equation:

$$TM_{0-35.9} = (N_{0-5.9} \times EBF_{0-5.9} \times Me_{0-5.9}) + (N_{0-5.9} \times PBF_{0-5.9} \times Mp_{0-5.9}) + (N_{6-11.9} \times PBF_{6-11.9} \times Mp_{6-11.9}) + (N_{12-23.9} \times PBF_{12-23.9} \times Mp_{12-23.9}) + (N_{24-35.9} \times PBF_{24-35.9} \times Mp_{24-35.9})$$

where *N* is the number of children in a given age group; *EBF* and *PBF* are the exclusive and partial breastfeeding rates in children of a given age group, respectively; and *M*e and *M*p are the average daily intakes of human milk by breastfed children of a given age group and breastfeeding practice (exclusive breastfeeding and partial breastfeeding), respectively.

Distribution of children and breastfeeding practices by age group

The distribution of children by age group was estimated using the 1998 United Nations Medium Population Projection. The use of a common demographic database allowed for greater consistency and comparability across countries. Table 1 shows that the projected population for the year 2000 of children zero to 35.9 months old in the countries included in the analysis was over 8.3 million, with more than 2.9 million infants.

Current breastfeeding practices were derived from the latest Demographic and Health Survey (DHS) data. Data were collected between 1994 and 1999 using comparable questionnaires, survey procedures, and methodological approaches. Table 2 shows the size of national DHS samples and the number of children included in the age groups relevant to our analysis. Altogether, this body of data includes national representative samples of about 30,000 children zero to 35.9 months old.

Table 3 shows exclusive and partial breastfeeding rates by age group and country. Infants were classified as exclusively breastfed if they were given only breastmilk (including expressed milk or milk from a wet nurse) in the 24 hours prior to the interview, with no other solid, semisolid, or liquid given (not even water). Children were classified as partially breastfed if they were given breastmilk (including expressed milk or milk from a wet nurse) as well as solids, semisolids, or liquids, including nonhuman milk [6].

TABLE 1. Number of children (0–35.9 months old) by age group and country according to 1998 United Nations medium population projection for the year 2000

Country	0–5.9 mo	6–11.9 mo	12–23.9 mo	24–35.9 mo	All ages
Benin	118,277	115,414	233, 922	196, 983	664,596
Burkina Faso	244,135	234,867	446,380	423,989	1,349,371
Côte d'Ivoire	258,013	249,317	477,724	457,432	1,442,486
Guinea	142,427	137,406	264,844	254,988	799,665
Mali	248,583	242,600	448,326	429,255	1,368,764
Niger	219,663	212,626	406,994	390,994	1,230,277
Senegal	173,587	169,132	327,867	317,875	988,461
Togo	88,706	86,012	166,272	160,470	501,460
Total	1,493,391	1,447,374	2,772,329	2,631,986	8,345,080

TABLE 2. Date of Demographic and Health Survey (DHS) data used in the analysis and number of children included in the sample by age group and country

Country	Date of latest DHS	No. of children				
		0–5.9 mo	6–11.9 mo	12–23.9 mo	24–35.9 mo	All ages
Benin	Jun–Aug 96	520	502	871	1,290	3,183
Burkina Faso	Nov 98–Jan 99	640	536	1,019	830	3,025
Côte d'Ivoire	Jun–Nov 94	664	606	1,104	959	3,333
Guinea	Feb 99	674	425	920	985	3,004
Mali	Nov 95–Apr 96	1,053	986	1,562	1,639	5,240
Niger	Mar 97–Jul 98	867	780	1,431	1,327	4,405
Senegal	Jan–Apr 97	780	588	1,328	1,170	3,866
Togo	Feb–May 98	670	699	1,135	1,191	3,695
Total	—	5,868	5,122	9,370	9,391	29,751

Volume of human milk consumed by breastfed children

In 1998, the World Health Organization (WHO) conducted a review of the literature to estimate the average breastmilk intake of breastfed children in developing countries as a function of their age and breastfeeding mode [7] (table 4). The use of WHO data posed two problems for our analysis. First, the age groups in the WHO meta-analysis (three-month age groups for infants) were different from those reported by DHS (two-month age groups for children zero to 35.9 months old). Second, the WHO meta-analysis provided no information on average breastmilk intake by children 24 to 35.9 months old, yet a significant proportion of West African children in this age group are still being breastfed (table 3).

To address the first problem, we decided to use average daily breastmilk intakes of 714 ml for all exclusively breastfed infants zero to 5.9 months old, 617 ml for all partially breastfed infants zero to 5.9 months old, 616 ml for all partially breastfed infants 6 to 11.9 months old, and 549 ml for all partially breastfed children 12 to 23.9 months old. These numbers represent the lowest end of average breastmilk intake in each age group (table 5). This approach underestimates the real volume of breastmilk consumed by children zero to 23.9 months old, yielding conservative estimates.

To address the absence of information on breastmilk intake in breastfed children 24 to 35.9 months old in the WHO meta-analysis, we used an average intake of 254 ml per day, as reported by Hatløy and Oshaug for this age group [8].

Net monetary value of breastmilk

The net monetary value of human milk was calculated by the following equation:

$$Nval_{BM} = Gval_{BM} - Pval_{BM}$$

where $Nval_{BM}$ is the net monetary value of breastmilk, $Gval_{BM}$ is the gross monetary value of breastmilk, and $Pval_{BM}$ is the monetary cost of breastmilk production.

Gross monetary value of breastmilk

The gross monetary value of breastmilk at the national level was estimated as the monetary value of the commercial breastmilk substitutes required to replace the human milk currently consumed by children zero to 35.9 months old. The additional cost of the water, fuel, and minimum equipment (bottles and teats) required

TABLE 3. Rates of exclusive and partial breastfeeding by age group according to the latest Demographic and Health Survey in each country

Country	Exclusive, 0–5.9 mo	Partial, 0–5.9 mo	Partial, 6–11.9 mo	Partial, 12–23.9 mo	Partial, 24–35.9 mo
Benin	0.100	0.896	0.896	0.846	0.509
Burkina Faso	0.055	0.944	0.985	0.926	0.488
Côte d'Ivoire	0.030	0.964	0.985	0.738	0.164
Guinea	0.113	0.876	0.905	0.865	0.275
Mali	0.083	0.914	0.963	0.682	0.207
Niger	0.008	0.985	0.995	0.786	0.119
Senegal	0.105	0.889	0.968	0.732	0.062
Togo	0.104	0.888	0.990	0.900	0.219

TABLE 4. Average daily intakes (ml/day) of breastmilk in breastfed children living in developing countries according to age group and breastfeeding practice

Breastfeeding practice	0–2.9 mo	3–5.9 mo	6–8.9 mo	9–11.9 mo	12–23.9 mo
Exclusive	714 ± 131	784 ± 128	776 ± 141	—	—
Partial	617 ± 168	663 ± 155	660 ± 153	616 ± 172	549 ± 187

Source : ref. 7.

TABLE 5. Average daily intake (ml/day) of breastmilk in breastfed children living in developing countries according to age group and breastfeeding practice

Breastfeeding practice	0–5.9 mo	6–11.9 mo	12–23.9 mo	24–35.9 mo
Exclusive	714	—	—	—
Partial	617	616	549	254

for the preparation of commercial breastmilk substitutes was factored in the analysis.

To estimate the cost of breastmilk substitutes required to replace the human milk currently consumed by children, two teams of public health nutritionists in Togo and Burkina Faso were requested to quantify the average cost of replacing one liter of human milk with commercial breastmilk substitutes, using the brands of infant formula most frequently purchased in their country. The resulting costing exercise yielded estimates of US$2.10* and US$1.75** for the commercial formula needed to replace one liter of human milk and US$0.27 and US$0.22 for the cost of water, fuel, and equipment needed per liter of human milk replaced. Being conservative, we used in our analysis US$1.97 (US$1.75 for the commercial formula and US$0.22 for the cost of water, fuel, and equipment) as the replacement cost of one liter of human milk.

Monetary value of breastmilk production

In our analysis we assumed that the caloric cost of breastmilk production (during or in preparation for lactation) is 940 kcal per liter of breastmilk [9]. The same teams of public health nutritionists in Togo and Burkina Faso were asked to quantify the cost of 940 kcal using locally available foods and a balanced diet. The resulting costing exercise yielded estimates of US$0.20 and US$0.25 per 940 kcal by the two teams. Again to be conservative, a cost of US$0.25 per 940 kcal was used in our analysis (probably overestimating the real cost of human milk production).

* The LINKAGES and MEASURE Communication Projects. Nutrition au Togo. Investissons aujourd'hui pour un développement durable. A PROFILES analysis for nutrition policy advocacy. Lomé, 1999. Academy for Educational Development (AED), Washington, DC.

** The LINKAGES Project. La Nutrition: Clé du développement durable au Burkina Faso. A PROFILES analysis for nutrition policy advocacy. Ouagadougou, 2000. Academy for Educational Development (AED), Washington, DC.

Results

Table 6 shows the daily breastmilk consumption by children zero to 35.9 months old by age group and breastfeeding practice. All countries show high levels of human milk production. In Francophone West Africa, lactating women currently produce over 3 million liters of breastmilk per day, or over 1.1 billion liters per year. Breastmilk production (total breastmilk consumption in children zero to 35.9 months old/total number of children zero to 35.9 months old) ranges from 350 ml/child/day in Senegal to 425 ml/child/day in Burkina Faso. Breastmilk consumption by infants (zero to 11.9 months old) and young children (12 to 23.9 months old) accounts for 56% and 38%, respectively (i.e., 95% of the total).

Table 7 shows the potential breastmilk consumption by children zero to 35.9 months old if breastfeeding practices were optimal. Optimal breastfeeding was defined as exclusive breastfeeding of all infants zero to 5.9 months old and continued breastfeeding with appropriate complementary foods for all children 6 to 23.9 months old, with current breastfeeding rates in children 24 to 35.9 months remaining unchanged. The analysis shows that the potential consumption of human milk by children zero to 35.9 months old, if they were optimally breastfed, would be more than 3.6 million liters per day, or more than 1.3 billion liters per year.

Table 8 shows the breastmilk "lost" as a result of current suboptimal breastfeeding practices in children zero to 35.9 months old (i.e., the difference between potential breastmilk production if breastfeeding practices were optimal and current breastmilk production). The comparison of these figures shows a "loss" of human milk of about 480 thousand liters per day, or more than 175 million liters per year.

Table 9 shows the national and per capita monetary values of the breastmilk currently consumed in Francophone West Africa. It compares them with the gross national product (GNP) and per capita GNP in each

TABLE 6. Current breastmilk consumption (liters per day) according to age group and breastfeeding practice (exclusive or partial) in children 0–35.9 months old

Country	Exclusive and partial, 0–5.9 mo	Partial, 6–11.9 mo	Partial, 12–23.9 mo	Partial, 24–35.9 mo	All ages
Benin	73,832	63,701	108,646	25,467	271,647
Burkina Faso	151,783	142,508	226,928	52,554	573,773
Côte d'Ivoire	158,990	151,276	193,556	19,055	522,876
Guinea	88,472	76,601	125,770	17,811	308,654
Mali	154,917	143,912	167,861	22,569	489,260
Niger	134,754	130,323	175,624	11,818	452,518
Senegal	108,229	100,851	131,759	5,006	345,845
Togo	55,189	52,454	82,155	8,926	198,723
Total	926,165	861,626	1,212,299	163,207	3,163,297

country. The net monetary value of the human milk currently consumed by children zero to 35.9 months old is about US$2 billion per year, which is equal to 6.7% of the gross national product of the countries included in the analysis. At the household level, the average net monetary value of the human milk consumed by a child zero to 35.9 months old amounts to US$240 per year (61.5% of the GNP per capita) or US$412 in the first year of life (106% of GNP per capita).

Discussion

Breastfeeding practices

In Francophone West Africa, breastfeeding is an almost universal practice. The percentage of children zero to 5.9 months old who have ever been breastfed ranges from 98.9% in Guinea to 99.9% in Burkina Faso. This means that nearly all children born in the six months preceding the survey were breastfed at some point. The median duration of breastfeeding (exclusive or partial) ranges from 20.3 months in Côte d'Ivoire to 27.7 months in Burkina Faso. This is consistent with

TABLE 8. Breastmilk production "lost" as a result of suboptimal breastfeeding practices in children 0–35.9 months old

Country	Liters per day	Millions of liters per year
Benin	37,789	13.8
Burkina Faso	42,834	15.6
Côte d'Ivoire	96,250	35.1
Guinea	40,891	14.9
Mali	106,370	38.8
Niger	70,557	25.8
Senegal	67,286	24.6
Togo	17,806	6.5
Total	479,782	175.1

TABLE 7. Potential breastmilk consumption (liters per day) according to age group and breastfeeding practice (exclusive or partial) in children 0–35.9 months old if breastfeeding practices were optimal

Country	Exclusive and partial, 0–5.9 mo	Partial, 6–11.9 mo	Partial, 12–23.9 mo	Partial, 24–35.9 mo	All ages
Benin	84,450	71,095	128,423	25,467	309,435
Burkina Faso	174,312	144,678	245,063	52,554	616,607
Côte d'Ivoire	184,221	153,579	262,270	19,055	619,126
Guinea	101,693	84,642	145,399	17,811	349,545
Mali	177,488	149,442	246,131	22,569	595,630
Niger	156,839	130,978	223,440	11,818	523,075
Senegal	123,941	104,185	179,999	5,006	413,131
Togo	63,336	52,983	91,283	8,926	216,529
Total	1,066,281	891,582	1,522,009	163,207	3,643,079

TABLE 9. Monetary value of breastmilk currently consumed by children 0–35.9 months old

Country	Net monetary value of breastmilk (million US$/yr)	1999 GNP (million US$)	Net monetary value of breastmilk (% of GNP)	Net monetary value of breastmilk (US$ per breastfed child/yr)	1999 per capita GNP (US$)	Net monetary value of breastmilk (% of per capita GNP)
Benin	171	2,300	7.4	257	380	67.6
Burkina Faso	361	2,600	13.9	267	240	111.4
Côte d'Ivoire	329	10,400	3.2	228	710	32.1
Guinea	194	3,700	5.2	243	510	47.6
Mali	307	2,600	11.8	225	240	93.6
Niger	284	2,000	14.2	231	190	121.7
Senegal	217	4,700	4.6	220	510	43.1
Togo	125	1,500	8.3	249	320	77.8
Global	1988	29,800	6.7	240	388	61.5

GNP, Gross national product.

data reporting that the median duration of breastfeeding in sub-Saharan Africa is 21 months [6].

In Francophone West Africa, breastfeeding practices are far from optimal, however. WHO recommends that infants be exclusively breastfed for about the first six months of life [10]. In the countries included in our analysis, exclusive breastfeeding rates for children zero to 5.9 months old ranged from 0.8% in Niger (the lowest exclusive breastfeeding rate for infants zero to 5.9 months reported in Africa) to 11.3% in Guinea. The median duration of exclusive breastfeeding was very short, ranging from 0.4 months in Burkina Faso, Côte d'Ivoire, Guinea, and Niger to 1.5 months in Mali (data not presented).

Most infants zero to 5.9 months old are partially breastfed. Partial breastfeeding rates in this age group ranged from 87.6% in Guinea to 98.5% in Niger. This is consistent with data reported in other countries in sub-Saharan Africa, the region with the lowest exclusive breastfeeding rates and the highest partial breastfeeding rates in children zero to 5.9 months old worldwide [6].

WHO recommends that infants be fed adequate amounts of appropriate complementary foods from about the age of 6 months, with continued breastfeeding up to the age of 24 months and beyond [10]. In the countries included in our analysis, partial breastfeeding is an almost universal practice in children 6 to 11.9 months old. Partial breastfeeding rates in this age group range from 89.6% in Benin to 99.5% in Niger. Most children continue to breastfeed through the second year of life. Partial breastfeeding rates in children 12 to 23.9 months old range from 68.2% in Mali to 92.6% in Burkina Faso. This is consistent with data reporting that sub-Saharan Africa shows the highest first-year breastfeeding continuation rates (proportion of children 12 to 15 months old still breastfeeding) worldwide, with over 90% of children still breastfeeding at this age [6]. Moreover, a significant proportion of children continue to breastfeed through the third year of life. Partial breastfeeding rates in this age group range from 6.2% in Senegal to 48.8% in Burkina Faso, with an estimated 25% of children 24 to 35.9 months old still breastfeeding.

Current breastmilk production

One of the most striking features of our analysis is the high output of human milk. In Francophone West Africa, children zero to 35.9 months old currently consume over 3 million liters of human milk daily (over 1.1 billion liters per year). This represents an average daily intake of 379 ml per child, with national values ranging from 350 ml per child in Senegal to 425 ml per child in Burkina Faso.

Human milk production for children zero to 23.9 months old represents about 95% of the total breastmilk production for children zero to 35.9 months old. The average daily intake of human milk in children zero to 23.9 months old is 528 ml per child, with national values ranging from 497 ml per child in Mali to 563 ml per child in Burkina Faso. This confirms that in Francophone West Africa, breastmilk is a key source of nutrients for infants and young children.

Human milk is also a key source of safe water. Scientific evidence shows that infants zero to 5.9 months old who are exclusively breastfed do not need supplemental water to maintain water homeostasis, even in dry and hot climates [11]. Moreover, after six months of age, when adequate complementary foods are needed for optimal growth and development, breastmilk is still the best source of safe water for children up to one year of age and beyond [12].

If we assume that the water content of human milk represents on average 87% of its total volume [9], our analysis shows that in Francophone West Africa lactating mothers are producing over one billion liters of safe water for their breastfed children each year—about 530 ml of safe water per infant per day. Human milk therefore represents a lifesaving source of safe water for infants in a region where as little as 28% of the population has access to safe water in some countries [13].

In conclusion, our analysis shows that in Francophone West Africa, human milk is a key source of nutrients and safe water for over 8.3 million children zero to 35.9 months of age. It also shows that an estimated 175 million liters of human milk are lost every year—including over 152 million liters of safe water—as a result of the suboptimal breastfeeding practices observed in the region. Given the high rates of partial breastfeeding in children 6 to 24 months old, most of the loss of human milk results from the very low exclusive breastfeeding rates in infants zero to 5.9 months old.

Monetary value of current breastmilk production

The monetary value assigned to human milk varies significantly across studies because of the different approaches used to estimate it. In a study in Nepal (1994), the monetary value of human milk was equated with that of cow's milk (US$0.27 per liter) [14]. In India (1999), total breastmilk production was valued by using the price of cow's milk (US$0.38 per liter) and canned milk (US$0.75 per liter) as equivalents [15]. In Mali (1997), the monetary value of human milk was estimated by using an arbitrarily chosen figure (US$1 per liter) [8]. In industrialized countries, the basis for the estimation of the monetary value of breastmilk has often been the cost of breastmilk stored in milk banks. In Norway, Sweden, and Denmark, donor mothers are paid US$19, US$21, and US$24, respectively, per liter of human milk. Moreover, when human milk enters the health-care system as a food-medicine, its market value increases significantly. The price of banked milk is US$40 to US$48 per liter in the United Kingdom, US$50 in Norway, US$80 in the United States, and US$90 in Denmark. These figures give an idea of the high monetary value placed on human milk in some industrialized countries [16].

In our analysis, the imputed gross monetary value of human milk was estimated on the basis of the cost of the commercial breastmilk substitutes required for safe replacement of human milk. The cost of water, fuel, and minimal equipment was factored in the analysis to account (conservatively) for some of the direct costs of replacing human milk with commercial substitutes. Moreover, our analysis factors the cost of breastmilk production, that is, the cost of providing lactating mothers with a nutritious and balanced diet to support breastfeeding while protecting their health and nutritional status.

Using a simple and conservative methodology, our analysis shows the outstanding monetary value of human milk in Francophone West Africa. If the human milk currently consumed by children zero to 35.9 months old were to be "safely" replaced with commercial breastmilk substitutes (i.e., ensuring that all children are fed adequate amounts of breastmilk substitutes so as to limit as much as possible the health hazards associated with artificial feeding), an annual investment of about US$2 billion would be needed.

The volume and monetary value of human milk in Francophone West Africa should in themselves justify the inclusion of human milk in national and regional food statistics. If human milk were included in national food balance sheets, the GNP—a good indicator of the economic activity of countries—would increase on average by 6.7%, with national increases ranging from 3.2% in Côte d'Ivoire to 14.2% in Niger.

Our analysis also shows that "safe" replacement of human milk is not an option for most West African households. The average replacement cost of the human milk consumed by an adequately breastfed infant (exclusively breastfed from birth to about six months and partially breastfed thereafter) amounts to about US$412 per year or US$1.13 per day. This is beyond the purchasing power of most families in West Africa, where, according to the latest World Development Report, the percentage of families living on less than US$1 per day ranges between 12% and 61% [13]. To put this in perspective, at the time of writing this paper, US$1.13 would allow a family living in Bamako (Mali) to buy half a kilogram of rice, two eggs, three pieces of smoked fish, one loaf of bread, and two mangoes.

Our analysis estimates the monetary value of human milk based on the market value of safely prepared breastmilk substitutes. This approach clearly underestimates the true monetary value of human milk, because commercial breastmilk substitutes are nutritionally and immunologically inferior to human milk. Less suitable options, such as home-prepared breastmilk substitutes, can certainly be more affordable. In choosing commercial breastmilk substitutes, we decided to use the safest, most suitable alternative for the survival, growth, and development of infants and young children, drawing a clear line in the compromise between quality and affordability.

The comparison of the cost-effectiveness of breastfeeding protection, promotion, and support with that of other efforts to improve social welfare, although of great interest, is beyond the scope of this paper. Such analysis would require a comprehensive examination of the costs and effectiveness of a variety of alternative programs. It would also require considering the full range of health, child-spacing, and time-saving benefits afforded by breastfeeding* [17, 18]. The major economic impact of breastfeeding at the national level in West Africa is probably associated with its health-promoting and birth-spacing effects [19, 20], neither of which is quantified in this paper. A comprehensive analysis of the economic value of breastfeeding should also include the long-term benefits of improved breastfeeding practices for child survival, growth and development, school readiness, school performance, productivity, and national development. The economic value of breastfeeding goes far beyond the monetary value of human milk.

Our analysis in the context of the HIV/AIDS epidemic

HIV/AIDS is, no doubt, one of the major development challenges in Africa. An estimated 36 million people are currently infected with HIV, two-thirds of whom live in sub-Saharan Africa [21]. More than 50% of adults living with HIV/AIDS in sub-Saharan Africa are women of reproductive age. It is now well established that HIV-infected women can pass the virus to their infants via breastfeeding. A meta-analysis published in 1992 estimated the average excess risk of mother-to-child transmission attributable to breastfeeding by women with established HIV infection to be 14% [22]. This situation creates a tragic dilemma: whereas breastfeeding prevents an estimated 6 million infant deaths each year worldwide [23], it also results in 200,000 to 300,000 infant HIV infections [24]. WHO recommends that HIV-negative mothers and those of unknown HIV status be supported to exclusively breastfeed their infants for six months [10]. In West Africa an estimated 95% of adult women are HIV-negative [21]. Policies and programs in this region should therefore support them to exclusively breastfeed their infants for 6

* Smith J, Ingham L. The economic value of breastfeeding in Australia. Presented at Breastfeeding, the Natural Advantage. International Conference of the Nursing Mothers Association of Australia, Sydney, Australia, 1997.

months and to continue breastfeeding until 24 months and beyond while introducing timely and appropriate complementary foods. Policies and programs should also ensure that women have access to information and counseling on HIV prevention. An estimated 5% of West African women are infected with HIV [21]. It is recommended that mothers who are HIV-positive avoid breastfeeding when replacement feeding is acceptable, feasible, affordable, sustainable, and safe [10]. Our analysis clearly shows that safe replacement of human milk with commercial infant formula is not an affordable option for the vast majority of West African households. This is probably even more so in households where the mother is HIV-positive, because of HIV-related medical expenses and limited income-generation potential. In such a situation, policies and programs should ensure that exclusive breastfeeding be promoted during the first months of life until its discontinuation is feasible [10]. Low-cost options for reducing the odds of HIV transmission (wet nursing and human milk pasteurization) and early cessation of breastfeeding need to take into account social acceptability (including women's stigma and marginalization) and the risks of replacement feeding (including malnutrition, psychosocial stress, and infections other than HIV), since these represent major changes in traditional infant care practices in West Africa [25].

Conclusions

Despite the conclusive body of evidence on the benefits of breastfeeding, policy makers in Francophone West Africa rarely consider the protection, promotion, and support of breastfeeding a sound economic investment. This has important policy consequences for the survival, health, growth, and development of young children and for the health and status of women.

A decline in breastfeeding rates will translate into increased levels of child mortality, morbidity, and malnutrition if adequate volumes of safe breastmilk substitutes are not available and accessible so as to minimize the negative consequences of suboptimal breastfeeding practices. Our analysis shows that this is not a realistic option for the vast majority of households in Francophone West Africa because of the high cost of commercial breastmilk substitutes, basic feeding equipment, clean water, and fuel. As a result, wherever breastfeeding is not protected, promoted, and supported, human milk is likely to be suboptimally replaced by breastmilk substitutes, leading to an increase in fertility levels and a reduction in the survival, health, growth, and development potential of children.

The message is clear. Safe replacement of human milk is not an option for the vast majority of households in Francophone West Africa. Appropriate policies to promote, protect, and support breastfeeding need to be developed and adequately implemented. Such policy action is more likely to happen when decision makers and their constituencies fully appreciate the monetary value of human milk.

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Targeting performance of three large-scale, nutrition-oriented social programs in Central America and Mexico

Mesoamerica Nutrition Program Targeting Study Group

Abstract

This study evaluated whether three nutrition-oriented programs in Central America and Mexico have been successful in targeting those households most vulnerable to undernutrition and poverty. For each country, nationally representative data sets were used to estimate cutoff points dividing the population into 10 equal-sized groups according to child anthropometric measurements (age-standardized height) and household income (per capita household expenditures). Households meeting eligibility criteria were then assessed using special baseline surveys or national data obtained before implementation of the program. Children in these households were classified according to national deciles of height-for-age, and households were classified according to expenditure deciles. In spite of markedly differing targeting strategies, each of the programs was well targeted, with 45% (Honduras and Mexico) and 52% (Nicaragua) of children in eligible households coming from the lowest two deciles of the national distributions, and virtually none from the upper two deciles. Similar results pertained to household income. These experiences demonstrate that vulnerable households can be targeted relatively straightforwardly, and that the need to do this does not in every case imply household-level income screening.

Key words: Honduras, Nicaragua, Mexico, nutrition programs, household consumption, household income, household expenditures

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Introduction

Definition of the target population is considered a critical component of project planning and design [1]. This is because projects and programs can achieve a satisfactory level of cost-effectiveness only if they are successful in reaching individuals who are at high risk of developing the condition that the program seeks to alter. Previous research has demonstrated that successful targeting of nutrition programs has the potential to substantially enhance their impact, especially on the more severe forms of malnutrition [2].

Targeting goals can be achieved either administratively, by explicitly specifying who is eligible to receive benefits and who is not, or by designing a "self-targeted" program that has no eligibility restrictions but is attractive only to individuals with particular characteristics. Unrestricted provision of a food supplement that is unpalatable to adults but well suited for use as a complementary food for infants would be an example of the latter approach, as would a cash-for-work program with wages so low that only the very poor would wish to participate. Administrative targeting includes geographic targeting, which can be broad (selection of a few large, subnational regions) or precise (selection of numerous relatively small communities scattered over a larger area). Administrative targeting also encompasses individual (or household) assessment mechanisms that restrict eligibility on the basis of defined characteristics, such as age or household income [3]. Many food and nutrition programs employ a mix of targeting tools to determine their final beneficiary pool, but to date there has been little documentation of the range of procedures used, or the extent to which these efforts have succeeded in concentrating program resources in favor of the most vulnerable.

In this paper, we examine three large-scale, nutrition-focused social programs in Central America and Mexico. All three programs were implemented in rural areas. We describe the methods that the programs used to determine eligibility, and show how these methods led to beneficiary pools of particular profiles. We focus on two characteristics likely to affect program impact: vulnerability to undernutrition (stunting) in young children and poverty. Specifically, we examine whether children in households that would later have become eligible to enter the programs were really those at highest risk of stunting in each of the three countries, and whether those households were truly the poorest.

Materials and methods

Programs

Honduras

In Honduras, the Family Allowance Program (*Programa de Asignación Familiar*, PRAF) began at the end of the year 2000 to implement a program of household cash transfers (PRAF/IDB Phase II) covering 40 municipalities with a total population of about 400,000. The beneficiary municipalities for Phase II operations were chosen by ranking all of the 298 municipalities in the country according to the rates of stunting observed in the VIIth National Census of the height of first-graders [4], conducted in 1997. The 70 municipalities with the highest rates of stunting were considered eligible for the program. Three of these municipalities, ranked 52, 54, and 55, were geographically removed from the remainder and were therefore replaced with municipalities 71 through 73 in order to facilitate project operations. Of the 70 eligible municipalities, 40 were selected by lottery to actually receive the transfers.

The Phase II interventions in these municipalities actually comprise two distinct sets of household transfers: one for primary schoolchildren (aged 6 to 12) and one for pregnant women and children under 3. In this analysis, we will consider only the latter, since this is the intervention that is specifically linked to nutrition. All households in the 40 municipalities with young children or pregnant women are eligible to receive the transfer, but they subsequently lose it if they do not keep up to date with prenatal checkups, growth-monitoring, and vaccinations. The transfer has a value of just under US$4 per month, and a maximum of two beneficiaries per household is permitted.

Nicaragua

In Nicaragua, the Social Protection Network (*Red de Protección Social*, RPS) began in late 2000 to operate the pilot phase of a similar program. The program operates in two of the country's 17 departments, selected for their high poverty rates, reasonably good access to schools and health centers, demonstrated organizational capacity, and ease of access from the capital, Managua. Within these two departments, 6 out of a total of 23 municipalities were selected because they met all of the same criteria at the municipal level and, in addition, were already involved in a participatory microplanning program, which it was felt would facilitate project operations. Within the six municipalities, the universe of census districts (*comarcas censales*) was ranked on the basis of a *marginality index*. This index is a weighted combination of average family size, access to potable water, illiteracy rate, and access to latrines and sewage. Forty-two census districts (over two-thirds of the total) with the worst marginality indices were considered eligible to receive the transfers. Of the 42 eligible census districts, 21 were selected by lottery to actually receive the transfers.

The program interventions include two sets of household transfers: one for primary schoolchildren (aged 7 to 13) and one universal transfer. In this analysis, we will consider only the latter, since this intervention was planned to raise household income by an amount equivalent to two-thirds of the difference between the average income of an extremely poor household in the region and the cost of purchasing a minimal food basket. Virtually all households (97.5%) in the 21 census districts were eligible to receive the transfer, exceptions for those that reported owning a vehicle of some kind or more than 14 hectares of farming or grazing land. Beneficiary households are required to take part in a program of health education and to attend child growth and development monitoring sessions and keep vaccinations up to date if they have children in the appropriate age group (zero to five years). Their attendance at these sessions is monitored, and they face discontinuation of their benefits if they fail to attend. The transfer has a fixed value of approximately US$19 per household per month.

Mexico

In Mexico, the Education, Health, and Nutrition Program (*Programa de Educación, Salud y Alimentación*, Progresa) has been undertaking similar activities since 1996. The current analysis refers to Phase II of the program, which began making transfers in March 1998,* following an initial phase implemented in just 9 of Mexico's 32 states. Phase II was implemented in 14 states, selected for a variety of reasons, including the large numbers of poor people living there. Within these states, localities with more than two dwellings were ranked according to a marginality index based on a weighted combination of adult literacy; access to potable water, drainage, and electricity; average number of occupants per room; proportion of dwellings with a dirt floor; and share of the population working in the primary sector. Nationwide, approximately three-quarters of all localities were characterized as having high or very high marginality according to this index, and only these localities were considered for inclusion in Phase II of the program. In addition, localities with fewer than

* This description of the beneficiary selection process draws on Skoufias et al. [5].

50 or more than 2,500 inhabitants were then excluded, as were those that were very geographically isolated. Also excluded were those localities without easy access to primary or secondary schools. In total, Phase II of Progresa was implemented in 12,210 localities out of a total of 105,000 nationwide.

Within localities, data were collected at the household level in order to form an index that discriminated between the "poor" and the "nonpoor." The index was a weighted mean of the ratio of family members to the number of rooms in the household, the age of the household head, the dependency ratio, the level of schooling and occupation of the household head, the number of children aged 5 to 15 not attending school, the number of children under 12 years of age, and binary variables characterizing the housing and the asset holdings of the household. In the early stages of the program, the Progresa beneficiary selection method led to approximately 52% of the households in a carefully constructed evaluation sample being classified as eligible for the program benefits. However, by July 1999, Progresa had added new households to the list of beneficiaries through a process called "densification," supposedly intended to remove a bias identified in the original selection method against the elderly poor who no longer lived with their children. In effect, however, the densification process simply relaxed the income exclusion criterion, so that 78% of households in the evaluation sample were classified as eligible following this adjustment.

Like the other two programs, Progresa has an education component and a health and nutrition component. In this analysis, we consider only the latter. The health and nutrition component is made up of several elements, including a fixed monthly transfer of around US$13 per household, which is conditioned on all household members attending scheduled preventive health checkups at their nearest health center. In addition, pregnant and lactating women, children aged four months to two years, and malnourished children aged two to five years are given regular food supplements, and beneficiary families, particularly mothers, are required to attend nutrition and health education lectures. Attendance at checkups and lectures is monitored, and beneficiaries are threatened with the loss of their benefits if they do not comply.

Table 1 provides a summary of the beneficiary selection procedures in each of the three programs.

Analytic methods

The current analysis focuses on economic welfare and vulnerability to undernutrition as two aspects of deprivation that are targeted by the three programs reviewed. As our measure of undernutrition, we use aged-standardized linear growth, expressed as height-for-age Z scores [6]. This indicator has been selected by a World Health Organization (WHO) expert committee as being the most appropriate for the identification of priority populations for health and economic interventions [7]. As our measure of economic welfare, we use the annualized money value of all goods and services consumed by the household, divided by the number of individuals enjoying this consumption (a quantity referred to by economists as *per capita household consumption*). This variable is easier to measure than household income in a developing country context and is less subject to abrupt short-term fluctuations [8]. Deaton and Zaidi [9] present a detailed discussion of how consumption aggregates are constructed in practice.

The statistical analysis aimed to characterize the national populations of each country with respect to child anthropometric status and household income,

TABLE 1. Beneficiary selection procedures in the three programs

Feature	PRAF/IDB Phase II (Honduras)	RPS Pilot (Nicaragua)	Progresa Phase II (Mexico)
No. of households	> 70,000	> 5,000	> 340,000
Geographic targeting[a]			
Broad	None	Poverty-based + criteria favoring less vulnerable areas	Poverty-based + other criteria
Midlevel	Based on prevalence of stunting in 1st graders	Poverty-based + criteria favoring less vulnerable areas	None
Precise	None	Poverty-based	Poverty-based + other criteria
Household-level assessment	None	Poverty-based (minimal)	Poverty-based

a. Broad geographic targeting refers to departments in Honduras and Nicaragua, and states in Mexico; midlevel refers to municipalities in all three countries; and precise refers to communities, defined as villages (*aldeas*) and smaller in Honduras, census districts (*comarcas censales*) in Nicaragua, and *Areas Geográficas Básicas* in Mexico.

and then to characterize the beneficiary pools of each program relative to their respective national distributions. For both anthropometric status and the proxy measures of household income, nationally representative data sources described in the following section were used to determine the cutoff points dividing the entire population into 10 equal-sized groups (deciles). For example, the 1998 Nicaragua Living Standards Measurement Survey (www.worldbank.org/lsms) was used to determine the values of the income proxy that divided the poorest 10% of households in the country from the remaining 90%, the poorest 20% from the remaining 80%, the poorest 30% from the remaining 70%, and so on, up to the 90% cutoff. Similarly, the 1996 Honduras National Micronutrient Survey [10] was used to determine the values of height-for-age Z score that divided the 10% most severely stunted children in the country from the remaining 90%, the 20% most severely stunted children from the remaining 80%, and so on. Using these cutoff values, households (in the case of the income proxy) and children (in the case of nutritional status) in the beneficiary pool were classified into the appropriate national decile. For example, the height-for-age Z score was calculated for each child under three years of age in the RPS baseline survey, and this Z score was classified into one of the 10 national deciles of height-for-age Z score determined from the 1998 Nicaragua Living Standards Measurement Survey. Assuming that the beneficiaries were drawn from a population that exactly resembled a random draw from the entire national population (no targeting), one would find equal numbers of program eligibles in each national decile group. On the other hand, if the program were effectively targeted to the most vulnerable, then one would tend to find relatively more eligibles in the lower national deciles, and fewer in the higher deciles.

Comparing expenditure (income) levels in national and beneficiary pool samples raises particular problems, since assessing household expenditures is laborious and therefore is usually restricted to relatively small survey samples. Furthermore, there is no single standardized method, so it would be difficult to ensure that data on program eligibles and nationally representative data were perfectly comparable. In the case of Honduras, PRAF/IDB Phase II households could be readily identified in the nationally representative data set, but this was not the case either for Nicaragua or for Mexico. In order to circumvent this difficulty, an alternative procedure was used for the latter two case studies. The procedure used has become familiar in the context of “proxy means testing” and is described in detail by Grosh and Baker [11]. The method involves the following steps.

First, in the nationally representative datasets described in the following section, variables strongly associated with per capita household expenditures are identified by regressing, in the nationally representative dataset, log per capita household consumption expenditure on a series of variables representing location, housing quality, family characteristics, and ownership of durable goods. All of these variables are known from previous studies to be strongly associated with poverty at the household level. Irrelevant variables (those that are not associated with the expenditure variable) are eliminated from the model by using a backwards stepwise procedure. The final models for Nicaragua and Mexico are shown in the Appendix, Tables A1 and A2. In the original application of the method, Grosh and Baker were able to explain approximately 41% of the total variation in log per capita household expenditures in Jamaica ($R^2 = 0.41$) [11]. Broadly similar levels of goodness of fit have been found in other applications, and indeed it is unlikely that much better predictive models will ever be forthcoming, since there is expected to be some idiosyncratic (and thus intrinsically unpredictable) variation in economic well-being, as well as short-term seasonal variation. Our model for Nicaragua explained 51% of the total variation in log per capita household expenditures, and our model for Mexico explained 56% of the variation.

The second stage of this procedure is to use the coefficients derived from these regressions to predict per capita expenditures among the universe of program eligibles. In order for this to be possible, all of the variables identified as important predictors of per capita household expenditures in the nationally representative dataset must be known for all of the program eligibles. This was the case for Progresa (Mexico) and RPS (Nicaragua), because the data collection procedures had been designed with this in mind. The resulting prediction, or score, has the significant advantage that it can be interpreted as a multidimensional measure of poverty and is independent of changes in price levels. At the household level, the score is an imprecise estimator of actual expenditure levels, but when households are grouped into large categories such as deciles, misclassification is less of a concern.

It should be noted that for child anthropometry, the exact age groups analyzed varied from country to country because of data limitations; within each country, however, the same age group was used for the nationally representative data and for the program eligibles.

Data

A variety of different data sources were used in this analysis. For each country and each indicator (child anthropometric status and household income), we used one source of data to identify a national reference distribution, and another—usually different—data source to identify the distribution of the indicator among households (or individuals) in the beneficiary pool. These latter households or individuals, who would have been beneficiaries had the program been operating at the time they were surveyed, we term *eligibles*. In all cases, the information used to characterize eligibles predates the beginning of the program by a small margin, in order to ensure that the data capture preintervention characteristics of the beneficiary pool, and not program impact. As far as possible, the national data are from the same time period. In the case of PRAF/IDB Phase II (Honduras), eligibles could easily be identified from the national data sources, since the only criterion for eligibility was municipality of residence, and the coverage of the program is relatively large. The various data sources used in this article are identified in table 2. Each survey is then described in some detail in the following paragraphs.

Nationally representative data on child anthropometry

The Honduran National Micronutrient Survey of 1996 is a nationally representative survey of 1,151 households, each with at least one child aged 12 to 71 months [10]. The survey was carried out by the Ministry of Health, with the administrative and logistic support of the International Eye Foundation and funding from the United States Agency for International Development. Because the sample was stratified by broad geographic region, the data must be weighted to obtain nationally representative summary statistics. Height-for-age Z scores are available for 1,705 children.

The Nicaragua 1998 Living Standards Measurement Survey is a multipurpose household survey implemented by the Nicaraguan National Statistics and Census Institute (INEC) and available from the World Bank (www.worldbank.org/lsms). Because the sample was stratified by broad geographic region, the data must be weighted in order to obtain nationally representative summary statistics. Height-for-age Z scores are available for 1,643 children under 36 months of age.

The Mexican National Nutrition Survey 1998–99 is a very large, nationally representative survey undertaken by the Mexican National Institute for Public Health (INSP) [12]. Height-for-age Z scores are available for 7,589 children under five years of age. Because a complex, multistage sampling procedure was used, the data must be weighted to obtain nationally representative summary statistics.

Data on child anthropometry: program eligibles

The Honduran National Micronutrient Survey of 1996 [10] also provides information on PRAF/IDB Phase II program eligibles, since 229 of the children surveyed (13%) were living in the 70 municipalities that later became eligible to receive the PRAF/IDB Phase II Nutrition and Health Bonus. By applying the appropriate survey weights, these children can be compared with those living in other, noneligible areas.

The RPS baseline survey was designed by the International Food Policy Research Institute for the Social Protection Network and implemented by the National Statistics and Census Institute (INEC) in 2000. Because the sample was stratified by census district, the data must be weighted to obtain summary statistics that are representative of the entire beneficiary pool. Height-for-age Z scores are available for 755 children under 36 months of age.

The Progresa baseline survey was designed and conducted by the Mexican National Institute for Public Health in 1998 in a special evaluation sample. The sample was stratified to include each of the major regions where the program was operating, but it should be noted that two states with relatively high prevalences of stunting—Oaxaca and Chiapas—were not repre-

TABLE 2. Data sources used to characterize the targeting performance of the three programs

Data type	Program	Nationally representative data	Eligibles[a]
Child anthropometry	PRAF/IDB Phase II (Honduras)	National Micronutrient Survey, 1996 [10]	
	RPS (Nicaragua)	Living Standards Measurement Survey, 1998[b]	RPS Baseline Survey, 2000[c]
	Progresa (Mexico)	National Nutrition Survey, 1998–99 [12]	Baseline Survey, 1998[c]
Income proxy	PRAF/IDB Phase II (Honduras)	National Household Consumption, Income, Expenditure, and Nutrition Survey, 1993–94 [13]	
	RPS (Nicaragua)	Living Standards Measurement Survey, 1998*b*	Beneficiary Census, 2000[c]
	Progresa (Mexico)	National Survey of Household Income and Expenditures, 1996 [14]	Beneficiary Census, Phase 2 Evaluation Sample, 1997[c]

a. Eligibles are children or households that would have been beneficiaries had the program been operating at the time they were surveyed.
b. www.worldbank.org/lsms
c. Unpublished data.

sented. Height-for-age Z scores are available for 1,957 children under 36 months of age.

Nationally representative data on the value of household consumption

The Honduran National Household Consumption, Income, Expenditure and Nutrition Survey of 1993–1994 was a nationally representative survey of 2,727 households [13]. The survey was carried out with the technical support of the IMPACT project and funding from the United States Agency for International Development. Because the sample was stratified by broad geographic region, the data must be weighted to obtain nationally representative summary statistics. Per capita household consumption expenditure was measured for all households.

The Nicaragua Living Standards Measurement Survey collected data on per capita household consumption expenditure for 4,040 households out of a total of 4,209 included in the survey. However, in order to facilitate comparison with the RPS eligible households, for which contemporaneous expenditure data were not available, observed values of per capita household consumption expenditure were replaced with predicted scores (see Analytic Methods, above). The prediction equation used accounted for 51% of the total variation in the per capita household consumption expenditure variable ($R^2 = 0.51$).

The Mexican National Survey of Household Income and Expenditures (1996) is a multipurpose household survey undertaken by the Mexican Institute of Statistics, Geography, and Informatics (INEGI) [14]. Because the sample was stratified by broad geographic region, the data must be weighted to obtain nationally representative summary statistics. Per capita household consumption expenditure is available for 13,649 of the 14,042 households included in the survey. However, in order to facilitate comparison with the Progresa eligible households, for which contemporaneous expenditure data were not available, observed values were replaced with predicted scores (see Analytic Methods, above). The prediction equation used was associated with an R^2 of 0.55.

Data on the value of household consumption: program eligibles

The Honduran National Household Consumption, Income, Expenditure and Nutrition Survey of 1993–1994 [13] also provides information on PRAF/IDB Phase II program eligibles, since 398 of the households surveyed (15%) were living in the 70 municipalities that later became eligible to receive the PRAF/IDB Phase II Nutrition and Health Bonus. By applying survey weights, these households can be compared to those located in noneligible areas.

The RPS beneficiary census was designed by the International Food Policy Research Institute for the Social Protection Network and implemented by the National Statistics and Census Institute (INEC) in 2000. The records contain all the data required to construct a predicted expenditure score that can be directly compared with data from the Nicaragua Living Standards Measurement Survey (see Analytic Methods, above).

The Progresa Beneficiary Census (Phase II, evaluation sample) contains detailed socioeconomic data on 24,077 households in the 506 localities sampled for the evaluation of the program. The sample was stratified to include each of the major regions where the program was operating. The information in the census was that used by the Progresa administration to select households eligible for the benefits of the program. The records also contain all the data necessary to construct a predicted expenditure score that can be directly compared with data from the National Survey of Household Income and Expenditures [14].

Results

Nutritional status

The distribution of program eligibles, according to national decile of height-for-age Z score, is presented in table 3. In each case, approximately one-fourth of program eligibles are drawn from the lowest decile of the national distribution, and 45% to 52% of eligibles are drawn from the lowest quintile. The vast majority (78% to 88%) of program eligibles are drawn from the lower half of the national distributions. In general, the three programs have very similar beneficiary profiles, although the RPS (Nicaragua) performs slightly better than the other two programs in focusing benefits on the most vulnerable.

Income proxy

The distribution of eligible households, according to national decile of income (as proxied by the predicted expenditure scores), is presented in table 4. All three programs achieve an impressive concentration of resources in favor of the poorest households in their respective countries. In the case of PRAF/IDB Phase II (Honduras) and Progresa (Mexico), 22% of eligible households are drawn from the poorest decile of the national distribution, with this proportion rising to nearly one-third in the case of RPS (Nicaragua). Approximately 40% of PRAF and Progresa eligible households are drawn from the poorest quintile nationally, and 55% of RPS eligible households fall into this category. Nearly 90% of PRAF and RPS eligible households are from the poorer 50% of households in each country, whereas only 71% of Progresa households meet this criterion. It is worth noting that, since poorer households tend to be larger, in all three cases the concentration of resources in favor of the poorest *individuals* in the respective countries is even higher than the respective figures for households.

The somewhat poorer performance of Progresa as compared with the other two programs is partly explained by the outcome of the "densification" procedure. Figure 1 shows that this process markedly increased the proportion of beneficiaries drawn from the upper half of the national income distribution, from 16% to 29%. Had this densification not been conducted, the profile of eligibles for Progresa would have looked very similar to that of the other two programs.

TABLE 3. Distribution of program eligibles according to national decile of height-for-age Z score

Decile	PRAF (Honduras)	RPS (Nicaragua)	Progresa (Mexico)
	% distribution of children of eligible households		
1	24.2	26.6	25.8
2	20.9	24.9	18.9
3	15.8	16.1	15.2
4	9.7	10.9	11.3
5	9.6	9.2	6.7
6	5.6	3.1	6.9
7	4.9	3.3	4.9
8	3.2	4.2	4.3
9	4.4	1.5	3.0
10	1.8	0.4	3.0
	Cumulative %		
1	24.2	26.6	25.8
2	45.0	51.5	44.6
3	60.8	67.6	59.8
4	70.6	78.4	71.1
5	80.2	87.6	77.8
6	85.7	90.7	84.8
7	90.6	94.0	89.7
8	93.9	98.1	94.0
9	98.2	99.6	97.0
10	100.0	100.0	100.0

TABLE 4. Distribution of eligible households according to national decile of income

Decile	PRAF (Honduras)	RPS (Nicaragua)	Progresa (Mexico)
	% distribution of eligible households		
1	22.1	32.6	22.0
2	20.4	22.4	17.6
3	24.4	15.2	12.4
4	12.6	10.7	10.5
5	9.2	8.7	8.5
6	4.8	4.6	9.6
7	3.6	2.8	7.3
8	0.3	2.0	5.2
9	0.4	0.7	5.0
10	2.3	0.2	2.0
	Cumulative %		
1	22.1	32.6	22.0
2	42.5	55.0	39.5
3	66.9	70.2	51.9
4	79.5	80.9	62.4
5	88.6	89.6	70.9
6	93.5	94.3	80.5
7	97.0	97.1	87.8
8	97.3	99.1	93.0
9	97.7	99.8	98.0
10	100.0	100.0	100.0

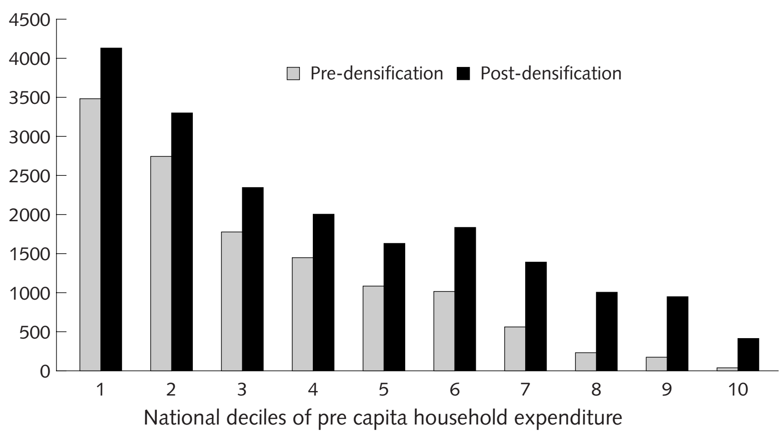

FIG. 1. Eligible households in the Progresa evaluation sample, before and after densification

With respect to PRAF/IDB Phase II, it is worth noting that the demographic targeting of the nutrition and health transfer played an important role in ensuring that the poorest families captured most of the program benefits. Figure 2 shows that among households living in the 40 municipalities ultimately selected to receive the transfers, the presence of a child under three or a pregnant woman was far more common among the poorest households than among the less poor ones. It could be argued that this is because the predicted expenditure variable has been expressed on a per capita basis, making larger families with more children appear poorer. However, re-expressing this indicator on a per adult equivalent basis* attenuated but certainly did not eliminate this association: 70% of households in the poorest decile (per adult equivalent) were eligible to receive the nutrition and health transfer, as compared with 84% when the deciles were expressed on a per capita basis. Similarly, in the least poor decile, 30% of households were eligible when the deciles were expressed on a per capita basis, as compared with 34% when the deciles were expressed per adult equivalent.

Discussion

This article presents recent experiences with targeting from three large, nutrition-focused social programs in Central America and Mexico. The broad developmental goals of the three programs are comparable, and the package of benefits that they offer as a means to achieve these goals is also similar. The main finding of our study is that all three programs have achieved an impressive concentration of resources in favor of the poorest households and those most vulnerable to stunting in their respective countries.

The three programs did differ markedly in scale and in the complexity of their targeting strategies. At one extreme, the PRAF/IDB Phase II project in Honduras used existing data on child nutritional status to pick a limited number of mid-size administrative areas, with no households living in these areas excluded from the program. Phase II of Progresa in Mexico represents the other extreme: this program ranked a very large number of small communities on poverty indicators before making its selection, and then proceeded to collect data on all households within these communities in order to distinguish between the "poor" and the "nonpoor." The RPS program in Nicaragua was interesting in that it combined explicitly pro-poor geographic targeting criteria with a number of other criteria, such as organizational capacity and access to schools and health centers, that one would have expected to favor less poor areas.

We assessed the outcomes of these targeting activities by characterizing the pool of eligibles (people or households that fulfilled all the criteria necessary to become beneficiaries once implementation began) according to reference data derived from representative samples of all households and children in the countries concerned. This permitted us to determine whether the program benefits were being focused toward a group of people who were relatively "vulnerable" according to the national standards of each country or were being sequestered by a group of relatively "nonvulnerable" households. This method of characterizing the beneficiary pool by using an external reference is referred to in the economics literature as analysis of the "incidence" of the program. Unlike a number of alternative approaches, it does not consider the characteristics of those persons who are excluded from the program. It does, however, effectively capture the range of outcomes that are attainable *once the coverage of the program has been agreed upon.* Readers interested in a more sophisticated analysis of the economic welfare losses associated with imperfect targeting in programs like Progresa in Mexico are referred to Skoufias and Coady [15].

Our analysis demonstrates that each of the three programs considered was largely successful in targeting households with a high vulnerability to stunting. This vulnerability was evidenced by the fact that children who would have been program beneficiaries had they been born a few years later (or could have actually become beneficiaries as soon as implementation started) had very low height-for-age Z scores accord-

* The following weights were used: under 3 years of age, one-third of an adult equivalent; 3 to 9 years of age, half an adult equivalent; 10 to 14 years of age, 65 or older, or unknown age, two-thirds of an adult equivalent; male 15 to 24 years of age, nine-tenths of an adult equivalent; female 15 to 64 years of age, three-fourths an adult equivalent.

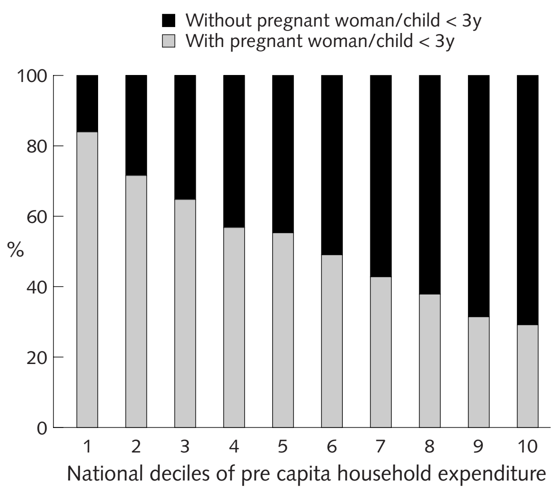

FIG. 2. Proportion of households in intervention area meeting demographic eligibility restriction according to (internal) decile of household income, PRAF/IDB Phase II

ing to their respective national standards. Stunting is a major nutritional problem in Central America and southern Mexico. The three programs were also successful in targeting households that were poor by national standards. This is important, because the poor are known to be at greater risk for a range of negative nutrition and health outcomes, and also for reasons of equity.

There was little evidence to suggest that the use of a specifically nutritional targeting criterion conferred any particular advantage over poverty-based criteria when it came to focusing resources on children at nutritional risk. PRAF/IDB Phase II, for instance, used a nutritional criterion for targeting and yet appeared to have a more progressive incidence when judged by the income yardstick than when judged by child nutritional status. Conversely, the Phase II of Progresa used poverty-based targeting, and yet appeared better targeted when judged according to child nutritional status than when judged on the basis of household income. The targeting efficiency of the RPS (Nicaragua) was similar whether it was assessed relative to nutrition or to poverty.

We deliberately refrain from concluding that any of the three programs was "better" at targeting than the other two, for the simple reason that each country provides unique conditions and challenges and the programs were not designed to be directly comparable. Nonetheless, it is possible to identify a couple of design features of particular programs that substantially affected the targeting outcomes. Our first concern is the "densification" process in Progresa. This allegedly sought to redress a bias against the elderly poor no longer living with their children, but ended up adding to the beneficiary pool substantial numbers of households from the upper half of the national distribution of income. Second, in the case of PRAF/IDB Phase II, restricting benefits to households with young children or pregnant women proved to be a highly effective means of targeting benefits to the poorest. This finding was not dependent on expressing economic well-being on a per capita basis. It is consistent with previous work by Coady and Skoufias [16], who showed that in Mexico, a combination of demographic and poverty targeting would produce the greatest welfare gains in a Progresa-style program. Finally, the very good targeting performance of the RPS (Nicaragua) adds weight to the conclusions of Grosh and Baker [11] and of Morris [17], who showed, using simulation data, that geographic targeting based on very small territorial divisions tends to produce better outcomes than that based on larger divisions.

Of the three programs considered, only Progresa excluded a significant number of less-poor households within the communities that it covered. Although the Nicaraguan RPS applied a household-level exclusion criterion, this was based on characteristics so unusual in the intervention area that virtually no households were affected (just 2.5% of all otherwise eligible households). In contrast, 48% of households in the Progresa evaluation sample were excluded by the original algorithm, and 22% were still excluded after densification. Clearly, the potential benefits of conducting household-level targeting within communities depend critically on the how heterogeneous those communities are. In homogeneously poor communities, virtually no households will be excluded, and the added value of conducting the household-level screening will be minimal. Adato [18] has raised a number of important questions about the impact that household-level targeting may have had on community cohesion in the Progesa communities in Mexico. She suggests that most households found the administrative distinction between "poor" and "nonpoor" to be arbitrary. This is probably because most households in the intervention communities were clustered close to one side or the other of the administrative cutoff value for eligibility, and were thus genuinely similar. On the other hand, as programs such as those considered here expand beyond the initial "priority regions" into more heterogeneous areas, they are forced to consider carefully the costs that they would incur by including significant numbers of the less poor. Probably the most important preparatory activity for any program wishing to focus its activities on the most vulnerable is a careful analysis of the heterogeneity of potential beneficiary communities.

The cost of the different targeting strategies has not been considered in this paper. In each case, the geographic targeting was virtually cost-free, since the relevant data existed already and only had to be tabulated and examined. It is important to note, however, that the marginality indices used in Mexico and Nicaragua can only be updated following a national census, which usually happens only every 10 years. Events such as hurricanes, droughts, and sector-wide economic crises can substantially alter the geographic distribution of poverty within a country, raising doubts about the continuing validity of population-census-based measures. School-height censuses, on the other hand, are cheap and can be updated regularly. As for household-level targeting, this would have been highly costly had the three programs not in any case needed to conduct a full census of the beneficiary areas in order to set up their administrative databases. Given this requirement, the marginal cost of collecting limited poverty data for each household was small.

Conclusions

The three programs reviewed differed markedly in scale and in the complexity of their targeting strategies, yet each of them succeeded in reaching some of the poorest households in their respective countries, as well as reaching some of the children at highest risk for stunting. Although a direct comparison would be imprudent because the program settings were quite different in terms of the heterogeneity of the target population, a number of lessons may be learned for future program planning. The first of these is that—at least in Mesoamerica—it appears that data on the geographic distribution of stunting can appropriately be used for poverty targeting, and data on the geographic distribution of poverty can appropriately be used for targeting children at risk for stunting. Second, program implementers working in relatively homogeneous rural communities should think carefully before embarking on household-level screening, since this is always more costly than geographic targeting, and may in some cases have relatively few benefits. Third, demographic targeting in favor of households with pregnant women or young children will in many locations have the additional advantage of concentrating resources among the poorest households.

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Appendix

Appendix tables A1 and A2 present the regression models used to identify the different factors associated with per capita household expenditure in Nicaragua and Mexico, respectively. The same results were used to predict per capita expenditure levels for eligible RPS and Progresa households, since all the variables entering the regression models were known for the universe of eligible households.

TABLE A1. Predictive model used to estimate the logarithm of per capita household expenditures in Nicaragua

Variable	Coefficient	*SE*	*t*	*P* >|*t*|
Central region, rural area? 1 = Yes, 0 = No	–0.1566	0.0240	–6.530	0
Own house, but title not registered? 1 = Yes, 0 = No	–0.0942	0.0240	–3.934	0
Floor of house of cement tiles, mosaic, or terrazo? 1 = Yes, 0 = No	0.2446	0.0481	5.090	0
House has kitchen? 1 = Yes, 0 = No	0.3404	0.0523	6.503	0
House has air conditioning? 1 = Yes, 0 = No	1.7091	0.4913	3.479	0
Household owns cattle? 1 = Yes, 0 = No	0.2222	0.0280	7.938	0
Someone in household owns motor vehicle? 1 = Yes, 0 = No	0.4437	0.1031	4.302	0
Someone in household owns fumigating pump? 1 = Yes, 0 = No	0.1189	0.0333	3.573	0
Someone in household owns cassette player? 1 = Yes, 0 = No	0.1170	0.0244	4.798	0
Household used fertilizer in last 12 mo? 1 = Yes, 0 = No	0.1207	0.0312	3.862	0
Someone in household has a loan? 1 = Yes, 0 = No	0.1577	0.0366	4.304	0
House lit by gas, kerosene, or oil lamp? 1 = Yes, 0 = No	–0.1236	0.0274	–4.514	0
House does not have toilet? 1 = True, 0 = False	–0.1043	0.0254	–4.103	0
Roof of house made of straw or similar material? 1 = Yes, 0 = No	–0.2044	0.0441	–4.637	0
Family size (log)	–0.4453	0.0301	–14.779	0
No. of persons in household who are employers or cooperative members	0.2146	0.0439	4.890	0
No. of workers in nonagricultural sector in household	0.0719	0.0181	3.973	0
No. of self-employed in nonagricultural sector in household	0.1288	0.0275	4.676	0
No. of family members per sleeping room	–0.0988	0.0160	–6.180	0
No. of family members per sleeping room (squared)	0.0048	0.0011	4.415	0
Age of household head (squared)	0	0	–3.066	0
Constant	9.1974	0.0521	176.426	0

R^2 = 0.51; root mean square error = 0.48

TABLE A2. Predictive model used to estimate the logarithm of per capita household expenditures in Mexico

Variable	Coefficient	SE	t	$P > \|t\|$
House wall made of cardboard, tarpaulin, sheeting, or tires? 1 = Yes, 0 = No	0.2119	0.3348	0.633	0.527
House wall made of reed, bamboo, palm, or shingle? 1 = Yes, 0 = No	0.1292	0.0603	2.143	0.032
House wall made of mud or wattle-and-daub? 1 = Yes, 0 = No	–0.0537	0.0518	–1.038	0.299
House wall made of metal, fiberglass, or plastic? 1 = Yes, 0 = No	–0.2854	0.1816	–1.571	0.116
House wall made of wood? 1 = Yes, 0 = No	0.094	0.0454	2.069	0.039
House wall made of concrete slab? 1 = Yes, 0 = No	0.2918	0.4678	0.624	0.533
House wall made of adobe, dry-wall, brick, or block? 1 = Yes, 0 = No	0.124	0.0408	3.042	0.002
House has access to piped water? 1 = Yes, 0 = No	0.0233	0.0509	0.458	0.647
Bathroom has running water? 1 = Yes, 0 = No	0.2667	0.0647	4.122	0
Someone in household owns a radio? 1 = Yes, 0 = No	–0.0289	0.0238	–1.214	0.225
Someone in household owns a TV? 1 = Yes, 0 = No	0.0957	0.0238	4.018	0
Someone in household owns a blender? 1 = Yes, 0 = No	0.0636	0.0246	2.587	0.010
Someone in household owns a refrigerator? 1 = Yes, 0 = No	0.0851	0.0285	2.990	0.003
Someone in household owns a washing machine? 1 = Yes, 0 = No	0.0617	0.0344	1.797	0.072
Someone in household owns a gas stove? 1 = Yes, 0 = No	0.1696	0.0275	6.172	0
Someone in household owns a fan? 1 = Yes, 0 = No	0.0576	0.0272	2.120	0.034
Someone in household owns a VCR? 1 = Yes, 0 = No	0.1555	0.0409	3.798	0
Someone in household owns a stereo? 1 = Yes, 0 = No	0.0697	0.0324	2.151	0.032
Someone in household owns a heater? 1 = Yes, 0 = No	0.0601	0.0684	0.879	0.379
Someone in household owns an automobile? 1 = Yes, 0 = No	0.1304	0.0602	2.167	0.030
House floor is dirty? 1 = Yes, 0 = No	–0.0700	0.0244	–2.875	0.004
Age of household head	0.0047	0.0011	4.411	0
Household head started but did not complete primary school? 1 = Yes, 0 = No	–0.0243	0.0239	–1.017	0.309
Household head completed primary school? 1 = Yes, 0 = No	0.0018	0.0325	0.055	0.956
Household head started but did not complete middle school? 1 = Yes, 0 = No	–0.0723	0.0765	–0.944	0.345
Household head completed middle school? 1 = Yes, 0 = No	0.1077	0.0490	2.200	0.028
Household head started but did not complete high school? 1 = Yes, 0 = No	0.3909	0.1172	3.335	0.001
Household head completed secondary school? 1 = Yes, 0 = No	0.1955	0.0968	2.020	0.044
Household head has post-secondary education? 1 = Yes, 0 = No	1.4971	0.4688	3.194	0.001
Dependency ratio	–0.3550	0.0456	–7.777	0
No. of children in household 0–4 yr old	–0.0569	0.0135	–4.210	0
No. of children in household 5–10 yr old	–0.0947	0.0112	–8.489	0
No. of boys in household 11–14 yr old	–0.1234	0.0183	–6.736	0
No. of girls in household 11–14 yr old	–0.0923	0.019	–4.847	0
No. of males in household 15–19 yr old	–0.1801	0.0186	–9.671	0
No. of females in household 15–19 yr old	–0.1046	0.0187	–5.586	0
No. of males in household 20–34 yr old	–0.1435	0.0176	–8.160	0

continued

TABLE A2. Predictive model used to estimate the logarithm of per capita household expenditures in Mexico *(continued)*

Variable	Coefficient	SE	*t*	*P* >|*t*|
No. of females in household 20–34 yr old	–0.1094	0.0195	–5.603	0
No. of males in household 35–54 yr old	–0.1957	0.0252	–7.762	0
No. of females in household 35–54 yr old	–0.0934	0.0250	–3.740	0
No. of males in household over 54 yr old	–0.2227	0.0304	–7.333	0
No. of females in household over 54 yr old	–0.0903	0.0280	–3.228	0.001
Fraction of children in household working	0.0518	0.1002	0.517	0.605
Fraction of children in household not in school	–0.3312	0.0515	–6.425	0
Ratio of family size to no. of rooms	–0.0243	0.0065	–3.720	0
Twenty-nine indicator variables representing state of residence	—	—	—	0
Constant	6.0202	0.184	32.726	0

$R^2 = 0.56$; root mean square error = 0.46

Dietary intake and nutritional status of young children in families practicing mixed home gardening in northeast Thailand

Steven Schipani, Frits van der Haar, Sangsom Sinawat, and Kandavasee Maleevong

Abstract

One current initiative to assist rural Thai families to increase home food production and security is the implementation of home gardens that produce fish, small animals, and vegetables. This paper presents the results of an investigation comparing seasonal dietary intake and nutritional status among northeastern Thai children in mixed-gardening and nongardening families (n = 30 for each group). Assignment to the gardening group was based on the presence of a mixed garden, whereas nongardening subjects were randomly selected and matched for comparison. Statistical analysis (paired t-*test) indicated that there was no significant difference in the observed biochemical variables (serum retinol, ferritin, hemoglobin) between groups at the* $p \leq .05$ *level. Nutritional status in regard to height-for-weight, weight-for-age, and weight-for-height Z scores was better among children of gardening families, although the differences were not significant. The small sample size and reported results indicate that the relationship between the practice of mixed home gardening and dietary intake and nutritional status needs further investigation.*

Key words: Thailand, vitamin A, iron, 24-hour recall, home gardening

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Introduction

In the aftermath of Thailand's economic crisis, the Thai monarchy and government agencies are actively promoting the establishment of mixed home gardens that produce fish, small animals, and vegetables in order to help bolster home food security. This is especially true in the rural northeastern region, which historically has lagged behind the rest of the nation in terms of economic and social development. Several studies have shown that in the northeast, the poor dietary intake and nutritional status of young children place them at risk for complications arising from vitamin A deficiency, anemia, and protein-energy malnutrition [1–4].

It is well documented that the health and developmental consequences of low vitamin A and iron intake can be severe [5–7]. To control vitamin A, iron, and other nutritional deficiencies on a population basis, the three strategies most frequently employed are supplementation, food fortification, and dietary diversification. Of the three, dietary diversification has been found to be the most sustainable [8]. Furthermore, in rural populations such as that of northeast Thailand, a dietary diversification approach based on mixed home gardening allows beneficiaries to participate directly in improving their nutrition and health status by using traditionally accepted agricultural practices.

An increase in home food production may not always lead to increased consumption, although studies that have examined the dietary patterns of families practicing vegetable cultivation in developing countries show that young children and mothers in such families are indeed eating more vitamin A–rich plant foods [9, 10]. Although several studies exist that examine the impact of vegetable gardening on dietary intake, there is a paucity of information on dietary intake and nutritional status among children residing in households that integrate fish, small-animal, and vegetable production. This paper presents the results of 24-hour dietary recall, anthropometric assessment, and biochemical indices of vitamin A and iron status among young children from a sample of mixed-gardening and nongardening households in northeast Thailand.

Methods

The study was carried out from August 1999 to May 2000 in Yang Si Surat District, Thailand. Yang Si Surat is a typical agricultural district located 450 km northeast of Bangkok in southern Mahasarakam Province. Families practicing mixed gardening were identified by a systematic procedure and were then considered for inclusion on the basis of standard criteria. Data were collected by a team of research assistants consisting of nurses, interviewers, nutritionists, and laboratory technicians from the Nutrition Division of the Thai Ministry of Health, assisted by staff from the district health office. To account for seasonal variation, data were collected during August 1999, December 1999, and May 2000. These periods correspond to the mid-rainy, cool, and late hot season in northeast Thailand. Each round of data collection lasted two days and was conducted at a centrally located community health center. From the 30 households that were identified and enrolled as mixed-gardening families, one young child from each family aged one to seven years was selected for inclusion in the study. The 30 children from gardening households were then matched with 30 children from randomly selected nongardening families on the basis of age, sex, number of siblings, mother's age and education, parents' occupation, religion, family landholdings, and reported annual income. Each of the two groups contained 17 male and 13 female children.

As expected, the size and diversity of mixed gardeners' home production systems was much larger and more diverse than that of nongardeners. The key factor used to differentiate mixed-gardening from nongardening families was the integration of a productive fishpond—an essential component of mixed gardening as promoted by the Thai Monarchy and government agencies—with small-animal husbandry, home vegetable gardens, and a fruit orchard. Because of the agricultural nature of the population, almost all inhabitants of Yang Si Surat plant small gardens and raise some animals for home consumption; therefore it was not possible to match mixed-gardening families with comparable families that did not practice any type of home food production at all. The ethics committee of the Thai Ministry of Health approved the study protocol, and written informed consent was obtained from the children's parents after local authorities had explained the intent of the study.

The mothers of each participating child were interviewed to obtain sociodemographic and 24-hour dietary recall data. If the child's mother was not available, the primary caretaker was interviewed. For children attending primary school, the mother or caretaker was interviewed first, followed by a secondary interview with teachers and the child to account for food the child may have eaten outside the home, i.e., school lunches and snacks. The nutrient values for daily intakes of energy, protein, vitamin A, iron, vitamin C, and fats were derived from 24-hour recall data using the Inmucal version 7 software package developed by Mahidol University. Standing height, weight, age, and sex were recorded and later converted to Z scores based on United States National Center for Health Statistics (NCHS) reference curves [11] using the Epi Info 2000 Nut Stat nutritional anthropometry program [12].

In order to measure serum retinol and ferritin levels, a 5-cc venous blood sample was drawn using a syringe. The sample was immediately transferred to a test tube, wrapped in foil, and then centrifuged within two hours. Serum was drawn off and placed in dark-brown glass containers, wrapped in foil, and frozen for analysis of retinol by high-performance liquid chromatography (HPLC). Serum ferritin was measured by enzyme immunoassay. Hemoglobin concentrations were measured on the spot by transferring a drop of blood directly from the syringe to a cuvette and immediately inserting the cuvette into a new HemoCue device. During each round of data collection, a new container of cuvettes was used. Both retinol and ferritin analyses were performed by experienced technicians at the Institute of Nutrition of Mahidol University (INMU). Comparisons between mean values shown in tables 2 and 3 were made by the paired-sample *t*-test. Statistics were calculated by the computer software package SPSS for Windows version 7.5 [13].

Results

The characteristics of mixed-gardening and nongardening households are presented in table 1. All families identified their primary occupation as rice farming. Although all families reported they were Buddhist, there were no vegetarians in the sample. No children from either group took vitamin or mineral supplements of any kind, nor did their parents. All 60 mothers had completed their primary education; 13% of mothers in the mixed-gardening group and 10% of those in the nongardening group had completed their secondary education. One mixed-gardening family had a retired civil servant residing in the household receiving an annual pension that raised the family's reported annual income to 210,000 baht, an unusually high amount for this population. If this family is excluded, the mean annual income of the gardening families shown in table 1 falls to 34,800 baht.

Table 2 shows the results of 24-hour dietary recalls according to season. For the three seasonal comparisons, there were no significant differences in mean nutrient intakes ($p < .05$) between children from mixed-gardening families and those from nongardening families. During the cool season, the higher protein intake among children from mixed-gardening families was the only comparison that approached significance at $p = .067$. For both groups, children's 24-hour recall data suggest that their diets generally did not supply the recommended daily intake of the reported nutrients [14], regardless of season. During the cool season, the guardians of one child from the mixed-gardening group and two from the nongardening group were unavailable for 24-hour dietary recall interviews. One child from the mixed-gardening group moved away during the cool season, followed by two additional children

TABLE 1. Characteristics of mixed-gardening and nongardening families in Yang Si Surat, Thailand, August 1999

	Mixed-gardening families ($n = 30$)		Nongardening families ($n = 30$)	
Characteristic	Mean	SD	Mean	SD
Annual income (Thai baht)[a]	41,800	39,820	25,582	15,531
Total landholdings (rai)[b]	22.1	11.4	20.7	10.6
Mother's age (yr)	28.5	4.4	29.2	5.5
Participating child's age (mo)	43.1	18.4	48.2	17.3
No. of siblings	1.5	0.5	1.5	0.5
Pond size (m^2)	391.2	605.1	—	—
Vegetable plot size (m^2)	304.8	650.8	60.9	190.8
No. of types of vegetables	9.6	5.9	3.0	3.1
No. of chickens	27.2	24.5	13.8	8.1
No. of ducks	6.7	8.5	2.1	3.7
No. of types of fruit trees	5.5	2.5	2.9	1.6
No. of fruit trees	72.6	64.1	16.6	14.4

a. 1999–2000: US$1 = 40 Thai baht.
b. 1 rai = 1,600 m^2.

TABLE 2. Daily nutrient intake by season among young children in mixed-gardening and nongardening families in Yang Si Surat, Thailand

	Rainy season ($n = 30$ per group)		Cool season ($n = 28$ per group)		Hot season ($n = 27$ per group)	
Nutrient	Mean	SD	Mean	SD	Mean	SD
Mixed-gardening families						
Energy (kcal)	1,108.8	304.7	1,215.1	434.2	1,181.9	453.5
Protein (g)	43.1	15.3	48.2	17.9	39.9	13.2
Vitamin A (IU)	1,306.1	2,507.6	594.5	1117.4	1,066.4	1,499.8
Iron (mg)	5.6	2.2	7.4	5.0	5.6	2.6
Iron: plant (mg)	3.2	1.9	3.8	3.0	3.5	2.1
Iron: animal (mg)	2.3	1.4	3.6	3.5	2.0	1.2
Vitamin C (mg)	41.5	65.0	27.2	29.0	61.1	69.8
Fats (g)	36.3	16.5	38.9	23.7	33.0	17.3
Nongardening families						
Energy (kcal)	1,213.7	512.5	1,157.8	469.1	1,336.1	422.7
Protein (g)	42.1	16.7	40.2	17.7	40.0	12.0
Vitamin A (IU)	902.6	1,690.9	603.2	1,240.8	734.9	1,107.1
Iron (mg)	6.8	5.2	6.2	5.0	6.3	2.2
Iron: plant (mg)	3.7	2.6	4.0	4.	4.2	2.0
Iron: animal (mg)	3.0	4.6	2.2	1.9	2.	1.0
Vitamin C (mg)	22.6	38.1	20.5	27.4	43.2	35.9
Fats (g)	34.7	24.6	30.2	17.8	41.7	21.5

during the hot season. In the hot season, dietary recall data were not obtained for three children from the nongardening group because one moved away from the study area and two guardians were unavailable for interview.

No significant differences in mean hemoglobin, ferritin, or retinol concentrations were found between the two groups for the three seasonal comparisons (table 3). Although the differences were not significant, (p = .13, .10, .70, respectively), the mean serum ferritin levels were consistently higher among the children from nongardening families. In contrast, children from mixed-gardening families consistently had higher mean serum retinol concentrations (p = .11, .10, .41). The observed differences were most pronounced during the hot season, traditionally a time of food scarcity in the region. Except for 6.8% of children from mixed-gardening families during the cool season, no children from either group had ferritin levels below 20 µg/L at any time. Ferritin levels of 12 µg/L or less were not observed in either group during the course of the study. Among children in the mixed-gardening group, 23% had hemoglobin concentrations of 11 g/dl or less during the rainy season. For the cool and hot seasons, the figures were 17.2% and 25.9%, respectively. The percentages of children in the nongardening group with hemoglobin concentrations of 11 g/dl or less were 36.6%, 31%, and 34.4% for the rainy, cool, and hot season measurements, respectively. The percentages of children from mixed-gardening families with serum retinol levels 20 µg/dl or less were 16.6% in the rainy season, 20.6% in the cool season, and 3.7% in the hot season. For the nongardening group, the figures are 10%, 10.3%, and 0%, respectively.

Figure 1 compares mean height-for-age, weight-for-age, and weight-for-height Z scores by season among the mixed-gardening and children from nongardening families. At the onset of the study, the youngest child was 18 months old, and 16.6% of all children were two years of age or younger. Figure 1 shows that as a group, children residing in families that practiced mixed gardening had better overall nutritional status than children of nongardening families. Moreover, the proportions of children from nongardening families with a height-for-age Z score ≤ –2 were 26.6% in the rainy season, 23% in the dry season, and 34% in the hot season. These figures were 20%, 16.7%, and 22% for children from mixed-gardening families. The percentages of children from nongardening families falling below the weight-for-age Z score cutoff value

TABLE 3. Seasonal hemoglobin, serum ferritin, and retinol concentrations among young children in mixed-gardening and nongardening families in Yang Si Surat, Thailand

	Rainy season			Cool season			Hot season		
Measurement	Mean	SD	*n*	Mean	SD	*n*	Mean	SD	*n*
Mixed-gardening families									
Hemoglobin (g/dl)	11.8	1.1	30	11.8	1.2	29	11.5	1.5	27
Ferritin (µg/L)	64.0	31.0	30	56.5	23.8	29	51.6	20.8	27
Retinol (µg/dl)	34.8	16.5	30	31.1	11.0	29	38.2	15.9	27
Nongardening families									
Hemoglobin (g/dl)	11.6	1.2	30	11.7	1.1	30	11.3	1.1	29
Ferritin (µg/L)	76.5	35.2	30	68.6	22.0	29	63.0	21.9	26
Retinol (µg/dl)	29.2	7.6	30	27.6	6.7	29	24.5	11.1	26

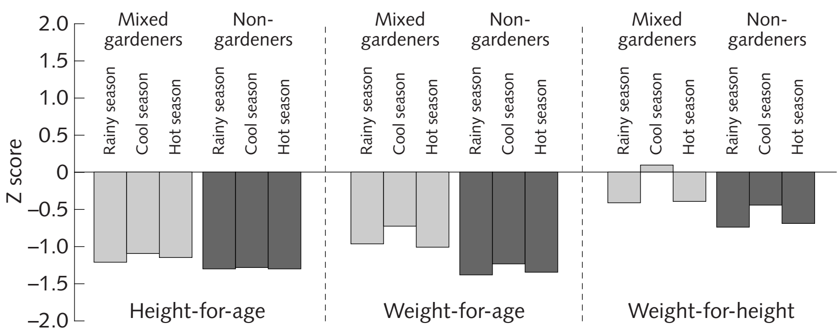

FIG. 1. Mean height-for-age, weight-for-age, and weight-for-height Z scores for children of mixed-gardening (light bars) and nongardening (dark bars) households during the rainy (R), cool (C), and hot (H) seasons, April 1999 to May 2000

of ≤ –2 were 16.6% in the rainy season, 16.6% in the dry season, and 20.6% in the hot season. In comparison, the proportions of children from mixed-gardening families with a weight-for-age Z score ≤ –2 were 10%, 6.8%, and 14.8%. Ten percent of children from mixed-gardening families were ≤ –2 Z scores below the reference median regarding weight-for-height during the rainy season, as compared with 6.6% from the nongardening group. Only one child (3.7%) from the mixed-gardening group was ≤ –2 weight-for-height Z scores during the hot season. Aside from that single child, there were no other observations below the ≤ –2 weight-for-height Z score cutoff point in either group during the cool and hot seasons. The visual discrepancy in figure 1 regarding mean weight-for-height Z scores and reported percentages of children falling ≤ –2 Z scores below the reference median can be attributed to the wide variance in anthropometric data and small sample size.

Discussion

The 24-hour recall results indicate that as a group, the dietary intake of children in both mixed-gardening and nongardening households was generally poor, alarmingly so for certain key nutrients. These findings are similar to a previous assessment of the dietary intake of young northeastern Thai children [1]; however, it has been demonstrated that the 24-hour recall method tends to underestimate average nutrient intakes for a group [15] and does not accurately estimate individual intakes of children [16]. Determining whether the 24-hour method accurately estimates dietary intake was not an objective of this study. We did attempt to obtain reliable measures of the subjects' nutritional status in reference to biological and anthropometric indicators. It is expected that the hemoglobin, ferritin, and retinol values presented in table 3 are reliable because the testing methods used were accurate and repeated seasonal measurements were obtained.

Our major weakness in investigating differences in dietary intake and nutritional status is the small sample size and less than ideal control group. In addition, because many families had recently adopted the practice of mixed gardening, it is not likely that the higher mean height-for-age, weight-for-age, and weight-for-height Z scores indicative of better overall nutritional status resulted from the implementation of mixed gardens. This is especially true regarding height-for-age, because recent nutritional benefits that older children may have derived from consuming home-grown produce would probably not have had a large impact on reversing earlier nutritional insults. The fact that the mixed-gardening group consistently fared better than nongardeners in relation to all three anthropometric indices suggests that children residing in mixed-gardening households are inclined to have better overall nutritional status than children residing in nongardening households. Whether the practice of mixed gardening or other factors are producing this effect deserves further investigation.

For vitamin A, the mean serum retinol levels of children from mixed-gardening families as a group were higher throughout the study, but the percentage of children falling below the World Health Organization (WHO) cutoff point of 20 μg/dl [17] was lower among nongardening families during all three seasons. During the course of the study, there was a very low prevalence of ferritin levels below 20 μg/L among children in both groups; however, 6.8% of children in gardening families fell below this threshold during the cool season. No children fell below 12 μg/L, regardless of season. On the other hand, although the mean seasonal hemoglobin levels were essentially the same for both groups, the proportion of children from nongardening families with hemoglobin levels of 11 g/dl or less was higher than that for children from mixed-gardening families.

One reason underlying these conflicting results may be that a high percentage of families in both groups have attained a level of prosperity (measured by annual income) that allows them to buy adequate amounts of nutritious food. Children in those households would have access to enough healthy food regardless of whether their family produces it in mixed gardens or simply purchases it. The variation in dietary intake and conflicting vitamin A and iron results probably indicates that in this population, diet and nutritional status depend more on child-rearing practices than the possession of a mixed garden. Furthermore, because mixed-gardening families tended to be slightly better off and more open to innovation than nongardening families, matching this group with nongardening households does not provide a true control group for comparison. Clearly more work needs to be done investigating the production patterns and food-consumption habits among mixed-gardening and nongardening families to assess whether or not mixed-gardening families are indeed eating the products of their gardens, and if not, how they are utilizing increases in disposable income derived from the sale or consumption of home-grown produce.

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Evaluation of a rapid field tool for assessing household diet quality in Mozambique

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Abstract

*The Nutrition Section of the Mozambican Ministry of Health recently implemented a low-cost, rapid field tool for assessing the quality of household diets. Such tools can play an important part in targeting development assistance in countries where resources are scarce. This paper evaluates how well the tool performs at describing household dietary intakes in northern Mozambique and explores ways to improve it. The food-group classification and scoring system that form the core of the tool were applied to household data (*n *= 1,140) collected in a previous quantitative diet study in Nampula and Cabo Delgado Provinces. Using mean intakes as a criterion, the diet assessment tool performed well on all nutrients studied, except vitamin A. Those classified by the tool into the top group of diet quality had the highest mean intakes of energy, protein, and iron as well as the highest mean scores on the Mozambican Diet Quality Index, whereas those classified in the bottom group had the lowest intakes. Sensitivity rates for the diet assessment tool could be substantially improved by raising the cutoff point for an acceptable diet from the current threshold of 20 points to 23 points. Regression analysis was used to suggest other possible improvements. Such improvements were only marginal and do not justify field implementation, given the added complexity in classifying and scoring. This paper provides evidence that, with some minor changes, the Ministry of Health diet assessment method can be a useful tool in describing the dietary situation of groups of Mozambican households. Since this tool is both inexpensive and simple to use, there may be interest in adapting it for use in other low-income countries. A series of steps for doing so is outlined at the end of this paper.*

Key words: Mozambique, rapid field tool, diet assessment, 24-hour recall

Introduction

In recent years, governments and development agencies have placed increasing emphasis on rapid appraisal techniques to assess the well-being of their target populations. Pioneered by Chambers [1], these techniques provide an approach that is qualitative in nature and allows for the assessment of various aspects of living conditions. The quick turnaround time is an obvious advantage these approaches have over more traditional surveys that are based on quantitative instruments. Policy makers and program planners often need answers quickly to make informed decisions about resource allocations. Carefully conducted scientific surveys may provide more accurate assessments of certain population indicators, but they will have little impact on decision-making if they are produced with a long lag time.

Realizing the importance of rapid information flow, the Food and Agriculture Organization (FAO) of the United Nations has supported the Nutrition Section of the Mozambique Ministry of Health in the development and implementation of methods to compile food-security and nutrition information in rural districts and urban areas [2–4]. These assessments rely heavily on rapid appraisal techniques. Key informant interviews, community focus groups, and detailed interviews with individual households are used to generate a range of outputs, including a table

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of socioeconomic characteristics of households, an annual calendar of food-security and nutrition stresses, and pie charts outlining sources of income and staple foods for different economic groups. One important part of the profiles conducted in urban areas is a tool used to assess the quality of household diets. The tool is both low in cost and simple to use, which suggests that it might have broader application in low-income countries.

Whether because of disciplinary boundaries or practical programming priorities, relatively few research studies have been conducted to evaluate rapid appraisal techniques with quantitative data. Such work is essential, however, in order to have confidence that these techniques are accurately measuring variables of interest. Research evaluating these techniques is also needed to disseminate the most successful tools to a wider audience.

In this paper, we evaluate the Mozambican Diet Assessment tool that forms part of the urban food-security and nutrition profiles carried out by the Ministry of Health. To implement this tool, field personnel use a simple scoring system to assign points to all foods reportedly consumed in the previous 24 hours. On the basis of the total score, the household's diet is then classified as acceptable, low-quality, or very-low-quality. This methodology was originally developed in Zambia [5]. Is it appropriate to use it in Mozambique? Does it do a good job of classifying groups of households with respect to their dietary intakes? If not, are there simple ways to improve it? We answer these questions by analyzing the scoring system at the heart of this diet methodology with data collected previously in northern Mozambique in the Nampula/Cabo Delgado Study.

Methods

The Mozambican Diet Assessment Tool

The Mozambican Diet Assessment Tool (MDAT) is based on a simple, *qualitative* 24-hour recall of household food intake. The person in charge of food preparation in each household is asked to recall all foods eaten by household members at each meal and snack time in the previous 24 hours. Field personnel, usually the provincial nutritionists, then assign points to each food consumed, using a simple scoring system.

The scoring system gives four points to meats and other animal protein foods, three to legumes, two to cereals, and one to fruits, vegetables, and other foods. Table 1 provides a more detailed listing of the foods in each group. This scoring system was originally developed for use in Zambia [5] and is based on the nutrient density of the food item, how well nutrients from each food are absorbed and utilized, and typical portion sizes. Foods were evaluated on these criteria and assigned to one of the four groups based on the judgment of professional nutritionists. Foods in the meat group contain high-quality proteins and a wide range of other nutrients, so they carry more points than vegetables, which are low in calories, proteins, and most nutrients other than vitamins A and C. Vegetables are also high in phytates, which inhibit absorption of some minerals. Legumes have more nutrients, such as protein and B vitamins, but the protein is of a lower quality and legumes are also high in phytates, so they are assigned fewer points than foods in the meat group. Although condensed milk has many nutrients, including high-quality protein, it is assigned a low score because it is consumed in very small portions (e.g., a spoonful with tea). Nutritionists in Mozambique revised the Zambian tool only slightly. Fluid milk, yogurt, and an egg and milk custard known as *pudím* were assigned to the highest-point group. These dairy products, though consumed infrequently, are high in nutrients and, when eaten, are consumed in portion sizes that can contribute substantially to the nutrient intake for a given day.

Points are assigned to foods for every meal or snack time that they are consumed. Some foods, such as staples, will be listed often and receive points more than once in a day. The points are then added up, and the quality of the household diet is judged based on the total number of points obtained. Diets that score 20 points or more are judged to be of *acceptable* quality. Diets scoring 12 to 19 points are judged to be of *low* quality, and those scoring less than 12 points are judged to be of *very low* quality

The Nampula/Cabo Delgado Study

The Nampula/Cabo Delgado (NCD) study was originally designed to identify the impacts of various smallholder cotton schemes on household incomes and food security in Mozambique [6, 7]. The study was conducted in Montepuez District in Cabo Delgado Province and Monapo and Meconta Districts in Nampula Province. These areas are typical of the interior of northern Mozambique, where maize- and manioc-

TABLE 1. Food grouping system and points assigned in the Mozambican Diet Assessment Tool (MDAT)

Points	Items in food group
1	Vegetables, fruits, juices, other beverages (excluding water, coffee, tea), oils, sugars, butter, jam, mayonnaise, tomato sauce, condensed milk
2	Cereals, tubers, bread, spaghetti, cookies, cakes
3	Beans, groundnuts, coconuts, other nuts
4	Meats, fresh and dried fish, shellfish, eggs, fluid milk, cheese, yogurt, milk, egg custard

based cropping systems predominate and where cotton and cashew are often grown. Using repeated visits on households in 16 villages from 1994 to 1996, the study collected information on a number of household variables, including daily food consumption, during three different periods during the year: May (harvest), September (post-harvest), and January (the "hungry season").

Food consumption was measured by using a 24-hour recall technique at the household level, in which trained enumerators conducted detailed interviews with the person in charge of food preparation. These interviews were conducted on two nonconsecutive one-day visits (about one week apart) during each period, and included the volumetric measurement of household utensils to more closely approximate exact quantities used. Quantitative data on household food consumption were combined with regional food-composition databases to calculate daily household nutrient intakes. The two days of information on each household's intakes were averaged for each period, thus supplying 1,140 observations on 388 households (dietary data were available for all three periods from 94% of households). The nutrients for most foods were obtained from data compiled by West et al. [8], supplemented with values from the food-composition table compiled for Mozambique [9]. Additional details regarding the NCD dietary data have been published previously [10, 11].

Household intakes were compared with international reference standards by summing the recommended intakes for all household members in attendance at meals on the survey days. Each member's recommended intake was determined by the age and sex of the individual. Recommended intakes for energy were also based on reference weight data for Mozambique [12] and include energy needed to maintain weight as well as energy necessary for occupational and "socially desirable" activities [13]. Occupational activities were assumed to be characteristic of a rural population in a developing country, i.e., requiring moderate to heavy energy expenditure. Protein recommendations were based on safe levels of intake, i.e., the average requirement plus two standard deviations, appropriately corrected for reduced digestibility and protein quality of traditional diets [13]. The recommended levels of intake for other nutrients were also based on levels that met the needs of most healthy people, i.e., average requirements plus a safety factor [14].

A composite measure of diet quality, which summarizes key nutrients important to public health in Mozambique, was developed in work on the NCD sample [11]. The Mozambique Diet Quality Index (MDQI) has five components, reflecting the intakes of energy, vitamin A, iron, and protein and a summary measure of dietary variety based on seven other nutrients. A maximum of two points is assigned for each component, so the score on the MDQI, a sum of the five component scores, ranges from 0 to 10. To compute each component score, the adequacy ratio for that nutrient (intake/recommendation) is first computed, then truncated at 1.0 if the household consumed more than the recommended amount, and then multiplied by two. On the basis of the scores on this index, household diets were divided into three categories. Households that scored 7.5 or more on this index were considered to have acceptable diets. Households that scored 6.0 or greater, but less than 7.5, were considered to have diets of low quality. Those that scored less than 6.0 were considered to have diets of very low quality. Note that, for various reasons, it can never be known whether a given diet is truly of low or acceptable quality for a given household. However, the terminology is useful for categorizing groups of households based on relative dietary quality. It is also worth emphasizing the distinction between the MDQI and the MDAT, since both classify diets into three groups and use the same terminology for the different groups. The MDQI is an index used to aggregate detailed information about nutrient intakes obtained from a classical quantitative 24-hour recall, whereas the MDAT is a simple field tool that classifies on the basis of a *qualitative* assessment of foods consumed. We use the MDQI, in addition to the intakes of individual nutrients, as a "gold standard" to judge how well the MDAT performs.

Evaluation of the Mozambican Diet Assessment Tool

The NCD data on the food consumption of households in northern Mozambique were used to assess the MDAT. First, each of the foods in the NCD database was assigned points according to the MDAT food groups described in table 1. Then each household's total points on a given day were summed. Finally, each household's diet for a given day was classified into one of three groups using the MDAT scoring system. After observations were classified into one of the three groups, the nutrient content of the actual amount of food reported consumed on that day was calculated by using food-composition databases described previously. The mean nutrient intakes for observations in each of the three categories of diet were calculated. One-way analysis of variance was used to determine whether the classification based on the MDAT provided groups whose nutrient intakes were significantly different from one another ($p < .05$). Post-hoc multiple comparison testing was performed by Bonferroni's test.

Dichotomous variables indicating when NCD household intakes were below 75% of their RDAs were also created. These variables were used to further assess the categorizations based on the MDAT. Households grouped in the bottom two MDAT categories (low and very low) were combined into one category with diets of "low or very low" quality. Sensitivities (percentage of households with low-quality diets classified by the MDAT as having diets of "low or very low" quality) and specificities (percentage of households with acceptable diets that were classified as having acceptable diets) were calculated in order to better evaluate the MDAT and to suggest possible improvements.

Improvements in the Mozambican Diet Assessment Tool

Various analyses were performed to suggest improvements in the MDAT. One type of analysis explored the sensitivities and specificities obtained by moving the thresholds for different categories of diets, e.g., moving the dividing line between the top two categories from 20 to 23 or more points.

A second set of analyses explored whether MDAT could be improved by altering the points assigned to the currently used food groups. The MDQI variable, since it represents overall diet quality, was used as the dependent variable in a linear regression model in which there were four independent variables, one for each of the food groups. The expression of these food-group variables was simply a count of the number of times in a day the household consumed a food from that group. In a model that predicts overall diet quality from information on food-group consumption, the coefficients on the food-group variables can be thought of as points to be used in scoring. After this regression had been estimated, the coefficients were multiplied by 10 and rounded off so that field personnel would not have to deal with an overly detailed scoring system. In the current scoring system, the points are allocated at 1, 2, 3, and 4 to groups 1 through 4, respectively. The regression analysis suggested an alternative scoring of 2, 2.5, 5, and 2 for the four groups, with the threshold being set at 30 points (see top section of table 5).

A third set of analyses explored whether additional improvements could be made by using linear regression in combination with *different* food groups. Various systems with five, six, and seven food groups were explored, with either MDQI or energy intake as the dependent variable. The results of two such systems are reported here. One system of six food groups began with the original MDAT grouping but split off vitamin A–containing fruits and vegetables into a fifth group and all other fruits and vegetables into a sixth group. Regressions were then run as before, with the MDQI indicator as the dependent variable. Another system of seven food groups took this grouping one step further and broke out energy-dense fruits and vegetables (bananas, fresh beans, fresh peas, etc.) into a seventh group. As before, a regression approach was used to generate points, but this time the dependent variable was the energy/nutrient adequacy ratio (see top section of table 5).

Results

After the MDAT scoring system had been applied to the NCD database, there were 616 observations, or 54.0% of the NCD sample, of diets that were classified as having acceptable quality, whereas 35.3% ($n = 402$) of diets were of low quality. Only 10.7% ($n = 122$) of diets were classified as being of very low quality. Among diets that were classified as having acceptable quality, the mean energy intake was 105.5% of the recommended level (table 2). Among low-quality diets, the mean energy intake was 78.4% of the recommended level, and among very-low-quality diets, it was only 50.1% of the recommended level. Assessment of the mean intakes of protein and iron, as well as the scores on the Mozambique Diet Quality Index (MDQI), also showed a significant ($p < .05$) main effect of the diet quality classification, significant differences between each of the groups on multiple-comparison testing, and an ordering that was in the expected direction. That is, the mean intakes of diets rated as acceptable were higher than those of diets rated as having low quality, which were higher than those of diets rated as having very low quality. The one exception to this pattern was with vitamin A, in which there was no difference between diets rated as acceptable and those rated as low quality. Diets rated as having very low quality actually had higher mean intakes of vitamin A than diets of acceptable or low quality.

TABLE 2. Mean nutrient intakes (% of recommendation ± SEM) of Nampula/Cabo Delgado (NCD) households according to MDAT diet quality classification[a]

	MDAT diet quality classification (no. of points)		
Nutrient	Very low (0–11 points) ($n = 122$)	Low (12–19 points) ($n = 402$)	Acceptable (≤ 20 points) ($n = 616$)
Energy	50.1 ± 2.8	78.4 ± 1.9	105.5 ± 1.7
Protein	56.0 ± 4.2	105.8 ± 3.1	159.6 ± 3.1
Vitamin A	37.4 ± 3.6	29.8 ± 1.9	28.3 ± 1.3
Iron	70.7 ± 5.3	98.2 ± 3.9	136.3 ± 3.5
MDQI (points)[b]	4.8 ± 0.2	6.4 ± 0.1	7.5 ± 0.0

a. The main effect of diet quality classification is significant (ANOVA, $p < .05$) for all nutrients. All pairwise comparisons showed significant differences in means, using Bonferroni's method, except for vitamin A for the "low" and "acceptable" groups, which were not significantly different from each other.

b. MDQI is the Mozambican Diet Quality Index, a composite measure based on the nutrient intakes of energy, protein, vitamin A, iron, and seven other nutrients. On a scale of 0 to 10, diets of acceptable, low, and very low quality are those with 7.5 or more points, 6.0 to 7.5 points, or less than 6.0 points, respectively. See Methods section and Rose and Tschirley[11] for a complete description.

Although the diets classified into separate groups according to the MDAT tool clearly had significant differences in nutritional content, there were many misclassifications with this approach. For example, a sizeable portion of households with low nutrient intakes were misclassified by the MDAT system as having acceptable diets—32.3% of households in the case of energy (table 3). The top half of table 3 shows that misclassification is a problem for the MDAT tool with other nutrients as well, such as protein, vitamin A, iron, and the overall index of diet quality, the MDQI. Correctly classifying those with a low intake is a measure of the sensitivity of a diet assessment tool. When the bottom two groups are combined into a group with diets of "low or very low" quality, the MDAT has a sensitivity of 67.7% for detecting the prevalence of low energy intakes in the NCD sample. Table 3 summarizes the sensitivities of the MDAT-combined tool for other nutrients (top shaded area) and also displays the specificities for these nutrients (bottom shaded area).

When assessment tools indiscriminately classify too many households into a low-intake category, the sensitivity of the tool may be high, but the specificity will show that the tool has not done a very good job of classifying those that have acceptable diets. Sensitivities and specificities are related by the threshold or cutoff point that an indicator uses [15]. The threshold for an acceptable diet currently being used in the MDAT system is 20 points. This means that diets with fewer than 20 points are rated as having "low or very low" quality, and those with more than 20 points are rated as having acceptable quality. Thus, simply by raising the threshold of what is considered an acceptable diet, the sensitivities for predicting low intakes of various nutrients should improve. Table 4 shows that this indeed happens. For energy, as the MDAT threshold is raised from 20 to 29 points, the sensitivity improves from 67.7% to 95.5%. But raising the cutoff point also lowers the specificity. As the MDAT cutoff increases to 29, the specificity for predicting low energy intakes declines from 69.2% to 21.1%. There is clearly a tradeoff between improving sensitivity and improving specificity.

How far should the cutoff be raised to improve sensitivity, thereby sacrificing specificity? A higher sensitivity is desirable to accurately identify most subjects at nutritional risk, as long as false positives do not cause other risks [15]. Although there are no other risks associated with false positives in this case, a high rate would increase the cost of delivering effective services. One simple strategy is to stop at the level that yields a prevalence of low intakes closest to that known to occur in the population. Earlier work showed that the prevalence of diets of "low or very low" quality in the NCD sample, based on the MDQI, was about 60% [11]. The prevalence of diets of "low or very low" quality was also calculated for each of the different cutoff-point groupings in the MDAT system. Not surprisingly, as the cutoff points for an acceptable diet go up, so do the prevalences of a low-quality diet. For MDAT-20 (i.e., MDAT with 20 points as the cutoff between an acceptable diet quality and a low quality), 46% of the observations would be classified as having "low or very low" quality, whereas with MDAT-29 the prevalence rate jumps to 86% (see numbers in parentheses in table 4).

MDAT-23 provides a reasonable compromise, since

TABLE 3. Percentage distribution of NCD households into MDAT diet quality categories[a]

Household nutrient intake	Nutrient	MDAT diet quality classification: Low or very low (< 20 points)	MDAT diet quality classification: Acceptable (≥ 20 points)
Low (< 75% of recommended)	Energy	67.7	32.3
	Protein	83.0	17.0
	Vitamin A	44.1	55.9
	Iron	65.1	34.9
	MDQI[b] (< 7.5)	60.4	39.6
Acceptable (≥ 75% of recommended)	Energy	30.8	69.2
	Protein	34.1	65.9
	Vitamin A	65.0	35.0
	Iron	34.5	65.5
	MDQI (≥ 7.5)	24.6	75.4

a. Percentages in the top left-hand shaded cells represent sensitivity estimates of the MDAT system, whereas those in the bottom right-hand shaded cells represent specificity estimates.

b. MDQI is the Mozambican Diet Quality Index, a composite measure based on the nutrient intakes of energy, protein, vitamin A, iron, and seven other nutrients. On a scale of 0 to 10, diets of acceptable, low, and very low quality are those with 7.5 or more points, 6.0 to 7.5 points, or less than 6.0 points, respectively. See Methods section and Rose and Tschirley [11] for a complete description.

it gives an improvement in sensitivity over the original MDAT-20, and yet yields a good estimate of the overall prevalence of diets of "low or very low" quality, 61% (i.e., very close to the rate found in previous research using the MDQI and full quantitative information on the intake of each nutrient [11]). With the threshold at 23 points, the sensitivities for predicting low intakes improve for all of the nutrients studied.

As can be seen in the first and second data columns of table 5, an alternative four-group scoring system (4GRP)—devised by reassigning points to each food group based on the results of regression analysis—only improves the sensitivity rate of the original tool (with the cutoff point raised to 23, i.e., MDAT-23) with

TABLE 4. Sensitivities and specificities with different thresholds for an acceptable diet

Measurement	Nutrient	MDAT-20[a] (46.0)[b]	MDAT-23 (61.3)	MDAT-26 (74.0)	MDAT-29 (85.7)
Sensitivity (%)	Energy	67.7	81.2	90.6	95.5
	Protein	83.0	90.2	95.6	98.2
	Vitamin A	44.1	60.5	73.6	85.6
	Iron	65.1	77.0	87.6	92.0
	MDQI	60.4	75.4	85.6	92.5
Specificity (%)	Energy	69.2	52.5	37.5	21.1
	Protein	65.9	47.9	32.9	18.3
	Vitamin A	35.0	30.1	21.4	13.6
	Iron	65.5	48.1	34.1	18.1
	MDQI	75.4	59.6	43.0	24.4

a. MDAT-20 refers to the Mozambican Diet Assessment Tool when 20 points is used as the threshold between an acceptable and a low-quality diet. MDAT-23, MDAT-26, and MDAT-29 are tools in which the threshold is set at 23, 26, or 29 points, respectively.
b. Numbers in parentheses refer to the prevalence of diets of low or very low quality in the NCD sample when assessed using each particular MDAT indicator.

TABLE 5. Sensitivities and specificities of alternative point scoring and food grouping systems

Systems		MDAT-23[a] (61.3)[b]	4GRP (59.1)	6GRP (60.7)	7GRP (60.5)
Description of diet assessment tool	Food groups	4 groups from original MDAT	4 groups from original MDAT	Original 4 + vitamin A fruits and vegetables + other fruits and vegetables	6GRP + energy-rich fruits and vegetables
	Points assigned	1, 2, 3, 4	2, 2.5, 5, 2	0, 3, 5, 2.5, 2.5, 2	2, 8.5, 8.5, 5, 0, 3.5, 4
	Acceptable diet threshold	23	30	33	69
Sensitivities (%)	Energy	81.2	79.5	79.9	82.7
	Protein	90.2	90.2	92	92
	Vitamin A	60.5	58.2	60.1	59.2
	Iron	77	78	79.6	79.2
	MDQI	75.4	74.6	76.5	75.4
Specificities (%)	Energy	52.5	55.1	52.7	54.9
	Protein	47.9	50.8	49.3	49.5
	Vitamin A	30.1	32	33	26.2
	Iron	48.1	52.2	50.6	50.6
	MDQI	59.6	63.7	62.6	61.5

a. MDAT-23 refers to the Mozambican Diet Assessment Tool with 23 points as the threshold that divides low-quality and acceptable diets. 4GRP is a four-food-group tool similar to MDAT with different points assigned to each group. 6GRP and 7GRP are six- and seven-group tools developed in regression analysis. See Methods section for additional details.
b. Numbers in parentheses refer to the prevalence of diets of low or very low quality in the NCD sample when assessed using each particular diet assessment tool.

regard to iron. For the other nutrients and overall diet measure, this approach does slightly worse. However, the 4GRP system does better than MDAT-23 on all the specificity measures.

To improve the assessment system even further, regression analysis was tried in combination with different food groups. Various systems with five, six, and seven food groups were explored. The results of the best of these trials are also reported in table 5. The sensitivities of the six-group approach are better for all nutrients than those of the four-group approach, and they are also better than those of MDAT-23 for protein, iron, and MDQI. The specificities of this six-group approach are also better than those of the MDAT-23 for all nutrients studied. Except for doing slightly worse with vitamin A, the seven-group approach improves on the sensitivities and specificities of the MDAT-23 system. It is to be expected that this approach might do worse with vitamin A, since the points for the groups were assigned on the basis of regression results that fit the energy intake variable, which is less correlated with vitamin A intakes than the MDQI variable.

Discussion

This paper examined the diet quality assessment tool used by the Nutrition Section of the Mozambican Ministry of Health in its urban profiles work. This Mozambican Diet Assessment Tool (MDAT) involves the listing of foods consumed in the previous day by the household, the scoring of these foods, and the classification of overall diets based on the total points assigned. To assess this approach, a previous quantitative study of diet in northern Mozambique was employed. This was possible because the earlier Nampula/Cabo Delgado (NCD) study also used a 24-hour recall instrument as a starting point, but then obtained precise quantitative information on household dietary intake.

The MDAT methodology does well in certain respects but falls short in others. NCD diets that were classified as having acceptable quality by the MDAT approach had significantly higher mean intakes of energy, protein, and iron than those classified as having low or very low oil quality. However, for vitamin A, the reverse pattern was observed.

Vitamin A intake is particularly difficult to classify in this population with a composite dietary tool, because the content of vitamin A in many food sources correlates inversely with energy, protein, and other nutrients. In fact, earlier work in this area of Mozambique found that vitamin A intake *improved* slightly in the "hungry season," while the intakes of most other nutrients declined to their lowest levels of the year. The increase in vitamin A intake was due to the reliance on pumpkin squash, leaves, and other fruits and vegetables when staple grains and beans were in short supply [10]. Efforts here to increase the correlation of the MDAT assessment with vitamin A intake by utilizing a separate food group for vitamin–A rich fruits and vegetables were unsuccessful (see table 5). The high variability in vitamin A intakes is not unique to Mozambique, a fact that cautions against the use of a single composite dietary tool to assess all aspects of nutritional intake. A second tool focusing exclusively on vitamin A–rich sources, such as that used by Helen Keller International [16], may be needed to adequately assess intakes of this nutrient.

The misclassification rates by the MDAT system were also a problem. One recommendation for improving the MDAT is to increase the threshold for the upper level of diet quality from the currently used 20 points to 23 points. When tested on the NCD data, this improved the sensitivities for detecting low intakes of all nutrients and yielded a prevalence of "low- or very-low-quality" diets that was similar to earlier work in the study area.

The analyses show that it is possible to devise other improvements in the MDAT system. Various systems of four, five, six, and seven food groups, each using a different scoring method, were tested. Improvements can be seen in the rates at which the six- and seven-group systems classify low-intake diets as low (sensitivity rate) or acceptable-intake diets as acceptable (specificity rate). The revised grouping systems may also have an educational advantage, since the original grouping of the MDAT system puts fruits and vegetables in the same group as sugars and butter, perhaps not the best of messages for nutrition programs to send out to their personnel.

However, the improvements made by these latter systems are relatively minor. In addition, the new scoring systems are more complicated than the very simple system that is in place at present. Although in theory, either of the new systems should give better results, errors in assigning foods to groups, or in assigning points, are more likely. Thus, in practice, a new system based on the six- or seven-group scheme is not likely to generate improvements in the classification of households and so is not recommended for field use in Mozambique.

As with all validation-type studies, there are limitations to this one. First, the analysis at the heart of this report was based on data collected in Nampula and Cabo Delgado Provinces. Although clearly it is better to assess dietary tools for Mozambique by using data from this area than by using data from Zambia, it would have been better to have used a nationally representative dataset. But, as has been pointed out previously, no such dietary dataset exists [11].

Second, it should be noted that the MDAT, as currently designed, is a household-level tool. Thus, if significant disparities exist in the intrahousehold allocation of foods, results based on this tool might misrepresent the conditions of specific individual types, for example, preschool children. If specific individual types are the focus, then the MDAT could be recalibrated to work with individuals. This would require interviewers to modify their questions to ask about consumption by a specific individual in the household. It would also require a validation study using a quantitative dietary dataset that was conducted at the individual level. A further validation research study on the MDAT could correlate the scores with child size or growth or other functional outcomes. However, many other factors besides food consumption, such as water supplies, sanitation, and availability of health services, affect child growth outcomes.

Third, field procedures, such as interviewing techniques or scoring of food recalls, were not evaluated here. However, the field techniques employed in the MDAT are relatively standard and easy to implement. Thus, there is no reason to believe that they would be a major stumbling block in the successful implementation of the MDAT.

In sum, this paper provides evidence that, with some minor changes, the MDAT can be a useful tool for describing the dietary situation of groups of Mozambican households. In the tradition of rapid techniques that have been suggested in previous research [17, 18], this tool is quite easy to implement under the difficult field conditions common to Mozambique and other parts of Africa.

The simplicity of the tool bodes well for its adaptation to other countries. In doing so, nutritionists and other public health workers might want to follow the experience of Mozambique. The process consisted of four main steps.

First, a group of nutritionists, knowledgeable about food-consumption patterns and the prevalence of deficient diets in Mozambique, studied the Zambian tool and made suggestions for changes. Because of broad similarities in the diets, the grouping of foods and assignment of points from the original Zambian tool were left largely intact. Some individual food items were reassigned to different groups based on portion size. For example, dairy products, which have high nutrient densities, were reassigned to the four-point meat group, since when eaten in Mozambique, they are consumed in quantities that contribute substantially to a day's intake of nutrients. Also, the Mozambique tool was used to classify households into three groups, rather than the four groups that were used in the original Zambian tool.

Second, pilot tests were conducted to determine whether the provincial nutritionists and household interviewers could use the tool under field conditions.

Based on the relative success of these tests, a third step was to undertake an analysis with quantitative food-consumption data to verify the scoring system and assignment of diets to different groups. This validation study, the subject of this paper, required a dataset based on a complete quantitative dietary survey. Given such a dataset, one could follow the methods outlined in the Methods section above to carry out this exercise.

As a fourth and final step, modifications developed from the analytical work in the third step (such as changing the thresholds or reassigning points to specific foods) should be incorporated into a training session for field personnel to allow them to use methods tailored for their population.

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Effect of amylase-rich flour (ARF) treatment on the viscosity of fermented complementary foods

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Abstract

Grains of cowpea and maize and slices of fresh cassava, cocoyam, plantain, and yam were steep-fermented in water, while flours from the same plant materials were fermented by backslopping for 24 to 30 hours. The pH and apparent viscosity of the gruels from the resulting flours were determined. Loss in weight due to fermentation was higher in fresh tubers than in dry grains. The pH of the flours decreased during fermentation. Measurements showed that the apparent viscosity only of gruels from flours produced by backslopping decreased after 24 hours. The apparent viscosity of gruels from steep-fermented flours was higher than that of the unfermented flours and those produced by backslopping. The apparent viscosity reduction of gruels from steep-fermented flours using amylase-rich flour (ARF) from five-day white sorghum malt was better with the prepared gruels than when applied to the flour-in-tap-water suspension before it was used to prepare gruels. Viscosity reduction using ARF was also better with the fermented gruels than with gruels from unfermented flours. The implications of these results for the formulation of complementary flour blends for infant feeding are discussed.

Key words: Nigeria, weaning foods, amylase-rich flour, fermentation, viscosity reduction

Introduction

Weaning is the slow adaptation of a child to adult foods while continuing to breastfeed. The weaning period varies from the 4th to the 24th month of life, but the recommended period is to start during the first 4 to 6 months [1] if adequate growth and nourishment are to be ensured. In Nigeria, particularly in rural communities, children are traditionally weaned on cereal- or tuber-based gruels that have been found to be highly viscous, and hence low in nutrient content and energy density. For example, *akamu* (also known as pap) as consumed contains only 0.5% protein and 1% fat, as compared with the 9% protein and 4% fat contents of the original corn [2]. Of the protein content, 98% of the original tryptophan in maize is lost during processing of *akamu*, making it the first limiting amino acid. There are also large losses of niacin [3].

Children under five years of age can consume only limited amounts of highly viscous complementary foods [4]. When the foods are diluted to reduce the viscosity, there is a concomitant decrease in energy and nutrient density to levels below those needed to meet the infant's daily needs. For a four- to six-month-old baby whose calorie and protein needs are 794 kcal (3,322 kJ) and 13 g protein per day, 950 g of *akamu* would be needed to meet these needs. In that case, a child consuming complementary food containing 1,090 kcal/kg (4,564 kJ) would need at least 3 kg of the food per day—which is impossible, considering the child's small stomach capacity. This inadequate food consumption in most cases precipitates protein-energy malnutrition, which is largely responsible for the high infant mortality rate in Nigeria. In addition, iron deficiency, rickets, and scurvy may develop at this time unless supplements are added.

This situation is complicated by several factors: the high cost of the technically standardized, factory-produced infant foods; the poverty of the average Nigerian family, which spends about Naira 400.00 (US$3.00) per month on complementary foods; and the absence of cheap, acceptable, and high-biological-value protein sources from local foods that can be used to supplement breastmilk during weaning. To improve this situation, attempts have been to process and blend flours from local cereals and legumes (whose amino acids are

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complementary) and in some cases to partially substitute tubers for cereals. Processing techniques used for this purpose have been largely fermentation [5, 6] and less often germination [7, 8].

The advantages of fermentation have been reviewed by Nout and Motarjemi [5]. The effect of fermentation on the viscosity of complementary foods is, however, controversial. Although microbial exoenzymes from the fermentation can have a thinning effect on the viscosity due to the hydrolysis of starch and proteins, lowering of the pH of the medium toward the isoelectric point of porridge proteins may induce a neutralizing effect [9, 10] by increasing apparent viscosity. This is a possible reason for using amylase-rich flour (ARF) to complement the thinning effect of fermentation. However, bulk reduction with ARF has cost, processing, and preparation implications that may be resolved by determination of the best method of ARF treatment.

This study was designed to determine how fermentation and treatment with ARF affect the apparent viscosity of complementary feeding gruels.

Materials and methods

Flours were prepared from cassava (*Manihot esculenta*), cocoyam (*Xanthosoma mafaffa*), cowpea (*Vigna unguiculata*), maize (*Zea mays*), plantain (*Musa paradisiaca*), and yam (*Dioscorea rotundata*).

Preparation of flours

Cowpea flour

Cowpea flour was prepared by three methods: cowpea was soaked in water for 30 minutes and wet dehulled, as practiced traditionally (sample A); cowpea seeds were steeped in water for 7 hours and wet dehulled (sample B); or cowpea seeds were soaked in water for 7 hours, dehulled wet, and then fermented in tap water (1:3, w/v) for 24 hours (sample C). The samples were then dried.

Cassava, cocoyam, maize, plantain, and yam flours

Unfermented flours

The maize grains were dried and milled into flour. The tubers were peeled, washed, and divided into two portions each. Portion A of cassava was grated and dried; the cocoyam, plantain, and yams were cut into thin (approximately 1-mm) slices and dried.

Fermented flours

The second portion (portion B) of the tubers was cut into approximately 1-mm slices and fermented in tap water (1:3, w/v) for 24 to 30 hours, as practiced traditionally. The maize grains were steeped in water for the same amount of time (1:3, w/v) and fermented. Fermentation was monitored by determination of pH. After fermentation, the water was drained and the ferments were dried.

Unfermented flours were also fermented by the backslopping method of Nout et al. [11] for 36 hours. Fermentation by backslopping involves the gradual selection of lactic acid bacteria as the principal fermenting microorganisms by repeated recycling of ferments as inoculum. Sixty grams of flour was mixed with 40 g of water and incubated at room temperature ($28 \pm 2^{o}C$) for 24 hours. The ferment, now referred to as the "concentrate," was used as an inoculum, forming 10% of the next flour-in-tap-water slurry (60:40, w/w) to be incubated for the next 24 hours. This was repeated for the third 24 hours, bringing the total fermentation time to 72 hours. The pH was monitored with a CRISON pH/mV meter standard 414; a 1:3 (w/v) suspension of the milled and dried flour in distilled-water slurry was used for pH determination.

The samples, fermented and unfermented, were dried at 50° to 55°C so as not to pre-gelatinize the starch. The samples were dried to a constant weight in trays with slotted bases in a Gallenkamp oven. The dried samples were each milled twice in a disk attrition mill (Bentall Plate Mill, Model 2000, F. H. Bentall, England) and sieved with a nylon cloth sieve between millings and after the second milling.

Determination of apparent viscosity

The apparent viscosity of the gruel prepared from a 5% (w/v) sample of each flour in tap water was determined at $40 \pm 2^{o}C$ with a Haake Rotovisco (Gebruder Haake, Berlin, Germany). After 5 minutes had been allowed for equilibration, measurements were made in a concentric/coaxial cylinder (4.5×8.75 cm). The spindle was run in the sample for 1 minute before stable readings were taken at a shear rate of 162 per second. Conversion into centipoise (cps) units was done using the specific factor of 0.162 for the spindle used.

Production of ARF

ARF was prepared from white sorghum grains malted for 5 days and also analyzed for α- and β-amylase activities using the methods of EtokAkpan and Palmer [12]. The malted grains were milled in the Bentall Plate Mill, and the flour was sieved through a nylon sieve cloth, as practiced domestically in Nigeria, before analysis for amylase activity.

Effect of amylase treatment on the apparent viscosity of the fermented gruels

A 5% (w/v) sample of each of the flours was used to prepare gruels, and the viscosity was determined as described earlier. A 7.5% (w/v) sample of each of the steep-fermented flours was used to prepare gruels by two different methods and was treated with 1% ARF (α-amylase activity = 153 U; β-amylase activity = 237 U) from 5-day white sorghum malt. The flour-in-tap-water slurry of each sample was treated with ARF for 10 minutes before the gruel was prepared by boiling for another 10 minutes (ARF_1). The second gruel samples were prepared by boiling the suspension as described above, cooling to 40°C in a water bath, and treating the gruel with the ARF for 10 minutes. The gruel was then heated for 5 minutes (ARF_2) to destroy microorganisms and enzymes introduced through the ARF. A control sample (ARF_0) was prepared without the addition of ARF. All the gruels were cooled to 40° to 42°C, and the viscosity was read in a Haake Rotovisco as described earlier.

Results and discussion

Process loss

The loss in weight during flour processing is presented in table 1. The process loss was generally lower in steep-fermented flours than in the flours produced by backslopping. The lower process loss in steep-fermented flours was limited possibly by the amount of soluble matter leached out of the produce. The higher process loss in flours produced by backslopping may therefore be due to the greater surface area over which microbial and enzyme activity took place during fermentation. The process loss due to steep fermentation was highest in the foods with high moisture contents—cassava (7.6%), yam (4.4%), cocoyam (3.2%), and plantain (0.6%)—and lowest in maize (0.3%). The high process loss for cowpea (1.5% and 2.6%) did not fit into any pattern. The lowest process loss for maize could be due to the structure of protein in the cell wall and the higher amount of water needed to saturate the grain before loss of dry matter by leaching could become noticeable.

pH

The pH of the liquor from steep fermentation became constant within 24 and 30 hours (fig. 1), indicating that fermentation of the native cereals and tubers beyond this time would possibly lead to production of off-flavor in the foods under the increasing anaerobic conditions. The practice of changing the steep water during fermentation would probably result in a better-flavored product but with a higher process loss and a lower nutrient content. The initial changes in pH are therefore due to leaching of soluble matter into the fermenting medium; in cowpea, cocoyam, plantain, maize, and yam, this could be ascribed to leaching of acidic compounds, with the cowpea and plantain containing the most leachable quantities.

The pH values of the flours from steep and backslopping fermentation are presented in table 2. Fermented flours had lower pH values than unfermented flours, due possibly to the production of organic acids from fermentable sugars. The flours fermented by backslopping had slightly lower pH values than the flours steeped in water for 24 to 30 hours ($steep_1$ flours) because of the larger surface area available for microbial action, which may have resulted in the production of more organic acids. As compared with the pH of the liquor during fermentation (data not presented), oven drying probably led to a slight decrease in pH resulting from the loss of organic acids, probably the short-chain organic acids, which have lower boiling

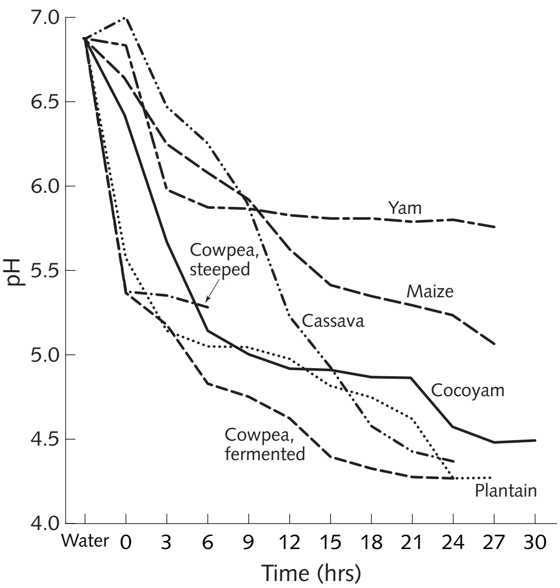

FIG. 1. Time course variation of pH during steep fermentation of raw materials for complementary food production

TABLE 1. Process loss (%) after 24 to 36 hours of fermentation

Fermentation method	Cassava, fermented	Cocoyam, fermented	Cowpea, steeped[a]	Cowpea, fermented	Maize, fermented	Plantain, fermented	Yam, fermented
$Steep_1$[b]	7.6	3.2	1.5	2.6	0.3	0.6	4.4
$Backslopping_{24}$[c]	8.7	10.1	—	15.9	18.8	13.1	12.6
$Backslopping_{36}$[d]	12.3	18.1	—	21.6	15.6	18.7	19.9

a. Steeped in water for 7 hours and dehulled.
b. Steeped in water for 24–30 hours.
c. Fermented by backslopping for 24 hours.
d. Fermented by backslopping for 36 hours.

points. This is, however, understandable, since toasting has been reported to reduce the level of titratable acidity, although not significantly [13]. The use of a lower drying temperature in our investigation would have had even less significant effects.

Viscosity

The effect of fermentation on the apparent viscosity of the flours is shown in table 3. The products of steep fermentation had higher percentage increases in viscosity, except for unripe plantain, which had lower values. It is possible that the higher viscosities were due to the loss of soluble and fermentable dry matter, thus concentrating the gel-forming/water-binding substances. The period during which this occurred might therefore coincide with the lag period of the organisms involved in the fermentation.

In flours produced by backslopping, apparent reduction of viscosity occurred in all the samples, except the cassava sample, within 36 hours. The decreases could be due to a faster rate of hydrolysis of macromolecules into the more soluble forms arising from damage to the granule structure during milling. The increase in the viscosity of gruels from the cassava sample could be due to a number of factors. These include the structure of the starch that is responsible for binding absorbed water [14], the intractability of the cell wall, or the presence of cyanide, which may have reduced microbial growth and activities during the fermentation period.

Based on these results, further investigations to show the effects of ARF treatment were carried out with the steep-fermented flours, which had higher apparent viscosities and pH values. The effects of ARF on apparent viscosities are presented in table 4, and the percent reductions in apparent viscosity due to ARF treatment are shown in table 5. It is postulated that the higher apparent viscosity of the fermented cowpea suggests

TABLE 2. pH of flours after fermentation for 24 to 36 hours

Fermentation method	Cassava		Cocoyam		Cowpea			Maize		Plantain		Yam	
	U	F	U	F	U	S	F	U	F	U	F	U	F
$Steep_1$[a]	5.19	4.40	6.33	4.75	6.15	5.65	4.63	5.93	5.08	6.10	4.80	5.98	4.57
$Backslopping_{24}$[b]	5.10	4.52	6.67	4.87	6.63	—	4.27	5.83	4.53	6.58	4.53	6.45	4.38
$Backslopping_{36}$[c]	5.10	3.95	6.67	4.53	6.63	—	4.15	5.83	3.79	6.58	4.15	6.45	4.18

U, Unfermented; F, fermented; S, steeped.
a. Steeped in water for 24-30 hours.
b. Fermented by backslopping for 24 hours.
c. Fermented by backslopping for 36 hours.

TABLE 3. Viscosity of flours produced by steep-fermentation and by backslopping

Fermentation method	Cassava		Cocoyam		Cowpea			Maize		Plantain		Yam	
	U	F	U	F	U	S	F	U	F	U	F	U	F
$Steep_1$[a]	493	909	472	556	416	592	719	289	345	1,169	712	522	1,283
$Steep_2$[b]	875	1,350	127	698	ND	ND	ND	324	317	1,430	1,197	1,142	1,444
$Backslopping_{24}$[c]	2,059	2,731	1,023	1,099	1,281	ND	317	2,549	875	1,932	169	1,716	169
$Backslopping_{36}$[d]	2,059	2,465	1,023	556	1,281	ND	540	2,549	135	1,932	305	1,716	292

U, Unfermented; F, fermented; S, steeped; ND, not determined.
a. Steeped in water for 24 hours.
b. Steeped in water for 30 hours.
c. Fermented by backslopping for 24 hours.
d. Fermented by backslopping for 36 hours.

TABLE 4. Effect of fermentation on reduction of viscosity (cP) by amylase-rich flour (ARF)

Treatment[a]	Cassava		Cocoyam		Cowpea			Maize		Plantain		Yam	
	U	F	U	F	U	S	F	U	F	U	F	U	F
ARF_0	4,256.38	5,126.56	2,142.28	1,874.50	1,691.28	2,410.07	1,751.16	2,042.22	2,156.38	3,805.38	3,805.38	4,002.69	1,892.12
ARF_1	169.128	126.846	2,100.00	1,409.40	725.841	479.196	1,155.78	2,903.36	1,726.51	4,030.88	2,508.73	2,191.61	1,564.43
ARF_2	133.893	183.222	84.564	162.081	225.504	225.504	267.786	197.034	218.458	239.598	119.799	105.705	288.927

U, Unfermented; F, fermented; S, steeped.
a. ARF_0, control, no ARF; ARF_1, flour-in-water slurry treated with ARF before gruel preparation; ARF_2 gruel treated with ARF.

TABLE 5. Percentage reduction of viscosity of the ARF_1 and ARF_2 gruels

Flour type	ARF_1		ARF_2	
	Unfermented	Fermented	Unfermented	Fermented
Cassava	96.027	97.526	96.854	96.426
Cocoyam	1.974	24.812	96.056	91.354
Cowpea	57.083	33.999	86.667	84.704
Maize	Negative	19.938	90.353	89.869
Plantain	Negative	34.074	93.704	96.852
Yam	42.247	17.319	97.359	83.730

ARF_1, flour-in-water slurry treated with amylase-rich flour (ARF) before gruel preparation; ARF_2 gruel treated with ARF.

that the duration of fermentation may have been too short for the synthesis of β-glucanases [15] needed for the breakdown of the granule cell wall prior to starch hydrolysis.

The effect of fermentation on the reduction in apparent viscosity by ARF treatment is best seen with the gruels prepared from the flour-in-tap-water slurry (ARF_1). The fermented samples had a higher percent reduction in viscosity, except for cowpea and yam flours. This follows from the fact that the higher apparent viscosity, as compared with that of the unfermented samples, was due to leaching of soluble matter. The higher reduction in apparent viscosity of fermented samples could therefore be due to damage to granule structure during milling, which may have resulted in a larger amount of soluble matter, including sugars and short-chain dextrins.

Gruels from the steep-fermented flours treated with ARF (ARF_2) had lower apparent viscosities than those from the flour-in-tap-water slurry treated with ARF (ARF_1) and the unfermented flours (ARF_0). The higher percent reduction in the apparent viscosity of ARF_2 gruels would be due to the prior gelatinization of starch during preparation. However, reducing the apparent viscosity of infant-feeding gruels by treating them with ARF and subsequent reheating may not be acceptable to rural women because of the energy and time needed for the preparation of ARF_2 gruels. It may therefore be better to produce precooked flours or to dry the flours at temperatures that would gelatinize the starch. Such flours would give a better reduction in viscosity if the flour-in-tap-water slurry is treated with ARF before heating to prepare the gruel. This would prevent the need for a second heating, as suggested by Nout and Ngoddy [6], to destroy microorganisms introduced by the ARF.

In ARF_2, unfermented flours had higher percent reductions in viscosity than fermented flours, with the exception of gruels from the plantain flour. This suggests that the unfermented flours had higher quantities of gel-forming components, and that a combination of fermentation and gelatinization makes the starch granule more susceptible to hydrolysis by amylases, as observed by Gopaldas et al. [7]. This therefore shows that with ARF_2, the lower percent reduction in the apparent viscosity of fermented flours is an indication that many of the macromolecules may have been prehydrolyzed during fermentation. The heat treatment during preparation would therefore have rendered the macromolecules more amenable to hydrolysis by enzymes from the ARF.

The effect of fermentation on the apparent viscosity of gruels could therefore be due to two factors: the method of fermentation and the length of the lag phase of fermenting microorganisms. The method of fermentation determines the rate of production of more soluble substrates utilizable by the organisms and hence contributes to the length of their lag phase, which in turn affects the reduction in apparent viscosity.

The results further suggest that in a maize-cowpea-vegetable combination designed to increase protein content and reduce cost [6], cowpea and, to a lesser extent, maize and cocoyam would be the rate-limiting substrates during exogenous amylase hydrolysis of prepared gruels. These rate-limiting substrates have higher protein contents, which would limit hydrolysis of cell wall components and gelatinization of the starch prior to hydrolysis of macromolecules.

Conclusions

Steep fermentation of cassava, cocoyam, cowpea, maize, plantain, and yam for 24 to 30 hours resulted in gruels with higher apparent viscosities than those produced from flours by backslopping, except for gruels made with flours from steep-fermented unripe plantain. The apparent reduction in viscosity by ARF treatment was better with gruels prepared from steep-fermented flours than with gruels from unfermented flours. Viscosity reduction was also better when the prepared gruels were treated with ARF than when ARF was applied to the flour-in-tap water-suspension before it was used to prepare gruels, with the effect on fermented gruels being better than that on unfermented gruels. In the absence of any interactions between components, the results suggest that a maize-cowpea-plantain complementary flour blend would be expected to have the lowest pH and viscosity and to be more stable microbiologically, and therefore that it would be more acceptable. This combination would be good for infants from families with a history of diabetes, for whom unripe plantain is a recommended food. In addition, using precooked (preferably by extrusion) flour blends dry-mixed with the ARF would avoid involving the consumer in the processing and also reduce cost.

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Iodine stability in salt double-fortified with iron and iodine

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Abstract

Deficiencies in small quantities of micronutrients, especially iodine and iron, severely affect more than a third of the world's population, resulting in serious public health consequences, especially for women and young children. Salt is an ideal carrier of micronutrients. The double fortification of salt with both iodine and iron is an attractive approach to the reduction of both anemia and iodine-deficiency disorders. Because iodine is unstable under the storage conditions found during the manufacturing, distribution, and sale of salt in most developing countries, the effects of packaging materials and environmental conditions on the stability of salt double-fortified with iron and iodine were investigated.

Salt was double-fortified with potassium iodide or potassium iodate and with ferrous sulfate or ferrous fumarate. The effects of stabilizers on the stability of iodine and iron were followed by storing the salt under three conditions that represent the extremes of normal distribution and sale for salt in developing countries: room temperature (25°C) with 50%–70% relative humidity, 40°C with 60% relative humidity, and 40°C with 100% relative humidity. The effects of stabilizers, such as sodium hexametaphosphate (SHMP), calcium carbonate, calcium silicate, and dextrose were investigated.

None of the combinations of iron and iodine compounds was stable at elevated temperatures. Essentially all of the iodine was lost over a period of six months. SHMP effectively slowed down the iodine loss, whereas magnesium chloride, a typical hygroscopic impurity, greatly accelerated this process. Calcium carbonate did not have a sparing effect on iodine, despite contrary indications in the literature.

Ferrous sulfate–fortified salts generally turned yellow and developed an unpleasant rusty flavor. Salt fortified with ferrous fumarate and potassium iodide was reasonably stable and maintained its organoleptic properties, making it more likely to be acceptable to consumers.

We confirmed that application of the iodine compounds as solutions resulted in a more even distribution of the iodine throughout the sample. The effect of the packaging materials was overshadowed by the other variables. None of the packaging materials was clearly better than any other. This may have been due to the fact that the polymer bags were not heat sealed, and thus some moisture penetration was possible. The results indicate that with careful control of processing, packaging, and storage conditions, a double-fortified salt could be stabilized for the six-month period required for distribution and consumption. Unfortunately, the processing and storage required are difficult to attain under typical conditions in developing countries.

Key words: Iodated salt, iron fortification, iodine fortification, iodine stability

Introduction

Over the past two decades, the magnitude and consequences of global malnutrition have been increasingly recognized. Deficiencies in small quantities of micronutrients, especially iodine and iron, severely affect more than a third of the world's population. In the less developed countries these deficiencies have serious health consequences, especially for women and young children.

The lack of iodine in the soil and water. and thus in food, leads to iodine-deficiency disorders, which include goiter and a wide spectrum of mental and intellectual defects of varying degrees of severity, including cretinism, paralysis, and deaf-mutism. Iodine-deficiency disorders can also lead to stunted growth and development, miscarriages, stillbirths, and infant deaths [1].

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Iron deficiency is prevalent in two-thirds of the children and women of childbearing age in most developing countries. Low iron intake or poor absorption leads to anemia, resulting in a major reduction in work capacity and impaired immune response, which leads to a higher incidence of infection, an increased risk of maternal and fetal morbidity, and a reduction in body growth. The combined impact of these deficiencies results in severe retardation of social and economic development of entire populations [2].

Deficiencies in iodine or iron can be inexpensively eliminated, prevented, or reduced by increasing their dietary intake through fortification of food. The fortification of commonly used foods is an important component of the strategy to combat micronutrient malnutrition [3]. However, it is critical that the carrier for the micronutrients be available to the entire population, especially those segments that are highly deficient in the nutrient, and it must be consumed at a constant rate independently of the social or economic status of each consumer.

Salt is an attractive vehicle for the provision of micronutrients in view of its almost universal and uniform regional consumption [4, 5]. Iodized or iodated salt has long been available in developed countries, and the problem of iodine deficiency has been virtually eliminated in North America and most European countries. As a result of a concerted international effort, 70% of the salt consumed is now iodized, raising hopes for significant reduction and eventual elimination of iodine-deficiency disorders.

Encouraged by the progress made, efforts have been directed to examining the feasibility of fortifying salt with iron along with iodine. With production and monitoring infrastructure for iodization programs beginning to be in place, such an integration and coordination should be the most cost-efficient method of ensuring adequate levels of both iron and iodine in the population.

This poses a challenge in developing a formulation in which both the iodine and the iron are stable and bioavailable. During the past 25 years, there have been many attempts to produce double-fortified salt [6, 7]. Indian scientists have been prominent in this effort. Unfortunately, none of the formulations developed earlier proved to be commercially viable.

Potassium iodide is used extensively for the fortification of refined salt. Unfortunately, iodide compounds can oxidize when in contact with oxygen at high humidity, resulting in the formation of elemental iodine, which readily sublimes. At the typical low levels found in salt, the iodine can completely evaporate within hours after forming. In the presence of acidic salt impurities, high temperatures, or sunlight, this process is accelerated [8]. In developed countries, salt fortification is accompanied by the addition of a stabilizer or reducing agent, typically dextrose, and an anticaking agent, such as calcium silicate.

Iodate salts are already oxidized, and thus they are more stable in conditions typical of tropical countries. Accordingly, potassium iodate is the iodine compound most often used in salt iodation programs in developing countries. Unfortunately, in the presence of typical salt impurities, iodated salt can lose most of its added iodine over extended periods of storage at high temperature and humidity [9, 10].

Iron is most bioavailable in the ferrous (Fe^{2+}) form. Through oxidation, ferrous iron is converted to the ferric form (Fe^{3+}), which is less bioavailable and has a darker color:

$$Fe^{2+} \text{ (green)} \rightarrow Fe^{3+} \text{ (orange/red)} + e- \qquad (1)$$

This reaction is more likely to occur under alkaline conditions or in the presence of an oxidizing agent, but it may also occur, less rapidly, by air oxidation. Impurities in food, such as magnesium chloride and magnesium sulfate in common salt, can promote the conversion of iron to the ferric form. High humidity also increases the rate of oxidation. In addition to lowered bioavailability, food fortified with ferrous compounds that undergo oxidation may have poor taste and discoloration due to the formation of ferric compounds.

Ferrous compounds can react with iodate, resulting in the formation and eventual loss of iodine, and the oxidation of the ferrous iron to the ferric form:

$$2\ I^{5+} + 10\ Fe^{2+} \rightarrow I_2 + 10\ Fe^{3+} \qquad (2)$$

Many researchers have investigated the use of salt as a carrier for iron. Narasinga Rao et al. [11] fortified salt with several iron compounds: ferric orthophosphate, sodium iron pyrophosphate, ferric pyrophosphate, ferrous ascorbate, and ferrous sulfate. They found that ferrous ascorbate was absorbed most efficiently, while ferric pyrophosphate, sodium iron pyrophosphate, and ferric orthophosphate were poorly absorbed. Ferrous sulfate had a low (approximately 3.5%) but acceptable iron absorption.

A formula consisting of 2,500 ppm ferrous sulfate and 2,500 ppm phosphoric acid prevented discoloration of the salt by ferrous sulfate. The formula was found to be stable for seven months and prevented the development of color when the salt to be fortified contained less than 5% moisture and less than 0.5% magnesium chloride.

Sayers et al. examined salt samples with ascorbic acid and iron compounds to determine their stability under various storage conditions [12]. They fortified salt with ferrous sulfate and ferrous orthophosphate at a level of 0.1%. The effect of 1.25% ascorbic acid on iron stability and availability was determined at two temperature and humidity levels (25°C with 55% relative humidity and

34°C with 77% relative humidity). They reported that the salt became discolored, especially at high temperature and relative humidity. The addition of 2.5% starch stabilized the color for a year.

The stabilizing effect of various compounds on the iron in fortified salt was investigated by Narasinga Rao et al. [4]. They found that sodium hexametaphosphate (SHMP)(3,125 ppm) with sodium acid sulfate (1,875 ppm) and orthophosphoric acid (3,125 ppm) protected 1,000 ppm iron, added as ferrous sulfate, from oxidation. The samples with orthophosphoric acid gave 2.2 times higher iron absorption in animal studies *in vivo*.

Salt fortified with ferric orthophosphate and sodium acid sulfate was used in a large community trial over a two-year period [13]. Although the results indicated no significant change in hematological status at 6 months, after 12 months the hemoglobin levels increased significantly.

Salt fortified with iron orthophosphate and sodium acid sulfate was tested on a large scale in three rural areas (located in the Calcutta, Hyderabad, and Delhi regions) and one urban area (Madras) in India [14]. It was reported that the uniformity of the iron distribution was satisfactory, and no development of color, taste, or odor occurred during several months of storage under natural conditions where the temperature varied from 20° to 38°C and the relative humidity was between 60% and 80%.

Contrary to the conclusions of Narasinga Rao et al. [4] on the use of orthophosphoric acid as a stabilizer for ferrous sulfate, Suwanik et al. [15] found that the addition of orthophosphoric acid gave the salt an acidic taste. Hence, SHMP was chosen as the stabilizer for ferrous sulfate. The minimal amount of additives required to prevent change in color, taste, and smell (before and after cooking) was 4 g of SHMP and 3 g of sodium acid sulfate per kilogram of iron-fortified salt.

While seeking an alternative iron source for fortification of salt, Narasinga Rao et al. investigated the suitability of ferrous citrate [16]. The results also indicated that iron absorption was significantly higher in women than in men. Salt fortified with this compound turned yellowish-green after 8 to 10 days of storage.

Although successful, fortification using ferric orthophosphate with sodium hydrogen sulfate as a promoter of absorption is costly. A less expensive process using ferrous sulfate with orthophosphoric acid as a stabilizer and sodium hydrogen sulfate as an absorption promoter was developed by Narasinga Rao et al. [16]. The formula was acceptable in terms of stability and bioavailability in the laboratory, but on a large scale the salt became discolored within a few days after fortification. The corrosive nature of orthophosphoric acid posed problems in handling on a commercial scale, and its hygroscopic nature posed a risk of adding less than the necessary amount to the salt during fortification. Aqueous sodium hydrogen sulfate was also strongly acidic. Large-scale manufacture in the factories at Tamil Nadu and Andhra Pradesh in India showed that extended use of these chemicals during fortification caused corrosion of the plant equipment [17].

The effect of polyphosphate stabilizers on the stability of salt fortified with ferrous sulfate was investigated [17]. Results using sodium hexametaphosphate (SHMP), sodium tripolyphosphate (STPP), and tetrasodium pyrophosphate (TSPP) were reported. The polyphosphate compounds were added at 0.5% and 1% levels to the salt. In less than two days, both the STPP and TSPP batches turned orange-red, whereas the SHMP batches remained white throughout the study period of one year. The absorption of iron from fortified salt was significantly higher than that of ferrous sulfate administered directly. The fortified salt was readily acceptable to consumers.

The combination of iron and iodine fortification technologies to produce double-fortified products has also been extensively investigated. The effects of calcium carbonate ($CaCO_3$), SHMP, STPP, and TSPP on the stability of salt fortified with ferrous sulfate and either potassium iodide, potassium iodate, or calcium iodate were investigated by Narasinga Rao [18]. He reported that after one month of storage at room temperature, batches initially fortified to provide 20 ppm iodine with potassium iodide (KI), potassium iodate (KIO_3), and calcium iodate ($Ca(IO_3)_2$) contained 16.0, 15.8, and 14.6 ppm iodine, respectively. Addition of calcium carbonate to two other control batches containing potassium iodide and potassium iodate stabilized the iodine level, maintaining it at 20 ppm after one month. When batches with the same formulas were fortified with ferrous sulfate to provide iron at the 1% level (1,000 ppm), the iodine levels dropped drastically from 20 ppm to values ranging from 1.1 to 7.1 ppm within one month.

Polyphosphates were more effective stabilizers. Whereas batches stabilized with TSPP or STPP lost 40% to 60% of the added iodine and turned to an unacceptable dark-brown color, the samples stabilized with 1% SHMP showed no color change and no iodine loss after three months. SHMP ($(NaPO_3)_x$), is used extensively in the food industry as a stabilizer, anticaking agent, water-binding agent, and preventer of rancidity [17]. The maximum allowable daily intake of phosphorus, through the intake of SHMP from regular diets, is 70 mg per kilogram of body weight [19], which is well above the maximum available from salt, even if used at the 10% level.

The use of ferrous fumarate and potassium iodide for the double fortification of salt without the use of stabilizers was investigated and found to be feasible [6]. Salt fortified with ferrous fumarate had a much more stable and pleasing flavor than that fortified with ferrous sulfate.

Because no satisfactory process for the use of salt double fortification has been developed and introduced, the Micronutrient Initiative contracted with the University of Toronto food-engineering program to undertake a systematic study of double fortification processes by identifying and testing potentially useful combinations of iodine and iron compounds with stabilizers, with the objective of devising an economically viable formulation that would be stable under conditions of high temperature and humidity for periods of at least six months.

A list of common iodine compounds and their water solubilities was compiled earlier [8] and is summarized in table 1. Similarly, the Micronutrient Initiative compiled the bioavailability and relative cost of iron compounds that have been used or suggested for use in food fortification [20]. These data are summarized in table 2. The relative costs were calculated on the basis of the iron content, cost, and bioavailability of each compound.

In the first phase of the program, we evaluated the double-fortification systems reported earlier, then tried to identify other potentially useful systems that could economically provide a double-fortified salt with acceptable stability and organoleptic properties. The effects of ferrous fumarate and ferrous sulfate on iodine stability were evaluated.

Since our previous work indicated that the iodine content of salt decreases rapidly under typical field conditions [9, 10], in the second phase of the work we systematically explored the effects of temperature, humidity, packaging materials, and a typical hygroscopic impurity, magnesium chloride, on the stability of iodine in salt formulations containing ferrous fumarate as the iron source. The following summarizes the results of these studies.

Experimental techniques

Materials

Noniodized, high-grade evaporated salt (food grade) was obtained from the Toronto Salt Chemical Company, Toronto, Canada, and locally manufactured table salt was obtained from Arumuganeri Salt Workers' Company, Chidambarnar Dt., Tamilnadu, India. Laboratory-grade potassium iodide, potassium iodate, ferrous sulfate heptahydrate, ferric ammonium sulfate hexahydrate, ferrous ammonium sulfate hexahydrate, ferrous fumarate, magnesium chloride hexahydrate, and analytical-grade hydrochloric acid were purchased from BDH Chemicals Limited of Toronto. Reagent-grade sodium hexametaphosphate and analytical grade nitric acid (69.0%–71.0%) were obtained from J. T. Baker of Toronto. Reagent-grade 1,10-phenanthroline monohydrate; dextrin (10% water-soluble), type II

TABLE 2. Cost of common iron compounds relative to that of ferrous fumarate

Compound	% Fe	Bioavailability in humans	Relative cost factor
Ferrous sulfate • $7H_2O$	20	Good	1.67
Ferrous lactate	19	Good	1.77
Ferric ammonium sulfate	14	—	—
Ferric glycerophosphate	15	Good	2.20
Ferric citrate	17	Poor	5.87
Ferrous fumarate	33	Good	1.00
Ferrous citrate	24	Fair	2.80
Ferric pyrophosphate	25	Poor	4.00
Ferric orthophosphate	28	Poor	3.57
Sodium iron pyrophosphate	15	Poor	6.67
Sodium ferric EDTA	13	Good	2.57

Source: ref. 20.

TABLE 1. Composition and water solubility of common iodine compounds

Compound	MW	% iodine	Solubility in water (g/L)				
			0°C	20°C	30°C	40°C	60°C
Iodine, I_2	254	100.0	0.3	0.4	0.6		
Calcium iodide, $CaCI_2$	294	86.5	646	676	690	708	740
Calcium iodate, $Ca(IO_3)_2 \cdot 6H_2O$	390	65.0	1	4	6	13	
Potassium iodide, KI	166	76.5	1,280	1,440	1,520	1,600	1,760
Potassium iodate, KIO_3	214	59.5	47	81	117	128	185
Sodium iodide, $NaI \cdot 2H_2O$	150	85.0	1,590	1,790	1,900	2,050	2,570
Sodium iodate, $NaIO_3$	198	64.0	25	90	150	210	

Source: ref. 8.

from corn; and potassium biphthalate were obtained from Sigma Chemical Company of Toronto. An iron atomic absorption standard was purchased from SCP Science of Toronto.

Equipment

Solid ingredients were mixed using a ribbon blender with a variable-speed DC motor (5-L capacity), model no. 34305351543-OA, purchased from LeRoy Somer–LSTronics, Montreal, Canada. Some compounds were ground before addition to the salt by a Moulinex coffee and spice mill, model 980, and a blender.

The samples were stored under two high-humidity conditions in a laboratory convection oven at 40°C and an environmental chamber manufactured by the Associated Environmental Systems Division of Craig Systems Corporation, Ayer, Mass., USA.

Sample treatment

Three-kilogram samples of salt were fortified to contain 50 mg/kg iodine and 1,000 mg/kg iron. The mixtures were blended to ensure uniformity using the 5-L ribbon blender. To ensure that the iodine was well distributed, potassium iodide or potassium iodate was premixed with 50 g of the salt from the weighed 3-kg batch, and then the mixture was added back to the blender.

In several batches, a stabilizer, in powder form, was added directly to the salt, prior to iron addition. In some experiments, the ferrous sulfate ($FeSO_4$) was added to the salt as an aqueous solution (approximately 10% w/v). The resulting slurry was thoroughly mixed and then dried in an oven at 110°C. The dried salt cake was manually broken up into smaller pieces, which were then ground, using the ribbon blender, to approximately the original salt particle size. The potassium iodide or iodate and the stabilizer (if required) were added as powder and mixed as above.

To obtain more uniform distribution of the fortificants in some batches, both were added as aqueous solutions. Two lots of salt weighing 1.5 kg each were placed in aluminum dishes. A solution containing 15 g of SHMP and 15 g of ferrous sulfate was prepared and added to one of these. Another solution containing 15 g of SHMP and 0.3 g of potassium iodate was prepared and added to the second lot. The contents of each of the two dishes were well mixed and dried at 110°C.

The cakes formed were manually broken into chunks that could fit in the ribbon blender. The two lots were then blended until all agglomerates were broken up and visual homogeneity was obtained.

Magnesium chloride (1% w/w) was added to several batches as a powder to examine the effect of typical hygroscopic salt impurities. In some cases, the batch was stabilized by adding potassium iodide as a solution with dextrose, as a reducing agent or stabilizer, after which calcium silicate, a free-flowing agent, was added to the salt.

When calcium carbonate was tested as a stabilizer, iodide was added as a powder prepared by co-drying a solution containing 4 g calcium carbonate per gram of potassium iodide. This solid was blended with salt.

Packaging materials

In tests of the effect of packaging materials, samples of each preparation described above were packaged in 500-g portions in high-density polyethylene bags, paper bags, polypropylene jars, or low-density polyethylene bags.

Storage conditions

The packages were stored under three conditions: ambient room temperature and humidity (approximately 25°C and 50%–70% relative humidity), elevated temperature and humidity (40°C and 100% relative humidity), and elevated temperature and low humidity (40°C and 60% relative humidity).

Analytical methods

Sampling

To ensure a representative sample, all of the salt (usually a 1-kg batch) was passed through a two-necked powder funnel, which divided the sample into two nearly equal heaps. One of these was then passed through the funnel again, and the procedure was repeated until a sample of about 20 g was obtained. Samples for analysis were taken from this 20-g batch

Determination of iron

The total concentration of iron in the batches was measured by atomic absorption spectrometry (AAS) according to AOAC Official Method 3.6.1.2 [21]. To estimate the changes in the bioavailability of iron, the amount of iron soluble in 1 N hydrochloric acid was determined by first dissolving 150 mg salt in 40 ml of 1 N hydrochloric acid. The solutions were filtered, and the liquid was analyzed directly by AAS by measuring absorbances at 248.3 nm using a Perkin Elmer Model 703 atomic absorption spectrometer.

The ratio of ferrous to ferric iron was determined in some of the samples by titrating for ferrous iron with 1,10-phenanthroline and determining the ferric iron by difference [22].

Moisture

The moisture content of the salt samples was determined gravimetrically by drying 5-g samples to constant weight at 110°C in a forced-air oven.

Iodine

The iodine content of the samples was measured by epithermal neutron activation analysis (ENAA) with the University of Toronto Slowpoke nuclear reactor. The technique is described in general by Heydorn [23]. Samples of salt ranging from 1 to 2 g were weighed into polyethylene vials. These samples were then shielded in cadmium and irradiated at 1 kW for 3 minutes using a neutron flux of 5.0×10^{11} $cm^{-2}s^{-1}$. The cadmium shielding was 0.7 mm thick and was used to reduce interference due to the high proportion of chlorine and sodium present in the samples. Following irradiation, the samples were rested for 6 minutes, and then gamma emissions at 44.3 keV were measured with a hyper-pure germanium-based gamma-ray spectrometer. The iodine concentrations within the samples were calculated based on a calibration obtained using a series of iodine standards covering a range of 0 to 1,000 ppm. The relative standard deviation of the analysis was determined to be 5%.

Color

The colors of the samples were compared visually. Several representative samples were also measured with the Hunter Laboratories L,a,b color measurement system, using the facilities of Ryerson Polytechnical University.

Results and discussion

Color and flavor

The stability in salt of the iron and iodine additives on their own was first established. A batch of salt containing 1,080 ± 40 ppm ferrous sulfate heptahydrate with no added iodine compound started to turn yellow after one week of storage. After one month of storage, the salt had turned canary yellow in color and developed the unpleasant odor associated with water from rusty pipes. The change in color of the salt was due to the oxidation of ferrous to ferric iron by the air.

Salt fortified with ferrous fumarate was stable in appearance and taste.

The color of salt fortified with iodide or iodate in the absence of iron remained white throughout the six-month storage period.

In the double-fortified batch containing ferrous sulfate and potassium iodate, the salt turned yellow after only one month of storage. The fumarate double-fortified salt darkened somewhat with storage, turning to a brown tinge, from the original light pinkish-tan color.

All of the freshly prepared ferrous fumarate–containing double-fortified samples had a light pinkish brown tinge due to the ferrous fumarate. The color might be marginally acceptable in refined salt, but it would be routinely acceptable in unrefined salt, where some dark or rusty hues are regularly present. After storage, the color of the samples became darker brown, which would reduce their acceptability.

There was only a slight difference in taste between solutions of salt and fumarate-containing double-fortified salt. We doubt that the difference would be objectionable, or even noticeable, in a food matrix. Nevertheless, this aspect of organoleptic acceptability must be considered when designing commercial double-fortification systems.

Blending and sampling

Because of the differences in particle size between the salt crystals (400 to 600 µm) and the added iodine and iron compounds (20 to 200 µm), segregation within the batches resulted in high standard deviations in replicate analyses. Variations of iodine content from 15 to 120 mg/kg were obtained in samples nominally containing 55 mg/kg iodine. This was improved somewhat when the fortificant was added as a solution. If too much water was used in making the solution, and the level of calcium silicate ($CaSiO_3$) added was not high enough to absorb all the moisture in the salt, agglomerates could form that had a high local concentration of iodine, thus contributing to a larger standard deviation.

Ferrous fumarate could not be applied as a solution because of its low water solubility. The iron-containing particles rapidly segregated during normal handling of the sample containers, resulting in iron concentrations that ranged between 25% and 175% of the nominal iron content in different parts of the storage container.

To overcome the analytical errors associated with this distribution problem, we started to use the complete sample for analysis. We subdivided it into two equal parts using a two-necked powder funnel, and repeated the procedure until the sample size was reduced to about 25 g. We found that even after this extensive sample splitting, the analyses were more reproducible if this subsample was first ground (table 3).

Iodine stability

Three iodized salt formulations were prepared. The first two contained only potassium iodate or potassium iodide at the 100 ppm level. A third sample was prepared with a formulation typical of commercially available Canadian iodized salt: a solution containing potassium iodide (1%) and invert sugar (6%) was added to refined salt (less than 36 mesh) to produce final concentrations of 50 and 300 ppm, respectively. Calcium silicate powder was then added (0.5% level) as a free-flowing agent that prevents the salt from caking

TABLE 3. Effect of sample grinding on the variability of iron analytical results in iron-fortified salt

Sample	A41a		B21a		A42a	
	Unground	Ground	Unground	Ground	Unground	Ground
Average	7.14	8.22	8.65	8.38	2.80	3.89
Relative standard deviation %	25.6	14.6	31.4	1.5	16.8	4.1

and absorbs all excess moisture from the solution. The salt was mixed and dried in a ribbon blender.

At 40°C and 60% relative humidity, the potassium iodate control batch retained 93% of the iodine after six months of storage. The potassium iodide control batch retained 88% of the iodine. The potassium iodide control batch with calcium silicate and dextrose retained all of its original iodine.

Double-fortified salt samples were initially prepared using ferrous sulfate or ferrous fumarate as the iron source, and either potassium iodide or potassium iodate as the source of iodine. A sample containing ferrous sulfate and potassium iodide retained no iodine after one month of storage under any of the three storage conditions tested.

Double-fortified samples made with potassium iodate and ferrous sulfate were equally unstable, losing 93% of their iodine content. Most of the iodine had disappeared after only one month of storage in the batch containing ferrous sulfate, and the salt had turned yellow. Samples containing ferrous fumarate retained more iodine than those containing ferrous sulfate. Salt fortified with potassium iodate and ferrous fumarate retained 80.9% of its iodine after seven months of storage at room temperature, and it retained 79.7% of its iodine after seven months of storage at 40°C and 60% relative humidity. Potassium iodide was reasonably stable at room temperature, with 79% remaining after six months. However, at 40°C and 60% relative humidity, it retained only 27% of the original iodine after six months; and at 40°C and 100% relative humidity, it retained only 23% of the original iodine.

Sodium hexametaphosphate (SHMP) was added to several double-fortified salt batches as a stabilizer. It was hoped that SHMP would prevent interaction between iron and iodine in the salt by chelating the iron. It was assumed that the chelate would release the iron at the slightly alkaline pH of the intestines, making it available for absorption.

We tested the double-fortification composition reported by Narasinga Rao [18]. SHMP representing 0.5% and 1% by weight was added directly to salt fortified by ferrous sulfate heptahydrate and either potassium iodide or potassium iodate. The Canadian salt used in these tests was of higher purity than that reported for the Indian salt used by Narasinga Rao.

Several batches were made using potassium iodide as the iodine compound. Potassium iodide was added either as a powder or as an aqueous solution (table 4). Ferrous sulfate was added either as a powder or as an aqueous solution. Batches containing SHMP made with the addition of iodide in solution were pale yellow in color due to slight oxidation of the ferrous ions. This color, due to the presence of Fe^{3+}, reverted to white after extended storage at high temperature and humidity, perhaps as a result of the formation of white ferric phosphate. All dry-mixed batches were initially white in color. Two stabilized batches were also made with the addition of 0.5% calcium silicate, with and without 0.05% dextrose.

At room temperature, the batch containing 1% SHMP with iron, dry mixed, retained the most iodine (77%) after six months of storage, whereas the batch with 0.5% SHMP and iron, wet mixed, retained the least (45%). Owing to the differences in particle size, segregation was a problem, which was indicated by high standard deviations.

At 40°C and 60% relative humidity in all of the batches, drastic declines in iodine levels were observed, which were already evident after two months of storage. After six months, the batch containing 1% SHMP with iron dry mixed retained the highest level of iodine (56%). Reducing the SHMP level to 0.5% resulted in significantly lower levels of retained iodine (approximately 10%)

At 40°C and 100% relative humidity, the iodine content dropped rapidly. After six months, no iodine was left in either of the two batches containing 0.5% SHMP, while 26% of the iodine was retained in the batch containing 1% SHMP dry mixed with iron. Since the batch containing calcium silicate retained 21% of the original iodine, it is clear that the system is stabilized somewhat by the desiccant function of calcium silicate. In the presence of dextrose and calcium silicate, the stability of potassium iodide increased dramatically. This series of tests indicated that 0.5% SHMP has insufficient chelating power to prevent the loss of iodine in the presence of air and water.

In another series of experiments, potassium iodate was used as the iodine source (table 5). At room temperature, the batch containing 1% SHMP with iron, dry mixed, was the most stable, retaining 96% iodine after six months of storage. When the SHMP was reduced to 0.5%, about 60% of the iodine was lost.

After six months at 40°C and 60% relative humidity, the dry-mixed batches were more stable: the sample containing 1% SHMP retained 82% of the iodine, compared with 40% for the wet-mixed sample. In this system, 0.5% SHMP again proved to be inadequate for stabilizing the iodine. The effects of SHMP concentra-

TABLE 4. Stability of salt samples fortified with potassium iodide and ferrous sulfate stabilized with sodium hexametaphosphate (SHMP)[a]

Mixing conditions	SHMP (%)	$CaSiO_3$ (%)	Dextrose (%)	$MgCl_2$ (%)	Storage conditions	Storage time (mo)		
						2	4	5
Wet	1.0				Ambient	98	86	68
					40°C, 60% RH[b]	97	72	54
					40°C, 100% RH	54	31	25
Wet	0.5				Ambient	95	96	45
					40°C, 60% RH	77	61	23
					40°C, 100% RH	43	9	0
Dry	1.0				Ambient	94	81	77
					40°C, 60% RH	48	71	56
					40°C, 100% RH	30	24	26
Dry	0.5				Ambient	93	81	60
					40°C, 60% RH	24	21	10
					40°C, 100% RH	18	8	0
Wet	0.5				Ambient	55	82	71
					40°C, 60% RH	41	23	6
					40°C, 100% RH	16	6	0
Dry	1.0	0.5			Ambient	82	76	73
					40°C, 60% RH	88	55	39
					40°C, 100% RH	95	48	21
Dry	0.5	0.5	0.05		Ambient	92	93	100
					40°C, 60% RH	100	88	98
Wet	1.0			1.0	Ambient	9		
					40°C, 60% RH	0		

a. All starting conditions were set to 100%.
b. RH, Relative humidity.

tion and storage conditions are illustrated in figure 1.

We repeated the test with commercial salt obtained from India. Because it contained 2.1% moisture, two treatments were tested. One sample was dried to constant weight in a forced-air oven at 110°C, while the other was used without pretreatment. The samples were fortified with 1% SHMP, potassium iodate (50 ppm as iodine), and $FeSO_4 \cdot 7H_2O$ (ferrous sulfate heptahydrate) (1,000 ppm as iron). The samples discolored within one week at high temperature and humidity. Although iodine stability was good for the dried sample at 40°C and 60% relative humidity, the wet sample lost 60% of its iodine after two months at 40°C. At high humidity, both samples lost most of their iodine in the first two months.

To confirm the destabilizing effect of a typical hygroscopic impurity, two blends were made by adding 1% magnesium chloride to pure iodized salt. After four months, the batch made with potassium iodide had lost most of its iodine under all of the storage conditions.

Venkatesh Mannar et al. [6] suggested that ferrous fumarate in combination with potassium iodide or iodate would be a stable formulation because of the stability and bioavailability of the ferrous fumarate. They suggested that the improved organoleptic properties and improved stability would more than offset the extra cost associated with using ferrous fumarate instead of ferrous sulfate.

Initial tests with potassium iodate resulted in a rapid discoloration of the salt from the oxidation of fumarate by iodate to form dark-brown ferric fumarate. The reaction reduces iodate to elemental iodine, and thus the iodine content of the salt declines very rapidly.

Double fortification with ferrous fumarate and potassium iodide was much more effective. When SHMP was used as a stabilizer in the presence of dextrose and calcium silicate, the formulation retained 90% of its iodine under low-humidity conditions but lost about 50% under high humidity after four months. The organoleptic properties—color, flavor, and odor—were stable. No hint of rusty flavor developed in these samples.

On the basis of this promising result, we have further investigated ferrous fumarate–based double fortification. The results indicate that at high temperature and humidity, most of the iodine loss occurs in the first months of storage. When potassium iodide was added, either as powder or as an aqueous solution, approximately two-thirds of the iodine in the sample disappeared in the first month, but the rate of iodine

TABLE 5. Stability of salt samples fortified with potassium iodate and ferrous sulfate stabilized with sodium hexametaphosphate (SHMP)

Sample	Mixing conditions	SHMP (%)	Storage conditions	Storage time (mo)		
				2	4	6
Regular	Wet	1.0	Ambient	97	78	44
			40°C, 60% RH[a]	86	77	40
			40°C, 100% RH	29	20	19
Regular	Wet	0.5	Ambient	94	81	39
			40°C, 60% RH	88	44	25
			40°C, 100% RH	8	0	0
Regular	Dry	1.0	Ambient	94	98	96
			40°C, 60% RH	92	88	82
			40°C, 100% RH	91	84	72
Regular	Dry	0.5	Ambient	100	94	41
			40°C, 60% RH	94	71	54
			40°C, 100% RH	19	0	0
Indian salt, as is	Dry	1.0	Ambient	39		
			40°C, 60% RH	40		
			40°C, 100% RH	27		
Indian salt, dried	Dry	1.0	Ambient	100		
			40°C, 60% RH	100		
			40°C, 100% RH	8		
Magnesium chloride added, 1%	Wet	1.0	Ambient	88	91	
			40°C, 60% RH	57	37	
			40°C, 100% RH	0	0	

a. RH, Relative humidity.

loss then slowed, and the amount remaining after six months was not much less than that at one month. This reduction in the rate of iodine formation and subsequent loss may be due to mass-transfer rates controlling the availability of iron or water in contact with the potassium iodide, thus controlling the conversion of iodide to elemental iodine.

The addition of iodine prepared by co-drying a solution containing 4 g of calcium carbonate per gram of potassium iodide did not seem to improve the uniformity or the stability of iodine. This is contrary to an earlier report [7].

The effect of adding magnesium chloride was dramatic. As indicated earlier, this is a hygroscopic impurity widely found in crude, unrefined salt. It picked up moisture immediately, and the moisture content of samples containing magnesium chloride was about 10 times that of the other samples. It is likely as a result of this moisture that the iodine oxidation reaction was greatly speeded up, and in six months about 90% of the iodine initially present in the salt had disappeared (fig. 2).

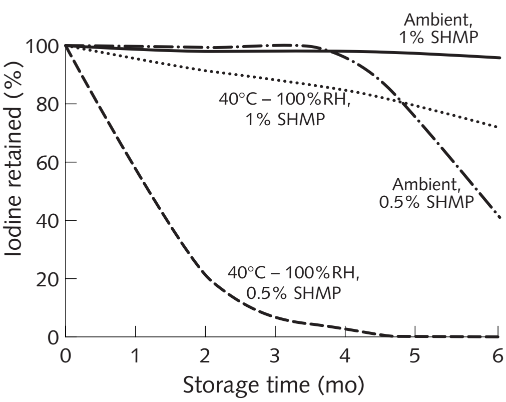

FIG. 1. Effect of sodium hexametaphosphate (SHMP) on iodine retention in double-fortified salt

Iron stability

As expected, the iron concentration was not altered during storage in any of the tests, since neither the ferrous fumarate nor its potential breakdown products are volatile. For nutritional purposes, biologically available iron is the most important measure of the success of fortification. Because the iron must be in solution when it is absorbed in the body, the ratio of total iron to hydrochloric acid–soluble iron was determined

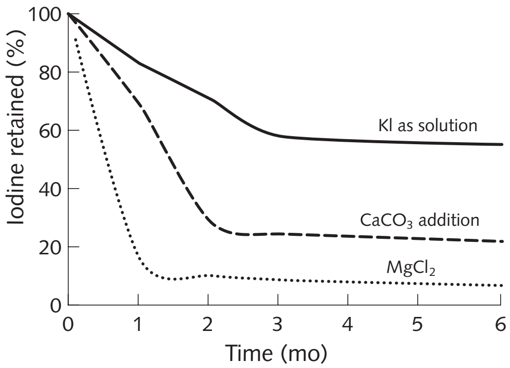

FIG. 2. Effect of calcium carbonate and magnesium chloride on iodine retention in double-fortified salt

and used as an indicator of *in vitro* bioavailability. The amount of HCl-soluble iron was essentially unchanged by any of the treatments and remained above 90% of the added iron in all of the samples.

Moisture

As expected, the moisture contents of the mixed salt samples were low (approximately 0.05%). The moisture content of all of the samples increased by 50% to 150% in the first two months of storage. The changes in moisture content showed no consistent relationship with the sample treatment. The moisture contents remained constant beyond the first two months of storage.

The strong hygroscopic effect of magnesium chloride is evident: samples containing 1% magnesium chloride increased their moisture levels from 0.22% to 3.07% in a sample iodized by potassium iodide in solution. Similar increases in moisture content were observed in all of the batches stored.

Effect of storage conditions

The high-temperature, high-humidity samples had the highest loss of iodine during storage for all samples. The extent of this difference varied with the type of treatment and packaging (table 6). The results confirmed that the chemical breakdown and evaporation of iodine is accelerated by both moisture and elevated temperature. This result was fully expected (table 7).

The effect of the packaging was somewhat less marked. Although the overall instability of the double-fortified salts was clear, we saw that the continuous film barrier provided more protection than the woven high-density polyethylene (HDPE) sacs, the open jar, or paper bags. The differences among the four types of containers were not very large when samples prepared from highly purified salt were compared (table 8). In the presence of hygroscopic impurities, the differences were striking. The open jars at high humidity collected enough moisture from the air to form a liquid layer covering the salt. In the woven HDPE bags, this adsorbed water dripped out, carrying away some of the salt. In both cases, the residual iodine levels were negligible after six months of storage at 40°C and 100% relative humidity.

The most effective treatment was addition of powder, combined with storage at room temperature in a closed

TABLE 6. Effect of temperature and packaging material on iodine retention (50 ± 4 mg/kg added) in double-fortified salt

Packaging	Temperature (°C)	Relative humidity (%)	Treatment: Addition of powder	KI solution	With $CaCO_3$	With $MgCl_2$
			Iodine retention after 6 mo (%)			
HDPE bag	25	50	46.9	33.8	21.2	
HDPE bag	40	100	24.5	24.3	9.0	
HDPE bag	40	60	30.6	30.7	12.3	
Paper bag	25	50	23.4	38.5	25.2	
Paper bag	40	100	20.0	34.0	15.9	
Paper bag	40	60	40.5	35.6	22.0	
Polyprop	25	50	99.1	54.5	23.1	
Polyprop	40	100	27.5	17.8	16.2	
Polyprop	40	60	23.1	23.5	15.8	
LDPE bag	25	50	26.7	38.8	24.5	6.3
LDPE bag	40	100	20.8	15.2	14.4	8.4
LDPE bag	40	60	16.3	28.1	15.4	4.4
Mean ± SD			33.5 ± 22.5	32.1 ± 9.6	17.9 ± 5.2	6.4 ± 2.0

HDPE, High-density polyethylene; LDPE, low-density polyethylene; Polyprop, woven polypropylene jar with lid.

TABLE 7. Averaged effect of temperature and humidity on iodine stability in double-fortified salt samples

Temperature (°C)	Relative humidity (%)	Iodine retention (%)[a]
25	50	38.0
40	60	24.5
40	100	20.8

a. Average of all treatments.

TABLE 8. Averaged effect of packaging materials on iodine stability in double-fortified salt samples

Packaging	Iodine retention (%)[a]
HDPE bag	25.9
Paper bag	24.3
Polyprop	25.6
LDPE bag	28.3

HDPE, High-density polyethylene; LDPE, low-density polyethylene; Polyprop, woven polypropylene jar with lid.
a. Average of all treatments.

polypropylene jar, where after six months 99% of the original iodine remained.

Since the salt will be stored in the final users' homes for a lengthy period during use, the salt will be essentially open to the atmosphere, independently of the type of bag used. Unfortunately, completely closable jars are probably not economically viable where fortification is needed. At present, salt is usually distributed in woven HDPE sacs, because of their strength and resistance to abrasion. It would be beneficial, and not very costly, to improve the storage stability of iodized and double-fortified salt by the addition of an internal liner made of a continuous film of either low-density polyethylene (LDPE) or HDPE. Still, the field technology should be able to stand up to the rigors presented by the end-user, and a more durable system of fortification must be sought to ensure that the beneficial effects of double fortification reach the population at risk.

Conclusions and recommendations

The formulation developed by Narasinga Rao et al. [7] is suitable for providing acceptable iodine and iron levels by double fortification of salt, but only if the salt is highly purified and if it is stored for periods not exceeding three months during distribution, sale, and consumption. Although this is encouraging, clearly a more stable system is required in much of the area where double fortification is justified. The flavor of ferrous sulfate is strong and persistent, and this may be a significant barrier to the acceptance of this product.

The results confirmed that the double-fortified salt systems are susceptible to major losses of iodine when stored at high temperature and humidity. Although SHMP significantly increases the stability of the iodine, the effects of impurities normally present in the salt seem to preclude the use of double-fortified salt containing ferrous sulfate and either potassium iodide or potassium iodate without purification to North American standards. Contrary to indications in the literature, calcium carbonate did not have a sparing effect on iodine.

The effect of the packaging materials was overshadowed by the other variables. In the presence of high humidity, there was a distinct advantage to storing the salt in a continuous film, in this case LDPE. Woven bags, paper bags, and open jars picked up large quantities of water when the salt contained hygroscopic impurities. This resulted in a very rapid loss of all of the iodine from the samples.

The highest iodine losses were observed at 40°C and 100% relative humidity. This is expected in systems in which mass transfer is not highly restricted. We were hoping that the waterproof barrier materials would protect the salt, but this will not happen in an unsealed bag, and accordingly, it is unlikely to happen in the end-users' homes.

Magnesium chloride, a hygroscopic impurity often found in crude salt, dramatically increased the moisture content of the salt and resulted in the almost immediate loss of more than 90% of the added iodine.

The work demonstrated that it is important that adsorbed water, iron, and iodine do not come into contact on the salt surface. The use of refined (purified) salt, which reduces the problems associated with moisture and other impurities that accelerate the loss of iodine, is technically feasible, but it may be economically inviable in many of the regions most in need of double-fortified salt. Segregation of iodine and iron by techniques such as microencapsulation would be a promising method for preserving the added iodine. We are confident that a cost-effective, simple industrial process for double fortification is possible, but its development requires the systematic solution of the specific problems identified in this study. We are pursuing this in our laboratory.

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Weaning foods: A review of the Indian experience

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Abstract

Although breastmilk is adequate to meet the energy and nutrient requirements of an infant up to four to six months of age, thereafter it is insufficient to sustain normal growth and needs to be supplemented with other foods, such as weaning foods. However, the capacity of a weaning diet to meet the protein and energy requirements of infants depends on its nutritional quality as well as its dietary bulk. This review highlights varieties of weaning foods, blend formulations, nutrient requirements, process characteristics, physicochemical parameters, quality evaluation, and other important aspects of developing a weaning food that satisfies all the requirements of the infant during the vulnerable transitional stage. Traditional weaning foods of India are briefly summarized.

Key words: India, weaning foods, energy density, dietary bulk, nutrient requirements, quality standards

Introduction

When a baby reaches four to six months of age, milk alone is no longer sufficient to meet its nutritional requirements. Calories and other nutrients are needed to supplement milk until the child is ready to eat only adult foods. This is the weaning stage. Weaning is the process of expanding the diet to include food and drinks other than breastmilk or infant formula. Weaning is a time of nutritional vulnerability. It represents a period of dietary transition, just when nutritional requirements for growth and brain development are high. Introduction of different tastes and textures promotes biting and chewing skills [1]. Chewing improves mouth and tongue coordination, which is important for speech development. Failure to introduce different textures and tastes by six to seven months can result in their rejection later. Developmentally, few infants are ready to handle anything but liquid food until 10 to 12 weeks of age. Any effort to force them earlier may result in a frustrating and unhappy feeding experience for both the mother and the child. The ability to handle foods other than milk also depends on the physiological development of the infant. The appearance of salivary amylase in the saliva between two and three months of age marks the time when the infant is ready to handle more complex carbohydrates, such as starch in cereals. By four to six months of age, most infants are able to handle most proteins. The kidney tubules become efficient by six to eight weeks, after which there is less concern over the use of a high-protein, high-sodium diet [1]. Concern over the safety of food additives has focused on the use of salt. The Food and Drug Administration has restricted the use of salt to 0.25% of total weight. The concern about the use of salt centers around the theory that a young infant with an immature kidney cannot cope with the increased electrolytes that must be excreted and retains salt, with the resultant increase in fluid volume and the potential of becoming predisposed to hypertension. Studies of the preferences of infants have shown that they eat the same amount of food regardless of whether or not salt is added [1].

Weaning foods

The Academy of Pediatrics, after a careful consideration of all the factors involved, recommends that the optimal time for introducing solid foods into the infant's diet is 2½ to 3 months of age [1]. The semisolid foods given to the child at this stage are generally called weaning foods. Weaning foods are adult foods, modified by processing the ingredients to make them easily digestible by the infant.

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The characteristics needed in a weaning food are the following [2]:

» The food should be rich in calories and adequate in good-quality protein, vitamins, and minerals.
» The food, when stirred with cold or warm water or milk, should form a slurry or semisolid mass of soft consistency, enabling the child to swallow it easily.
» The prepared food should have low dietary bulk.
» The food should be precooked and predigested or processed in such a way that it needs minimum preparation prior to feeding and is easily digested by the child.
» The food should be free from antinutritional factors and low in indigestible fiber content.
» It is advisable not to add artificial colors and flavors to weaning foods, and the composition of the food must follow the guidelines and standards recommended by competent agencies, such as the Bureau of Indian Standards. According to the guidelines of the Protein Advisory Group, weaning foods should have a protein content of at least 20% (on a dry weight basis), a fat content of 10%, a moisture content of 5% to 10%, and a total ash content of not more than 5%.

A nutritionally adequate weaning diet is essential for achieving optimal growth in the first year. Growth in the first year influences both the well-being of the child and the long-term health of the adult. As the infant‘s digestive capacity develops, the strained foods of early infancy can be replaced by less finely chopped foods, with a final transition to table foods. The low acidity of the stomach of young infants is conducive to the growth of microorganisms that facilitate the conversion of nitrates to nitrites, which, when absorbed, will in turn cause the conversion of hemoglobin to the abnormal methemoglobin, with reduced oxygen-carrying capacity. Since the infant lacks the enzyme necessary to reform hemoglobin, it is advisable to minimize the ingestion of nitrates in the first few months of life. The use of vegetables such as spinach, broccoli, and beets, which are high in nitrates, should thus be avoided early in life.

The first weaning stage lasts from four to six months. Suitable first weaning foods include vegetable and fruit purees, nonwheat cereals, and unsweetened yogurt [3]. The quantity, consistency, flavor, potential allergenicity, and preparation of first foods all need to be considered. Only tiny quantities are required initially. The small quantity of food consumed in the first stage of weaning is of little nutritional value. Breastmilk or infant milk formula will remain the major source of nutrients until a fully mixed diet is achieved. The aim is to accustom the infant to taking food from a spoon. Increasing the quantity of solid food given and the frequency with which it is offered depends on an infant’s willingness to take it, but solid food should be accepted two or three times per day by about six months of age. First foods need to have the consistency of a thin, smooth puree to allow the baby to use the sucking reflex. Purees should be thickened gradually as the baby develops the ability to move food to the back of the mouth. Salt should not be added to weaning foods, and sugar should be used sparingly. Adding sugar appears to encourage a preference for sweet foods, which can contribute to excessive weight gain. Unsweetened cereals and yogurts should be encouraged. First weaning foods should be bland and smooth, but once food is accepted from a spoon, introduction of foods with a variety of different tastes should be encouraged. The period from four to six months is thought to be one when infants will accept any new taste, and familiarity at this stage prevents food rejection later. Introduction of new foods one at a time is only considered advisable when there is a strong family history of allergy, but the gradual introduction of new foods may facilitate taste differentiation.

Current guidelines recommend that cereals given to infants less than six months old should preferably be gluten-free. When there is a family history of celiac disease, further delay in the introduction of gluten-containing foods may be considered appropriate. The following foods containing gluten are not generally advised before six months: most rusks, whole or ground, wheat-based cereals, oats or oat cereals, multigrain cereals, and all varieties of bread.

Infants are most vulnerable to developing food allergies in the first month of life, and the risk of allergy is greatly increased by a family history of atopic diseases such as eczema and asthma. For these at-risk infants, potential food allergens should be avoided until at least six months of age. Common food allergens include cow’s milk, eggs, citrus fruits, nuts, wheat, and fish [4]. Both homemade and commercial baby foods have a place in the infant’s diet. The use of appropriately prepared homemade foods should be encouraged, but recent research shows that they are not always nutritionally sound. Commercial products are convenient, and their contents conform to strict compositional guidelines. The first-stage weaning foods include smooth pureed fruits except those with seeds, such as raspberries; all pureed vegetables except fibrous vegetables, such as celery; cooked, mashed pulses except those with tough skins; meat; and unsweetened yogurt.

The second weaning stage is from six to nine months. During this stage, the baby should be encouraged gradually toward a pattern of three meals per day. Encouraging as varied a diet as possible is the best means to ensure an adequate intake of all nutrients. By six months of age, infants should be offered textured food and soft lumps [3]. Failure to do so may lead to refusal to eat “lumps” and disinclination to chew. The consistency of the food should change gradually from soft lumps to a mashed texture. Finger foods given from around seven months of age encourage chewing. Suitable finger foods include toast fingers, cheese cubes, and vegetable sticks. Salt should not be added to food or cooking water, but after seven to eight months, a small amount of salt in cooked dishes is not a cause for concern. Sugar should not be added to foods except to make sour fruits palatable, and attention should be drawn to the fact that honey, fructose, syrup, malt, and concentrated fruit juices are as harmful as sugar to incoming teeth. Artificial sweeteners are not permitted in manufactured baby foods. Solid foods made from milk and dairy products, meat, fish, vegetables, bread, cereals, potatoes, fruits, and fatty foods such as butter and margarine are suitable. The use of home-cooked foods, after suitable alteration of their consistency, is to be encouraged from six months onwards. Manufactured foods continue to offer convenience for occasions such as traveling, but home-made foods should be given whenever possible.

The third weaning stage is from 9 to 12 months. After 9 months, a pattern of three meals per day is appropriate [3]. Food should progress from mashed to minced to a finely chopped texture. Finger foods should be given, and a wide variety of foods should be eaten unless there is a required dietary restriction.

Recommended daily dietary allowances for infants

The daily dietary allowances recommended by the National Academy of Sciences, USA, for infants are shown in table 1 [5]. Table 2 shows the estimated amino acid requirements for infants [6]. Table 3 summarizes the intakes recommended by the World Health Organization (WHO) with respect to protein, vitamins, and minerals [6].

The report by a panel on dietary antioxidant and related compounds was released in mid-April 2000 [7]. The list of 17 dietary reference intake (DRI) nutrients (table 4) includes 3 macro minerals (calcium, phosphorus, and magnesium), 2 micro minerals (fluoride and selenium), 10 water-soluble vitamins (9 B vitamins and vitamin C), and 2 fat-soluble vitamins (vitamins D and E). There are six other nutrients for which the 1989 Recommended Dietary Allowance (RDA) will continue to stand (table 1) until revised: protein, 2 fat-soluble vitamins (A and K), and 3 micro minerals (iron, zinc, and iodine).

TABLE 1. Revised recommended daily dietary allowances for infants, 1989 [5]

Value	0–0.5 yr	0.5–1 yr
Weight (kg)	6	9
Height (cm)	60	71
Energy (kcal/kg)	108	98
Protein (g/kg)	2.2	1.6
Vitamin A (μg RE)[a]	375	375
Vitamin D (μg)[b]	7.5	10
Vitamin E (mg α TE)[c]	3	4
Vitamin K (μg)	5	10
Vitamin C (mg)	30	35
Thiamine (mg)	0.3	0.4
Riboflavin (mg)	0.4	0.5
Niacin (mg NE)[d]	5	6
Vitamin B_6 (mg)	0.3	0.6
Folacin (μg)	25	35
Vitamin B_{12} (μg)	0.3	0.5
Calcium (mg)	400	600
Phosphorus (mg)	300	500
Magnesium (mg)	40	60
Iron (mg)	6	10
Zinc (mg)	5	5
Iodine (μg)	40	50
Selenium (μg)	10	15

a. Retinol equivalents (RE). 1 RE = 1 μg retinol/6 μg β-carotene.
b. As cholecalciferol; 10 μg cholecalciferol = 400 International Units (IU) vitamin D.
c. α-Tocopherol equivalents (TE). 1 μg *d*-α-tocopherol = 1 αTE.
d. Niacin equivalents (NE). 1 NE = 1 mg niacin/60 mg of dietary tryptophan.

TABLE 2. Estimated amino acid requirements for infants [6]

Amino acid	Requirement (mg/100 kcal)
Histidine	26
Isoleucine	66
Leucine	132
Lysine	101
Phenylalanine	57
Methionine	24
Cysteine	23
Threonine	59
Tryptophan	16
Valine	83

Requirements of weaning foods

Concept of calorie density or dietary bulk of foods [2]

The amount of calories in a quantity or volume of a food preparation is called the calorie density of the food, and is a good index for comparing the true value of different foods. Because people consume food more according to volume than to weight, it is the calorie content per unit volume (milliliters or liters) that is generally more important than the calorie content per unit weight (grams or kilograms). The calorie density is very important in the preparation of weaning foods. The stomach capacity of babies is limited, so they

TABLE 3. Recommended intakes for infants (WHO 1990) [6]

Age (mo)	Median weight (kg)	Energy requirement		Safe protein intake (g/kg)
		kcal/kg	kJ/kg	
3–6	7.0	100	418	1.85
6–9	8.5	95	397	1.65
9–12	9.5	100	418	1.50

Age (mo)	Vitamin A (μg retinol/day)	Folate (μg/day)	Vitamin B_{12} (μg/day)	Vitamin C (mg/day)
0–3	350	16	0.1	20
4–6	350	24	0.1	20
7–9	350	32	0.1	20
10–12	350	32	0.1	20

Age (mo)	Vitamin D (μg/day)[a]	Iron absorbed (μg /kg/day)[b]	Zinc (mg/day)
0–3	10	120	3.1
4–6	10	120	3.1
7–9	10	120	2.8
10–12	10	120	2.8

a. 2.5 μg of cholecalciferol = 100 IU of vitamin D.
b. The amount of absorbed iron is a variable proportion of the intake, depending on the type of diet

cannot eat more than a certain amount in one feeding. There may also be difficulty in feeding the baby too many times in a day. Therefore, it is important that the calorie density in the weaning food preparation should be as high as possible so that the baby will get sufficient calories and other nutrients in a small number of feedings. If the weaning food contains largely unchanged starch, the food will absorb a large amount of water and swell when cooked, resulting in a very low calorie content of the final food preparation [4].

The concentration of ingredients in a prepared gruel is a function of the consistency or viscosity of the product that can be fed, which in turn is related to the functionality of the product ingredients, particularly starch. Products having their starch gelatinized and intact will produce thick gruels at relatively low concentrations of solids and, as a consequence, will have a low calorie density.

The minimum energy densities of complementary foods have recently been estimated, taking into account the age and gastric capacity of infants, the number of meals per day, and the quantity of breastmilk consumed [8]. These estimates indicate that gruels should have minimum energy densities of 77 and 116 kcal (322 and 485 kJ) per 100 g in order to meet the energy requirements of well-nourished infants 9 to 11 months of age with average breastmilk intakes, receiving, respectively, three and two meals a day. These minimum energy densities are lower for adequately breastfed 6- to 8-month-old-infants (59 and 88 kcal, or 247 and 368 kJ, per 100 g, respectively) but are higher for infants with low breastmilk intakes, for growth-retarded infants, and for children 12 to 23 months old.

Weaning foods are almost always shear thinning fluids. Nout [9] has proposed that infant gruels must have an easy-to-swallow semiliquid consistency ranging from 1 to 3 Pa•s (pascal-seconds). Gopaldas et al. [10] reported that Indian mothers preferred to feed older children (10 months or more) thicker porridges with viscosities ranging between 2 and 6 Pa•s, rather than free-flowing gruels (1 Pa•s) like those fed to younger children.

Methods to increase the calorie density of weaning foods

Most of the first supplementary foods introduced are prepared from cereals or starchy roots, commonly mixed with water. Starch granules become gelatinized when they are cooked, making the food mix viscous and difficult to feed to infants. Hence, the infants' food intake becomes inadequate to satisfy their nutritional requirements. One possible solution is to reduce the dietary bulk of the weaning foods without significantly reducing their nutritional value. Malting, a traditional processing method, reduces viscosity due to amylolytic breakdown of starch and thus reduces bulk. The addition of 5% malted barley flour to the weaning food after it has been drum-dried reduces the viscosity of the gruel. However, when amylase is added prior to drum drying of the ingredients, there is a reduction in the biological value of proteins and reduced lysine availability. At commercial levels, instead of malt flour, fungal amylase at a level of 0.2% may be added [2].

TABLE 4. Dietary reference intakes: adequate intakes for infants [7]

Nutrient	0–6 mo	7–12 mo
Calcium (mg/day)	210	270
Phosphorus (mg/day)	100	275
Magnesium (mg/day)	30	75
Vitamin D (μg/day) [a,b]	5 (25)	5 (25)
Fluoride (mg/day)	0.01 (0.7)	0.5 (0.9)
Thiamine (mg/day)	0.2	0.3
Riboflavin (mg/day)	0.3	0.4
Niacin (mg/day)[c]	2	4
Vitamin B_6 (mg/day)	0.1	0.3
Folate (μg/day)[d]	65	80
Vitamin B_{12} (μg/day)	0.4	0.5
Pantothenic acid (mg/day)	1.7	1.8
Biotin (μg/day)	5	6
Choline (mg/day)[e]	125	150
Vitamin C (mg/day)	40	50
Vitamin E (mg/day)[f]	4	6
Selenium (μg/day)	15 (45)	20 (60)

a. As cholecalciferol, 1 μg of cholecalciferol = 40 IU of vitamin D.
b. In the absence of adequate exposure to sunlight.
c. As niacin equivalents (NE), 1 mg of niacin = 60 mg of tryptophan; 0–6 mo = preformed niacin (not NE).
d. As dietary folate equivalents (DFE). 1 DFE = 1 μg of food folate = 0.6 μg of folic acid from fortified food or as a supplement taken on an empty stomach.
e. Although acceptable intakes (AIs) have been set for choline, there are few data to assess whether a dietary supply of choline is needed at all stages of the life cycle, and it may be that the choline requirement can be met by endogenous synthesis at some of these stages.
f. As α-tocopherol. α-Tocopherol includes RRR-α-tocopherol, the only form of α-tocopherol that occurs naturally in foods, and the 2R- stereoisomeric forms of α-tocopherol (RRR-, RSR-, and RSS-α-tocopherol) that occur in fortified foods and supplements. It does not include the 2S-stereoisomeric forms of α-tocopherol (SRR-, SSR-, SRS-, and SSS-α-tocopherol), also found in fortified foods and supplements. Figures in parentheses indicate the tolerable upper intakes (UIs). In the absence of UIs, extra caution may be warranted when levels above recommended intakes are consumed.

Roller drying is known to decrease the formation of resistant starch as compared with boiling or pressure cooking [11]. Although fat can add more calories, the fat content cannot be increased beyond a certain limit because fat may spoil the taste of the food, make it difficult to digest, and impair its keeping quality [2].

Evaluation of food-intake studies in young children [12, 13] indicates that the weaning diet must have an energy density of about 1.0 kcal/g to satisfy energy requirements [14]. Human milk has an energy density of about 0.7 kcal/g [15], and it is therefore reasonable to assume that the energy density of a weaning diet should be at least 0.7 kcal/g and preferably should be about 1.0 kcal/g [16]. It is desirable to aim at gruels that have a calorie density of at least 1 kcal/ml of gruel. Thus, 100 ml of gruel would provide about 100 kcal [17].

Requirements of nutrients in weaning foods

The chief carbohydrate in milk, lactose, helps in the absorption of calcium and phosphorus and in maintaining normal intestinal microflora. Other carbohydrates commonly added to infant-feeding mixtures are sucrose, malt-dextrin mixture, invert sugar syrups, and dextrose [18]. The amount of increase in fasting blood sugar after the ingestion of different carbohydrates is in the following order, starting with the highest: glucose, dextri-maltose, honey, sucrose, fructose, and lactose. Sucrose is commonly added because it has the advantage of being digested and absorbed more rapidly than lactose, although less rapidly than glucose and maltose. Because it is too sweet, a mixture of dextri-maltose and sucrose could be used. The United Nations Protein Advisory Group suggests an upper limit of 5% crude fiber in supplementary foods [19].

The protein content in milk-cereal blends of follow-up formulas and weaning foods as recommended by the Codex Commission [20] should be 3.0 to 5.5 g/100 kcal. According to the Food and Agriculture Organization and the World Health Organization (FAO/WHO)[14], the RDA for reference protein during infancy is 14 g/day, and the net dietary protein (NDP) calories percent values are 8.0% and 7.8% for infants and toddlers, respectively [21]. The Protein Advisory Group recommends a minimum protein efficiency ratio (PER) of 2.1 [22] and a net protein utilization (NPU) of not less than 0.6 [23].

The amounts of ingredients required to give the best possible protein value (i.e., amino acid score) are presented in table 5 [24], although the total protein contents may differ.

Medium-chain triglycerides (MCTs) are digested, absorbed, transported, and metabolized differently, and because of their unique properties they have been found useful as substitutes for conventional edible fats and oils in weaning foods, especially in cases of malabsorption [25–27]. The value used to calculate the calorie energy contribution of MCTs in a diet is only 6.8 kcal/g [25].

The fat content of milk-cereal blends of follow-up formulas and weaning foods recommended by the Codex Commission [20] is 3.0 to 6.0 g/100 kcal. The linoleic acid content in baby foods meeting the FAO/WHO Codex standard should be 300 mg/100 kcal [22]. Linoleic acid is a dietary essential, and its deficiency in infants may cause drying and flaking of the skin, poor growth, and lowered resistance to infections [28].

The minimum requirement for linoleic acid is 4.5% of the calories consumed [3]. The desirability of adding vegetable oils rich in polyunsaturated fatty acids (PUFAs) to increase the linoleate content of infant formulas is well established. PUFAs play a nutritional role in the development of the central nervous system during infancy. With an increase in the level

TABLE 5. Amounts of ingredients (grams) required to give the best possible protein value

Staples (g) / Supplements	Wheat	Rice	Sorghum, millet	Maize	Banana	Plaintain
Legumes	80 / 10	65 / 25	75 / 10	55 / 35	105 / 55	85 / 55
Soy beans	60 / 15	55 / 20	55 / 15	50 / 25	140 / 25	115 / 30
Dried skim milk	65 / 10	65 / 15	60 / 15	60 / 15	165 / 20	150 / 20
Dried whole milk	55 / 15	45 / 25	45 / 20	40 / 25	100 / 30	90 / 30
Chicken/lean meat	65 / 20	65 / 25	65 / 25	65 / 35	185 / 40	160 / 45
Eggs	65 / 25	65 / 30	60 / 30	65 / 25	190 / 30	150 / 45
Fresh fish	70 / 30	70 / 30	70 / 25	70 / 20	210 / 40	180 / 45

Source: ref. 24.

of unsaturated fatty acids in the formulations, the products become more susceptible to oxidative deterioration. The higher ambient temperatures in tropical countries bear a special significance with respect to oxidative changes in PUFA-rich products. Methyl siloxane is therefore used as an antioxidant. The oxidative stability of vegetable oils is on the order of those of milk fat and coconut oil, which are greater than that of palm oil, which is greater than that of groundnut oil, which is greater than that of safflower oil. Dried skim milk increases the oxidative stability of groundnut oil, decreases that of palm oil, and has no effect on that of coconut and safflower oil [29].

Iron is one of the most important mineral requirements of infants. The amount of iron storage at birth depends on the adequacy of the mother's diet, the length of gestation, and the amount of blood received by the baby. The infant born at term of a healthy, well-fed mother will maintain a good hemoglobin level at least up to six months of age. If the infant receives some iron-containing foods daily after the fourth month of life, probably no other supplements will be necessary [30]. An infant receiving only the iron in milk will show a slow decrease in hemoglobin level during the second half of infancy, and if the infant's original iron store is poor, iron-deficiency anemia will occur in late infancy. Iron supplements given to infants three to six months of age (5 mg of iron daily, ferrous form) and to older infants (10 mg daily) prevent the development of iron-deficiency anemia. The RDAs for calcium, magnesium, sodium, potassium, iron, copper, and zinc for six-month-old infants are 600, 60, 200, 700, 10, 0.6, and 5 mg, respectively [5]. A high calcium intake may inhibit the intestinal absorption of iron, zinc, and other essential minerals [31]. A high intake of magnesium impairs renal function, resulting in magnesium retention, which is associated with hypermagnesemia, including nausea, vomiting, and hypotension [5].

Taurine is a sulfur-containing nonessential amino acid. It is an antioxidant and neutralizes free radicals. It helps to raise calcium levels in the body by transporting calcium (and sodium) ions across the intestinal wall into the bloodstream. It is also a component of bile, which is essential for the digestion of fats, the absorption of fat-soluble vitamins, and the control of cholesterol levels. Taurine is produced in the body from cysteine with the help of vitamin B_6. It is thought to have an inhibitory action on epilepsy and has been used to reduce seizures. Its inhibitory action can also help counteract anxiety and stress, especially when it is combined with histidine and glycine. Supplementation of weaning foods with taurine improves fat absorption and leads to increased growth in terms of both weight gain and bone growth. The biologic functions of taurine are bile acid conjugation, reduction of platelet aggregation, enhancement of cardiac contractility, enhancement of growth, and enhancement of insulin activity. As regards its influence on the heart, taurine acts as an antiarrhythmic agent, an osmotic agent, and a hypotensive agent [32].

Carnitine is the betaine of β-hydroxy-aminobutyric acid; it is a nonessential amino acid that plays a part in the oxidation of fatty acids by facilitating their transport across the mitochondrial membrane [33]. Choline, a potent lipotropic substance and a constituent of phospholipids such as the lecithins and sphingomyelins, has important physiological functions. It helps in the formation of phospholipids in the liver, and thereby the disposal of triacylglycerols as lipoprotein complexes and the prevention of fat infiltration of the liver, and is also needed for the formation of acetylcholine, one of the chemical mediators of nerve activity

[34]. Biotin plays a central role in fatty acid synthesis as the coenzyme for acetyl coenzyme A carboxylase and is an essential factor in the processes and maintenance of normal metabolism. In biotin-deficient infants, dermatitis develops, usually in breastfed infants [35], associated with persistent diarrhea. Beneficial effects from the treatment of seborrheic dermatitis of infants and Leiner's disease with biotin have been reported both in the United States and in Europe. Inositol is generally regarded as a lipotropic agent with the ability to prevent deposition of fat and hasten its mobilization from the liver. Phosphatidylinositol has the role of a messenger for some hormones [33]. It also forms a complex with tocopherols needed for proper storage of creatine in the muscle.

According to recommended nutrient densities, a weaning food should provide 12% of its calories from protein, 30% from fat, and 58% from carbohydrates [36]. According to current recommendations, a complementary food should contain at least 15 g of protein per 100 g dry weight, and about 21% of its energy should come from fat [8]. An imbalance of calories from different nutrients may affect the quality of the diet. The Codex Alimentarius states that when a supplementary food for older infants and young children is supplemented with one or more nutrients, the total amount of the added vitamins and minerals should be at least two-thirds the reference daily requirements per 100 g of the food on a dry-matter basis [37]

Weaning foods with improved nutritive value can be prepared by using cereal-legume blends, fermented and germinated cereals, and legumes. Weaning foods could be improved by using flours that complement each other in such a way that the pattern of amino acids created by this combination is similar to that recommended for infants.

Quality standards of weaning formulas [38]

The immunity of young infants against various infective agents is almost absent. Infants who are undernourished or otherwise sick are in an even worse situation. Such children are therefore particularly liable to food-borne bacterial, viral, and helminthic enteric infections, which cannot be controlled effectively by vaccination. Hence, the only mode of control is to feed such infants exclusively with microbiologically wholesome commodities.

However safe the dried formula may be, the infant may nevertheless be exposed to massive infective doses of organisms, especially if the water used for reconstitution is not of impeccable microbiological and chemical quality. Further, the most difficult aspect of quality assurance is the avoidance of microbial proliferation subsequent to reconstitution, because this rests with the mothers. This danger can be overcome by supplying only acidified formulas, where mishandling would at worst lead to spoilage by lactic acid bacteria, yeasts, and occasionally molds, but virtually never to the growth of pathogenic bacteria. Inclusion of sufficient citric acid or tartaric acid in the formulas will reduce the pH of the liquid food to below 4.5. The microbiological specifications for UNICEF weaning formulas and other specifications are described in table 6.

Generally, not more than 2 out of 10 samples tested should show counts in excess of the limits aimed at, and none should exceed the maximum limits tolerated. Table 7 shows the Bureau of Indian Standards specifications for milk-cereal based weaning foods [39].

TABLE 6. Microbiological specifications for dried weaning formula (UNICEF) [38]

Class/group	Organism	Limit aimed at	Maximum level tolerated
I (pathogenic)			
1	*Salmonella arizona* *Edwardsiella* *Shigella*	Absent in 15 g	Absent in 1 g
2	*Escherichia coli*	Absent in 10 g	Absent in 1 g
3	*Staphylococcus aureus*	Absent in 1 g	Absent in 1 g
4	*Bacillus cereus,* per 1 g	$< 10^2$	$< 10^3$
5	Mold spores, per 1 g	$<10^2$	$< 10^2$
6	Enterobacteriaceae	Absent in 1 g	Absent in 0.1 g
II (indicator organisms)			
7	Total aerobic count, per 1 g	$< 10^4$	$< 10^5$
8	Lancefield D streptococci, per 1 g	$< 10^2$	$< 10^3$
9	*Clostridium* species, per 1 g	< 10	$< 10^2$

Commercial preparation of weaning foods

All the commonly eaten cereals are used in weaning foods. In the draft standard of the Codex Committee, the ingredients are listed as flours of one or more cereals, such as wheat, rice, barley, oats, maize, millet, sorghum, and buckwheat, and also groundnut, sesame, soybean (defatted or low-fat), and other legumes [40]. When legumes are used, sufficient heat processing is included to destroy the heat-labile antinutritional factors. Particular care must be taken with respect to phytic acid levels in such preparations. Optional ingredients include protein concentrates and amino acids, fruits, nutritive sweeteners, malt, milk or milk products, fats and oils, salt (including iodated salt), and spices. Vitamins and minerals may be added in accordance with the legislation of the country in which the food is sold [40].

The nonmilk, cereal-based weaning foods are usually intended to be eaten with milk, and the protein content of the food eaten is therefore greater than that of the formulation. Since cereals are mostly limited by lysine, and milk contains a surplus of this amino acid, there is a complementation between the two foods so that the nutritional value of the mixture is high.

Canned baby foods are defined by the Codex Committee as products prepared from any nutritive material commonly used as a food ingredient. They are foods intended for use during the normal weaning period and for the progressive adaptation of infants and children to ordinary food. Optional ingredients include spices, protein concentrates, vitamin and mineral supplements, and salt, with a tentative maximum of 0.25 g per 100 g. The levels of vitamins and minerals are subject to the legislation of the country of sale [40].

Strained foods are defined as those consisting of fairly uniform, small particles of a size that does not require and does not encourage chewing before being swallowed. Junior foods ordinarily contain particles of a size to encourage chewing by infants and children. The preparation of canned and strained meats, fruits, and vegetables is shown in figures 1 and 2.

Some strained fruits and vegetables contain modified cornstarch or tapioca starch. In such cases, the starch is cooked for a short time with the puree before canning.

As with all infant foods, the ingredients must be practically free from pesticide residues and the food must not be exposed to ionizing irradiation. The foods should conform to the limits specified for toxins, trace elements, heavy metals, and solvent residues.

Many vegetables, such as beets, cabbage, broccoli, cauliflower, and rhubarb, contain more than 1,000 ppm of nitrate. Nitrates themselves are nontoxic, but they are converted into toxic nitrites during storage. Their effect is due to oxidation of the ferrous iron of the red blood cells to the ferric state to form methemoglobin; when more than 5% methemoglobin is present in the blood, light cyanosis becomes obvious, and when the concentration rises to 70% of the total blood pigments, death occurs from asphyxia. Cases of methemoglobin toxicity have been reported in infants after eating spinach. The Joint FAO/WHO Committee

TABLE 7. Bureau of Indian Standards specifications for milk- and cereal-based weaning foods [39]

Ingredient	Amount
Moisture, % by mass, max	5
Milk solids, %	≥ 20 (min 5% by weight of milk fat)
Total proteins, % by mass, min	12
Fat, % by mass, min	7.5
Total carbohydrates, % by mass, min	55
Total ash, % by mass, max	5
Acid insoluble ash, % by mass, max	0.1
Crude fiber (on dry weight basis), % by mass, max	1
Vitamin A (as retinol), µg /100 g, min	350
Vitamin C, mg/100 g, min	25
Added vitamin D, µg /100 g	300–800
Thiamine (as HCl), mg/100 g, min	0.5
Riboflavin, mg/100 g, min	0.6
Nicotinic acid, mg/100 g, min	5
l-Ascorbyl palmitate, mg/kg fat, max	200
Iron, mg/100 g, min	5
Bacterial count/g, max	50,000
Escherichia coli count/0.1 g	Nil

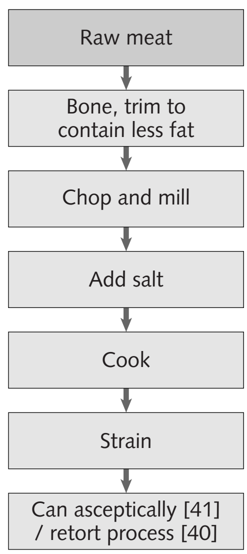

FIG. 1. Preparation of strained meat. Vegetables can be mixed with meat, either beef + carrots + potatoes or lamb + peas + carrots + potatoes

on Food Additives [40] recommends that nitrate not be added to baby foods and that water of high nitrate content not be used.

The addition of ascorbic acid to spinach reduces the number of bacteria responsible for the reduction of nitrate. Spinach used for infant feeding should not contain more than 300 mg of nitrate per kilogram. Some authorities have suggested that spinach should not be fed to very young infants [40].

Salt is usually added to manufactured foods to suit the palate of the mother rather than that of the baby, and the fear is that if none is added, the mother will add an uncontrolled amount. It is therefore suggested that in order to exercise some control, manufacturers should add salt with an upper limit of 0.25% [40].

For commercial preparation of weaning foods, the most commonly adopted methods are roller drying and extrusion cooking.

Roller drying [2]

Preparation of weaning foods by roller drying (fig. 3) is extensively practiced throughout the world. The basic ingredient, such as polished rice or wheat flour, is mixed with chickpea (*Cicer arietinum* L.) or defatted soy flour, sugar, and milk powder. The blend is mixed with cold water (about 30% slurry) and homogenized. The slurry is allowed to flow on two stainless steel drums heated by live steam (approximately 5 kg/cm^2 pressure) and rotating in opposite directions at 3 to 10 rpm. In the process, the ingredients are cooked and dried at the same time on the drums, and the resulting product is a flaky material. It is powdered and blended with vitamins and minerals and packed in airtight tins.

The process allows for the use of a wide range of materials; using polished or refined grains can regulate the fiber content of the food. The finished product is fully cooked so that cooking before feeding is not needed. The product mixes well when stirred with water or milk and becomes a soft mass. The heat treat-

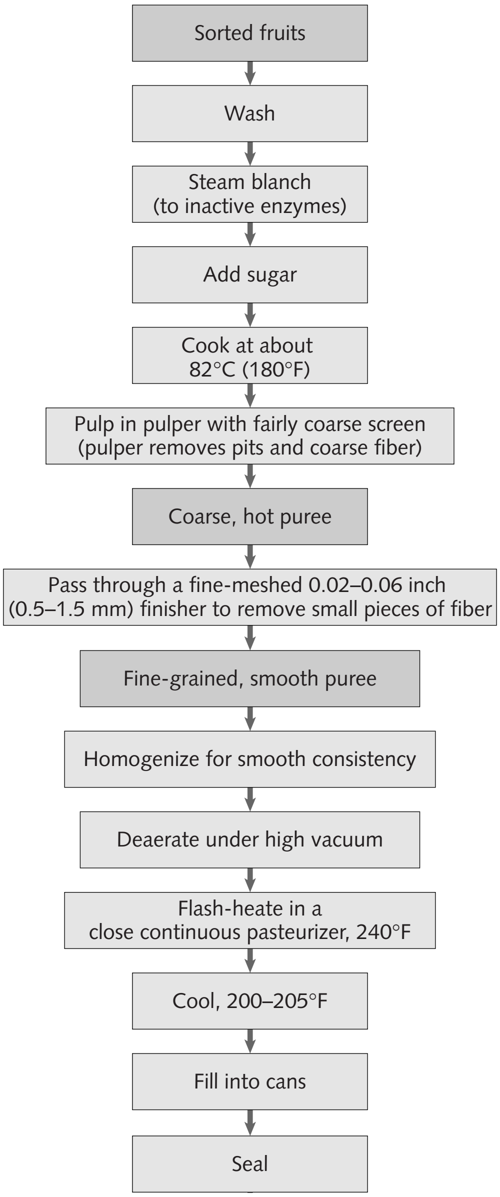

FIG. 2. Preparation of strained fruits and vegetables [42]

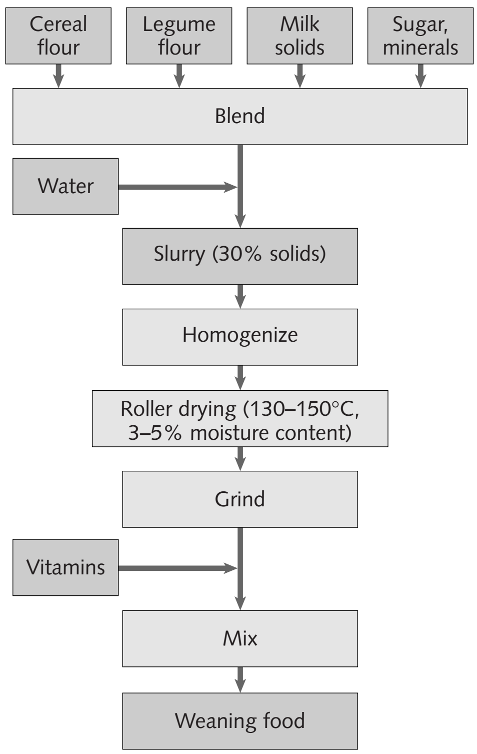

FIG. 3. Manufacture of roller-dried weaning food

ment reduces some of the antinutritional factors and improves digestibility, and the process permits mixing of additional desirable nutritious ingredients (sugars, flavors) after roller drying.

However, the process has some disadvantages. The product needs a large package because it is fluffy and very light in weight. It is hygroscopic, i.e., it absorbs moisture or water when exposed to high humidity or a damp atmosphere. Hence, it needs to be packed in tins or other materials that protect it from moisture. Such packaging is expensive and increases the cost of the product. The product absorbs a large quantity of water when prepared for feeding and becomes bulky; however, the dietary bulk of the food can be reduced using malt enzymes. The severe heat treatment slightly reduces the nutritional quality of the protein, because lysine, the nutritionally important amino acid, binds with sugar and becomes unavailable. The process involves the use of sophisticated and expensive machinery, requiring a high capital investment.

The addition of 2.5% barley malt flour or 0.15% fungal α-amylase to a proprietary brand of roller-dried weaning food reduced the paste viscosity of a 20% slurry from 15 to 1 Pa•s [38].

Extrusion cooking [2]

An extrusion cooker is basically a pump that simultaneously transports, mixes, cooks, cuts, stretches, and shapes the material under high pressure and temperature. It consists of one or two screws that rotate in a tightly fitting barrel with a disk, in which a die of the desired shape can be fit at the outlet. The ingredients for the weaning food (cereal flours, legume flours, milk, and sugar, mixed together) are moistened to contain about 20% moisture, and the mixture is fed into the extruder. It begins to be compacted, and it becomes heated to about 120°C from the high friction. The material is cooked and thoroughly mashed, and it finally comes out through the die in the form of a dry, fluffy strip. The product is powdered and blended with the necessary vitamins (fig. 4). According to Tomas et al. [43], in the case of wet extrusion of rice flour, the maximum amount of starch is hydrolyzed when 600 g of water is used per kilogram of rice flour. The amount of α-amylase mixed in the feed slurry can be between 0.1 and 1 g per kilogram of rice flour, and the temperature between 70° and 100°C.

Extrusion cooking is a versatile process. The product is fully cooked and ready to eat. It mixes well with water or milk. As in roller drying, the process permits the use of a variety of ingredients. Because the drying step is almost avoided, the process is economical as compared with roller drying, but the equipment is very expensive. The process has almost all the advantages and drawbacks of roller drying. Further, for extrusion-cooked infant foods, the milk proteins should be blended into the infant foods after the balance of the formula has been extrusion cooked. High-temperature extrusion cooking will result in a lower biological value of the protein if it is cooked in the presence of milk proteins. When extrusion-cooked foods contain milk proteins, it is desirable to use maximum extrusion temperatures of 250° to 280°F. Higher extrusion temperatures can result in some reduction in NPU, probably due to partial tie-up of lysine by thermal bonding of milk sugars with amino acids [44]. It is suggested that reduced processing time, high feed ratio, lower processing temperature, and increased moisture content increase the protein nutritional value of the product [45].

Fortification of commercial weaning foods

Fortification of weaning foods serves to correct the nutritional deficiency of the average diet, thereby improving the health of the child. Lower contents of various nutrients per se and their poor bioavailability necessitate their addition to the weaning foods. The method of addition of vitamins is dependent on the processing system and preferences: e.g., vitamins must be added before the heat-processing steps in the preparation of canned fruits and vegetables, whereas in flaked cereals they are added after processing. Oxygen, humidity, heat, acids, redox agents, and light can affect vitamins. Furthermore, other components of foods, such as heavy metals, can interfere with the stability of some vitamins. Technology exists to prevent losses, but

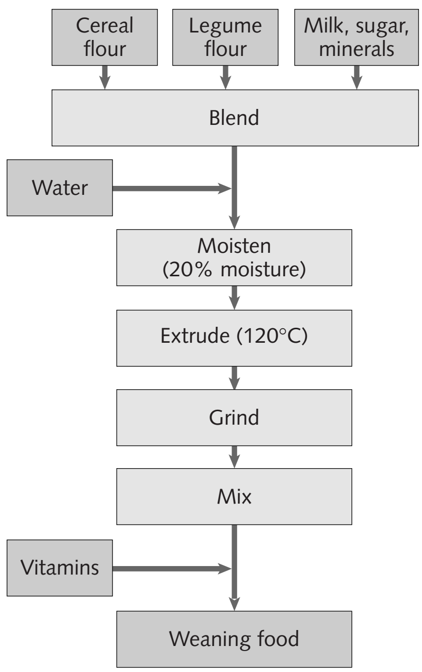

FIG. 4. Extrusion cooking for manufacture of weaning food

losses cannot be totally avoided. To ensure that the food contains the declared vitamin levels when it is ingested, the food industry adds extra nutrients to compensate for losses during processing and over the shelf-life of the finished product [46].

It is easier to add vitamin A in an oily solution to the food before drying. However, water-dispersible, dry stabilized vitamin A beadlets, palmitate or acetate, can be used to fortify infant foods. These are very stable for long periods of storage and form a dispersion in hot water. Vitamin D is available in oil and dry forms similar to vitamin A. Vitamin C, if added in dry form to weaning food, maintains its potency, but if it is added in solution to the wet material before drying, then, in addition to the destruction during drying, which will vary with the severity of the conditions, the vitamin left in the finished dried product will be very unstable. The method of choice is therefore to add vitamin C as a powdered solid to the finished dried product or to use it in stabilized form. The B vitamins usually added to weaning foods are thiamine, riboflavin, and nicotinic acid [40]. Pyridoxine, pantothenic acid, folic acid, and vitamin B_{12} are added to a small number of special foods, but one or more of the first three mentioned are added to most weaning foods. They are far more stable when added in the powdered form to the already dried food. Thiamine is commercially available both as mononitrate and as hydrochloric acid salts. The latter is more soluble in water (50% vs. 2.7%). Riboflavin causes a few problems in food fortification because of its poor solubility and intense yellow color. A more soluble analogue, riboflavin 5' phosphate, has a solubility of 3% to 5% in water. Niacin is commercially available both as nicotinic acid and as nicotinamide. The amide has a bitter flavor but is preferred because of its superior solubility [40]. It is possible to microencapsulate the fat-soluble vitamins in order to get them into a water-soluble powdered form and to protect them from oxygen and other components of food. These powdered forms can be mixed with water-soluble vitamins and added to foods [46].

The technical problems in mineral fortification pertain more to organoleptic properties and bioavailability than to stability of the compounds per se or to methods of incorporation in foods [47]. Large amounts of calcium and magnesium salts are required to obtain nutritionally significant levels of these minerals. These rather large quantities can produce chalky flavors, sandy mouth-feel, opacity, sediment, and color changes in foods [48]. The commonly used calcium salts are calcium phosphate dibasic, anhydrous Ca (HPO_4), calcium phosphate tribasic, and calcium carbonate. The poor solubility suggests poor absorption as compared with soluble salts such as calcium gluconate and calcium lactate. However, the soluble calcium salts have reactivity and an undesirable flavor. Fortification with magnesium is done using magnesium oxide and magnesium phosphate dibasic. Phosphorus fortification is not necessary when calcium phosphate is used for calcium fortification. Although a dietary shortage of phosphate appears to be extremely unlikely, the Codex Alimentarius Committee suggests that complete infant foods should contain phosphate in amounts such that the ratio of calcium to phosphorus is 1:1.2-2. This suggestion is made to assist the absorption of calcium rather than to provide a source of phosphate [40]. For the addition of iron, stable soluble complexes of iron (ferric ammonium citrate) and soluble ferrous compounds (sulfate, fumarate, and lactate) are nutritionally preferred sources. Ferrous sulfate catalyzes fat oxidation, and it produces greenish tints and has a metallic flavor. Ferric orthophosphate and sodium ferric pyrophosphate have been used commercially to fortify infant foods.

Nutrition labeling regulations

Nutrition labeling is an approach to help consumers understand nutrition and select foods wisely in the marketplace [49]. The US Food and Drug Administration originally advanced this voluntary approach in 1973.

Nutrition labeling is voluntary except when a nutrient is added to a food product or when a nutritional claim is made for a food. Nutrition information on the label includes serving size, servings per container, and calorie, protein, carbohydrate, and fat content. Provisions are made for declaring sodium, cholesterol, and saturated and polyunsaturated fatty acid content.

The eight mandatory nutrients are protein, vitamin A, vitamin C, thiamine, riboflavin, niacin, calcium, and iron, in that order, and they must be expressed as a percentage of the US RDAs, which are listed in table 8 [50]. These are slightly higher than those recommended by the National Academy of Sciences (table 1). Optional nutrients, which include vitamin D, vitamin E, vitamin B_6, vitamin B_{12}, folacin, phosphorus, iodine, magnesium, zinc, copper, biotin, and pantothenic acid, may be listed; they must be listed (mandatory) when they are added to a food.

Percentages of the RDA must appear on labels expressed in the following increments: 2% increments up to 10% of nutrient per serving, 5% increments from 10% to 50% per serving, and 10% increments above 50% per serving. Thus, if a serving contains 23% of the US RDA for niacin, the label may declare only 20%. If the level of nutrient is below 2% of the US RDA, this may be stated or a zero may be indicated.

For nutrients naturally present in a product, analytical values may equal or exceed 80% of the label claims. Analytical values for calories, carbohydrates, fat, saturated fat, cholesterol, and sodium must not exceed 120% of label claims. If vitamins or minerals

TABLE 8. US RDA values for nutrition labeling for infants up to one year [50]

Nutrient	Quantity
Mandatory	
Protein (PER >2.5)	28 g
Protein (PER <2.5)	20 g
Vitamin A	1,500 IU
Vitamin C	35 mg
Thiamine	0.5 mg
Riboflavin	0.6 mg
Niacin	8 mg
Calcium	600 mg
Iron	15 mg
Optional	
Vitamin D	400 IU
Vitamin E	5 IU
Vitamin B_6	0.4 mg
Folic acid	0.1 mg
Vitamin B_{12}	2 µg
Biotin	0.05 mg
Pantothenic acid	3 mg
Phosphorus	600 mg
Iodine	45 µg
Magnesium	70 mg
Zinc	5 mg
Copper	0.6 mg

are added to a food so that a serving contains 50% or more of the US RDA for any one, such a food becomes a dietary supplement and is specially regulated as such. If vitamins or minerals bring the serving to 150% or more of the US RDA for any one, the food is classified as a drug and is subject to drug regulations.

Preparation of weaning foods based on some traditional technologies in India [2]

Malting of cereals and legumes

The process of malting has many technological and nutritional advantages for weaning food preparation. Finger millet or ragi (*Eleusine coracana*) and green gram (*Phaseolus radiatus*) possess some special characteristics with regard to their malting qualities and suitability for preparation of weaning foods. Malting of ragi does not pose problems such as mold growth as is observed with jowar (*Sorghum vulgare*) or bajra (*Pennisetum typhoideum*). Ragi malt has an acceptable taste and desirable aroma, and it keeps well. Ragi contains high levels of calcium, and its protein is rich in methionine.

At the household level, the practice followed is generally to germinate cleaned ragi for one to three days, and the sprouted grains are then dried, toasted, and powdered to obtain the malt flour. The malt flour is cooked in the form of porridge and fed to the child. This method of preparation of malt flour has a few drawbacks: steeping ragi for less than 10 hours is insufficient to hydrate the grains fully, as required for proper germination; wrapping the soaked grains tightly prevents proper germination or sprouting, because it affects aeration and rootlet development; grinding of roasted germinated grains with the roots and shoots increases the fiber content of the food, and the food tastes bitter; and sieving through a fine sieve results in a very low yield. Considering all these points, the recommended method for preparing ragi malt for use in weaning foods is shown in figure 5.

Chapati/roti-based weaning food [2]

It is better to polish the grains and use the debranned or polished flours for preparation of weaning foods so that the fiber content of the final product is low. Flour from toasted or popped split green gram dal flour alone or a mixture of green gram and Bengal gram flours may be used as legume ingredients. Cereal flours blended with toasted green gram flour in the ratio of 70:30 or 70% cereal flour mixed with 20% toasted green gram dal flour and 10% popped split chickpea dal flour should be used for making roti (fig. 6). Popped chickpea flour improves the palatability of the food. Fresh rotis, which contain 25% to 35% moisture, can be soaked in milk to soften them or mashed to give to the child immediately after preparation. Chapatis dried hygienically in the sun or on a baking pan can be powdered, packed, and stored in tins for use. When the powdered meal is added to milk or water and cooked, a paste is obtained. The addition of milk powder to the dry food enhances its taste and nutritive value.

Vermicelli-based weaning foods [2]

Generally, vermicelli is prepared from wheat rice, jowar, maize, or millet flours. Vermicelli can be prepared from a blend of polished cereal and legume flours to give a very nutritious product. Dough prepared from the mixture of flours should be steamed and extruded through a perforated die of a hand-operated press. The strands are called vermicelli. Alternatively, the dough may be extruded and the strands steamed or cooked. For storage, the strands can be dried with hot air. The dried vermicelli should be powdered and stored (fig. 6). The food mixes well with water or milk and becomes a soft mass. Jowar and rice are more suitable ingredients.

Rice flakes–based weaning food [2]

Rice flakes (poha or beaten rice) should be cleaned and toasted mildly to lower their moisture content and increase their crispiness, and then powdered. The flour (70%) should be mixed with toasted green gram flour (20%) and puffed chickpea flour (10%) to make the weaning food (fig. 7). The food should be cooked in milk or water before feeding.

Popped cereal–based weaning food [2]

Popped or puffed products from cereal grains such as popcorn, puffed rice, popped jowar, and even popped ragi flour can be used as a base material for weaning food formulations (fig. 7). Popped grains should be powdered and blended with toasted green gram and popped chickpea flour in proportions of 70:20:10. Popped cereal–based weaning foods are hygroscopic and become soggy when exposed to the atmosphere. Hence, they must be stored in closed tins. Because it is difficult to debran popped grains or to pop the dehusked grains, the fiber content of popped cereal–based formulations is generally high.

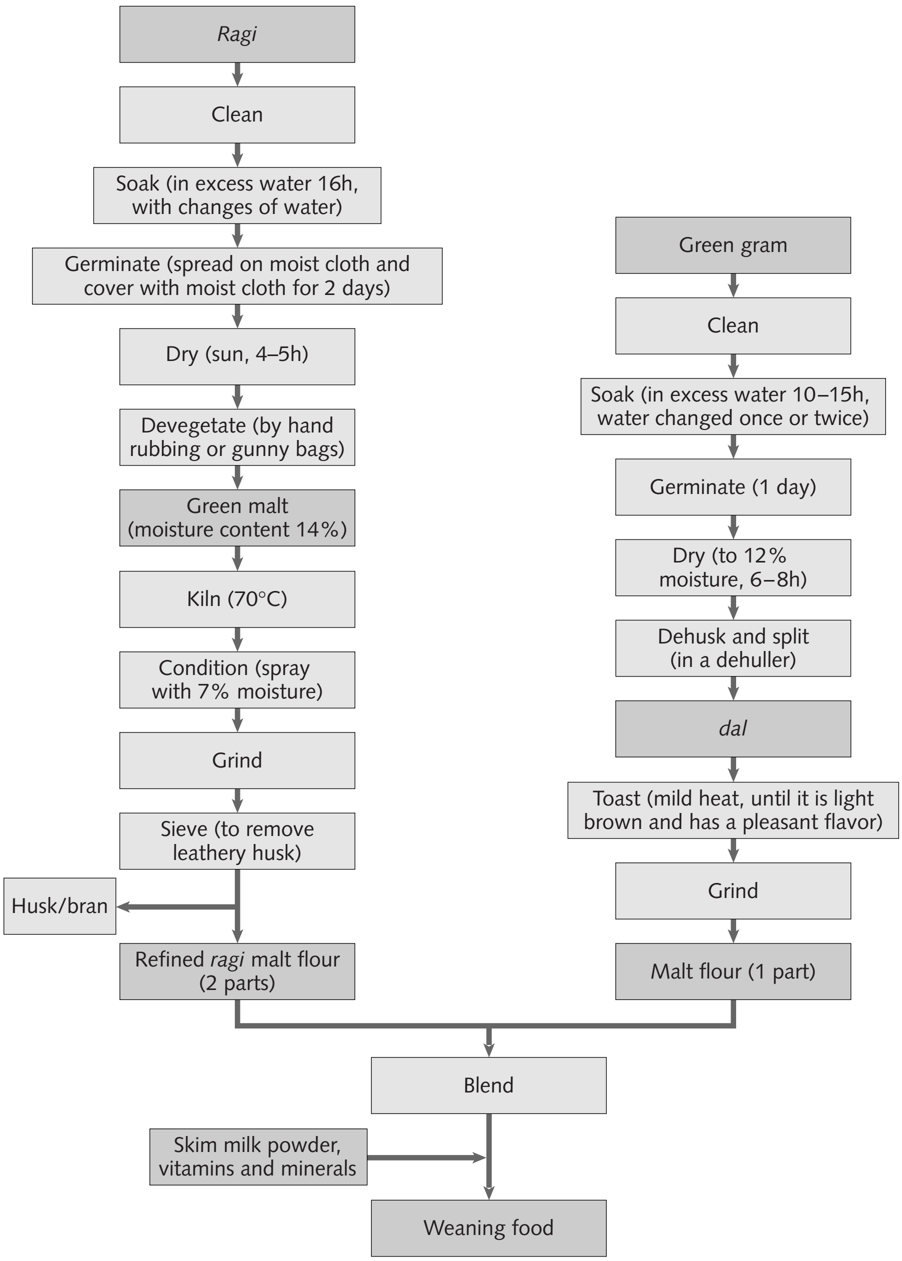

FIG. 5. Preparation of weaning food based on malted ragi and green gram

Sattu: a traditional weaning food [51]

Traditional sattu is a mix of Bengal gram, wheat, and jaggery (crude brown sugar). The Bengal gram and wheat are usually combined in a 1:3 proportion. Jaggery is added as required. For a food mix, wheat and Bengal gram are roasted and powdered separately, then mixed and stored. To prepare sattu as a porridge, the required amount of jaggery is dissolved in 220 to 240 ml of warm water, and 30 to 50 g of sattu mix is added and mixed well. Sattu of improved nutritional quality using Bengal gram dal, green gram dal, wheat, soybeans, and groundnuts has been attempted.

Banana-based weaning foods [2]

Bananas or plantains are fed to weaning children extensively in Kerala and Assam, and also in many African countries. Normally a special variety of banana (nendra) is used. Mashed and cooked banana pulp is mixed with rice and fed to the child. If bananas that are just ripe or nearing ripeness are peeled and the pulp is sliced and cooked in thin rice gruel, then dried and powdered, a banana flour is produced that can be stored for some time (fig. 8). The banana flour may be mixed with processed cereal (malted, popped, expanded, or flaked) or legume (toasted or popped) flours.

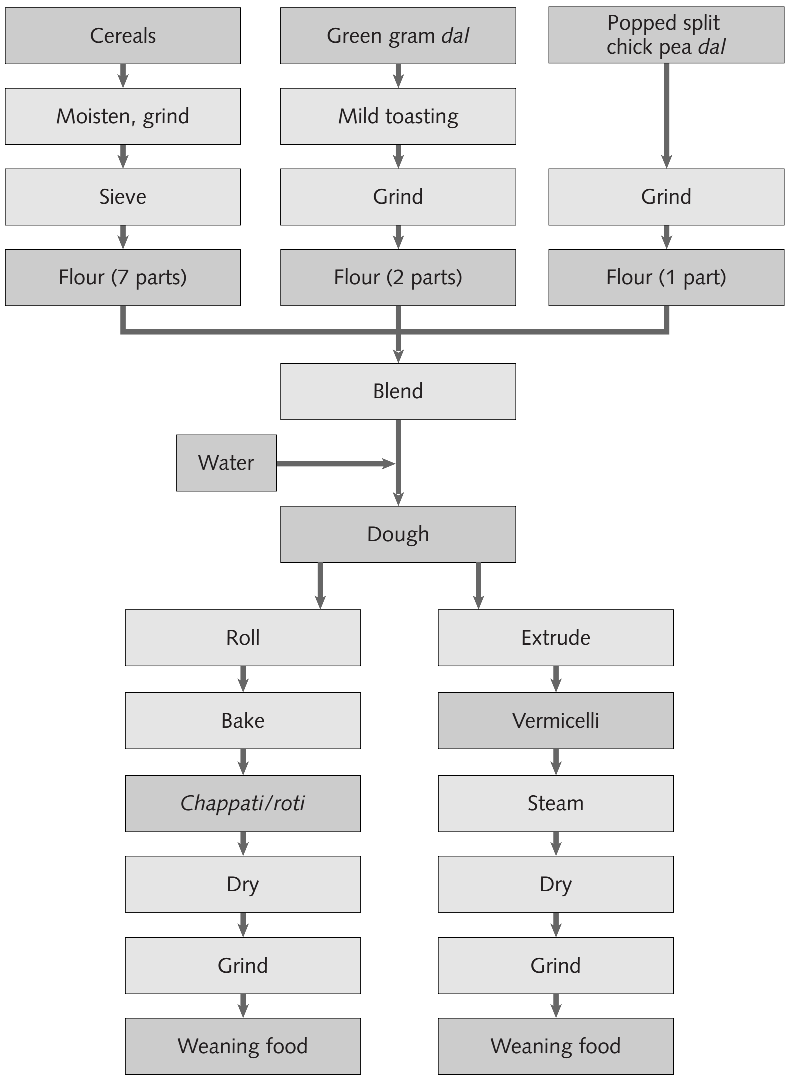

FIG. 6. Preparation of weaning foods based on chapatis and vermicelli

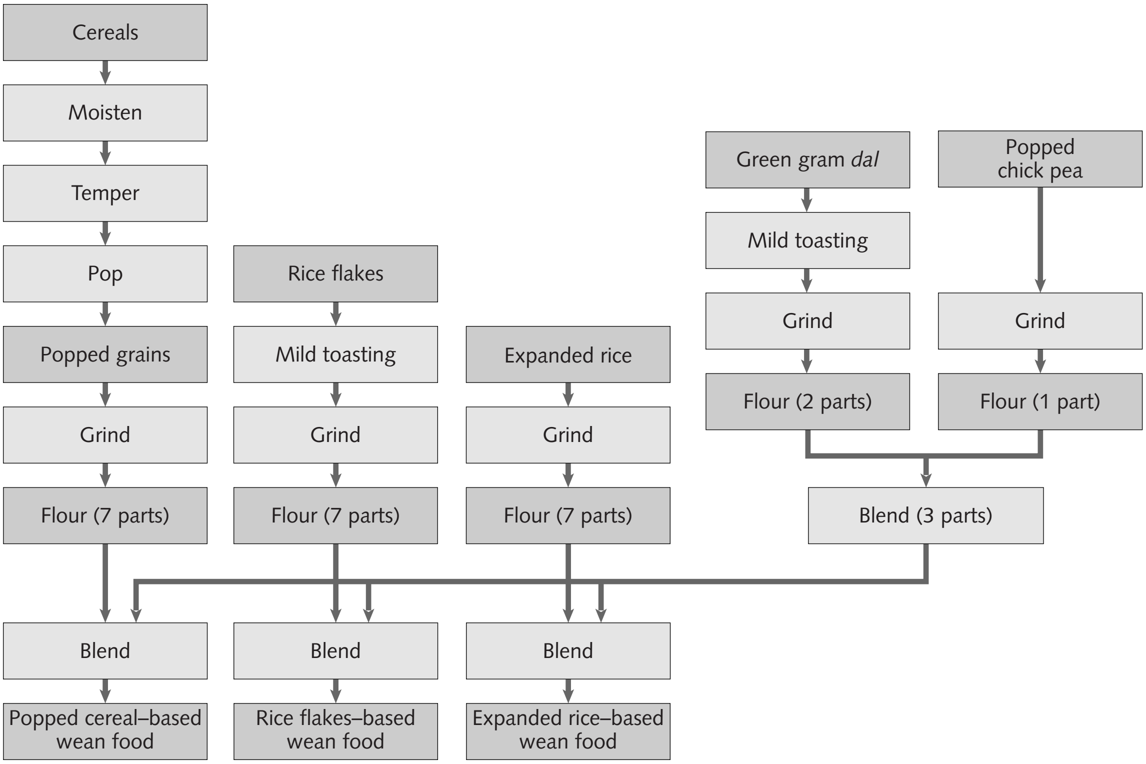

FIG. 7. Preparation of weaning foods based on popped rice flakes and expanded rice

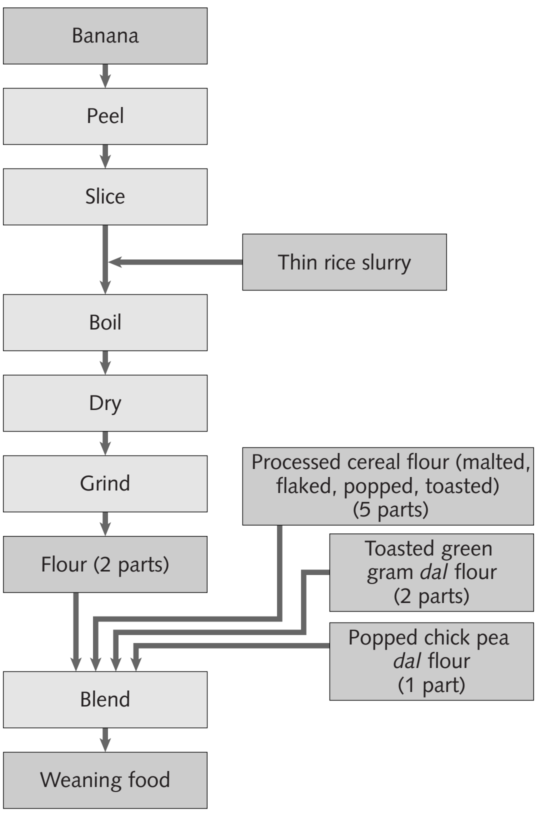

FIG. 8. Preparation of banana-based weaning food

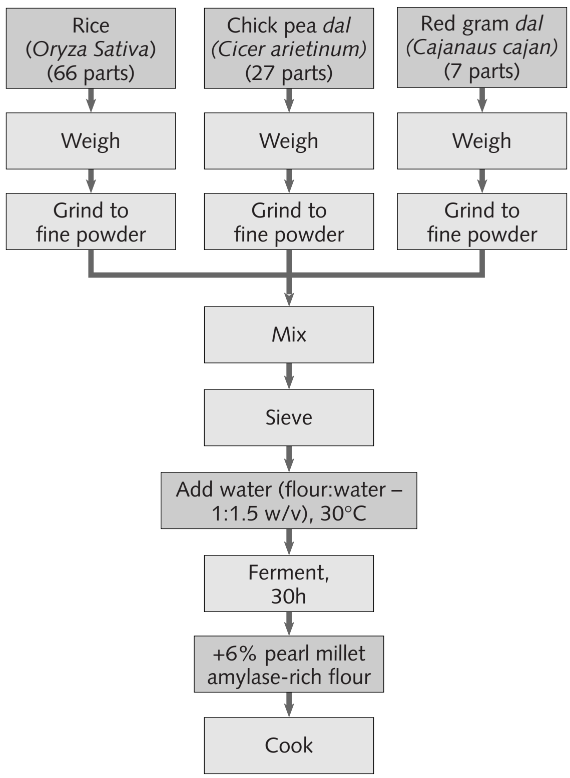

FIG. 9. Preparation of weaning food based on fermented cereal and legumes

Varieties of weaning foods

A variety of weaning foods have been developed containing rice, chickpea, and red gram [52], amaranth (*Amaranthus paniculatus* L.), chickpea and green gram [53], finger millet [54], soy and whey [55], and split pea and ham [56]. Processes for these are described in figures 9 to 13. Other varieties of weaning foods have been reported [57–63].

To reduce the bulk of gruels from popped and roller dried foods, 95 g each of the foods can be mixed with 5% barley malt. These are called popped weaning food with malt (PWFM) and roller dried weaning food with malt (RWFM). Germination of barley for 48 hours enhances its amylase activity substantially, resulting in a considerable reduction in viscosity.

Sprouting chickpea for about 24 hours reduces its content of flatulence-causing oligosaccharides and improves protein and carbohydrate digestibility. Kilning barley (green malt) at about 65°C and chickpea at 80°C for about 45 minutes improves the taste and gives a desirable aroma without seriously affecting amylase activity. Kilning also reduces the microbial load of the product considerably. To formulate low-bulk weaning foods of finger millet, sorghum, and wheat, two-day malted cereals are blended with one-day malted legumes.

A blend of amaranth seeds (28.8%), pearled oats (28.7%), soybeans (16.1%), sucrose (18.3%), and vegetable oil (5.6%) has the following approximate composition: protein 17.2%, fat 15.2%, carbohydrate 61.1%, crude fiber 1.9%, ash 2.6%, and moisture 1.7%. The PER is 2.9 [64]. Toasted amaranth flour increases the nutritional quality of maize and grain amaranth in preparations and can enhance the protein and lipid content of the diet significantly. Different formulations can be prepared from cereal, amaranth, spinach, and skim milk powder [65]. A high-quality weaning food from maize-cowpea-crayfish mixtures was proposed by Abbey and Kanga [66] to closely resemble Cerelac, a commercially available weaning food.

Blends prepared from wheat flour, rice flour, and

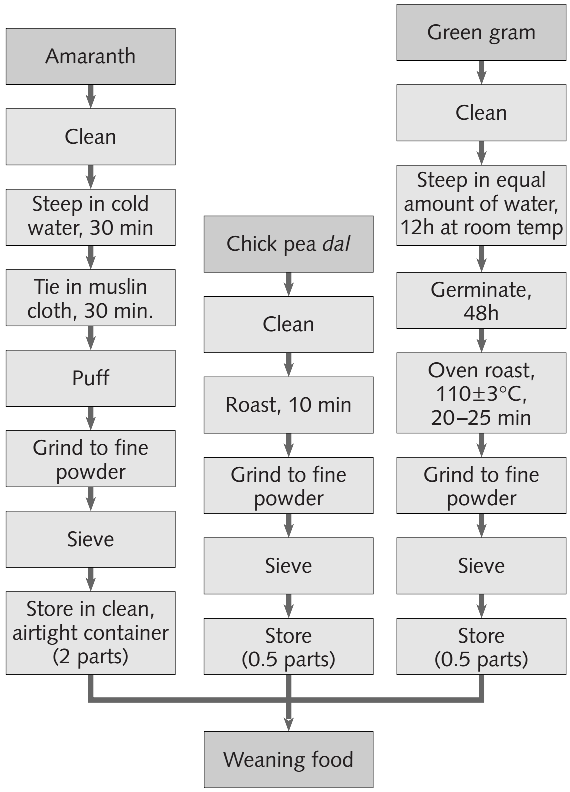

FIG. 10. Preparation of amaranth-based weaning food

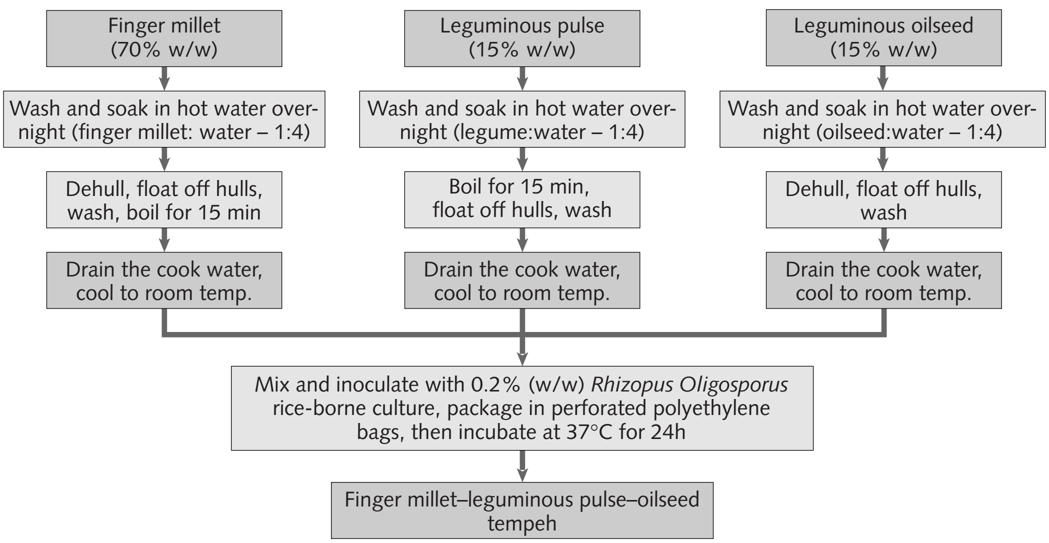

FIG. 11. Preparation of finger millet–based tempeh

milk powder in the ratio of 30:30:40 were found to be an ideal food for infants [67]. The quantities of lecithin, sugar, and salt added were 1.3, 4, and 0.7 g per 100 g of the blend mixture, respectively. The mixture was mixed with water and cooked at 100°C and then oven dried at 60° to 70°C for 12 hours. Vanilla, 0.1 g per 100 g of the dried sample, was added. The mixture was milled and then packed. The final blend had 11.8 g of moisture, 243.6 g of total solids, 28.9 g of protein, 17.7 g of lipid, 190.4 g of carbohydrate, and 5.7 g of ash per 255.2 g.

A fermented weaning food based on germinated sorghum, ungerminated wheat, germinated maize, and 5% soybean has been recommended as an ideal weaning food [68]. Maize and sorghum were soaked in water for 18 hours at ambient temperature (30°–32°C). The seeds were germinated at 30°C for four days. The dried germinated and ungerminated seeds were separately milled and stored at 5°C. About 150 g of the blends of cereal flour were separately weighed and sterilized at 121°C for 10 minutes, and soybean flour was aseptically incorporated into the blends at 5% w/w. The flour was stirred with a glass rod, followed by the addition of 500 ml of sterile water. The resulting mixture was inoculated with 1 ml each of *Saccharomyces cerevisiae* and *Lactobacillus plantarum* (3×10^6 CFU/ml). Fermentation was carried out at 30°C for 24 hours. The porridges met the requirements for an infant weaning food in terms of protein, mineral, vitamin, and amino acid contents.

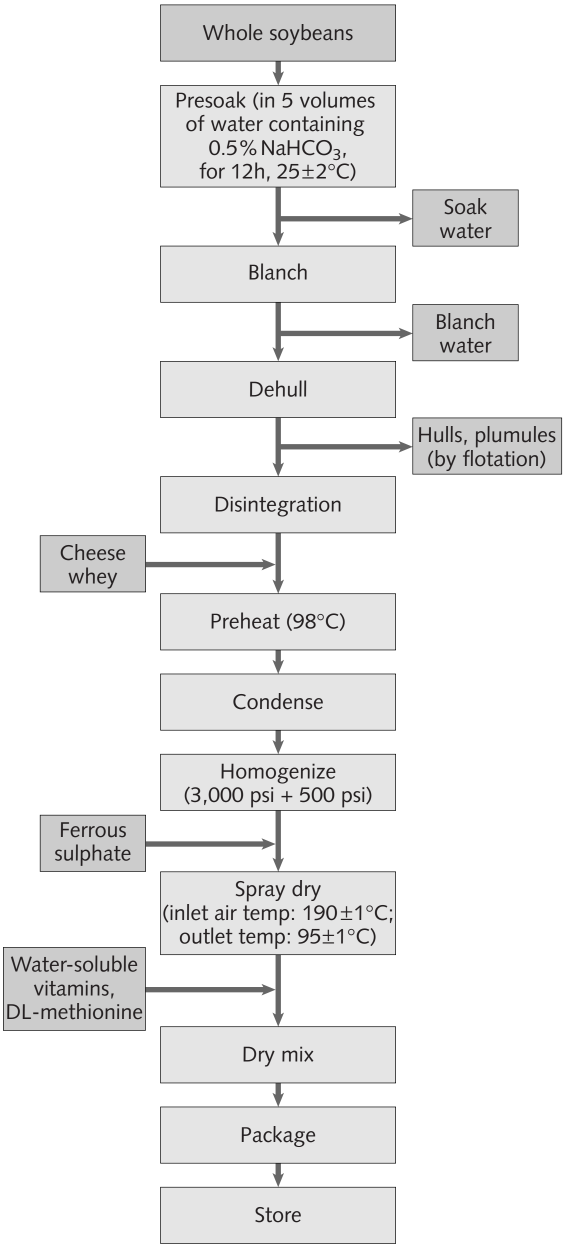

FIG. 12. Preparation of soy-whey weaning food

Conclusions

Weaning foods with good protein quality and energy density can be prepared by processing a variety of raw materials. Using 0.2% α-amylase or 5% barley malt at the commercial level can combat the high viscosity of cereal-based weaning foods. The main criterion is to satisfy the daily requirements of an infant receiving two or three feedings per day while at the same time meeting the quality standards prescribed by the legislation of the concerned country. It is also desirable to formulate weaning foods that produce a calorie density of at least 1 kcal per milliliter of gruel.

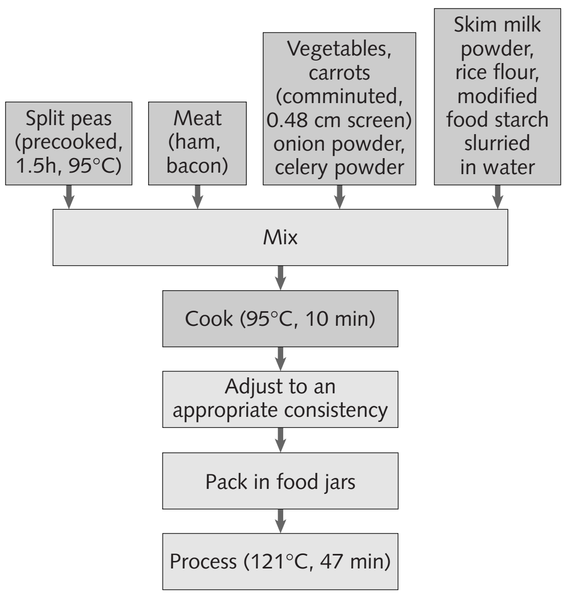

FIG. 13. Preparation of split pea and ham baby food

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Seasonal undernutrition in rural Ethiopia: Magnitude, correlates, and functional significance

Anna Ferro-Luzzi, Saul S. Morris, Samson Taffesse, Tsegaye Demissie, and Maurizio D'Amato

Marked seasonal variation of both production and consumption is characteristic of virtually all farming systems in the developing world. Seasonal variations in food security are linked to many other structural and economic problems, including agricultural stagnation and poor markets and infrastructure. Such conditions prevail in Ethiopia, where the decline in cereal production since the 1960s, the lack of rural infrastructure, and poorly functioning markets are major determinants of the country's notorious periodic famines. The widespread mortality and disease that accompany these famines are well documented, but less is known about the effects of seasonal energy stress in the "normal" years in between. It is therefore crucial to understand the effects of the seasonal energy stress that forms the background against which the more devastating effects of large-scale famine are drawn.

Understanding seasonal energy stress

Seasonal energy stress arises when dwindling household food stocks and purchasing power result in reduced energy intake, even as energy needs to produce the next season's food supply increase. People in more fortunate rural households find ways to avoid or resist seasonal energy stress, but many experience significant loss of body weight.

Seasonal loss of body weight in adults and impaired growth in children have significant human costs. In populations that lack large body-fat stores, much body-weight loss occurs in lean tissues, such as muscle and internal organs. Adults with very low body weight are more prone to illness, which can decrease income-generating capacity and cast the entire household into a downward spiral of impoverishment, debilitation, and undernutrition. Stunting in childhood is also associated with irreparable damage to cognitive function and increased susceptibility to disease.

This study examines the magnitude and significance of seasonal undernutrition in south-central Ethiopia: southern Shewa and Zigwa Boto, a peasant association in the Gurage Zone. These settings are vulnerable to even small stresses because of their extreme poverty and isolation.

The study seeks to answer five questions:

- Does seasonal energy stress affect individuals of different age groups and sexes differently?
- Do members of the same household show divergent responses to seasonal energy stress?
- What are the functional consequences of different levels of undernutrition?
- Are the current anthropometric cutoff points for adults appropriate for rural Ethiopia?
- What household characteristics are associated with vulnerability to seasonal undernutrition?

How policy can help reduce seasonal undernutrition

A number of important findings emerge from this research, even though the case study approach may make it difficult to generalize these to other areas of Ethiopia.

First, the problems of seasonal weight loss and chronic undernutrition are intimately linked. Among adults of both sexes in southern Shewa, chronic undernutrition is more common than weight loss at virtually all ages. The research suggests that Ethiopian parents may be "protecting" the nutritional status of their school-age children, who show almost no impact of seasonality. Adolescents are much less affected than adults. Government investments in education and training could reinforce this behavior.

Second, seasonal undernutrition is highly unpredictable; the impact of seasonal stress varies considerably within localities and within households. As a result, central authorities may find it difficult to target seasonal safety-net interventions appropriately. A large number of self-targeting public works programs have been implemented in Ethiopia, and these appear to have been reasonably successful in reaching more vulnerable segments of the population. In addition, community-based organizations have far better local information than central authorities and thus may be better equipped to implement small-scale insurance and relief programs.

Education, livestock holdings, and health are potentially important areas for intervention. Education of the household head strongly protects against seasonal undernutrition in adults, but not against chronic undernutrition. This finding supports investment in education as a long-term solution to seasonal undernutrition.

Households with more livestock are also less prone to seasonal undernutrition in adults and to seasonal wasting in children. In the highlands of Ethiopia, the labor-saving benefits of oxen may reduce the energy stress on adult men. Livestock also offer a form of savings that can be liquidated in times of hardship. Improving the livestock asset base of households at risk might therefore be a promising approach to protecting vulnerable households.

Finally, at least for young children, seasonal weight loss appears to be much more strongly associated with seasonal patterns of diarrheal disease than with seasonal changes in food availability in the household. Initiatives that reduce diarrheal disease are an integral component of rural development in areas with marked seasonality. The impact of seasonal energy stress on the incidence of low birthweight is also important. Supplementary feeding for pregnant women in the "hungry season" has been shown to be an effective intervention.

The study clarifies some points of contention in the field of adult undernutrition. First, this analysis strongly suggests that proposed cutoffs for body-mass index provide meaningful classifications of undernutrition, at least for men. Second, the data from Zigwa Boto show that adults are unable to "adjust" to undernutrition, either metabolically or mechanically. Third, seasonal undernutrition is more common among men than among women, and men's functional capacity appears to be much more sensitive to weight loss than women's. Since men do the bulk of agricultural work in the area studied, improving their nutritional status is imperative. Finally, seasonal undernutrition is merely one symptom of numerous problems in rural Ethiopia that include poorly developed labor markets, lack of financial resources, inadequate investment in human capital, and environmental degradation. This study shows how seasonal undernutrition operates as an intermittent warning signal, reminding us not to miss opportunities to promote good nutrition throughout the life cycle.

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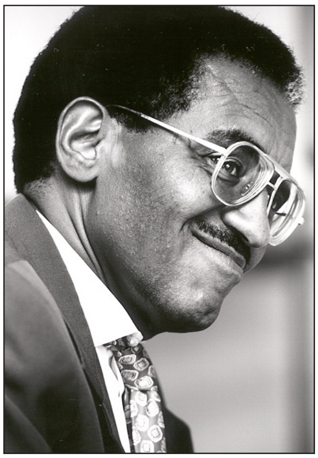
In Memoriam

Abraham Besrat, 1938–2002

With the death of Abraham Besrat in Addis Ababa, Ethiopia on April 4, 2002 Africa and the entire developing world lost one of its most devoted and effective supporters. For most of the past 20 years he guided the United Nations University (UNU) Fellowship Program for advanced training in nutrition and food science. He came to UNU as Fellowship and Training Officer in 1986 and was so highly regarded that he was promoted to Senior Officer, Principal Officer and finally Vice Rector. Before that, in 1984–85, he served as FAO consultant for projects dealing with the integration of nutrition into agriculture. All who came in contact with him were captivated by his sincerity, integrity, good judgment and modest manner. His death from complications of malaria and pneumonia at only 64 sent shock waves throughout the nutrition world.



Abraham Besrat obtained his BSc in general agriculture at the Imperial Ethiopian Agricultural and Mechanical Arts College. His MSc thesis from Oklahoma State University was concerned with the biological value of tef, the most important crop in his native Ethiopia. His PhD thesis from the University Minnesota focused on the mammalian metabolism of glutamic acid. He returned to Ethiopia in 1961 and for 15 years taught biochemistry at Addis Ababa University (originally Haile Selassie University). In this period he served the university in various positions including Dean of the College of Agriculture, Associate Vice President for Research and Publications and founding Dean of the School of Graduate Studies. His publications in national and international journals concerned capacity building, tef composition and fermentation, thyrotoxicosis, porphria cutanea, and glutamic acid metabolisms.

I first met Abraham when he was one of the principle speakers at a Symposium on Nutrition and Agriculture convened by the UN ACC Subcommittee on Nutrition (SCN) in 1981. I was so impressed by his presentation and personality, that I arranged a UNU Senior Fellowship for him to spend two years in the International Food and Nutrition Program at the Massachusetts Institute of Technology. There, he was much admired and highly regarded. At the end of his fellowship, the political situation in Ethiopia had become difficult and he accepted a position with FAO that gave him an opportunity to continue to serve Africa. He was highly effective and greatly admired in the region.

When I served in Tokyo for a year as Vice Rector of the UNU Development Studies Division in 1985, I arranged his initial appointment. His UNU years were not only successful and much appreciated but also happy ones. When he came to MIT, his wife Tsehai and two young children were not allowed to leave Ethiopia until near the end of his stay. With his traveling in Africa during his FAO period they remained in the United States with his wife's sister in Minnesota. Finally the family was reunited in Tokyo for a long period. His children thrived in the International School and all enjoyed their stay in Japan. After leaving UNU at the mandatory UN retirement age, he continued to carry out missions for the UNU Rector requiring his experience and diplomacy in many parts of the world.

Abraham, never lost sight of the needs of his country and during his time in Tokyo saved money to return and help it. However, this became a difficult decision since his wife's parents, who had spent most of their lives in Ethiopia, were expelled to their native Eritrea during the Ethiopian-Eritrean war and his wife could not safely return with him. Yet he did return and with his own funds had been enthusiastically supporting the introduction of high lysine maize into Ethiopia, and returning periodically to visit his family in New Jersey.

His death is a serious setback for our common dream—reestablishment of the original UNU Fellowship program with a special emphasis on Africa. In January of this year he became a co-director of the five million dollar five-year Ellison Medical Research Foundation fellowship program for strengthening developing country centers of excellence for research on nutrition and infection. This program is administered by the International Nutrition Foundation in cooperation with UNU and the International Union of Nutritional Sciences. He was responsible for its implementation in Africa and at the time of his death was about to embark on a series of site visits to selected institutions in Africa to identify fellowship candidates.

Abraham Besrat was one of the finest human beings I have ever known. His absolute integrity, gentleness, kindness, and objectivity were almost saintly. His good judgment and honesty could always be depended upon. Even as UNU Vice Rector, he remained modest and unassuming. Among Ethiopian nutritional and agricultural scientists and nutritionists throughout Africa, his name was always a recommendation and a basis for admiring conversation. He will remain a model for all of us who knew him. We can aspire to be like him, but will inevitably fall short. As a former UNU fellow from Bangkok wrote "I cried at the news." All who knew him share this grief.

Nevin S. Scrimshaw

Dr. Rajammal P. Devadas, 1919–2002

Dr. Rajammal P. Devadas, the recipient of the Quadrennial Award of International Union of Nutritional Sciences (IUNS) at the International Congress of Nutrition in Vienna last August died on March 17, 2002. She was an exceptional administrator, renowned scientist, and outstanding educator and teacher. Her achievements include integrating nutrition education in the primary schools of four of the States of India, training thousands of personnel for the Tamil Nadu Integrated Nutrition Project and directing the adult education and functional literacy program in 300 villages in Coimbatore District and 100 centers in the slums or Coimbatore city.

She has represented India in over 60 international conferences in about 50 countries. She was elected first Vice-President of the 1970 FAO World Food Conference in The Hague, Holland. Fifty of her graduate students received doctoral degrees and an equal number masters degrees. She has not only written 350 research papers published in scientific journals in India and abroad, but also over 350 popular articles on nutrition. Of her 37 books, 18 are in English and 19 in Tamil. She was editor of the monthly Journal of Nutrition and Dietetics, Coimbatore.

After her early education in India, she received MSc, MA, and PhD degrees from Ohio State University in the United States and returned to India as a Lecturer at Queen Mary's College, Madras, and then Dietician and Professor of Nutrition, College of Nursing, New Delhi. From 1953–55 she served as Dean and Professor of Nutrition, Faculty of Home Science, University of Baroda. In 1960 she begin her long career at Sri Avinashilingam Home Science College in Coimbatore, India where she served successively as Professor, Dean of Graduate Studies, Vice Chancellor, and since 1994 as Chancellor.

Within India she held many positions in professional associations and committees including President of the Home Science Association of India from 1971–1981 and President of the Nutrition Society of India from 1983–1990. Internationally she was regional Vice President of the International Federation of Women in Agriculture, member of the Association of Women in Development (USA), member of the regional coordinating group for research for the World Alliance for Breast Feeding Actions (WABA), International Organization for Science and Technology Education (IOSTE), and several committees of the International Union of Nutritional Sciences.

At her IUNS award lecture in Vienna, she stunned the audience by the number and achievements of her students at all professional levels and received a prolonged standing ovation. She received honorary degrees from Oregon State University, Ohio State University, and the University of Ulster, and the University of Agriculture and Technology, Kanpur, UP. She was awarded the National Rafi Ahmed Kiowal gold medal for original research in human nutrition and 14 other national awards in India.

Rajammal Devadas was diminutive in stature but she had a powerful personality and drive, dedication to nutrition, and commitment that led to her extraordinary contributions to nutrition in India and the world.

Doris Howes Calloway, 1923–2001

Teacher, Mentor Scholar, Humanist, Friend She made a difference

Doris Calloway died August 31, 2001, in Seattle, Washington, USA, after a long battle with Parkinson's disease, at the age of 78. Born in Canton, Ohio, she earned her Ph.D. at the University of Chicago and became an outstanding nutrition scientist, widely known for her work on protein and energy metabolism and requirements and highly respected for the honesty and objectivity of her work. In metabolic studies conducted at the University of California in Berkeley, she led the development and application of new methodologies for the quantification of intake, using carefully controlled nitrogen balance studies that included nitrogen losses in hair, flatus, desquamated skin, and sweat. Many of her innovative approaches were subsequently adopted in metabolic research around the world.

The results of the research conducted under her direction have had a marked impact on human requirement estimates. A major international contribution was her organization of the longitudinal field studies using a common protocol in Egypt, Kenya, and Mexico to explore the functional consequences of malnutrition. As in this case, she tried to answer what "adequate nutrition" really meant in terms of the life and function of individuals and households in the developing world, as well as the obverse, "What is the human cost of inadequate food and nutrient intake?" Equally important was her contribution as a role model for generations of students from all over the world. She was also dedicated to improving opportunities for women and members of minority races. The scientific issues she explored were often linked with, but not limited by, their needs.

Doris Calloway joined the Department of Nutritional Sciences at Berkeley in 1963 and later became head of the Department, and from 1981 to 1987 she was Provost for the Professional Schools and Colleges. She was appointed to the WHO Expert Panel on Nutrition in 1972 and to the Technical Advisory Committee of the Consultative Group on International Agricultural Research in 1989, and she served on many other international committees and advisory groups. In the United States, she participated in several revisions of the NRC Recommended Dietary Allowances and chaired the 1995 USDA Dietary Guidelines Advisory Committee.

Her contributions were recognized by many awards, including the Conrad Elvejhem Award of the American Institute of Nutrition, the Bristol-Myers Squibb/Mead Johnson Award for distinguished achievement in nutrition, and membership in the US National Academy of Sciences Institute of Medicine. With both wry humor and pride, she hung her first award, received for work with the US Army nutrition laboratories in Chicago, in her office for many years. It reads: "Outstanding Man of the Year."

Books received

Environmental stressors in health and disease. Edited by Jorgen Fuchs and Lester Packer. Marcel Dekker, New York, 2001. (ISBN 0-8247-0530-0) 504 pages, hardcover. US$195.00.

This book deals with molecular and cellular aspects of oxidative stress induced by environmental xenobiotics and their effects on the key target organs: lung, skin, and eye. Disappointingly, reference to the widespread modulating effects of nutritional status is limited to nutritional influences on the risk for cataracts.

Healthy documents. A source book of important documents and instruments that impact on people's health. Compiled by Lakshmi Menon. WABA, PO Box 1200, 10850 Penang, Malaysia, secr@waba.org.br, 2001. US$20, including international airmail postage and handling. Payment can be by bank draft or personal check drawn on a US bank.

Healthy Documents is a compilation of resolutions, declarations, and charters on health made at international meetings as well as UN instruments, including covenants, treaties, programs, and platforms of action ratified by various governments or states parties. They are divided into the following categories: medical ethics (2), health rights (6, including 2 UN instruments), public health (16, including 9 UN instruments), health and social development (5 declarations and UN instruments), nutrition (3 declarations and UN instruments), children's health (4, including 2 UN instruments), and women's health (10, including 6 UN instruments). An appendix provides the website addresses for 37 of these 46 documents.

The World Alliance for Breastfeeding Action (WABA) produced a first draft of this document as a contribution to the People's Health Assembly held in Bangladesh in December 2000, but the final version was only published in July 2001. For those who doubt the value and potential impact of such documents, two brief examples are provided within the breastfeeding field of how they have been put to good use for making important changes in public health policy and practice throughout the world.

One would be hard put to find any other book containing the texts of so many documents broadly or specifically relevant to the health field: for example, the Hippocratic Oath, the Declaration of Helsinki, the People's Health Charter, the Declaration of Alma Ata, the Universal Declaration of Human Rights, the Convention Relating to the Status of Refugees, the Rio Declaration, the Framework Convention on Tobacco Control, the UN Convention on the Rights of the Child, the Beijing Declaration and Platform for Action, and the ILO Maternity Protection Convention 183. I highly recommend the book to all medical libraries and health policy makers, though I suspect that many health practitioners and students will also find it invaluable.

The nutrition documents included are the Rome Declaration on Hunger (1982), the World Declaration on Nutrition (1992), and the Rome Declaration on World Food Security (1996). The following documents related to breastfeeding are included: the Innocenti Declaration on the Protection, Promotion and Support of Breastfeeding (1990) and the International Code of Marketing of Breast-Milk Substitutes (1981).

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Iron deficiency and malaria as determinants of anaemia in African children. Hans Verhoef. Universal Press, Veenendaal, Netherlands. (ISBN 90-5808-471-X) 191 pages, paperback.

Approximately three-quarters of East African children less than five years of age suffer from anemia, which is usually due to iron deficiency, often augmented by the effects of malaria. This publication is based on doctoral research that had as one objective measurement of the efficacy of biweekly iron supplements, a monthly therapeutic dose of sulfadoxine-pyrimethamine, or both measures in improving the iron status of children 1 to 26 months old to reduce the incidence of malaria attacks, as compared with a placebo group. Iron supplementation alone decreased anemia, but combined therapy was more effective. The malaria suppression dose alone had no effect on hemoglobin levels.

Malaria-induced hemolysis was accompanied by an increase in erythropoiesis that would be expected to be limited by iron availability. Survival analysis indicated no increased risk of malaria following iron supplementation. These research findings support the World Health Organization recommendations for both treatment and iron supplementation of children in endemic malaria areas.

Nutritional anemias. Edited by Usha Ramakrishnan. CRC Series in Modern Nutrition. CRC Press, Boca Raton, Fla., USA, 2001. (ISBN 0-8493-8569-5) 260 pages, hardcover. US$89.95, £59.99.

Nutritional anemias are the most widespread nutritional disorders remaining in the world today. Those due to iron deficiency alone affect one-fifth of the world's population and are heavily concentrated in the women and children of developing countries. When iron deficiency is corrected, other nutritional causes of anemia are revealed. The chapters on the prevalence and causes of nutritional anemias, the assessment of nutritional anemias, and the functional correlates of nutritional anemia in infancy and early childhood are particularly good, but the information provided in the other chapters is also reliable.

It is impossible, however, for any book to keep up with the rapid progress in this field, particularly as applied to different populations at varying levels of development and need. It must be supplemented by referral to current literature on specific issues, and particularly to the reports that are emerging from international meetings on this topic. The need for iron supplementation in infancy is well covered, and iron-fortified cereals are recommended to meet this need. However, these are not available to populations in most developing countries, and there has been much recent progress and experience with friable and soluble multivitamin supplements for this age group. The demonstrated success of maize and wheat flour fortification on a national scale since 1983 in Venezuela is not mentioned. Despite such limitations, this is a concise, authoritative, timely, and welcome resource.

Nutrition and growth. Edited by Reynaldo Martorell and Ferdinand Haschke. Nestlé Nutrition Workshop Series, Pediatric Program, Volume 47. Lippincott Williams & Wilkins, Philadelphia, Pa., USA, 2001. (ISBN 0-7817-3467-3) 423 pages, hardcover. US$89.00.

This volume presents new data for the assessment of infant and child growth, reviews major causes of growth retardation, and analyzes the effects of nutrition intervention programs on growth and development. Progress in generating new growth standards and public health approaches to prevent growth failure are well covered. So are the effects of acute and chronic infection on nutrition-related growth failure. The problem of the simultaneous rise of obesity and malnutrition in the more advanced developing countries receives appropriate attention, as does evidence for a link between early growth retardation and chronic diseases in adulthood. The 20 chapters are authoritatively written and well documented, with relevant discussions after each. This volume is highly recommended for those concerned with issues of nutrition and growth.

Nutrition and health in developing countries. Edited by Ricard D. Semba and Martin W. Bloem. Humana Press, Totowa, N. J., USA, 2001. (ISBN 0-89603-806-8) 569 pages, hardcover. US$125.00.

There has long been a need for a comprehensive and authoritative book that examines the continuing transition in nutrition and health in developing countries. The dramatic improvements in mortality, life expectancy, and stature in the industrialized countries are spreading rapidly to the more advanced developing countries, and changes are occurring even in the most backward. This book covers exceptionally well the epidemiology of acute and chronic nutrition disorders and related infections. It is quite appropriate that chapters deal with diarrheal diseases, respiratory infections, measles, malaria, tuberculosis, and HIV infection.

It also explores issues such as urbanization, food and nutrition security; the impact of nutrition and health programs; the economics of nutrition intervention, planning, and policy development; and the nutritional and health significance of the epidemiological and demographic transition in developing countries. Many countries must cope with an increase in overnutrition, obesity, and chronic degenerative diseases as well as an epidemic of HIV/AIDS at a time when their future generations are still being crippled by micronutrient deficiencies.

Each chapter includes a historical perspective and suggestions for future research. They provide a better understanding of both the positive and the negative changes in the determinants of health that developing countries are experiencing in the 21st century. Written by well-known experts, the chapters are well planned and integrated to provide comprehensive coverage of their topics. This volume is highly recommended for all who are struggling with the nutrition and public health problems of developing countries. It is unfortunate that its price will put it out of the reach of most developing-country nutrition and health workers.

The politics of precaution: Genetically modified crops in developing countries. Robert L. Paarlberg. Johns Hopkins University Press, Baltimore, Md., USA, 2001. (ISBN 0-80188-6823-8) 180 pages, paperback. US$19.95.

The potential revolution in farming made possible by genetically modified crops has created an international divide in policies toward this new technology. Farmers in Argentina, Canada, and the United States have adopted these crops quickly, but most others have adopted a precautionary approach or banned them entirely. This book presents the first clear picture of how some developing countries are dealing with the shifting scientific and policy environment surrounding genetically modified crops. It compares China, which has officially approved the planting of these crops, with Brazil, India, and Kenya, which have pursued a precautionary approach, often over the objections of their own farmers. The author shows how these countries are not necessarily responding to scientific evidence, but rather to political and social pressures from international environmental and nongovernmental organizations and donors outside their borders. This study, published under the auspices of the prestigious International Food Policy Research Institute (IFPRI), is of great interest to anyone involved in or attempting to follow the international debate over genetically modified foods and crops.

The unfinished agenda: Perspectives on overcoming hunger, poverty and environmental degradation. Edited by Per Pinstrup-Andersen and Rajul Pandya-Lorch. International Food Policy Research Institute, Washington, DC, 2001. (ISBN 0-89629-706-7) 299 pages, paperback. US$19.95.

In the early 1990s, a world free of hunger and poverty seemed a long way off. Today the International Food Policy Research Institute (IFPRI) finds that some parts of the world have made great strides toward sustainable food security, others are moving more slowly, and some are losing ground. This book is a compilation of the policy briefs providing state-of-the-art information gathered for the IFPRI "2020 Vision for Food, Agriculture and the Environment." Because libraries do not collect and catalogue such publications, they have been assembled in this volume as a way to make them readily available for policy debate and action.

Multiple chapters, 40 in all, are grouped under each of the following topics: The Unfinished Agenda and Prospects for the Future, Nutrition and Health as the Ultimate Goals, Demographic Issues, Diet Trends, Food Production and the Environment, the Hot Spots of Sub-Saharan Africa and South Asia, Microcredit for the Rural Poor, Gender and Education Issues, Globalization, Biotechnology, and Information Technology. The editors contribute the final chapter on Putting the Knowledge to Work for the Poor, Required Policy Options. These are the policy issues that the world must address to overcome poverty, hunger, and environmental degradation. Everyone concerned with these issues should obtain a copy of this affordable paperback in order to have ready access to this wealth of material.

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The editors of the *Food and Nutrition Bulletin* welcome contributions of relevance to its concerns (see the statement of editorial policy on the inside of the front cover). Submission of an article does not guarantee publication—which depends on the judgement of the editors and reviewers as to its relevance and quality. All potentially acceptable manuscripts are peer-reviewed. Contributors should examine recent issues of the *Bulletin* for content and style.

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—corporate author:

2. Committee on Enzymes of the Scandinavian Society for Clinical Chemistry and Clinical Physiology. Recommended method for the determination of gammaglutamyltransferase in blood. Scand J Clin Lab Invest 1976;36:119–25.

Book or other monograph reference

—personal author(s):

3. Brozek J. Malnutrition and human behavior: experimental, clinical and community studies. New York: Van Nostrand Reinhold, 1985.

—corporate author:

4. American Medical Association, Department of Drugs. AMA drug evaluations, 3rd ed. Littleton, Mass, USA: Publishing Sciences Group, 1977.

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5. Medioni J, Boesinger E, eds. Mécanismes éthologiques de l'évolution. Paris: Masson, 1977.

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