Contents

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The National Vitamin A Supplementation Program and subclinical vitamin A deficiency among preschool children in the Philippines

M. R. A. Pedro, J. R. Madriaga, C. V. C. Barba, R. C. F. Habito, A. E. Gana, M. Deitchler, and J. B. Mason

Abstract

The prevalence of vitamin A deficiency (serum retinol [SR] < 20 µg/dl) in children from one to five years of age in the Philippines rose from 35.8% to 38% between 1993 and 1998, despite a twice-yearly universal vitamin A capsule distribution program. The Philippines 1998 National Nutrition Survey, with one-time SR measurements from 11,620 children from one to four years of age, collected over an eight-month period from one month to more than six months after distribution of vitamin A capsules, was an opportunity to examine the impact of the program on the children's vitamin A status, using post hoc analysis. Overall, a detectable impact of vitamin A capsules on SR was limited to groups with the highest prevalence of vitamin A deficiency and lasted up to four months after dose administration. In highly urban cities in Visayas, where very high prevalences of deficient SR (SR < 10 µg/dl) were found, the prevalence of deficient SR was reduced from 27% to 9% one to two months after distribution of vitamin A capsules, and to 16% at three to four months. In Mindanao, a statistically significant reduction from 38% to 32% was seen in the prevalence of deficient to low SR (SR < 20 µg/dl) one to four months after distribution of vitamin A capsules. There was no overall reduction in the prevalence of vitamin A deficiency or deficient and low SR (SR < 20 µg/dl) in Luzon, but a significant interaction with stunting was observed in Luzon non-highly urbanized cities. Two aspects are of concern. First, the magnitude of the effect of high-dose vitamin A capsules on SR, and hence on the extent of reduction in deficiency, is limited. Second, the effect does not persist for six months, which is the interval between doses. Thus there is no decrease in the prevalence of deficiency over time. With more frequent dosing (especially to those most deficient in SR), a progressive reduction in vitamin A deficiency could, however, be expected; this hypothesis could be tested. The policy implication arising from these results is that a shift in resources is warranted. In areas of low prevalence of vitamin A deficiency, distribution of vitamin A capsules should be targeted to stunted children. In areas of high prevalence, vitamin A capsules should be distributed to children one to five years old at least three times a year.

Key words: Philippines, serum retinol, vitamin A, vitamin A deficiency, vitamin A supplementation

Introduction

In the 1970s, local surveys on xerophthalmia by the Nutrition Center of the Philippines [1] demonstrated that vitamin A deficiency among preschool children was a public health problem in Cebu and other provinces and in Metro Manila. Since 1982 the problem has been documented for the whole country by National Nutrition Surveys [1, 2]. In 1993 the government launched, and has since been implementing, the National Twice-Yearly (six-monthly) Vitamin A Supplementation Program for one- to five-year-old children in an effort to alleviate the problem of vitamin A deficiency and reduce childhood morbidity and mortality. The distribution of 200,000 IU vitamin A capsules is carried out on "Child Health Days" (previously called *Araw ng Sangkap Pinoy*, or ASAP) in April and November of each year, through the Department of Health, Local Government Units, and a network of community volunteers or *barangay* (the smallest political unit

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throughout the Philippines) health workers. Vitamin A supplementation of pregnant women at low dose levels and of postpartum women at high levels (200,000 IU) was piloted in one province in 2003 and will be implemented on a national scale to address vitamin A deficiency among children under one year of age and thereby prevent new cases of vitamin A deficiency among one-year-olds.

There has been no national and systematic effort to evaluate the impact of the country's high-dose vitamin A supplementation program. National Nutrition Surveys found that the prevalence of deficient to low SR among children six months to five years of age was 35.8% in 1993 and 38% in 1998. However, these two surveys employed different sampling frames. The 1993 survey included 3,773 children from a subsample representing 50% of the survey's 4,050 sample households, which was drawn by two-stage sampling with the barangay and the household as the primary and secondary sampling units, respectively [2]. The 1998 survey included 14,291 children who were randomly sampled, also by the use of a two-stage design, with the barangay and the individual, instead of the household, as the primary and secondary sampling units [3]. Nonetheless, the prevalence estimates are taken to be broadly comparable. At a minimum, the lack of an improving trend was cause for concern. Although the National Nutrition Surveys were not designed to evaluate the effectiveness of the vitamin A supplementation program, the 1998 National Nutrition Survey data* provided an opportunity to examine the relation of the vitamin A capsule distribution program to children's vitamin A status as assessed by SR. A summary of these findings was presented at the International Vitamin A Consultative Group (IVACG) meeting in early 2003 [4].

Methods

Description of the 1998 National Nutrition Survey

National Nutrition Surveys are carried out every five years in the Philippines to assess household dietary intakes and the nutritional status of various age groups of the population, using anthropometric, biochemical, and clinical indicators. The 1998 National Nutrition Survey included one-time SR measurements in blood taken from children six months to five years of age, collected over the eight-month period during which the survey was in the field. This period occurred more than six months after the national distribution of high-dose vitamin A capsules took place during the year.

*Food and Nutrition Research Institute-Department of Science and Technology. Philippine Nutrition Facts and Figures. http://www.fnri.dost.gov.ph

Survey sampling design and coverage

The 1998 National Nutrition Survey used a two-stage stratified sampling design that covered all 16 regions of the country, including the National Capital Region or Metro Manila, 76 of the 78 provinces, 10 cities, a cluster city-municipality in the case of the National Capital Region, and 10 highly urbanized cities. Barangays served as the primary sampling units and children six months to five years old as the secondary sampling units. A total of 778 barangays and 28,698 children zero to five years old were included in the sample [5]. For the Biochemical Nutrition Survey component of the National Nutrition Survey, only 763 barangays and 14,291 children were included. Two provinces, Basilan and Lanao del Sur, and Marawi City, in Mindanao, were excluded due to dangerous conditions at the time of the survey [3]. The number of primary sampling units ranged from 6 to 10 per province or city, or per cluster city-municipality, depending on the total household population.

The survey period was from May to December 1998. Because of the large area of coverage, data were collected from one region at a time. Most areas of the National Capital Region were surveyed from May to July. The survey teams covered the northern part of Luzon in June and July, and then moved south to the Visayas region from July to September and the Mindanao region from August to October. The survey teams returned to the National Capital Region in November and December to cover the remaining survey areas and complete data collection.

Collection of blood and serum samples

Blood samples were collected by fingerprick using disposable lancets. Approximately 0.4 ml of blood was collected in heparinized capillary tubes. Serum was separated from red cells by centrifugation, and serum samples were kept frozen at all times in the field and while in transit to the Food and Nutrition Research Institute (FNRI) laboratory. The samples were stored at –20°C for later analysis.

Laboratory analysis of SR

SR was determined by the high-pressure liquid chromatography (HPLC) method described by Furr et al. [6]. The accuracy of the method was assessed using a standard reference material for fat-soluble vitamins and cholesterol in human serum (SRM 968B). The interassay coefficient of variation for the SR analyses was 3.26 %. The cutoff points established by the World Health Organization/UNICEF/Helen Keller International/International Vitamin A Consultative Group (WHO/UNICEF/HKI/IVACG) [7] were used to interpret SR values. SR values < 10 μg/dl (0.35 μmol/L) were classified as deficient, values between 10 and < 20 μg/dl (0.35 and < 0.70 μmol/L) as low, and values of ≥20 μg/dl (0.70 μmol/L) as acceptable to high.

Other variables

The 1998 National Nutrition Survey included a number of other variables [8]; relevant here were “participation in ASAP,” “months after ASAP,” “infections,” and nutritional status classification using weight-for-age, weight-for-height, and height-for-age indices and the National Center for Health Statistics (NCHS)/WHO reference [9]. ASAP referred to the Philippines micronutrient program, which included distribution of vitamin A capsules to children one to five years old, held in April–May and October–November 1998. “Participation in ASAP” was recorded as “yes” or “no” at any of the scheduled ASAP periods for the year. Since blood samples were collected at different months in different regions, “months after ASAP,” i. e., the number of months since the last vitamin A capsule dose (whether April or October), was recorded for each child who participated in the vitamin A capsule program; those not participating were recorded as having received no dose. “Presence of infections” referred to a report of one or more episodes of diarrhea, cold, cough, sore throat, fever, or measles during the month that preceded data collection. The children’s weight and height were measured by standard procedures [5]. Weight was measured with a calibrated 160-kg capacity platform-type beam-balance scale and recorded to the nearest 0.1 kg. Standing height, for children two years of age or older, was measured with a microtoise and recorded to the nearest 0.1 cm. For children under two years old, recumbent length was measured with an infantometer or wooden length board and also recorded to the nearest 0.1 cm. The child’s age was based on the date of birth reported by the mother or caregiver and verified from birth or other health records during the interview.

Although the important contribution of dietary vitamin A intake to SR was recognized, the 1998 National Nutrition Survey, unlike that of other years, did not include a food-consumption survey component. The “month of data collection” nonetheless may reflect the season of the year and the availability of vitamin A–rich fruits.

Characteristics of data and data analysis

Data from the 1998 National Nutrition Survey were entered and processed by the Statistical Package for the Social Sciences (SPSS) program. For the analysis reported in this paper, sample children from one to five years of age and with SR less than 100 µg/dl were included (i.e., all data from children less than one year of age as well as from those with SR of at least 100 µg/dl were set as missing values). Infants less than 12 months of age were excluded because children in this age group were not given vitamin A capsules under the National Supplementation Program. The data (sample size, mean SR, and prevalence of low or deficient SR) were tabulated according to geographic area, month of data collection, receipt of vitamin A capsules, and number of months after the receipt of vitamin A capsules to note general characteristics. The data were then aggregated by major geographic areas of the country to distinguish differences in SR and prevalence of vitamin A deficiency that may be due to the months during which the survey or data collection was conducted or the season. The geographic groupings were Luzon (Northern Philippines, with the National Capital Region), Visayas (Central Philippines), and Mindanao (Southern Philippines) (fig. 1). The data were also aggregated by two- to three-month bands for month of data collection to distinguish seasons, and by two-month intervals of the number of months after receipt of vitamin A capsules.

The mean SR and prevalence of vitamin A deficiency in highly urbanized cities in Visayas and Mindanao, and the National Capital Region in Luzon, were different from the values in the rest of the provinces and in less urbanized cities within the geographic groups. Groups defined as Visayas highly urbanized cities, Mindanao highly urbanized cities, and the National Capital Region were therefore examined separately from the respective geographic groups without highly urbanized cities and excluding the the National Capital Region. For Visayas highly urbanized cities, the data were further disaggregated to low (≤ 10% prevalence of SR < 10 µg/dl) and high (> 10% prevalence of SR < 10 µg/dl) prevalence of vitamin A deficiency in some of the analyses, as described later.

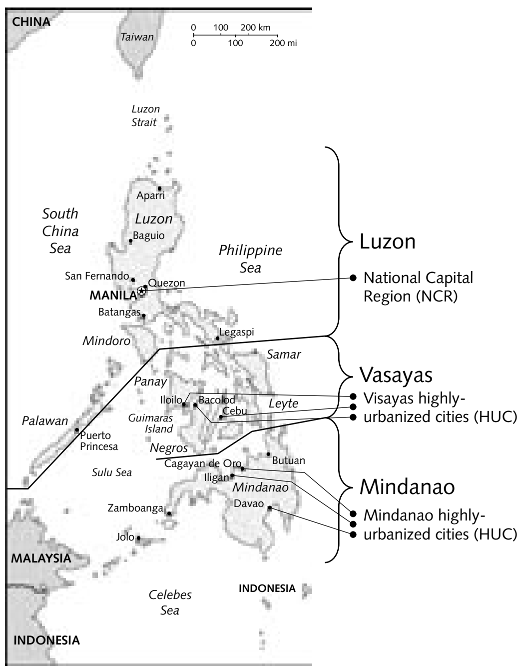

FIG. 1. Study areas in the Philippines. HUCs, highly urbanized cities

TABLE 1. Number of Filipino children one to five years of age with serum retinol (SR) < 100 µg/dl according to month of data collection, island group, and number of months after receipt of vitamin A capsules (VAC), 1998 National Nutrition Survey, Philippines

			No. of months after VAC							
Month	Island group	No VAC	1	2	3	4	5	6	> 6	Total
May	Luzon	49	180				1	1	3	234
	Subtotal	49	180				1	1	3	234
Jun	Luzon	285	431	471	54	1		30	19	1,291
	Subtotal	285	431	471	54	1		30	19	1,291
Jul	Luzon	236	2	480	823	24	2	2	126	1,695
	Visayas	34	6	45	150	8	1		1	245
	Subtotal	270	8	525	973	32	3	2	127	1,940
Aug	Luzon	78	9	10	341	285	83	174		980
	Visayas	144	8	25	226	433	46	49	1	932
	Mindanao	152	23	4	191	207		27	1	605
	Subtotal	374	40	39	758	925	129	250	2	2,517
Sept	Luzon	36	95			230	79	8		448
	Visayas	184	53	62	29	373	428	153		1,282
	Mindanao	310	199	17	12	279	275	44	1	1,137
	Subtotal	530	347	79	41	882	782	205	1	2,867
Oct	Luzon	18	41					4		63
	Mindanao	232	662	14		1	160	304	1	1,375
	Subtotal	250	703	14		1	160	308	1	1,438
Nov	Luzon	67	598	170		13	3	99	2	952
	Subtotal	67	598	170		13	3	99	2	952
Dec	Luzon	12	63	247	15			37	7	381
	Subtotal	12	63	247	15			37	7	381
Total		1,837	2,370	1,545	1,841	1,854	1,078	932	163	11,620

Table 1 shows the number of children in the 1998 sample one to five years of age with SR levels < 100 µg/dl according to the month of data collection, island group, and number of months after receipt of vitamin A capsules. The geographic group is shown, corresponding to the progress of the fieldwork through the country (thus, for example, only in August and September were all three island groups covered). A total of 11,620 children from one to five years old were included in the analysis.

The main outcome variables for the analysis were the mean SR concentration and the prevalences of deficient and deficient and low SR. Tabulation, descriptive analysis, simple linear regression using SPSS, and logistic regression using Stata were carried out. In the regression analyses, mean SR and classification of deficient and deficient and low SR (as dummy variables*) were dependent variables. Independent dummy variables VAC 1–2 (received vitamin A capsules one to two months before serum collection), VAC 3–4 (received vitamin A capsules three to four months before serum collection), and VAC 5–6 (received vitamin A capsules five to six months before serum collection) were entered in the regression equation, to determine the effects of supplementation at various periods after the administration of the dose, and to test their significance, as compared with the no-dose group. The month of data collection, nutritional status, and presence of infections at the time of data collection (variables that tend to affect a child's SR level as well as the child's participation in the national vitamin A capsule

* The dummy variables were as follows. VAC 1–2: 1 = received vitamin A capsule one to two months before serum collection; VAC 3–4: 1 = received vitamin A capsule three to four months before serum collection; VAC 5–6: 1 = received vitamin A capsule five to six months before serum collection. Stunted: 1 = height-for-age Z score ≤ 2; infection: 1 = had one or more episodes of diarrhea, cold, cough, sore throat, fever, or measles during the month that preceded data collection.

TABLE 2. Mean serum retinol (SR) level and prevalence of SR levels below 20 μg/dl in children 12 to 59 months old according to island group, season of data collection, and months after receipt of a vitamin A capsule (VAC), 1998 National Nutrition Survey, Philippines[a]

Island group	Season	No VAC	No. of months after VAC 1–2	3–4	5–6	Total
Luzon	May–Jun	24.1 33% (334)	25.9[b] 26% (1,082)	29.2 18% (55)	[23.5] 38% (32)	25.5 27.9% (1,525)
	Jul–Sep	23.7 35% (350)	24.6[b] 33% (596)	23.6[b] 34% (1,703)	23.0 30% (348)	23.9 33.3% (3,123)
	Nov–Dec	22.4 38.1% (97)	21.8 39.5% (1,119)	[18.7] 46.4% (28)	21.2 41% (143)	21.7 39.7% (1,396)
	All	23.7 34.8% (781)	24 33% (2,797)	23.7 33.9% (1,786)	22.5 33.8% (523)	23.8 33.4% (6,044)
Visayas	Jul–Sep	20 50% (362)	22.3[b] 41.6% (199)	22.5 39.3% (1,219)	20.3[b] 45.9% (677)	21.5 41.8% (2,458)
Mindanao	Aug–Oct	21 45.0% (694)	25[b] 30% (919)	23[c] 37% (690)	21.2 43% (810)	22.7 38.2% (3,117)
Total for all areas and periods		22 41.6% (1,837)	24.1[b] 32.7% (3,916)	23.2[b] 35.9% (3,695)	21.2[b] 41% (2,010)	23 36.5% (11,620)

a. From top to bottom, the values in cells are as follows: mean SR level (μg/dl), prevalence of SR levels < 20 μg/dl (%), and sample size (n) (in parentheses). The mean SR levels are in square brackets [ ] where $n < 50$.

b. $p < .05$ (paired contrasts in one-way ANOVA) comparing SR level with the previous value in the row to test whether the mean SR level within an island group changed significantly with time after receipt of vitamin A capsules. The level 1–2 months after receipt of capsules is compared with the level among those not receiving capsules.

c. The level 3–4 months after receipt of a vitamin A capsule is compared with the level among those who did not receive a vitamin A capsule. For the comparison between the levels 5–6 months after receipt of a vitamin A capsule and the levels among those who did not receive vitamin A, no differences were significant. The columns labeled "No. of months after VAC" do not include children whose SR was measured more than 6 months after receiving vitamin A; the "Total" column does include children whose SR was measured more than 6 months after receiving vitamin A.

program) were added into the regression equation to check the extent to which these may have influenced the effect of vitamin A capsules. Logistic regression was done to validate the results of the linear regression analysis, in which dummy variables for deficient and deficient and low SR were the dependent variables.

Results

Table 2 shows the SR levels and the prevalences of low and deficient SR (< 20 μg/dl) according to island group and season of data collection, in relation to the number of months after receipt of a vitamin A capsule. To simplify analysis and presentation, paired tests of significance are shown reading along rows, examining whether mean SR changed with time after receipt of the vitamin A capsule by comparing each value with that in the previous cell. For example, in Luzon during July to September, the mean SR for children receiving a vitamin A capsule in the preceding two months was 24.6 μg/dl ($n = 596$), significantly higher than the value of 23.7 μg/dl ($n = 350$) in the group that had not received a dose in the last six months. The group in the next cell ($n = 1,703$) had a mean SR of 23.6 μg/dl three to four months after receiving a vitamin A capsule, a significantly lower value than that at one to two months (24.6 μg/dl). The value at five to six months was 23 μg/dl; this was not significantly lower than that in the previous cell (23.6 μg/dl), but it was also not significantly different from that in the group that had not received a vitamin A capsule in the preceding six months (23.7 μg/dl) (see notes to table 2). Significance is tested on the means (hence on the overall distribution, using one-way ANOVA with post hoc multiple comparisons), and the results are also shown, for additional interpretation, as prevalences. Thus, the trend in the prevalence of SR levels less than 20 μg/dl was 35%

for those not receiving vitamin A capsules. For those receiving a capsule, the trend in prevalence was 33% one to two months after receiving the capsule, rising to 34% at three to four months, then falling to 30%; the last change is considered more likely to be due to seasonal effects than to the vitamin A capsule.

It should be noted that the "No VAC" group may not be directly comparable with the groups receiving vitamin A; for example, they may have less access to services as a contributing reason for not receiving the vitamin A capsules. This can be tested to some extent by using stunting, which was not significantly different between the "No VAC" group and the "1–2 months after vitamin A capsule" group, in any of the island group areas. This indicates that the "No VAC" group is at least not grossly noncomparable with the groups receiving vitamin A.

The findings can also be stratified by stunting levels, to control for some potential differences between groups. Doing this for the analysis shown in table 2 indicates somewhat greater increases in SR for the stunted children, but generally the findings remain similar; this was investigated by other methods, as described below.

Interpreting the shape of the response, taking account of the "No VAC" group but recognizing that it may not be fully comparable, is also helped by comparing the latest measure (at five to six months after the dose) with the "No VAC" group. In no cases were these significantly different. Thus, the general pattern is of a rise in SR followed by a return to predose levels after three to four months. These results are now described according to area and season in table 2.

The extent of vitamin A deficiency is greatest in the Visayas, with an average prevalence of deficient and low SR (< 20 μg/dl) of 41.8% and a mean SR of 21.5 μg/dl. The mean SR rose significantly following dosing in months one to two and three to four, then fell back to about the predose level in months five to six; this pattern was reflected in the prevalence of SR levels less than 20 μg/dl, with a drop of about 10 percentage points up to three to four months after the dose. This trend was similar in Mindanao, averaging over the three periods with a lower underlying prevalence than Visayas. Again, 8 percentage points of improvement in prevalence was seen up to three to four months after the dose. In Luzon, where the underlying prevalence was generally the lowest, the drop in prevalence was hardly detectable, emerging when these are separated by season (see May–June), but still less than in the other regions, for up to three to four months after dosing.

In the Visayas and Mindanao, the overall picture is of a greater (and an important increase relative to the VAD problem) increase in mean SR of around 2 to 4 μg/dl in the first one to two months after dosing, falling but still detectably elevated in months three to four, then returning to predose levels by months five to six. The prevalence trends show the corresponding pattern.

This pattern was somewhat enhanced, but with a more transient impact, for stunted children, particularly in Mindanao, as shown in table 3. The prevalence of deficient and low SR (< 20 μg/dl) was lower by 16 percentage points in the stunted group one to two months after dosing, and by 13 percentage points in the nonstunted group. The improvement in SR did not persist into months three to four among the stunted children. A similar significant but smaller difference in mean SR related to stunting was seen in the Visayas, but not in Luzon.

TABLE 3. Mean serum retinol (SR) level and prevalence of SR levels below 20 μg/dl in stunted and not stunted children 12 to 59 months old in Mindanao, August–October 1998, according to months after receipt of a vitamin A capsule (VAC), 1998 National Nutrition Survey, Philippines[a]

Stunting status	No VAC	No. of months after VAC			Total
		1-2	3-4	5-6	
Stunted	20.6 47.3% (243)	25.4[b] 31.4% (293)	22.4[c] 41.6% (245)	20.3 47.4% (310)	22.2 41.8% (1,094)
Not stunted	21.5 42.1% (428)	24.9[b] 28.9% (603)	23.4 33.9% (440)	21.9 40.1% (491)	23.1 35.7% (1,963)

a. From top to bottom, the values in cells are as follows: mean SR level (μg/dl), prevalence of SR levels < 20 μg/dl (%), and sample size (*n*) (in parentheses).

b. $p < .05$ (paired contrasts in one-way ANOVA) comparing SR level with the previous value in the row to test whether the mean SR level changed significantly with time after receipt of vitamin A capsules. The level 1-2 months after receipt of capsules is compared with the level among those not receiving capsules. For the comparison between the levels 5-6 months after receipt of a vitamin A capsule and the levels among those who did not receive vitamin A, no differences were significant. The columns labeled "No. of months after VAC" do not include children whose SR was measured more than 6 months after receiving vitamin A.

c. SR 3-4 among stunted children is significantly lower ($p < .05$) than at 1-2 (or the previous value in the row), meaning the improved SR levels at 1-2 months was not sustained through 3-4 months

The results were disaggregated further by area, in particular to examine the relation with urbanization. The prevalence of deficient and low SR was highest in the highly urbanized cities in the Visayas, where the mean SR was 16.9 µg/dl, the prevalence of SR levels less than 20 µg/dl was 40%, and the prevalence of SR levels less than 10 µg/dl was 27%. In the areas of the Visayas highly urbanized cities with the highest prevalences of vitamin A deficiency, the mean SR was 12.6 µg/dl, and 38% of the one- to four-year-olds had SR levels under 10 µg/dl—an extremely high prevalence of severe deficiency. The prevalences of deficient and low SR (< 20 µg/dl) in Mindanao and in Visayas non-highly urbanized cities were within the range of 37% to 39%.

Seasonal changes in SR could be observed in Luzon, where the data collection spanned eight months, as indicated in table 2, which shows lower mean SR and higher prevalence of deficient and low SR among children whose serum samples were collected between November and December than among children whose serum samples were collected between May and June ("No VAC" and "Total" columns). The seasonal effect is also shown in figure 6; this was largest in Luzon non-highly urbanized cities, where the mean SR and the prevalence of deficient and low SR (< 20 µg/dl) were 22.5 µg/dl and 43.8% respectively, among children who did not receive VAC and whose serum was collected in November to December and 25.1 µg/dl and 32.1% among those whose serum was collected in May to July. These differences between the values of mean SR and vitamin A deficiency prevalence in May to June and October to December may be explained by the decreased availability of vitamin A–rich fruits in October–December compared with May–June. Vitamin A deficiency was of least magnitude in the National Capital Region. The mean SR and the prevalences of deficient and low and deficient SR were 25.9 µg/dl, 19.7%, and 2.5%, respectively.

The areas most severely affected by vitamin A deficiency also tended to show the greatest improvements in the dosed groups. In the highly urbanized cities in the Visayas, as shown in figures 2 and 3, one to two months after the administration of the dose, the mean SR increased by 7.36 µg/dl ($p = .00$) and the proportion of children with deficient SR decreased by 18 percentage points ($p = .08$). The effect of vitamin A capsules in these areas tapered and remained significant up to the three- to four-month band after the dose: the increment in mean SR was 4.02 µg/dl ($p = .00$), and there were reductions of 11 ($p = .04$) and 20 ($p = .00$) percentage points in the prevalences of deficient SR (< 10 µg/dl) and deficient and low SR (< 20 µg/dl). In the areas of the highly urbanized cities in the Visayas with a high prevalence of vitamin A deficiency (≥ 10% with SR < 10 µg/dl) (shown in figs. 2 and 3), mean SR increased from 12.6 to 18.0 µg/dl, while the prevalence of deficient SR dropped from 38.3% to 20.6% three to four months after the administration of vitamin A capsules, then slid back towards baseline levels (figs. 2 and 3). No significant effects were evident in the areas of the Visayas highly urbanized cities with low prevalences of vitamin A deficiency (figs. 2 and 3). The extent of severe vitamin A deficiency (SR < 10 µg/dl) was less in the Mindanao highly urbanized cities than in the Visayas highly urbanized cities, and the apparent effects of vitamin A capsules appear to be correspondingly

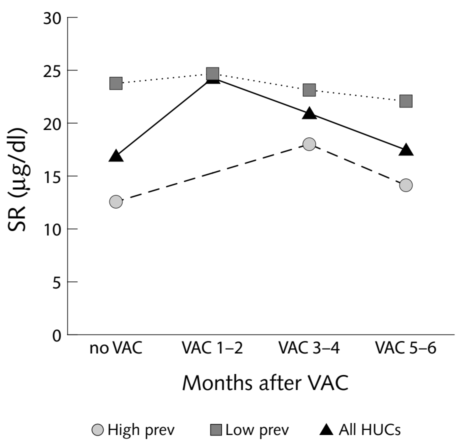

FIG. 2. Mean serum retinol (SR) of one- to five-year-old children in areas of Visayas highly urbanized cities (HUCs) with high (≥ 10%) and low (< 10%) prevalence of vitamin A deficiency (SR < 10 µg/dl) according to receipt of vitamin A capsules and the number of months after receipt of vitamin A capsules (VACs)

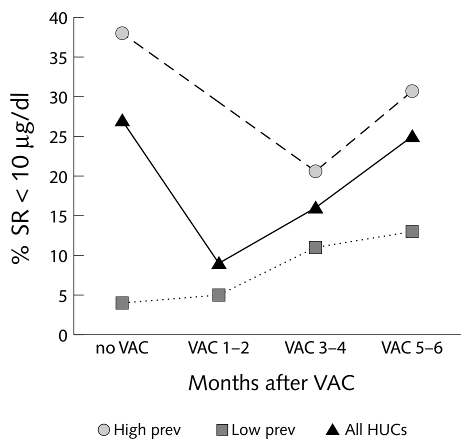

FIG. 3. Prevalence of vitamin A deficiency (serum retinol [SR] < 10 µg/dl) among one- to five-year-old children in high- (≥ 10%) and low- (< 10%) prevalence areas of Visayas highly urbanized cities (HUCs), according to receipt of vitamin A capsules and number of months after receipt of vitamin A capsules (VACs)

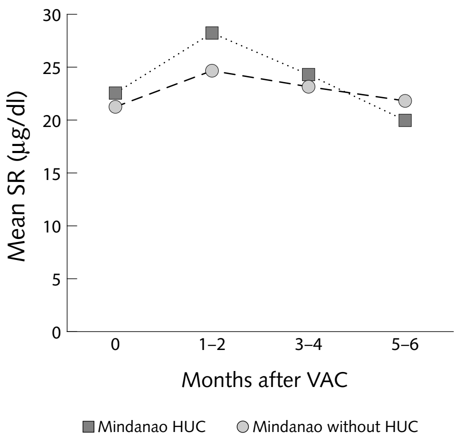

FIG. 4. Mean serum retinol (SR) of one- to five-year-old children in areas of Mindanao with and without highly urbanized cities (HUCs), according to receipt of vitamin A capsules and number of months after receipt of vitamin A capsules (VACs)

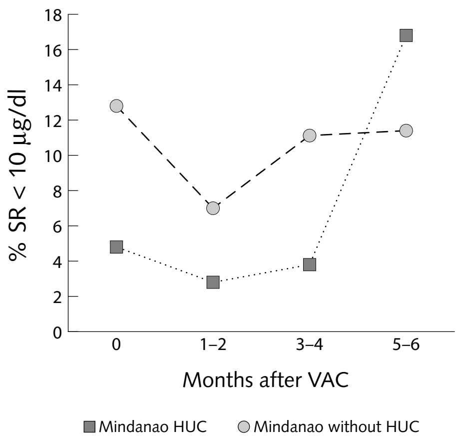

FIG. 5. Prevalence of vitamin A deficiency (serum retinol [SR] < 10 μg/dl) among one- to five-year-old children in areas of Mindanao with and without highly urbanized cities (HUCs), according to receipt of vitamin A capsules and number of months after receipt of vitamin A capsules (VACs)

less, although significant (figs. 4 and 5). Here the comparison was made between highly urbanized cities and those less highly urbanized (non-highly urbanized cities). In Mindanao, the prevalence of untreated SR deficiency (< 10 μg/dl) was highest in the less urbanized areas (non-highly urbanized cities), in contrast to the Visayas. In these areas (non-highly urbanized cities), mean SR increased by 3.4 μg/dl ($p = .00$) and 1.9 μg/dl ($p = .00$) (fig. 4), and the prevalence of SR deficiency (< 10 μg/dl) decreased by 5.8 ($p = .00$) and 1.8 ($p = .02$) percentage points (fig. 5), at one to two and three to four months after vitamin A capsule administration, respectively. The significant effect on the prevalence of SR deficiency occurred up to three to four months after the distribution of vitamin A capsules and was seen only in the less urbanized areas (without highly urbanized cities) (see figs. 4 and 5, "Mindanao without HUC").

In Mindanao's highly urbanized cities, the effects of vitamin A capsules on mean SR and the prevalence of deficient and low SR were also transient, lasting only up to one or two months after the distribution of vitamin A capsules. Mean SR increased by 5.7 μg/dl ($p = .00$); the effect on the prevalence of deficient SR within the same period was not significant. In fact, after the fourth month from distribution of the vitamin A capsules, the prevalence of deficient SR appeared to increase by 12 percentage points over the baseline prevalence (fig. 5). This increase was not explained by infection or stunting, since the dummy variable remained significant for five to six months after dosing, as shown in figure 5.

In Luzon, the apparent overall effect of vitamin A capsule supplementation was limited (fig. 6). It was discernible only among children from whom serum was collected in June or July, and only up to one to two months after the distribution of vitamin A capsules. Mean SR increased by 1.25 μg/dl in non-highly urbanized cities ($p = .06$) and by 0.78 μg/dl in the National Capital Region ($p = .06$). In the National Capital Region, the prevalence of deficient and low SR decreased by 7.6 percentage points ($p = .07$; not shown).

There was, however, a significant interaction of receipt of vitamin A capsules (one to two months after dosing) with stunting in Luzon non-highly urbanized cities. Among the stunted children who received vitamin A capsules, the mean SR was 24.1 μg/dl, compared with 21.7 μg/dl among those not receiving vitamin A capsules ($p = .09$) (fig. 7). The prevalences of deficient SR and deficient and low SR were respectively 5.8 percentage points ($p = .06$) and 16.2 percentage points ($p = .01$) lower in the supplemented group. In contrast, the mean SR was much the same in the nonstunted group, with or without vitamin A capsules (top line in fig. 7). In other words, the results suggest that the effect of vitamin A capsules is greater and more significant in the stunted children one to two months after receiving the vitamin A capsule.

A similar interaction was noted in Mindanao non-highly urbanized cities, such that the SR of stunted children who received vitamin A capsules was greater than those who did not: 23.4 μg/dl compared with 20.4 μg/dl ($p = .00$). The prevalence of deficient and low SR was correspondingly 8 percentage points lower ($p = .05$).

In summary, a significant association between the Philippines semiannual vitamin A capsule supplementation program and changes in SR among one- to five-year-old children was shown where the prevalence of vitamin A deficiency was high. This association was observed in the highly urbanized cities of the Visayas region as well as in the non-highly urbanized cities of

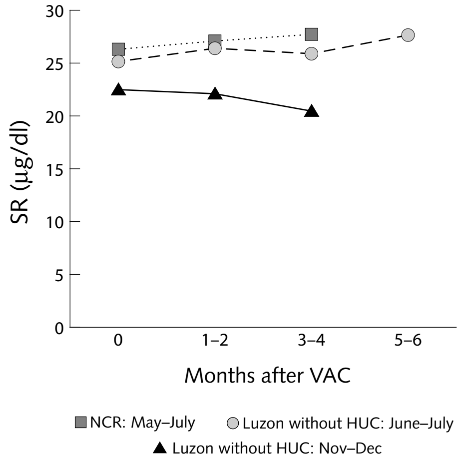

FIG. 6. Mean serum retinol (SR) of one- to five-year-old children in areas of Luzon without highly urbanized cities (HUCs) and in the National Capital Region (NCR) according to month of data collection, receipt of vitamin A capsules and the number of months after receipt of vitamin A capsules (VACs)

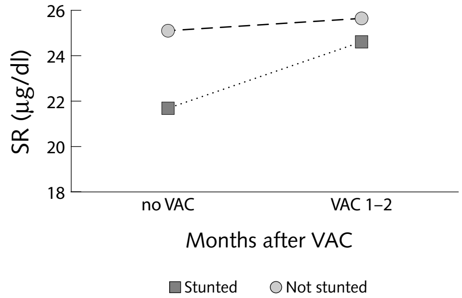

FIG. 7. Mean serum retinol [SR] of one- to five-year-old stunted and nonstunted children in areas of Luzon without highly urbanized cities one to two months after receipt of vitamin A capsules

Mindanao, although it was of less magnitude in the latter region. The impact in all these cases was transient, lasting about four months. In Mindanao highly urbanized cities, the effect of vitamin A capsules was discernible only up to two months after the dose was administered. These results are also generally in line with the extent and timing of the earlier efficacy trial by Perlas et al. [10]. In Luzon, which is generally more progressive in terms of household incomes [11] and diversity of processed and fortified foods, the effect was limited, although perhaps statistically significant in stunted children.

Two aspects are of concern: first, the size of the effect of high-dose vitamin A capsules on SR, and hence on the extent of reduction in deficiency, is limited; second, the effect does not persist for six months, which is the interval between doses. Thus, there is no ratcheting down of the extent of deficiency over time. With more frequent dosing (especially to those most deficient in SR), a progressive reduction in vitamin A deficiency could, however, be expected, and this could be tested.

Similar findings were also reported recently by Gorstein et al. [12] from Orissa, India, where the prevalence of vitamin A deficiency (indicated by deficient and low SR, < 0.7 µmol/L) was 63.8%, which was as high as that in the high-prevalence areas in the Visayas region in the Philippines study. Improvements in the various parameters of vitamin A status for the overall sample (prevalence of Bitot's spots and deficient SR) that were noted by the 4th week after administration of high-dose vitamin A capsules were not sustained through the 16th week; the SR levels of children with vitamin A deficiency at baseline increased more at 4 weeks, and remained slightly above their baseline values at the 16th week. Thus, both studies show that the benefits of vitamin A supplementation are greater among children who are most depleted or at risk; this may be indicated at the population level by higher prevalences of deficient SR or possibly by anthropometric measurements. As far as we are aware, the Orissa study and the present Philippines study are the only ones to assess changes in SR related to a routine national- or state-level high-dose vitamin A supplementation program. The consistency of the results suggests that policy changes should be considered to enhance the impact, and that other such investigations should be undertaken.

Discussion and conclusions

A United Nations Administrative Coordinating Committee/Subcommittee on Nutrition (ACC/SCN) Consultative Group stated in 1993 that the eradication of vitamin A deficiency can be achieved through an appropriate combination of interventions, including dietary modification, breastfeeding promotion, and food fortification and supplementation, and that the combination may change over time, depending on the trends in the level of deficiency, program outreach to vulnerable groups, and other factors [13]. This was based on a review of experience (up to 1993) that showed periodic high-dose supplements to be the most common, for practical reasons, noting that more frequent doses were likely to be more effective [14].

The elimination of vitamin A deficiency as a public health problem by universal vitamin A supplementation has been identified as a priority health measure by the Philippines Department of Health, based on reported findings of recent National Nutrition Surveys on the magnitude of the problem of vitamin A deficiency in the Philippines. As such, universal supplementation has been considered more cost-effective in terms of a targeted approach [15].

The picture that has been drawn from the results of the analysis, however, reveals that the extent of vitamin A deficiency and the impact of vitamin A supplementation vary across regions, warranting a review of the policy and guidelines for vitamin A supplementation. The differences in the extent of vitamin A deficiency and the impact of vitamin A supplementation may be attributed to the combination of the extent of distribution of vitamin A supplements, the dietary intake of vitamin A, other micronutrient and related public health promotion interventions, and the presence of other underlying factors that affect vitamin A status in the regions. For example, fortified foods are more available in the National Capital Region than in other parts of the country, and more available in Luzon than in Visayas or Mindanao. In terms of socioeconomic status, the National Capital Region has the lowest incidence of poverty in the country, while provinces in Luzon, excluding NCR, are among the least poor provinces in the Philippines [11].

The policy implications drawn from the analysis—similar to the conclusions reached by Gorstein et al. [12]—suggest a shift in resources from areas of low prevalence of vitamin A deficiency (where distribution of vitamin A capsules might be changed to a targeted scheme) to areas of high prevalence, where a three-times-yearly schedule is warranted. Specifically, three recommendations are indicated:

» In order to eradicate vitamin A deficiency as a public health problem, which is the stated policy of the government, using distribution of high-dose vitamin A capsules, administration at least every three to four months appears to be necessary.
» Since there are areas with very high prevalences of severe deficiency (SR < 10 μg/dl), and in these areas the response to dosing seems greatest, there is a case for targeting a more frequent vitamin A capsule program to the most affected areas. From the current data, this applies particularly to highly urbanized cities in the Visayas.
» Since stunted children appear to have a greater response, in terms of raised serum retinol, to receipt of vitamin A capsules, screening to detect stunted children to receive vitamin A capsules more frequently might be considered in less severely affected areas.

Like the Philippines, many other countries have invested considerable effort in establishing a program for distributing vitamin A capsules regularly to children, with a high rate of coverage. Research of this type (i.e., in-depth analysis of national nutrition survey data), or operational research designed to explicitly test whether provision of vitamin A capsules every three to four months to the groups most deficient in vitamin A will progressively reduce and eliminate the public health problem of vitamin A deficiency, even in other contexts, will need to be done. It would be a great achievement now to fine-tune the program and demonstrate a progressive reduction in vitamin A deficiency, and undoubtedly the health and survival of many children would benefit.

Vitamin A supplementation is indeed important to alleviate vitamin A deficiency; however, it remains a short-term and costly solution. In the long term, a multipronged approach including a combination of food fortification, promotion of locally available and culturally acceptable vitamin A–rich foods, and other public health measures will bolster a sustained eradication of vitamin A deficiency as a public health problem.

The present study provides a model for systematic program development using national surveys for program monitoring and evaluation, and applying these to progressively improving the program and enhancing the impact until the problem is overcome.

Acknowledgments

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Fatty acids in Chinese edible oils: Value of direct analysis as a basis for labeling

John C. Wallingford, Rebecca Yuhas, Shufa Du, Fengying Zhai, and Barry M. Popkin

Abstract

Edible oil is an important element in the diet of most transitional countries; nevertheless, little is known about the fatty acid composition of these oils. We examined the consumption of edible oils and the fatty acid composition of these oils obtained from a market survey conducted in seven Chinese provinces and in Beijing. Three days of measured household food intake from the 1997 China Health and Nutrition Survey households provided data on the consumption of edible oils. Edible oils sold in the capital cities of eight provinces were purchased. One hundred twenty-six samples, representing 14 different oils according to their labels, were assayed for their fatty acid content in 2001. Fatty acids were analyzed by standard gas chromatographic methods. More than 76% of households in China consume edible oil, providing an average of 29.6 g of edible oil per day to persons aged two years or older. Rapeseed was consumed by one-quarter of individuals. Rapeseed is rich in C22:1n9 cis *(erucic acid). About 33% of edible oils differed from their labeled identification. Rapeseed oil, identified by the presence of C22:1n9 (erucic acid), was most frequently not labeled as such. In another 28% of the samples,* trans *isomers of linolenic acid were detected. Deviations from the label identification were more common in southern than in northern provinces. Regulations requiring complete labeling of mixed edible oils in China might help prevent unintentional consumption of fatty acids associated with adverse health outcomes. In particular, consumption of erucic acid and* trans *fatty acids might be reduced. The results suggest the need for closer control of food oil labeling in China, especially in the South.*

Key words: China, edible oils, erucic acid, fatty acid composition

Introduction

In low- and moderate-income countries in Asia, Africa, and the Middle East, edible oil represents a major element in the diet. As income increases and as urbanization occurs, the intake of edible oil goes up rapidly, particularly in low- and middle-income households [1, 2]. In the United States, labeling of saturated fats and other fats and widespread public education are used to promote consumption of more healthful edible oils. In 2003 the US Food and Drug Administration (FDA) added a requirement that foods must be labeled for their content of *trans* fatty acids, although the requirement does not go into effect until 2006. Recently the FDA reopened the period for comments on its consideration of adding criteria for *trans* fatty acids to health claims. Despite the greater importance of edible oils in the food-consumption pattern in transitional and poor economies, comprehensive food labeling is not typical in most countries, and little is known about the actual composition of many marketed edible oils. The Chinese diet is rapidly changing, with a remarkable increase in the consumption of affordable plant oils from 15 to 37 g per capita per day in the eight years from 1989 to 1997 [2, 3]. There has been extensive focus on the possible role of dietary oils as a key element in the shift from a high-fiber, low-fat diet to a refined carbohydrate-based diet of much higher energy density. In particular, the focus is on the role of such food-choice patterns in the development of obesity

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and associated chronic diseases [4]. However, little attention has been given to the changes in intake of fatty acids and the consequent potential health effects [4]. Given the increasing importance of oils in dietary intake in these countries in transition, it is important to begin to examine their composition. Some plant oils are promoted for their healthfulness, because they are unsaturated or contain omega-3 fatty acids or gamma linoleic acid. Other oils, however, may have high levels of saturated fatty acids, *trans* fatty acids, or other fatty acids that have potential adverse health effects, such as erucic acid or *trans* isomers of linolenic acid [5–9]. To understand more clearly the potential health implications of dietary fat changes in China, we examined consumption patterns of key edible oils and then assayed a representative sample of commercially available plant oils from Beijing and seven provinces in this food-consumption survey. The oils sampled were from various types of markets, a reflection of distribution channels in the provinces. The fatty acid profiles of the oils were assayed and compared with the information on the labels. We report here that there are numerous occurrences of mislabeling of commercial oils, and that some mislabeled oils may contribute undesirable fatty acids to the new Chinese diet. Our findings identify potential adverse outcomes related to particular fatty acids that may be revealed as the total dietary fat in China increases.

Methods

Edible oil samples

A total of 126 oil samples were collected and analyzed. The samples were collected by the Institute of Nutrition and Food Hygiene at the Institute of Nutrition and Food Safety, Chinese Center for Disease Control and Prevention. Samples were collected from Beijing, Shangdong, Henan, Jiangsu, Hubei, Hunan, Guizhou, and Guangxi Provinces. These are seven of the nine provinces represented in the current China Health and Nutrition Survey and one "mega-urban" area, Beijing, chosen to reflect the most modern eating patterns found in the elite urban areas of China. In each province all edible oils manufactured by local companies were purchased, and some oil samples not manufactured in the seven provinces plus Beijing were also purchased if the total number of samples from a province was less than 10. The oils were collected most frequently from supermarkets (62 samples, 49%), open markets (43 samples, 26%), the manufacturer (15 samples, 12%), and state stores (6 samples, 5%; all from Hubei). The labels on each bottle of oil were translated and interpreted at the Chinese Center for Disease Control and Prevention. The University of North Carolina-Chapel Hill coordinated receipt and shipment of survey samples, and sent coded samples to Wyeth Nutrition for analysis.

Fatty acid composition

Fatty acid analyses were conducted at Wyeth Nutrition (Radnor, Pa., USA). As an internal check, 12 coded samples selected at random were assayed at the University of North Carolina-Chapel Hill using different gas chromatographic parameters. Fatty acid methyl esters were prepared and extracted using a modified Morrison and Smith [4] boron trifluoride:methanol protocol. Gas chromatographic conditions used a Supelco Omegawax column (32 m, 0.32 mm internal diameter) that allowed separation of some *cis* and *trans* geometric isomers of linoleic and linolenic acids, identified by comparison to reference standards (Nu-Chek Prep, Elysian, Minn., USA). *Cis* and *trans* isomers of monenes coelute and cannot be quantified under these chromatographic parameters. Chromatography at the University of North Carolina-Chapel Hill was performed on a Perkin Elmer AutoSystem XL gas chromatograph with a 30 m × 0.25 mm inside diameter column, DB 225 (J&W Scientific, Folsom, Calif., USA). Fatty acids are reported as percentages of total fatty acids to the nearest 0.1%. Samples with fatty acid patterns (as identified by comparison with fatty acid databases [10]) that were discrepant from the labeling were retranslated and reanalyzed to confirm the initial results. The typical run-to-run variation for fatty acids in a single sample in our laboratory is less than 2% relative standard deviation. The comparative weight percent results for fatty acids generated by the two laboratories differed by no more than 10%.

Dietary intake data

China Health and Nutrition Survey

The China Health and Nutrition Survey (CHNS) is an ongoing longitudinal survey of households in nine provinces in China (Heilongjiang, Guangxi, Guizhou, Henan, Hubei, Hunan, Jiangsu, Liaoning, and Shandong). We draw on one round of data collected as part of the CHNS for 1997. The CHNS sample consists of 3,780 households from 188 villages plus urban neighborhoods. In 1997 we sampled more than 16,000 individuals. The sampling of the CHNS is described in more detail elsewhere [11].

Collection of dietary data

A detailed layout of the dietary intake data is presented elsewhere [2]. The results are based on three days of household intake of oil, measured directly before and after use, and three consecutive days of 24-hour recall from each individual.

Results

Dietary intake of edible oils

Thirteen kinds of oils were consumed in the CHNS sample households. Table 1 presents the mean intake per capita, the proportion of the sample who consumed the oils, and the mean intake among those who consumed oil for all individuals aged two years or older in 1997. The most frequently consumed edible oils were peanut, rapeseed, and soybean. During the three survey days, the proportions of people who consumed these three oils were 31.6%, 24.1%, and 11.7%, respectively. About 8.1% of urban residents consumed salad oil, which is more expensive than rapeseed oil. Most consumers do not know that salad oil is actually a kind of deodorized rapeseed oil.*

The proportions of people who consumed mixing oil and palm oil were not high, but the intakes of the two oils were very high among those who did consume them. Mixing oils usually contain rapeseed oil, palm oil, and a little bit of sesame oil, which gives the oil a pleasant smell. Only 0.1% of the sample population consumed mixing oil, but the average intake for those who did consume it was 58.3 g per day. This is notable, as palm oil (i.e., red palm oil) is rich in β-carotene.

In other research on this same topic, we show that higher-income individuals consume more edible oil than those with lower incomes. Furthermore, we have shown in longitudinal research that there is a very high income elasticity for edible oil intake [12, 13]. That is, for each percentage increase in income, there is a corresponding increase in edible oil intake.

* Please note that the lists of oils in the China food composition table and the oils noted in Table 1 are different from those actually sold and measured (and thus specified in Table 2).

Composition of edible oils

Table 2 shows the commercially available types of oil and the number of samples of each obtained from Beijing and seven provinces. Sesame, peanut, rapeseed, salad, and soybean oil together represented 81% of the samples. Samples of a number of less frequently consumed oils were also obtained and analyzed, including teaseed, cottonseed, maize, perilla, and fungi oil. The names of some oils (mixing, salad, and health oils) did not indicate their contents.

Most samples (85 of 126) had fatty acid profiles that corresponded closely with standard database values [10]. For 41 samples (32%) there was evidence of some deviation from the fatty acid pattern predicted by the label. Sesame oil is readily identified by the preponderance of oleic and linoleic acids; soybean by the ratios of oleic, linoleic, and α-linolenic acid; and peanut oil by the presence of C20, C22, and C24 saturated fatty acids. By regulatory definition, 5% to 60% of the fatty acids of rapeseed oil must be C22:1n9 (erucic acid), whereas low-erucic acid rapeseed oil (LEAR)(known also as canola oil in the United States) typically has less than 2% erucic acid, as permitted by the FDA. In Canada, edible oils may not contain more than 5% erucic acid, and infant formula in the European Community may not contain more than 1% erucic acid. Samples in which the proportion of C22:1n9 is between 2% and 35% are most likely contain some rapeseed oil, or they could represent a change in phenotype, or reversion, of the LEAR crop back to the native rape phenotype. Table 3 shows examples of fatty acid pat-

TABLE 1. Consumption of edible oils among all persons aged two years or older, China Health and Nutrition Survey, 1997[a]

	Mean daily intake per capita (g)			% of sample consuming the oil			Mean daily intake per consumer (g)		
Oil	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total
Peanut	11.2	12.2	11.5	31.5	31.8	31.6	32.4	34.4	33.0
Rapeseed	8.5	10.6	9.1	23.0	26.9	24.1	33.9	35.8	34.5
Soybean	5.1	4.5	4.9	12.5	9.9	11.7	37.6	41.3	38.5
Cottonseed	1.5	1.2	1.4	4.6	2.6	4.1	29.0	40.3	31.2
Salad	0.8	4.0	1.8	1.6	8.1	3.5	48.5	44.9	46.0
Sesame	0.2	0.3	0.2	2.1	3.4	2.5	8.5	7.4	8.0
Teaseed	0.2	0.3	0.3	0.8	0.9	0.8	25.5	31.2	27.4
Sunflower	0.2	0.1	0.1	0.5	0.4	0.4	30.0	23.3	28.3
Palm	0.2	0.1	0.1	0.3	0.2	0.3	46.1	39.4	44.7
Hempseed	0.0	0.1	0.1	0.1	0.4	0.2	34.7	31.2	32.2
Linseed	0.0	0.0	0.0	0.1	0.1	0.1	3.4	27.8	8.7
Mixing oil	0.0	0.2	0.1	0.0	0.3	0.1	0.0	58.3	58.3
Chili	0.0	0.0	0.0	0.1	0.0	0.0	20.3	0.0	20.3
Total	27.9	33.5	29.6	74.9	81.1	76.8	34.1	37.5	35.1

a. Based on three days of dietary intake and measurement of all edible oils used in the household.

terns for three oils that corresponded to database values and three samples that differed from the expected fatty acid pattern. When the sample patterns were compared with identifying patterns of fatty acids, some fatty acid patterns were observed that varied from the claims on the product label. The most common discrepancy occurred when rapeseed oil was present but not specified on the label, which occurred in 10 samples

TABLE 2. Samples of oil according to province and name on label

Label name	Beijing	Jiangsu	Guizhou	Hubei	Hunan	Henan	Guangxi	Shangdon	Total
Sesame	9	2		5	1	3		6	26
Peanut	2	2		1		1	10	7	23
Rapeseed		4	8	4	4	2	1		23
Salad	3	1	5	5	2	4			20
Soybean	1	5				3	1	1	11
Mixing	2	1			3	2			8
Maize	2				1			1	4
Teaseed					2		1		3
Safflower	2								2
Cottonseed				2					2
Sunflower	1								1
Perilla				1					1
Health oil					1				1
Fungi					1				1
Total	22	15	13	18	15	15	13	15	126

TABLE 3. Fatty acid patterns in oils (% of total fatty acids) according to the province from which the sample was collected and the name on the label

No. of carbons[a]	Hunan, rapeseed	Henan, rapeseed	Shangdong sesame	Hubei, sesame	Henan, soybean	Shangdong, soybean
C10	0.2	—	0.2	0.1	0.2	0.2
C14	—	0.1	—	0.1	0.1	0.1
C16	3.0	8.4	8.8	6.0	11.2	10.8
C16:1n7	0.2	0.2	0.1	0.2	0.1	0.1
C17	—	0.1	0.1	—	0.1	0.1
C17:1n7	—	—	—	—	0.1	0.1
C18	1.2	3.1	5.2	2.8	3.7	4.3
C18:1n9	19.3	26.1	37.6	28.9	22.9	20.3
C18:1n7	1.1	1.6	0.8	1.3	1.5	1.3
C18:2n6	12.7	37.7	45.4	28.1	50.8	51.0
18:2n6 c,t or t,c[b]	—	0.1	0.2	0.2	0.1	1.8
C18:3n3	7.9	7.9	0.3	5.5	6.9	4.1
C20	0.8	0.5	0.6	0.6	0.4	0.4
C20:1n9	8.3	2.9	0.1	4.8		0.2
C20:1n7	1.2	0.5	0.2	0.6	0.4	0.2
C20:2n6	0.5	0.2	0.1	0.3	0.1	
C22	0.7	0.5	0.1	0.4	0.1	0.4
C22:1n9	39.7	9.2	—	17.9	0.4	
C22:1n7	0.6	0.2		0.3	0.4	0.1
C22:2n6	0.6	0.2	—	0.3		0
22:3n3	0.1				—	
C24	0.3	0.2		0.2	0.2	0.2
Unknown	0.4	0.2	0.0	0.0	0.1	0.2

a. The number of carbons in the fatty acid backbone is indicated by the number following the letter C. After the colon, the number of unsaturated double bonds in the fatty acid backbone is indicated. The number following the omega (represented by the letter “n”) indicates the number of carbons from the methyl end of the fatty acid to where the first double bond occurs.

b. c, *cis*; t, *trans*

(in table 3, the sample labeled Hubei contained sesame oil with nearly 18% of its fatty acids as erucic acid). The presence of soybean oil without its being specified on the label was also common and was evident when linolenic acid levels were elevated without elevated levels of oleic or erucic acid. Of 26 samples labeled as sesame oil, 4 had evidence of the presence of rapeseed oil (30%–60% of total fatty acids), 2 contained soybean oil (20% and 70% of total fatty acids), and 1 other may have contained LEAR. The apparent inclusion of rapeseed oil among otherwise labeled oils was common among specialty oils. One of the two samples labeled as cottonseed was approximately 75% rapeseed oil, although cottonseed is considered an inferior oil. The single sample of fungi oil had a profile identical to that of rapeseed oil. The single sample of peanut oil from Hubei had a fatty acid pattern characteristic of cottonseed oil.

Of 23 samples labeled as rapeseed, 4 had fatty acid patterns identical to that of LEAR, with less than 5% erucic acid, and two contained intermediate levels of erucic acid (5.9% and 8.4%), possibly suggesting a reversion of the LEAR oilseed to the native rapeseed. Two samples labeled as rapeseed appeared to contain soybean oil (60%–70%), and one had a fatty acid pattern that suggested it was 100% soybean oil. The samples consisting of LEAR labeled as rapeseed are not strictly mislabeled according to species, but the percentage of erucic acid is not correctly indicated. In 21 of 28 cases where the labels “oil mixture” and “salad” were used, the oils were identified as either rapeseed or LEAR oil. Oils labeled with ambiguous names like “vegetable,” “salad,” and “mixing” nearly always contained LEAR or rapeseed.

There were many samples (36 of the 126 samples, or 28%) that contained *trans* isomers of linoleic and α-linolenic acid, indicating partial hydrogenation or possible thermal damage to the oil (table 4). Among oils labeled as “salad oil” or “mixing oil,” nearly all samples (16 of 20 and 7 of 8, respectively) contained α-linolenic acid isomers.

Many oils labeled as other than rapeseed oil actually contained significant amounts of erucic acid. In Shangdong and Guangxi, there were no samples with more than 5% of fatty acids as erucic acid, but in 1 of 22 in Beijing, 3 of 15 in Jiangsu, 4 of 15 in Henan, 12 of 18 in Hubei, 9 of 13 in Guizhoui, and 12 of 15 in Hunan, erucic acid constituted more than 5% of fatty acids.

In the sample labeled teaseed oil that did not contain significant C22:1n9, 78% of fatty acids were oleic acid, and only 7.7% and 0.4% were linoleic acid and α-linolenic acid, respectively.

Discussion

Edible oil represents a major source of energy in all transitional countries. In China there has been a rapid rise in consumption of edible oil, with the intake more than doubling in the past decade [14]. The increase in dietary fat is related to improved income; total dietary fat has increased even more among higher socioeconomic subsets of the population [13]. This suggests that as income in China continues to rise, the level of dietary fat will continue to increase. This increase in total fat consumption is one reason that our findings are relevant. Adverse health outcomes related to dietary fat are generally only observed when total dietary fat is high; thus, our findings identify potential adverse outcomes related to particular fatty acids that may be revealed as total dietary fat increases.

This rapid rise in the consumption of edible oils in China may be linked with a number of potentially adverse health effects. One dimension rarely examined is the potential adverse health effects of the fatty acid composition of many of these oils [3]. The optimal balance of omega-6 and omega-3 fatty acids, for instance, has been related to a number of chronic diseases in the West, such as atherosclerosis, hypertension, and inflammatory diseases [7, 15]. Similarly, high levels of *trans* fatty acids and erucic acid are of concern [5, 6, 9, 16–18].

Using individual fatty acid percentages to identify oils depends on each oil’s having a stable but unique fatty acid pattern and accurate labeling borne out

TABLE 4. Linoleic and α-linolenic acid *trans* isomers in oil samples

	Type of oil						
Location	Soybean	Sesame	Mixing	Salad	Rapeseed	Cottonseed	Teaseed
Beijing	1		2	3			
Jiangsu			1	1	1		
Guizhiou				2	1		
Hubei		1		5	1	1	
Hunan			3	2			1
Henan	1	1	1	4			
Guangxi	1				1		
Shangdong	1						

by analysis. We did not set quantitative criteria for identification of the presence of a nonlabeled oil, so there may be some misclassification in our tables. Similarly, the sampling plan was rather comprehensive and unbiased with respect to the possible presence of mislabeled product, but it was not intended to provide a representative sample of food oil consumption in China. Consequently, our results should be viewed qualitatively. At the same time, the differences from expected fatty acid patterns were sometimes pronounced, so we are confident that there are mislabeled oils in the Chinese marketplace, more frequently in the South than in the North.

This research definitively shows that many Chinese are unknowingly consuming a variety of types and amounts of fatty acids considered unhealthful as hidden components in edible oil. Hidden rapeseed oil may increase the intake of erucic acid, since we found that about 15% of all samples in the current study contained more than 5% of fatty acids as erucic acid. The literature remains inconclusive about the possible harm from high intakes of erucic acid. Young animals have been disposed to develop cardiolipidosis [8] and reduced proliferation of platelets [5], but there is no direct evidence of harm in young humans. The erucic acid intake among Chinese women appears to be greater than among women from eight other countries (Chile, Philippines, United States, Mexico, United Kingdom, Australia, Canada, and Japan), based on erucic acid levels in the breastmilk of Chinese women (1.2% of fatty acids, nearly 10 times the percentage in breastmilk of women from other countries; Yuhas R, Wyeth Nutrition, unpublished data). Unintentional maternal consumption of erucic acid from mislabeled oils may contribute to milk erucic acid, thus increasing the exposure of breastfed infants to erucic acid. Our data may be useful for the design of subsequent studies of the effects of erucic acid consumption in China, especially in southern China, where we found the most frequent occurrence of mislabeling.

The biological effects of erucic acid that have been discovered since the affirmation of LEAR as generally recognized as safe (GRAS) suggest new reasons for caution about the consumption of high levels (more than 2% of total fatty acid by FDA regulatory definition) of erucic acid in dietary fats. Similarly, there is a proposal before the *Codex Alimentarius* and another before the Chinese Government to limit the content of erucic acid in infants' diets.

Reversion of LEAR to the native plant can occur in field conditions. Variants of rape that have been specifically bred to contain extremely high erucic acid for industrial applications [19] may need to be segregated from other varieties intended to enter the human food supply.

Other plant oils contain lipid substances that may have physiological effects. For example, cottonseed oil contains gossypol, which affects the reproductive system and has been investigated as a male contraceptive agent [20]. Thermal processing may also affect the fatty acid composition of oils, producing *trans* geometric isomers of linoleic and α-linolenic acids [21]. The effects of dietary *trans* fatty acids have been studied mainly with respect to changes in blood lipoprotein levels, especially low-density lipoprotein (LDL) cholesterol. Consequently, the health effects of the increase in oil consumption during the shift to energy-dense diets in transitional countries may be compounded by increased consumption of unhealthful fatty acids.

Some oils in China are labeled not according to plant origin, but simply as "health oil." The high added value of oils promoted for health purposes, or expensive oils used for flavoring, may make them susceptible to mislabeling by addition of undeclared, less costly oils.

It is apparent from our results that there is little distinction in labeling between rapeseed oil and its LEAR counterpart. The unlabeled inclusion of rapeseed oil in unusual oils used for flavor, or represented as healthful, appears to occur with about the same frequency as its admixture with common edible oils in China, so there is no obvious association of mislabeling with the cost, availability, or use of oils. Our results also indicate that when oils are ambiguously labeled, it is likely they have also been subjected to thermal abuse. It is unlikely that consumers understand the consequences of consuming low-grade oil for their intake of isomers of fatty acids, including *trans* fatty acids. Perhaps manufacturers refine cottonseed oil and label it peanut or rapeseed oil to avoid a poor image associated with cottonseed oil.

By analyzing the pattern of fatty acids in food oils, we have obtained evidence that oils in China are often incompletely and incorrectly labeled. The presence of unlabeled oils may have health consequences by increasing the exposure to erucic acid or by adding isomers of fatty acids that may adversely affect health. The improved understanding of the consequences of consumption of rapeseed oil for the maternal diet similarly suggests that unlabeled oils consumed during lactation could contribute to the exposure of infants to higher than expected levels of erucic acid [7]. Estimates of the types of dietary fat consumed in China should consider the possibility that dietary survey data may misrepresent actual fatty acid intake.

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Progress in salt iodization and improved iodine nutrition in China, 1995–99

Jinkou Zhao and Frits van der Haar

Abstract

In 1993, the State Council of China announced the policy to virtually eliminate iodine-deficiency disorders (IDD) by 2000 and adopted universal salt iodization (USI) as the national strategy. Biennial province-based monitoring from 1995 onward aimed at capturing the use and iodine content of household salt, along with urinary iodine concentrations among schoolchildren from the same households. This paper reports on the progress made in China toward the goal of virtually eliminating iodine-deficiency disorders on the basis of 85 population-representative surveys in China's provinces during 1995–99. The percentage of households using adequately iodized salt (iodine ≥ 20 mg/kg) increased from 43.1% in 1995, to 82.2% in 1997, to 89.0% in 1999. In 1999, at least 90% of the households in 15 (48%) of the 31 provinces used adequately iodized salt, and a median urinary iodine concentration of less than 100 µg/L in children was reported in only one province. Across provinces, the median urinary iodine concentrations in children were positively correlated in each survey year with the median household salt iodine contents (combined $r_s = 0.74$, $p < .001$) *and with the proportions of households using adequately iodized salt (combined* $r_s = 0.81$, $p < .001$)*. Also in each survey year, the percentage of children with urinary iodine concentrations of at least 300 µg/L was correlated (combined* $r_s = 0.69$, $p < .001$) *with the proportion of households using salt with iodine content of at least 40 mg/kg. The median urinary iodine concentration in children had reached 300 µg/L or more in 13 provinces (42%) by 1999. In a little more than five years, then, China has achieved outstanding progress toward the goal of virtual elimination of IDD through USI. Policy recommendations include improvement of quality assurance by salt manufacturers, along with a modest reduction in the mandated salt iodization levels.*

Key words: China, IDD, iodine-deficiency disorders, iodine nutrition, policy analysis, universal salt iodization

Introduction

Universal salt iodization (USI) is agreed upon [1] as the recommended strategy to eliminate iodine-deficiency disorders (IDD) in a population. USI is defined as the iodization of all food-grade salt [2] for consumption by humans and livestock. USI can ensure optimal population iodine nutrition and thereby protect each generation of newborns from brain damage due to iodine deficiency [3]. When USI has been practiced for 5 to 10 years, the recommended core standards to ascertain that the goal of sustained elimination of iodine-deficiency disorders is reached include the use of adequately iodized salt by at least 90% of households, along with an associated median urinary iodine concentration in the population in the range of 100 to 299 µg/L [4].

The elimination of IDD gained prominence among global development priorities during the last 15 years, and much progress has been made worldwide [5, 6]. National survey data consolidated at UNICEF show that nearly 70% of the world's households were using iodized salt by the end of the twentieth century, although more recent trends indicate a likelihood of some backsliding. Nevertheless, the goal of virtual elimination of IDD by the year 2000 was reached in a number of countries, together with evidence of conditions considered critical for sustainability [4, 5].

In China, the IDD problem was acknowledged as a

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public health threat early during the 1990s [7]. The Chinese Academy of Preventive Medicine had estimated that about 450 million people lived in iodine-deficient areas, with more than 30% of the population considered at risk [8]. In 1993, the State Council of China committed itself to the virtual elimination of iodine-deficiency disorders by the year 2000 and introduced USI as the national strategy [9]. Until that time, iodized table salt was directed to areas where goiter was regarded as an endemic public health problem, combined with provision of iodized oil capsules through schools.

Following the decision by the high-level political leadership, the Ministry of Light Industry and the Ministry of Health jointly publicized the outlines for accomplishment of the USI strategy, and in August 1994 the State Council enacted the national specifications for salt iodization to eliminate health hazards due to iodine deficiency in China [10]. Legal supervision of the quality of iodized salt became authorized as part of the food inspection mandate of the health administration department, while the salt administrative department was made responsible for manufacturing and marketing of iodized salt. Potassium iodate (KIO3) had already replaced potassium iodide (KI) as the iodating agent of salt in China by 1990. The new national regulations called for salt iodine contents in households to be at levels no less than 20 mg/kg. To reach this desired consumption level, the level of salt iodization during manufacturing was set at 50 mg/kg to ensure a level of not less than 40 mg/kg in the manufacturer's supply outlets. In the spirit of the solid political commitments by the State Council, a comprehensive national effort began, mobilizing many sectors and institutions. The China National Salt Industry Corporation undertook drastic industry reform and modernized its production and marketing operations, and the Ministry of Health increased enforcement measures to stop the leakage of unauthorized raw salt into consumer markets [10].

Between 1993 and 1995, a national monitoring system was also devised to track trends in goiter prevalence among schoolchildren, household use of iodized salt, and the iodine nutrition status of schoolchildren, based on provincial prevalence surveys conducted every two years and county-based household salt iodine testing conducted every month. Because of the well-known delay in the decrease in the prevalence of goiter after improved iodine nutrition [11, 12], the earlier evidence of adequate population iodine nutrition rested on trends in the use of iodized salt in households, along with trends in urinary iodine excretion among members of these households.

The present report uses the biennial province-based survey data collected in China between 1995 and 1999 to describe changes in the above indicators over time and to determine the relationships between iodine nutrition indicators of household salt and urinary iodine excretion of school-aged children from these households. The objective is to assess the practical functioning and outcomes of the USI strategy in China and suggest ways of improving its effectiveness to ensure the optimal iodine status of the population.

Methods

Survey design

In each provincial survey, a multistage, probability proportionate to population size (PPS) cluster sample was obtained. The county served as the primary sampling unit, and 30 counties (clusters) were selected systematically in each province from a county population list. In each province, in each survey year, a list of all counties was used to select 30 counties at random without putting the name of the county back on the list after its selection.

In each selected county, a school was then sampled at random. Schoolchildren aged 8 to 10 years served as the index population. For each cluster, 40 children were selected at random from the enrolment list. All children were examined for thyroid size by palpation and/or ultrasound, and the iodine content of a salt sample brought by the child from home was determined by titration. From among the 40 children in our sample, a subsample of at least 12 children was randomly selected to provide a urine sample for iodine concentration analysis. A uniform survey protocol, including sample selection, questionnaires, and record sheets, was designed and used nationally for all the provincial surveys in 1995, 1997, and 1999. The provincial surveys in 1995 were conducted between March and June, before all the previously manufactured noniodized salt had disappeared from the salt delivery channels [13].

Determination of iodine concentration in urine and salt

Urinary iodine concentration was analyzed using an acid-digestion method modified from the method of Dunn et al. [14]. The iodine content in salt samples was determined by iodometric titration [15]. All chemical analyses were conducted in provincial laboratories, accredited by the national iodine-deficiency disorders reference laboratory in Beijing. The results of urine or salt iodine analyses from field collection were not accepted unless the criteria for accreditation of a provincial laboratory were met. These criteria required that the accuracy and precision from analyzing external quality specimens provided by the reference laboratory be less than 5% of the specimen target.

Data entry and analyses

Public health professionals from each province entered the data for analysis using Epi Info 6.04b (Centers for Disease Control and Prevention, Atlanta, Georgia, USA). A training course on survey methods, sample analyses, and Epi Info was held in Beijing every year with participants from each province before the survey and data entry. During data entry, an Epi Info check-file was used to minimize errors. After entry, the raw data were cleaned in each province and then sent to the National Institute of Iodine-Deficiency Disorders in Harbin, where a further data check was performed.

Each of the datasets collected by provinces in 1995, 1997, and 1999 was handled as a separate cohort. Therefore, the provinces were the primary units for the present analysis. Distributions of salt iodine contents were available for the categories < 5 (noniodized salt), 5–19.9, 20–39.9, and ≥ 40 mg/kg; and urinary iodine concentrations for the categories < 100, 100–199, 200–299, ≥ 300, and ≥ 500 µg/L. For urinary iodine data analysis, individuals who reported the use of oral iodized oil within one year prior to the survey were excluded. Medians and 95% confidence intervals (CIs) were calculated by standard statistical methods. Because the iodine contents of salt and urine were not normally distributed, nonparametric Spearman rank correlation was used to examine associations between the various iodized salt indices and urinary iodine parameters [16]. Confidence intervals were calculated as described by Altman et al. [17].

Results

Description of dataset

In 1995, complete surveys were reported from 23 provinces; in 1997 and 1999, all 31 provinces of China provided complete data. Thus, the present dataset is composed of results from 85 province-based surveys.

The sample sizes for salt iodine by province ranged from 1,200 to 2,400 (mean, 1,259) in 1995, from 1,197 to 1,246 (mean 1,204) in 1997, and from 1,161 to 1,324 (mean 1,213) in 1999. For the urinary iodine assays, the sample sizes by province ranged from 90 to 1,190 (mean, 457) in 1995, from 36 to 1,195 (mean, 319) in 1997, and from 278 to 1,291 (mean, 442) in 1999. The present dataset therefore contains data from 103,891 salt iodine and 34,573 urinary iodine determinations, arranged as 85 cohorts from three survey rounds over six years.

The percentage of children reported to have received an oral iodized oil supplement within one year prior to urine collection was close to 50% in 1995 and 1997, but in 1999 none of the selected schoolchildren reported having received oral iodized oil in the previous year.

TABLE 1. Iodine content and use of iodized salt in households in provinces of China, 1995–99

		Salt iodine content (mg/kg)			Use of iodized salt (% of households)								
					Any iodized salt			Adequately iodized salt (≥ 20 mg/kg)			Salt with iodine ≥ 40 mg/kg		
Year	No. of provinces	Median	95% CI	Range	Median	95% CI	Range	Median	95% CI	Range	Median	95% CI	Range
1995	23	18.4	14.8–21.7	0.0–29.8	77.2	57.8–86.0	3.2–95.3	43.1	32.1–54.3	3.1–77.1	6.4	5.2–13.3	1.5–32.8
1997	31	38.1	35.0–41.3	4.2–50.8	91.0	87.7–93.6	44.5–98.7	82.2	74.0–85.7	8.7–92.3	46.3	38.0–52.6	3.8–70.7
1999	31	43.4	40.5–45.5	5.3–50.0	94.3	90.3–97.1	51.7–99.7	89.0	83.6–92.1	27.6–96.5	63.0	52.1–67.7	3.0–78.9

CI, Confidence interval of provincial pooled medians.

Household salt iodine content and use of iodized salt

From 1995 through 1999, the median household salt iodine content and the percentage of households using iodized salt (table 1) showed a steady increase with each survey year. In 1999, the percentage of households using adequately iodized salt (iodine content ≥ 20 mg/kg) reached 89.0% (95% CI, 83.6–92.1), and the median iodine content of household salt reached 43.4 mg/kg (95% CI, 40.5–45.5); these were more than twice the levels seen in 1995. In 1995, none of the 23 participating provinces reported that 90% or more of households used adequately iodized salt; however, in 1999, 15 (48%) of the 31 provinces reported that 90% or more of households used adequately iodized salt. During the same period, the percentage of household samples with iodine content of at least 40 mg/kg increased, so that by 1999, 63% of the samples brought from households had an iodine content of at least 40 mg/kg (95% CI, 52.1–67.7).

Urinary iodine concentration

As shown in table 2, the national median urinary iodine concentration in schoolchildren progressed from 160 µg/L in 1995 (95% CI, 138–188) to 300 µg/L (95% CI, 237–326) in 1997 and 282 µg/L (95% CI, 246–345) in 1999. The median varied considerably among provinces, however, and particularly in 1997, the lowest and highest provincial medians of child urinary iodine concentrations differed by more than fivefold. For the country, the proportion of children with urinary iodine levels less than 100 µg/L decreased by 50% to 60%, while the proportion with urinary iodine levels of 300 µg/L or higher increased by a similar extent during the six-year observation period. In 1999, the median urinary iodine concentration in children was below 100 µg/L in only one province of China, while in 13 provinces the median had surpassed 300 µg/L.

Relationships between salt iodine content and use of iodized salt, and urinary iodine concentration

The median iodine content of household salt and the median urinary iodine concentration in children were positively correlated during each year of the survey (fig. 1). For the combined dataset of 1995–99, r_s = 0.74 (p < .001), and significant positive correlations were also obtained within each year. A positive correlation was also apparent (fig. 2) within each survey year between the percentage of households using adequately iodized salt (iodine content ≥ 20 mg/kg) and the median urinary iodine concentration among children from these households (combined r_s = 0.81, p < .001). Figure 3 shows that over the survey years, the

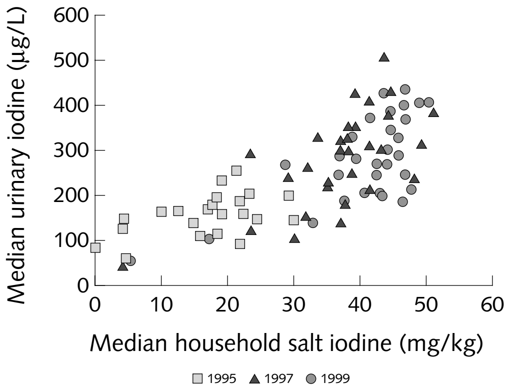

FIG. 1. Median household salt iodine content and median urinary iodine concentration in school-aged children in China, 1995–99. Nonparametric Spearman rank correlations: 1995: r_s = 0.43, p < .05; 1997: r_s = 0.61, p < .001; 1999: r_s = 0.56, p < .01

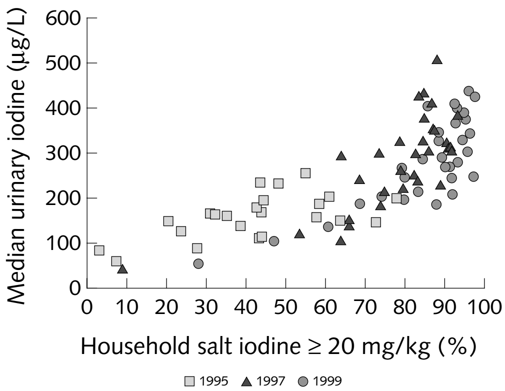

FIG. 2. Percentage of households using adequately iodized salt (iodine content ≥ 20 mg/kg) and median urinary iodine concentration in school-aged children in China, 1995–99. Nonparametric Spearman rank correlations: 1995: r_s = 0.56, p < .01; 1997: r_s = 0.72, p < .001; 1999: r_s = 0.72, p < .001

TABLE 2. Urinary iodine concentration among schoolchildren in provinces of China, 1995–99

Year	No. of provinces	Urinary iodine (µg/L)			% of children with urinary iodine < 100 µg/L			% of children with urinary iodine ≥ 300 µg/L		
		Median	95% CI	Range	Median	95% CI	Range	Median	95% CI	Range
1995	23	160	138–188	60.6–256.4	29.0	25.0–40.0	13.9–63.8	19.5	11.7–24.1	0.0–41.6
1997	31	300	237–326	41.2–506.9	9.5	6.1–18.4	2.6–78.3	50.5	33.6–57.7	4.7–72.1
1999	31	282	246–345	54.8–437.7	10.8	8.1–15.0	1.6–73.6	46.4	36.3–56.4	2.6–76.6

CI, Confidence interval of provincial pooled medians.

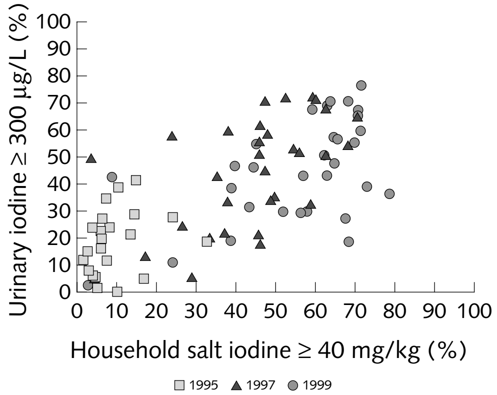

FIG. 3. Proportion of households using iodized salt with iodine content ≥ 40 mg/kg and proportion of school-aged children in China with urinary iodine concentrations ≥ 300 µg/L, 1995–99. Nonparametric Spearman rank correlations: 1995: $r_s = 0.38$, $p < .05$; 1997: $r_s = 0.57$, $p < .01$; 1999: $r_s = 0.48$, $p < .01$

proportion of children with urinary iodine concentrations of at least 300 µg/L increased with an increase in the proportion of households using salt with iodine content of at least 40 mg/kg (combined $r_s = 0.69$, $p < .001$).

Discussion

Starting out from a strategy focused on delivering iodized salt combined with iodized oil supplements in selected populations, the State Council of China in 1993 decided on a national policy to virtually eliminate iodine-deficiency disorders by 2000 and adopted USI as the strategy [9]. The results of representative monitoring of the iodine content of household salt and urinary iodine excretion in children from 1995 through 1999 show the solid progress made in China toward the implementation of USI and elimination of iodine-deficiency disorders. By the end of the six-year period in 1999, half of the provinces of China had met the target level of use of adequately iodized salt by at least 90% of households recommended by the World Health Organization/UNICEF/International Council for the Control of Iodine Deficiency Disorders (WHO/UNICEF/ICCIDD) expert consultation [4]. Also in 1999, the national median of this key iodine nutrition supply indicator had shifted closer to 90%. Measurements of the iodine content of household salt over time show a concurrent increase in salt iodine levels at consumption. In 1999, the national median salt iodine content had reached more than double the median content observed in a subsample of provinces in 1995.

The biennial provincial monitoring system was designed to collect data on urinary iodine concentrations among those schoolchildren selected to bring the salt used in their households. The distributions of urinary iodine concentrations in children may therefore be expected to reflect the iodine content of the salt used in the households where these children resided. From 1995 to 1999, during the period when both the national median salt iodine content and the proportion of households using iodized salt were seen to increase twofold, the median urinary iodine concentration in children increased from 160 to 282 µg/L, and the proportion of children with urinary iodine concentrations under 100 µg/L decreased by 50% to 60%. The consistent positive correlations found between provincial median household salt iodine contents and median urinary iodine concentrations in children lend further credibility to the implicit relationships between, on the one hand, household salt iodine content and its level of use, and on the other, urinary iodine concentrations in children. Along with improvements in the adequacy of salt iodization and increases in the use of iodized salt in households (fig. 2), an upward shift can be seen in the distribution of urinary iodine concentrations among schoolchildren. Thus, the progress in population iodine nutrition in China during 1995–99 can be attributed to both an improvement in the quality of the iodized salt supply and an increase in its use in households. Separating the proportional contributions of these two factors was not possible from the present dataset, however.

The mandated iodization levels of food-grade salt in China aimed at an addition of at least 100 µg iodine per day to the diet of the average individual [8]. From the present dataset, an accurate estimate of the national baseline urinary iodine concentration cannot be obtained, because the data obtained in 1995 were collected after USI had already been launched, although it had not yet taken hold in the salt supply channels everywhere [8]. The data points in figure 1 for provinces with a median salt iodine content of less than 10 mg/kg would suggest, however, that the national baseline child urinary iodine concentration may have started out at a median near or below 100 µg/L. For the 15 provinces (with 5,047 determinations of urinary iodine) in which, during any survey year, at least 90% of households reported using adequately iodized salt *and* the median iodine content of household salt was between 20 and 39.9 mg/kg, a median urinary iodine concentration of 245 µg/L was reported in children. Thus, it would seem from this simple comparison that the additional iodine consumption provided through the mandated policy was higher in practice than what the national policy had aimed for. At the same time, however, it is notable that under conditions considered optimal in USI practice, the observed urinary iodine concentration among children in China fell within the range recommended internationally [4].

The present dataset shows that by 1999 USI practice in China had progressed to the extent that the median household salt iodine content in the majority of provinces (22 of 31, or 71%) had reached levels considerably above what the policy aimed for. Figure 3 shows that the proportion of households using salt with an iodine content of 40 mg/kg or more was strongly associated with the proportion of children with a urinary iodine concentration of at least 300 μg/L. In 1999, the median urinary iodine concentration was 333 μg/L and the median household salt iodine content was 43.7 mg/kg in the 15 provinces (with 5,369 determinations of urinary iodine) reporting that at least 90% of households were using adequately iodized salt. Based on these observations, a reduction of the legislated salt iodization levels would be justifiable.

Although the practice of salt iodization in China improved overall, considerable variation remained in the measured iodine content of household salt. As table 1 shows, the more than 10-fold range between provinces in median salt iodine content observed in 1997 remained in 1999. Although the median household salt iodine content increased over time, along with a sizable reduction in the proportion of households using salt with an iodine content of less than 20 mg/kg, the proportion of household salt samples with iodine contents between 20 and 39.9 mg/kg remained rather constant in each province, at about one-third of samples. These observations show that the national salt industry in China still faced a challenge to improve performance enough to ensure a narrower range of iodine content during the production of iodized salt.

These considerations of USI outcomes in China were among the factors that led to a decision in October 2000 to revise the nationally mandated salt iodine levels to 35 ± 15 mg/kg at production. The monitoring results in 2002 should confirm whether this adjustment, in tandem with continuous improvements in quality assurance procedures by salt manufacturers, has prompted further improvement and optimization of the iodine nutrition situation in China.

In conclusion, following the high-level political decision in China in 1993 to virtually eliminate iodine-deficiency disorders by 2000 through the national practice of USI, steady improvements took place in the iodine content of salt and the proportion of households using iodized salt, as well as in the urinary iodine concentrations of children from these households. By 1999, China had basically achieved the goal of USI: almost half of the provinces had reached USI, and in only one province was the urinary iodine concentration in children still below the recommended range. Biennial data collection from 1995 to 1999 based on representative household salt samples and urine samples from children in China's provinces shows an intrinsic relationship between these indicators of iodine supply and nutrition. At the same time, however, it became apparent that the salt iodization practice in China had resulted in iodine consumption among schoolchildren in 1999 above the desired level. In addition, the variation in household salt iodine content remained considerable over the period of observation.

The data from 1999 show that China was tantalizingly close to achieving the national policy goal of virtual elimination of iodine-deficiency disorders set in 1993. The adjustment in 2000 of the mandatory levels of salt iodization at production, in combination with stronger efforts by the Chinese salt industry to ensure a narrower range of iodine contents in iodized salt, strengthens the expectation that the progress made toward optimum iodine nutrition of the population in China will continue.

Acknowledgments

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Advancing human nutrition without degrading land resources through modeling cropping systems in the Ethiopian Highlands

Tilahun Amede, Ann Stroud, and Jens Aune

Abstract

*Food shortage in sub-Saharan Africa is generally considered a function of limited access to food, with little thought to nutritional quality. Analyzing household production of nutrients across farming systems could be valuable in guiding the improvement of those systems. An optimization model was employed to analyze the scenario of human nutrition and cropland allocation in enset (*Enset ventricosum*)/root crop-based and cereal-based systems of the Ethiopian Highlands. The type and amount of nutrients produced in each system were analyzed, and an optimization model was used to analyze which cropping strategies might improve the nutritional quality of the household using existing resources. Both production systems were in food deficit, in terms of quantity and quality of nutrients, except for iron. The energy supply of resource-poor households in the enset/root crop-based system was only 75% of the recommended daily dietary allowance (RDA) of the World Health Organization (WHO), whereas resource-rich farmers were able to meet their energy, protein, zinc, and thiamine demands. Extremely high deficiency was found in zinc, calcium, vitamin A, and vitamin C, which provided only 26.5%, 34%, 1.78%, and 12%, of the RDA, respectively. The RDA could be satisfied if the land area occupied by enset, kale, and beans were expanded by about 20%, 10%, and 40%, respectively, at the expense of maize and sweet potato. The cereal-based system also had critical nutrient deficits in calcium, vitamin A, and vitamin C, which provided 30%, 2.5%, and 2% of the RDA, respectively. In the cereal system, the RDA could be fully satisfied by reducing cropland allocated to barley by about 50% and expanding the land area occupied by faba beans, kale, and enset. A shift from the cereal/root crop-dominated system to a perennial-enset dominated system would decrease soil erosion by improving the crop factor by about 45%. This shift would also have a very strong positive impact on soil fertility management. However, any policy suggestions for change in cropland allocation should be done through negotiations with households, communities, and district stakeholders.*

Key words: C-factor, cropping systems, human nutrition, modeling, land allocation

Introduction

The food situation in sub-Saharan Africa is continuing to deteriorate as a consequence of multiple calamities such as drought, occasional flooding, decline in soil fertility, increasing pests and diseases, land scarcity, and poor market access, coupled with discouraging policy environments. The effect is visible as recurring food shortage, malnutrition, and poverty. Food shortage in sub-Saharan Africa is generally regarded as a function of limited access to food, with little thought given to nutritional quality [1]. Malnutrition in the most vulnerable groups (children and women) could occur even in good crop harvest years because of nonbalanced food intake. Studies in Ethiopia showed that about 45% of the children were stunted and about 42% were underweight, in association with zinc, iron, and vitamin A deficiencies [2]. The most important documented forms of malnutrition countrywide in Ethiopia were protein-energy malnutrition and vitamin A, iodine, and zinc deficiencies [2, 3]. A recent survey showed that 53% of boys and 26% of girls aged between 6 and 72 months had night-blindness or Bitot's spots, with the highest prevalence in those between 36 and 72 months [2].

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Analyzing household production of nutrients across farming systems may be valuable for guiding the improvement of those systems, particularly in situations where markets are less important than securing subsistence. For instance, in Papua New Guinea, communities farming in flat wetland areas had significantly higher energy and protein intakes than those in the drier hills [4]. In Uganda, both banana-based and cereal-based systems failed to satisfy a range of nutritional needs, with calcium and zinc being the most deficient [5]. However, there is scant information on the interaction of enset/root crop-based and cereal-based systems of the Ethiopian Highlands in relation to household nutrition and human health. Enset (*Enset ventricosum,* known also as false banana) is a carbohydrate-rich perennial crop with a strong pseudostem and edible bulbs and corms [6], which is a staple of millions of households in the Ethiopian Highlands.

The nutritional quality of food may be improved by various practices, such as application of fertilizers and soil fertility improvement, selection of varieties with high micronutrient content, use of indigenous high-nutrient-value crops, and genetic modification of plants to improve micronutrient supplies [1, 7]. However, the application of these methods to address malnutrition depends upon the availability of technological and policy interventions that are commonly not within the reach of small-scale farmers. It may also be possible to supplement the diet with animal products where livestock is an integral part of the system, but animal products are rarely consumed by rural households, because they are scarce sources of cash [3]. Dietary supplements are also rarely available to the rural poor.

One option to minimize the risk of malnutrition is reallocation of cropland in favor of crops with high contents of the nutrients in deficit. Once the nutrient budget of these systems has been quantified and the type of the nutrient in deficit or excess has been identified, the nutritional balance may be improved by reallocation of cropland and by increasing the land area allocated to crops rich in the requisite nutrients [5]. Modeling the cropping system, by considering the adaptability of the crop to the environment in question, could offer a better and faster method of reversing malnutrition. However, the possible acceptance or rejection of the model depends largely on the compatibility of the new crop adjustment with cultural values, food habits, labor, input demands, and soil fertility management options.

Ethiopia is one of the most severely affected countries in sub-Saharan Africa in terms of land degradation, having lost about 17% of its potential gross domestic product (GDP) because of physical and biological soil degradation [8, 9]. Land degradation may be the major cause of recurrent crop failure, i.e., food insecurity. Hence, any attempt to efficiently exploit the potentials of land resources to produce more food should be integrated with strategies to rehabilitate depleted land resources [10]. Changing the plot size of one crop and reallocating it to another crop may have significant implications on soil erosion [11] because the change in crop type, which may be characterized by different leaf area, root density, and vegetative cover index, would affect the interception of rain by the vegetative cover. This is presented as a “crop factor” (C-factor) in the universal soil loss equation (USLE) [12]. The relationship between relative erosion and crop cover of the soil surface is strongly parabolic: a 25% increase in cover would yield a 50% reduction in erosion [10]. A shift from a cereal-dominated system to a perennial-dominated system may improve the C-factor, whereas the reverse may cause more erosion and land degradation. Therefore, altering crop allotment to improve human nutrition should take soil fertility, conservation, and management into account.

The objective of this study was to estimate the type and amount of nutrients that enset/root crop-based or cereal-based systems furnish, in terms of protein, energy, zinc, calcium, iron, thiamine, vitamin A, and vitamin C, to model cropping strategies that may improve the nutritional quality of the household using the existing resources, and to estimate the effect of reallocation of crops on land management and soil erosion.

Methods

Site description

The research was conducted in two contrasting farming systems of the Ethiopian Highlands: Areka and Ginchi. Areka is characterized by a multiple cropping system, with strong perennial components of enset and coffee, accompanied by sweet potato, taro, maize, wheat, and many others (table 1). The population pressure is high (> 400 inhabitants per square kilometer), with average landholdings of less than 0.5 ha per household. The elevation ranges from 1,880 to 1,960 m above sea level, with a mean annual rainfall of about 1,300 mm and an average temperature of 19.5°C. Rainfall is bimodal, with a short rainy season from March to June and the main rainy season from July to October. The dominant soils are eutric nitisols, which are characterized by high water-holding capacity, moderately acidic pH, low levels of nitrogen, and high phosphorus fixation.

Ginchi is an example of a mountainous Ethiopian plateau with an elevation of 2,700 to 3,000 m. The area has a weak annual bimodal rainfall of 1,200 mm and an average temperature of 15°C. The farming system is dominated by barley-fallow-barley rotation and livestock, which are grazed according to a communal management system. Crop diversity is restricted by

TABLE 1. Crop yield and nutrient composition of major crops grown in Areka and Ginchi

Crop	Yield (dry) (qt/ha)	Nutrient content/kg edible yield							
		Energy (kcal)	Protein (g)	Zinc (mg)	Iron (mg)	Calcium (mg)	Thiamine (mg)	Vitamin A (μg)	Ascorbic acid (mg)
Enset (*kocho*)[a]	119.08	2,111	6	6	37	320	0.3	0.2	0
Taro	29.66	1,038	13	1.4	20	550	0.4	0	90
Pumpkin	6.78	249	11	1.9	9	400	0.3	0	40
Kale[a]	18.75	401	25	8.6	22	50	0.4	112.5	13.2
Sweet potato	39.35	1,370	0.7	2	7	130	0.2	0	14.2
Irish potato[a]	14.46	840	15	4	36	184	0.1	0.4	2.83
Maize	14.84	2,234	41	13.3	20	80	0.2	0	0
Teff	4.09	1,620	41	11	115	690	0.3	0.03	0
Wheat[a]	8.93	2,220	68	2	27	270	2.1	0.8	0
Barley[a]	5.81	2,020	44	15.8	35	160	2.1	0	0
Pea	6.97	2,071	109	24.6	31	450	2.4	10.5	0
Faba bean[a]	6.77	2,759	164	13.8	43	870	1.9	1	0
Common bean	6.52	1,700	91	3	33	560	2.6	0.6	0
Sorghum	8.31	2,360	50	4.9	49	150	2.2	1.1	0

a. Crops grown both in Ginchi and Areka.

low average temperature. Population pressure on the land is exerted by humans (100/km^2) and livestock, with an average farm size of 3 ha. About 24% of the farmers own more than 4 ha. On the upper side of the watershed, the system is predominantly barley-fallow-barley accompanied by wheat, potato, and enset. The soils in the Ginchi plateau are litisols, which are acidic and low in organic matter, nitrogen, and phosphorus. The fertility of the soil is so low that it does not currently support continuous cropping.

Data collection

A household survey was conducted over two years (2000–01) in the two communities of the enset/root crop-based and cereal-based systems. Farmers from two wealth categories (relatively rich and poor) were considered for the study in Areka ($n = 24$) and Ginchi ($n = 31$). A participatory wealth-ranking exercise, which was undertaken by the African Highlands Initiative Program, grouped households into three wealth categories based on the size of landholdings, number of livestock, perennial crops grown, and sources of income, was used in this study [8]. During the household surveys, the researchers were able to observe and quantify over a period of two years. The major parameters considered for the analysis were farm and household size, household family composition by age and sex, cropland allocation, household food items available over seasons, household food allocation or distribution among family members, crop yield on the farm, and crop purchase or sales over seasons. Household food consumption was monitored in each household on a weekly basis by interviewing the women. The consumption unit (CU) of each household was calculated by adding the CU of each household member using Food and Agriculture Organization (FAO) designations [13]. Secondary data were also collected on average crop yield in the district [14], nutritional composition of each crop [15] (table 1), and other relevant factors. For crops for which reliable data were not available, measurement of yield, moisture content, and estimation of edible components was done on the farm at harvest. The survey was composed of a stratified questionnaire, household group discussion, and direct measurement of crop yields during harvest, and was administered by a technical assistant residing in a nearby village. Continual follow-up was made at all levels.

Since the bimodal rainfall supports at least two crops per year at Areka, land size per household was calculated as the sum of land used for growing crops in both seasons per year. Hence, the farm size presented here is larger than the actual land size. In the process, intercropping and relay cropping practices complicated the establishment of land area and yield per individual crop. However, for the purpose of this exercise, we followed a procedure similar to that used by McIntyre et al. [5], whereby the dominant crop is assumed to occupy the entire area if the populations of the crop mixtures are sparsely grown. The area occupied by the companion crop was calculated from the current plant population density and the optimal plant population density. In situations where none of the crops grown in the crop mixture comprised the highest ratio, crop area was calculated based on the proportional areas they occupied.

The nutrient yields of annuals were determined by measuring the edible yield per area, analyzing the nutrient content of the produce, and converting it to household nutrient supply as the sum of all consumable crop products of the household in the respective systems. Besides annuals, the system comprises perennial crops (e.g., *Enset ventricosum*) of various ages. The nutrient yield of perennial crops *in situ* was determined by estimating crop yield per plant from measurements of corm height and the circumference of plants, as described earlier [16], supplemented by sample weighing, and multiplied by the nutrient content of the product [15] and the number of plants to be harvested per year.

Alterations in crop area and crop species may affect erosion by changing the vegetative cover. Therefore, the relative farm erosivity index (FEI) was calculated by considering the C-factor in terms of cover effect on soil erosion [10] and by considering the cropland size allocated to each crop at present and after optimization of the cropping system for optimum human nutrition, as follows:

$$\text{FEI} = \frac{\sum \text{CF} \times \text{optimized cropland area}}{\sum \text{CF} \times \text{current cropland area}}$$

where
FEI = cumulative farm erosivity index
CF = C-factor of respective crop species

The model

An optimization model was developed using the Solver in Microsoft Excel and employed to analyze the scenario of human nutrition and cropland allocation. After the land size allocated per crop, yield data, percent edible yield, moisture content, and nutrient composition of each crop had been assembled, an annual nutrient budget and household consumption unit was calculated. The recommended dietary nutritional allowance defined by the World Health Organization (WHO) [17] was used to establish optimal nutrient balances.

The objective function used in the model was energy availability per consumption unit and day:

$$\frac{\sum_{i=j}^{N} LS_j \times EY_j \times DM_j \times NC_j}{CU \times 365}$$

where
LS = land allocated to crop *i*
EY = edible yield of crop *i*
DM = dry matter yield of crop *i*
NC = nutrient content of crop *i*
CU = number of consumption units in the household (number of people eating in the house)

Farm land size and daily nutritional requirements for protein, zinc, calcium, iron, thiamine, vitamin A, and vitamin C were used as constraints in the model (see list of constraints below). The constraints differ between the locations because the farming systems were different. The constraints were set to ensure that the households would continue to cultivate, at least partly, their current staple crops. The staple crops in Areka are enset, sweet potato, and maize, whereas those in Ginchi are barley, faba beans, and kale.

Constraints for Areka communities:

Total farm land ≤ 1,659 m^2/CU
Land size of enset ≥ 100 m^2/CU
Land size of sweet potato ≥ 100 m^2/CU
Land size of maize ≥ 100 m^2/CU
Protein ≥ 35 g/day/CU
Vitamin C ≥ 25 mg/day/CU
Zinc ≥ 15 mg/day/CU

Constraints for Ginchi communities:

Total farm land ≤ 4,081 m^2/CU
Land size of barley ≥ 1,000 m^2/Cu
Land size of faba bean ≥ 80 m^2/CU
Land size of kale ≥ 50 m^2/CU
Protein ≥ 35 g/day/CU
Calcium ≥ 500 mg/day/CU
Vitamin A ≥ 25 μg/day/CU
Zinc ≥ 15 mg/day/CU

The decision variables in the model are land allocation for different crops, energy availability per consumption unit, and day, subject to the constraints given above.

Results

Although the average family size is equal in the two regions, the land size per consumption unit is much higher in the cereal-based system (Ginchi) than in the enset/root crop-based system (Areka) (table 2). The difference in land size would be even higher if the fallow land in Ginchi were considered as a potential area for expansion of current crop fields. Both systems are considered nutrient deficient, especially in drought years; the Ginchi farmers have a better ability to cope with drought by selling small ruminants, whereas the Areka system includes very few animals.

Enset/root crop-based systems

The population density in Areka is relatively high (> 400/km^2), and the landholdings are relatively small, about 816.8 m^2/CU. More than 50% of the land is allocated to root/corm crops, in particular sweet

TABLE 2. Characteristics of an average household in enset/root crop-based (Areka) and cereal-based (Ginchi) systems in Ethiopia

Characteristic	Areka	Ginchi
Household size		
Males	3.2	3.1
Females	3.1	3.3
Total	6.3	6.4
Mean CU	4.59	4.65
Actual cropland/household (m^2)	3,749.7 (± 511)*	17,499.7 (± 1,149)
Cropland used/household (m^2)	5,218.7 (± 679)	10,402 (± 709)
Actual cropland/CU (m^2)	817	3,764
Cropland used/CU (m^2)	1,137	2,237
Land used for cash crops (%)	6	0

CU, Consumption unit. Numbers in parentheses indicate standard deviation.
* Mean (±SD).

potato, Irish potato, enset, and taro, with land areas of 25.8%, 16.2%, 10.1%, and 2.75%, respectively (figs. 1 and 2). Most of these crops are grown in the homestead or the mid-field, which is halfway between their home and the end of their farm. Another 45% of the land is allocated to cereals, with maize as the dominant grain crop in the system. The total land allocated to legumes and vegetable crops is less than 5%.

The current enset/root crop-based system was found to be in deficit for most of the nutritional components, regardless of household wealth status. Except for iron, the system failed to cover the needs for macro- and micronutrients (table 3). The daily energy supply of resource-poor households was only 75% of that recommended by WHO [17]. Extremely high deficits were found of zinc, calcium, vitamin A, and vitamin C, at 26.5%, 34%, 1.78%, and 12% of the required levels, respectively (table 3). The situation was similar even for relatively resource-rich farmers, except for energy, which was higher.

Cereal-based systems

The average landholdings are much larger in the cereal-based system (4 ha per household) than in the enset/root crop-based system. However, in the cereal-based system the farmers leave about 40% of their land fallow, due to declines in soil fertility and lack of grazing land for keeping livestock. Crop diversification at Ginchi is very low, with only six crop species. The greatest proportion of land is allocated to barley (63.5%), followed by wheat and Irish potato (fig. 3). Similar to the situation in Areka, the amount of land allocated to legumes and vegetables in Ginchi is relatively small. Hence, it is predominantly a barley-fallow-barley system.

The current production system is unable to satisfy the human requirements for most nutrients. The system is able to deliver relatively high amounts of iron and thiamine. The resource-rich farmers can satisfy their energy, protein, zinc, iron, and thiamine

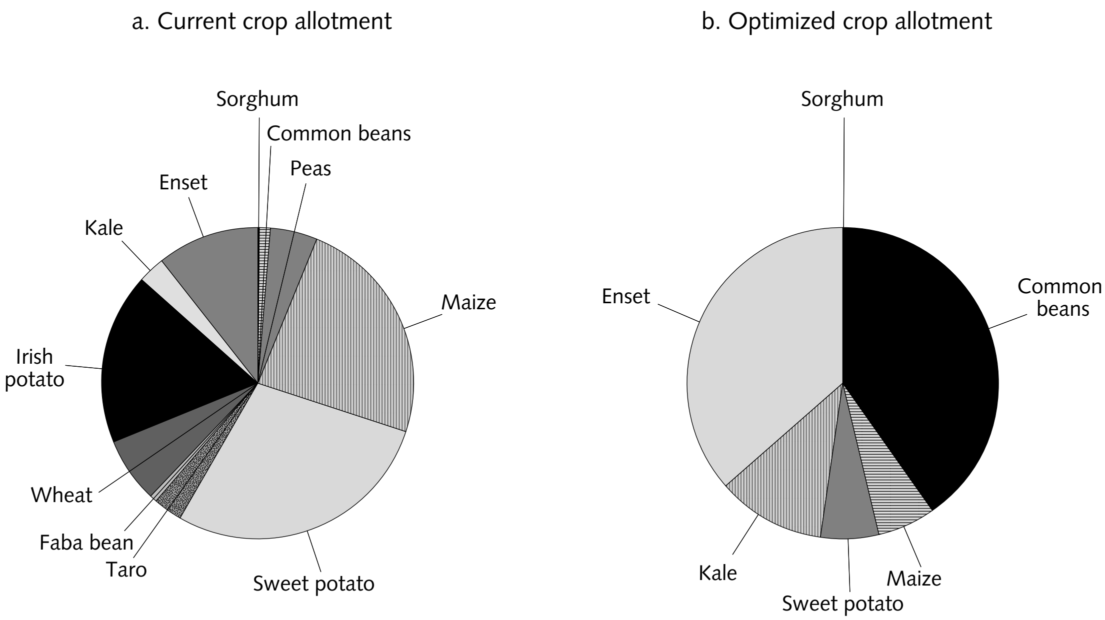

FIG. 1. Land allocation by resource-rich farmers in the enset/root crop-based systems for various food crops, currently (a) and after optimization for improved human nutrition (b)

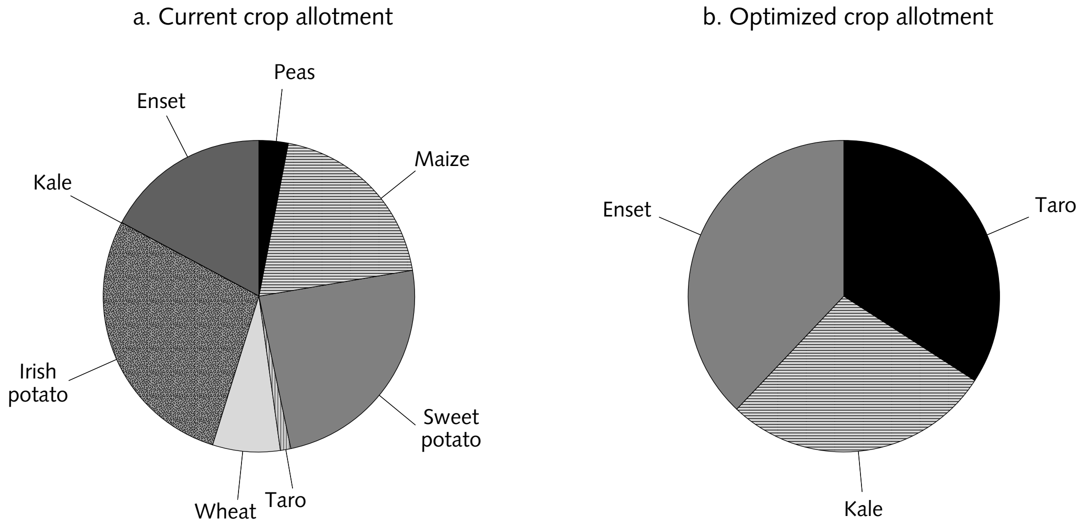

FIG. 2. Land allocation by resource-poor farmers in the enset/root crop-based systems for various food crops, currently (a) and after optimization for improved human nutrition (b)

requirements. However, they can provide only 30%, 2.5%, and 2% of the RDA for calcium, vitamin A, and vitamin C, respectively [17] (table 3).

Modeling results

The modeling was run by taking system constraints into account, including household food habits, the adaptability of crops, and the effects of pests and diseases. In Areka enset and sweet potato are the major components of household nutrition, whereas in Ginchi barley is currently the major staple crop. Thus, we ran a simulation model that included barley in Ginchi and enset and sweet potato in Areka.

In Areka, the major constraint affecting the model was the extremely low landholdings of the majority of community members, who were regarded as resource-poor in the analysis. When the whole system was considered in modeling, it was not possible to improve the system with regard to most nutrients, except in terms of energy. However, when the simulation was run separately for the relatively resource-rich households, the energy supply became much higher than the recommended levels, while the demand for all other nutrients was fully covered (table 3). This finding recommends a significant shift from cereals and root crops to an enset-bean dominant system. There needs to be a shift in land allocation, from about 10% to 36% and from 0.1% to 40% for enset and the common bean, respectively (figs. 1 and 2).

At Ginchi, there was a better possibility for the model to improve the nutritional quality of the household by increasing the amount of cropland per consumer unit, if the land was not compromised by a decline in soil fertility and a shortage of livestock feed. The existing cropland, at 2,237 m^2/CU, is enough to provide bal-

TABLE 3. Nutrient budget of households in enset/root crop-based and cereal-based systems of Areka and Ginchi, at current cropping systems and after the system was optimized for improved human nutrition.

		Areka				Ginchi			
		Resource-poor		Resource-rich		Resource-poor		Resource-rich	
Nutrients	RDA	Current	Optimized	Current	Optimized	Current	Optimized	Current	Optimized
Energy (kcal)	2,000.00	1,293.66	2,000.00	2,284.18	4,758.4	1,397.5	3,329.00	2,081.50	3,695.60
Protein (g/kg)	37.53	7.82	9.31	17.39	35.98	32.39	40.00	42.40	42.75
Zinc (mg/kg)	15.00	3.98	6.09	7.38	15.00	7.39	15.33	19.75	20.80
Iron (mg/kg)	7.61	21.48	36.63	35.68	81.664	26.41	78.00	33.55	68.56
Calcium (mg/kg)	528.00	178.76	362.42	310.00	758.70	163.25	694.00	194.50	547.04
Thiamine (mg/kg)	0.92	0.21	0.35	0.41	0.89	1.17	1.08	1.52	1.30
Vitamin A (μg/kg)	10.00	0.18	10.00	2.54	10.00	0.25	12.51	1.45	20.80
Vitamin C (mg/kg)	25.42	2.98	14.95	9.08	2.41	0.54	1.62	0.01	2.61

RDA, Recommended dietary allowance [17].

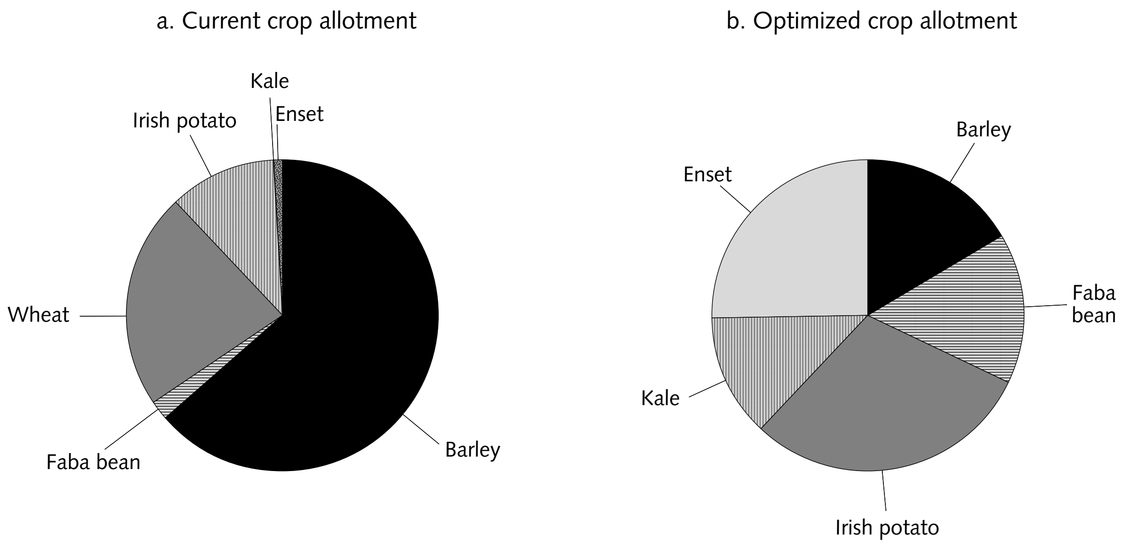

FIG. 3. Land allocation in the cereal-based systems for various food crops, currently (a) and after optimization for improved human nutrition (b)

anced nutrition with a moderate change in the cropping system. The suggested shift was intended to reduce the area occupied by barley by about 50% and expand the land area available for enset, kale, and faba bean to 25.3%, 17.7%, and 15.6%, respectively (fig. 3). By doing so, the requirements for the nutrients of interest were fully satisfied, except for vitamin C. In this case, vitamin C supplements could be used, or a new vegetable crop could be introduced into the system.

Implications of crop reallocation for soil erosion

A shift from one cropping system to another may have a considerable effect on soil loss and nutrient management [10]. In the enset/root crop-based system, a shift from the enset-root crop mix to an enset-bean system improved the C-factor at the farm level by 42%, indicating that soil erosion could be significantly minimized. The same applies to the cereal-based system, in which FEI was improved by 45% (table 4). This has a very strong implication for soil-fertility management, since the enset system traditionally attracts more organic matter into the system [6, 8, 18] because it does not grow in soils with low organic matter content.

Discussion

Integrating human nutrition with sustainable land management

An attempt to address food security cannot be complete without a thorough consideration of the relationship between land degradation and nutritional availability. Initiatives and policies directed toward food security should integrate strategies to turn the negative chain reactions between productivity and land use into positive balances.

Crop reallocation with human nutrition as the sole criterion could affect land management in at least two ways. First, the system may demand intensified soil fertility management because of the expansion of perennials. Traditionally, farmers have divided their farms into three categories, homestead, mid-field, and outfield, based on fertility status, type of soil management, and type of crops grown. About 80% of a farm's available organic fertilizer is applied to the homestead area, where enset is traditionally grown [6, 8]. Hence, it is the most fertile corner of the farm because of the addition of manure, crop residues, and household wastes [6, 8]. Farmers even export crop residues from the outfield to the enset field because the local wisdom considers enset a mulch-loving crop. The expansion of enset at the expense of cereals may, therefore, improve the nutrient budget of the system by encouraging farmers to intensify soil fertility management options, such as composting, better manure management, and fair distribution of resources across soil fertility gradients. Fertilizing the expanding enset fields may have a strong effect on labor and the availability of organic resources. In this case, farmers would be encouraged to practice better organic resource production and management. Second, a shift from a cereal-dominant system to an enset-dominant system may minimize erosion effects by improving vegetative cover, thus reducing the erosivity power by about 45%.

Implications for human nutrition

Malnutrition is common in the farming communities

TABLE 4. Effect of crop reallocation on soil erosion at Areka and Ginchi[a]

		Cumulative C-factor			
		Areka		Ginchi	
Crop	C-factor	Current	Optimized	Current	Optimized
Enset	0.04	6.48	24.20	0.88	24.56
Taro	0.35	16.17	np	np	np
Kale	0.26	11.17	48.47	0.73	80.32
Sweet potato	0.23	99.45	23.00	np	np
Potato	0.22	59.73	np	59.21	159.98
Maize	0.35	127.67	35.00	np	np
Sorghum	0.40	0.94	np	np	np
Teff	0.40	58.84	np	np	np
Wheat	0.42	43.39	np	228.89	np
Barley	0.42	np	np	648.48	167.96
Faba beans	0.24	4.16	np	11.61	91.00
Common beans	0.19	2.132	126.83	np	np
Pea	0.15	11.21	np	np	np
∑C-factor	0.28	441.35	257.51	949.82	523.81
FEI (%)		100	58.3	100	55.1

np, Not planted; FEI, farm erosivity index.
a. Data show the effects of current and suggested (optimized) cropping on C-factor as a component of the universal soil loss equation (USLE).

of the Ethiopian Highlands [2, 3]. This study suggests that one affordable remedy may be reallocation of cropland in favor of perennial crops with a high content of the nutrients that are in deficit. This could be done by considering community food habits, the adaptability of crops to the environment under consideration, and the potential effect of reallocation on the health of the agro-ecosystem.

The conventional wisdom was that enset/root crop-based systems may produce sufficient amounts of carbohydrates and vitamins to cover the household's nutrient requirements, but may be deficient in protein and micronutrients. Our results, however, showed that the system was deficient in most of the required micronutrients, especially vitamin A, vitamin C, zinc, and calcium (table 3). Even the available energy and protein for the resource-poor families was only 75% of the recommended amounts. This was confirmed by the fact that the system has relied heavily on food aid for at least three months a year for the last decade. This was partly the consequence of small landholdings (817 m^2/CU cropland) and very low crop yield caused by low soil fertility, use of low-yield varieties, and occasional drought. Malnutrition was severe in the resource-poor households (table 3), because resource-poor farmers concentrate on annual crops whereas resource-rich farmers allocate large plots to enset [6, 8], in agreement with our findings. Resource-poor farmers would have to allocate about 38% of their land to enset, an increase of 20% from the current system, to increase crop yield by about 20% and thus be able to partially cover the nutritional demands of the household (table 3). As it stands now, unless external supplementation is considered, the resource-poor households will remain deficient in most of the micronutrients.

The constraints on the cereal-based systems were similar to those on the enset/root crop systems except for the severe deficiency of vitamins. Malnutrition in Ginchi could be even more severe in the resource-poor families, because the crop yield is much lower there than in Areka, mainly because of the low temperatures in the mountains. Yet, there is more opportunity to expand cropland and increase productivity by improving the existing fallow-barley system through integration of soil fertility management options and high-yield varieties. Malnutrition was aggravated by limited diversification of crops, and even reallocation of the existing crops would not be enough to fulfill the requirement for vitamin C. Introduction of frost-resistant vegetable crops to be grown under a layer of expanded enset fields may satisfy the vitamin requirements (fig. 3). Households occasionally buy green peppers and citrus fruits (crops high in vitamin C) from the nearby markets in the valley bottoms. Earlier reports also showed that the lowest rates of vitamin A deficiency in Ethiopia were found in predominantly enset/root crop-based systems [3].

Nutrient deficiencies (e.g., protein and calcium) in the two systems could have been alleviated by livestock products. However, 93% of the interviewed households in both systems sold livestock products to cover household cash needs. Hence, livestock contributes little to household nutrition.

Our results indicate that if food security and environmental health are to be achieved in the Ethiopian Highlands in the short term, there is an urgent need to shift from a cereal-dominant to an enset-legume-dominant system. Expansion of the land area allocated to beans in Areka and to faba beans in Ginchi is vital to alleviate protein malnutrition. Enset is already supporting 7 to 10 million people as a staple or costaple with cereals and root crops [8, 18], and increasing its land allocation is expected to be an attractive option. The shift would have a positive impact on food security, not only because of the high energy yield of enset, but also because of its protective functions for the land, its greater ability to provide food at any time of the year, and its potential for being drought-resistant.

This approach differs from biofortification in that it does not require the introduction of nutrient-extracting crops or varieties with higher nutrient concentrations. Farmers may adopt the recommendations to reallocate their existing crop fields without the problems in adopting a new crop, i.e., one with a different color and/or different cooking quality. Biofortified varieties could also aggressively consume soil nutrients and might lead to unsustainable production unless the system is continuously supplemented by external inputs.

Implications for policy

The current policy of the Ethiopian Government gives great attention to food security, with limited emphasis on natural resource management. On the other hand, the continual quest for food, pasture land, and fuel for mere survival and to meet basic community needs has forced the increased cultivation of marginal lands, regardless of ecological soundness. The current model favors the expansion of perennial crops to address household food security and environmental degradation, while the current system of land tenure, in a situation where the government owns the land, may not encourage farmers to expand their perennial crops and practice sustainable land use.

Integration of the suggested cropping system will need strong policy support in many ways. First, an expansion of enset fields would have a strong impact on labor, mainly that of women, who are commonly responsible for managing enset fields. The most labor-intensive operation is the processing of enset into *kocho* (the bulk of the fermented starch obtained from the mixtures of the decorticated leaf sheath and grated corm) and *bulla* (a white powder produced from squeezing the liquid containing starch from the corm), which is currently estimated to take about seven hours to process one single enset plant. Hence, integration of more enset into the system should be accompanied by the integration of processing implements at affordable prices to minimize pressure on household labor. Second, the expansion of perennials calls for an immediate policy decision on land tenure and guarantees. Third, initial policy support, in terms of credit, would be needed, because the expansion of enset may demand more input of organic and mineral fertilizer into the system to establish and grow the crop in the less fertile outfields. However, the farmers' choices of livelihood strategies substantially influence cropping choice decisions and welfare and resource outcomes. Hence, any policy suggestion for change in cropland allocation should be done through bottom-up negotiations at the levels of the individual farmer, the community, and the district. Increasing awareness of nutritional deficiencies inherent to the current system and their implications for health, and of the benefits that could accrue from modification of the current production system, may lead to an early adoption.

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Influence of socioeconomic status on the prevalence of stunted growth and obesity in prepubertal Indonesian children

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Abstract

*This cross-sectional study assesses the prevalence of stunting, overweight, and obesity in prepubertal children from different socioeconomic groups in Indonesia. Children from rural, poor urban, and nonpoor urban communities were studied (*n = 3,010*). The prevalences of stunting, wasting, overweight, and obesity were 19.3%, 5.0%, 2.7%, and 0.8%, respectively. The odds ratios (OR) for stunting, as compared with nonpoor urban children, were higher among rural children (2.92; 95% confidence interval [CI], 2.37–3.59) than among poor urban children (1.58; 95% CI, 1.18–2.13). The prevalence of wasting was not influenced by socioeconomic status. Both rural and poor urban children were significantly less likely to be overweight than were nonpoor urban children: in comparison with nonpoor urban children, the OR values were 0.19 (95% CI, 0.10–0.36) for rural and 0.13 (95% CI, 0.04–0.43) for poor urban children. Boys were more likely to be stunted or obese than girls: OR for stunting, 1.75 (95% CI, 1.44–2.12); OR for obesity, 4.07 (95% CI, 1.40–11.8). Stunted children were less likely than non-stunted children to be overweight: OR, 0.10 (95% CI, 0.03–0.43). In Indonesia, undernutrition is still related to poverty, whereas obesity is more related to prosperity.*

Key words: obesity, overweight, socioeconomic status, stunted growth

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Introduction

Stunted growth affects 32% of children under five years of age in the developing world [1]. The process of becoming stunted due to chronic undernutrition begins at birth, or even before, and continues during the first three years of life. The stunting that occurs during these early years cannot be restored thereafter [2]. Unfortunately, when energy intake is adequate, these stunted children are at higher risk of overweight [3]. Besides being a risk factor for adult obesity, childhood obesity is associated with chronic diseases in later life, such as hyperinsulinemia, hypertension, hyperlipidemia, type 2 diabetes mellitus, and atherosclerotic cardiovascular disease [4, 5]. Increasing levels of these chronic diseases will pose a particular burden for developing countries. They will face the double burden of infectious and poverty-related diseases (e.g., malaria, chronic undernutrition), and the emerging concerns of chronic diseases related to early malnutrition, e.g., stunting and a related likelihood of being overweight.

Indonesia, a developing country with a total population of approximately 200 million, underwent a significant improvement in standard of living (defined by higher income and improved nutrition and health care) from 1960 to 1998. The infant mortality rate decreased from 128 to 40 per 1,000 live births, while the mortality rate among children under five years of age decreased from 216 to 58 per 1,000 live births [6]. However, this new prosperity was not evenly distributed. In 1999, 27% of the population was still living below the national poverty line [7]. With a documented increase in the prevalence of obesity among urban adults in Indonesia from 4.9% in 1988 to 7.6% in 1993 [8], it is important to know the prevalence of under- and overnutrition among children from different socioeconomic levels in Indonesia.

The aim of this study was to assess the prevalence of stunting, overweight, and obesity in school-aged prepubertal children from different socioeconomic levels (rural, poor urban, and nonpoor urban) in Indonesia. The study was also intended to investigate the association between stunting and overweight or obesity in relation to socioeconomic status.

Subjects and methods

Study population and design

The study was performed in two adjacent areas in Central Java. Yogyakarta, an urban area, was a city with approximately 487,115 inhabitants at the time of the study. Gunung Kidul, a rural area located about 20 to 40 km from Yogyakarta, had approximately 710,691 inhabitants [9]. We chose these two study areas because of the relatively homogeneous ethnicity of their populations. Most of the people in both areas are of Javanese descent. The altitude of both study areas is less than 500 m above sea level [9].

A cross-sectional study was conducted in school-aged prepubertal children in both areas. We randomly selected 33 of 509 public primary schools in the rural area and 37 of 172 public primary schools in the urban area. In Indonesia, it is obligatory for children to enter primary school at the age of six or seven years. Prepubertal children (under eight years old for girls and under nine years old for boys) from the first- and second-year class of every school were included. The ages of the children finally studied ranged from 6 to 7.9 years for girls and from 6 to 8.9 years for boys. This study selected prepubertal children because puberty, which normally occurs after the age of eight in girls and nine in boys, may interfere with the interpretation of measurements due to changes in body composition and differences between children in the timing of the adolescent growth spurt.

We excluded children with prominent chronic diseases, such as congenital heart disease or major thalassemia. Also excluded were children who had physical handicaps that might interfere with the measurements.

The study was performed from February to May 1999 and was approved by the ethical committee of Gadjah Mada University, Yogyakarta, Indonesia.

Data collection

Anthropometric data were collected by health professionals. Heights and weights were measured using the standard techniques described by the World Health Organization (WHO) [10]. Training for standardization of the measurements, followed by field practice and testing, was performed prior to data collection. All measurements were performed between 8 and 10 a.m. The children, wearing light clothing, were weighed to the nearest 0.1 kg with a Seca digital scale (Germany). Height was measured to the nearest 0.1 cm with a portable stadiometer. Height was measured with the child standing facing the fieldworker, without shoes.

Birth dates were verified by a copy of the child's birth certificate filed at the school. Definitions of rural and urban populations were based on agricultural activities and population densities. Yogyakarta had a population density of 14,988/km^2, while Gunung Kidul had a population density of 498/km^2 [9]. In the urban area, the socioeconomic status of each child was individually deduced from his or her living environment. Children living in the urban slum area were considered poor, and those not living in this area were considered to be not poor.

Data on height-for-age and weight-for-height were converted to z-scores of the WHO/National Center for Health Statistics (NCHS) reference population using the EPINUT component of the Epi Info 6.04 package (Centers for Disease Control and Prevention, Atlanta, Ga., USA). Biologically implausible values, such as z-scores below –6.00 or above +6.00, were excluded from the analysis. Values that were most likely to represent errors, i.e., those that were 4 z-score units (standard deviations) outside the observed mean for every age in one full year, were also excluded (flexible exclusion range) [11].

Children were classified as stunted if they had height-for-age z-scores (HAZ) below -2.00, and as not stunted if they had HAZ of –2.00 or more. Children were classified as overweight if they had weight-for-height z-scores (WHZ) based on WHO-NCHS references above +2.00. Wasting or thinness was defined by weight-for-height z-scores (WHZ) below –2.00 [11].

The body-mass index (BMI) was calculated by dividing the weight in kilograms by the square of the height in meters (kg/m^2). The BMI reference proposed in 2000 by the International Obesity Task Force (IOTF) was used to classify children as overweight or not overweight and as obese or not obese. According to the IOTF cutoffs for persons 18 years of age, overweight is defined by a BMI above 25 kg/m^2 and obesity by a BMI above 30 kg/m.^{2} The cutoff points were tabulated at the exact half-year of ages. The cutoff points for overweight ranged from BMIs of 17.34 to 18.35 in 6- to 8-year-old girls and from 17.55 to 19.10 in 6- to 9-year-old boys. For obesity, the cutoff points ranged from 19.65 to 21.57 in 6- to 8-year-old girls and from 19.78 to 22.77 in 6- to 9-year-old boys [12]. Seven classes of age at midyear in our study population were defined as follows: 6 years old (6 to < 6.25 years), 6.5 years old (6.25 to < 6.75 years), 7 years old (6.75 to < 7.25 years), 7.5 years old (7.25 to < 7.75 years), 8 years old (7.75 to < 8.25 years), 8.5 years old (8.25 to < 8.75 years), and 9 years old (8.75 years or older). The maximum ages were 8 years for girls and 9 years for boys.

Data entry and analysis

Data were entered and analyzed using SPSS for

Windows (Version 9, SPSS, Chicago, Illinois, USA). The odds ratios for stunting, wasting, overweight, and obesity within socioeconomic and sex groupings were compared by χ^2 tests. Odds ratios are presented with 95% confidence intervals (95% CI). Quantitative data, i.e., data on height-for-age z-scores (HAZ) and weight-for-height z-scores (WHZ) and BMI, were analyzed by *t*-tests and Pearson's correlation.

Results

We visited 70 schools to examine a total of 3,689 prepubertal children who were listed as first- and second-year students. We excluded 674 children because they were not in the required age range. Of the remaining 3015 children, four missed the measurement session and one had a HAZ and a WHZ in the flexible exclusion range.

Of the 3,010 children for whom complete data were available, 1,218 were from the rural area and 1,792 were from the urban area. The children from the urban area were then subdivided into 440 poor (from the urban slum area) and 1,352 nonpoor children. The total population studied consisted of 1,738 boys (57.7%) and 1,272 girls (42.3%).

In our sample, the prevalence of stunting was 19.3% (HAZ < –2.00, 580 children). The prevalence of wasting was 5.0% (WHZ < –2.00,152 children), while the prevalence of overweight was 2.3% (WHZ > +2.00, 70 children). However, when the BMI reference was taken, the prevalence of overweight was 2.7% (80 children). The level of agreement between these two cutoffs for overweight was good ($\kappa = 0.89$, $p < .001$, Fisher's exact test). The prevalence of obesity based on the BMI reference proposed by IOTF was 0.8% (25 children). Details on the odds ratios for stunting, wasting, overweight, and obesity based on socioeconomic status are given in table 1.

Urban children, whether they were poor or nonpoor, were on average taller than rural children ($p < .001$), with mean (95% CI) differences in HAZ of 0.61 (0.54–0.68) and 0.20 (0.11–0.30), respectively. Nonpoor urban children were heavier than rural children ($p < .001$), with mean (95% CI) differences in weight-for-height z-scores (WHZ) and BMI of 0.24 (0.16–0.32) and 0.46 (0.32–0.59), respectively. There were no significant differences in WHZ and BMI between poor urban and rural children ($p > .05$).

The odds ratios for stunting (OR, 1.75; 95% CI, 1.44–2.12; $p < .001$) and obesity (OR, 4.07; 95% CI, 1.40–11.8; $p = .005$) were higher in boys than in girls. Details on the odds ratios and prevalences of stunting, wasting, overweight, and obesity in boys and girls are presented in table 2. The differences between boys and girls in the odds ratios for stunting were observed in both the rural and the urban areas (table 3).

Stunted children had lower odds ratios for over-

TABLE 1. Socioeconomic differences in the prevalence and odds ratio of stunting, wasting, overweight, and obesity

Characteristic	Socioeconomic status	*n*	Prevalence (%)	Odds ratio (95% CI)	p^a
Stunted[b]	Rural	1,218	28.2	2.92 (2.37–3.59)	< .001
	Poor urban	440	17.5	1.58 (1.18–2.13)	.002
	Nonpoor urban	1,352	11.8	1.00 (reference)	—
Wasted[c]	Rural	1,218	4.8	0.97 (0.68–1.40)	0.89
	Poor urban	440	6.4	1.32 (0.84–2.09)	0.23
	Nonpoor urban	1,352	4.9	1.00 (reference)	—
Overweight based on IOTF[d]	Rural	1,218	1.0	0.19 (0.10–0.36)	< .001
	Poor urban	440	0.7	0.13 (0.04–0.43)	< .001
	Nonpoor urban	1,352	4.9	1.00 (reference)	—
Overweight based on NCHS/WHO[e]	Rural	1,218	1.0	0.23 (0.12–0.43)	< .001
	Poor urban	440	0.5	0.11 (0.03–0.44)	< .001
	Nonpoor urban	1,352	4.1	1.00 (reference)	—
Obese based on IOTF[f]	Rural	1,218	0.2	0.09 (0.02–0.39)	< .001[g]
	Poor urban	440	0.0	Not calculated	.005[g]
	Nonpoor urban	1,352	1.8	1.00 (reference)	—

CI, Confidence interval; IOTF, International Obesity Task Force; NCHS, National Center for Health Statistics; WHO, World Health Organization; BMI, body-mass index.
a. χ^2.
b. Height-for-age z-score (HAZ) < –2.00.
c. Weight-for-height z-score (WHZ) < –2.00.
d. Percentiles passing BMI of 25 kg/m^2 (IOTF); see Subjects and Methods section for detailed information.
e. Weight-for-height z-score (WHZ) > +2.00.
f. Percentiles passing BMI of 30 kg/m^2 (IOTF); see Subjects and Methods section for detailed information.
g. Fisher exact test.

weight (OR, 0.10; 95% CI, 0.03–0.43; $p < .001$). Overall, the mean WHZ and BMI of stunted children were lower than those of nonstunted children. The differences were statistically significant for the rural, poor urban, and nonpoor urban children (table 4). There were significant positive correlations between HAZ and WHZ ($\rho = 0.24$, $p < .001$) and between HAZ and BMI ($\rho = 0.30$, $p < .001$).

Discussion

The overall prevalence of stunting in rural children was almost three times higher than in nonpoor urban children. To a lesser degree, poor urban children also had significantly higher ($p = 0.002$, table 1) odds ratios for stunting than the nonpoor urban children. A similar study comparing the prevalence of stunting in slightly older (seven to nine years) urban and rural children in Malaysia found comparable results [13]. Two studies on urban schoolchildren in Jakarta and Manila also found higher prevalences of stunting in children of lower socioeconomic status. These two studies used attendance at public or private schools as a proxy for socioeconomic status, whereas in our study we used the child's area of residence as a proxy for socioeconomic status [14, 15]. Characteristics such as family income or parental education would be better indicators of socioeconomic status, but in these populations these were not always easy to assess. Many families had multiple irregular incomes, and extended families with multiple breadwinners and child caregivers were common. Our study and the other three studies mentioned above seem to suggest that, at least in these three Asian

TABLE 2. Sex differences in the prevalence and odds ratio of stunting, wasting, overweight, and obesity

Characteristic	Sex	*n*	Prevalence (%)	Odds ratio (95% CI)	*p*[a]
Stunted[b]	M	1,738	22.8	1.75 (1.44–2.12)	< .001
	F	1,272	14.5	1.00 (reference)	—
Wasted[c]	M	1,738	5.5	1.24 (0.76–2.03)	0.22
	F	1,272	4.5	1.00 (reference)	—
Overweight based on IOTF[d]	M	1,738	3.0	1.40 (0.88–2.24)	0.15
	F	1,272	2.0	1.00 (reference)	—
Overweight based on NCHS/WHO[e]	M	1,738	2.5	1.25 (0.76–2.03)	0.38
	F	1,272	2.0	1.00 (reference)	—
Obese based on IOTF[f]	M	1,738	1.3	4.07 (1.40–11.8)	.005
	F	1,272	0.3	1.00 (reference)	—

CI, Confidence interval; IOTF, International Obesity Task Force; NCHS, National Center for Health Statistics; WHO, World Health Organization; BMI, body mass index.

a. χ^2.

b. Height-for-age z-score (HAZ) < -2.00.

c. Weight-for-height z-score (WHZ) < –2.00.

d. Percentiles passing BMI of 25 kg/m^2 (IOTF); see Subjects and Methods section for detailed information.

e. Weight-for-height z-score (WHZ) > +2.00.

f. Percentiles passing BMI of 30 kg/m^2 (IOTF); see Subjects and Methods section for detailed information.

TABLE 3. Odds ratios for stunting and obesity among boys relative to girls in rural and urban areas

Characteristic	Socioeconomic status	Prevalence (%)		Odds ratio (95% CI)	*p*[a]
		Boys	Girls		
Stunted[b]	Rural	31.8	22.9	1.57 (1.21–2.04)	.001
	Poor urban	22.3	10.9	2.35 (1.36–4.07)	.002
	Nonpoor urban	14.4	8.6	1.79 (1.26–2.54)	.001
Obese based on IOTF[c]	Rural	0.3	0.0	Not calculated	0.24
	Poor urban	0.0	0.0	Not calculated	—
	Nonpoor urban	2.6	0.7	4.00 (1.36–11.8)	.007

CI, Confidence interval; IOTF, International Obesity Task Force; BMI, body mass index.

a. χ^2.

b. Height-for-age z-score (HAZ) < -2.00.

c. Percentiles passing BMI of 30 kg/m^2 (IOTF); see Subjects and Methods section for detailed information.

TABLE 4. Mean weight-for-height z-score (WHZ) and body mass index (BMI) of stunted compared with nonstunted children

Characteristic	Socioeconomic status	Stunted[a]	Nonstunted[b]	p^c
Mean weight for height z-score (WHZ)	Overall	–0.85 (0.77)	–0.56 (1.07)	< .001
	Rural	–0.86 (0.66)	–0.66 (0.91)	< .001
	Poor urban	–0.97 (0.77)	–0.72 (0.86)	.02
	Nonpoor urban	–0.78 (0.96)	–0.44 (1.22)	< .001
Mean BMI (SD)	Overall	14.20 (1.06)	14.70 (1.73)	< .001
	Rural	14.18 (0.90)	14.49 (1.37)	< .001
	Poor urban	14.06 (1.03)	14.41 (1.25)	.02
	Nonpoor urban	14.31 (1.35)	14.93 (2.03)	< .001

a. Height-for-age z-score (HAZ) < –2.00.
b. Height-for-age z-score (HAZ) ≥ –2.00.
c. *t*-test.

countries, stunted growth is still strongly associated with poverty.

Boys in our study had a higher odds ratio for stunting than girls. For reasons that are unclear, similar findings have been reported from Kuala Lumpur, Jakarta, Manila, and South Africa [13–16]. This difference in prevalence persisted after the data had been stratified into the three socioeconomic levels, suggesting the relative independence of the difference from socioeconomic status. Our previous study in children under two years of age in another area of Indonesia showed that beginning at the age of seven months, the difference in mean length-for-age between the Indonesian children and the NCHS/WHO reference population was larger in boys than in girls [17]. Another study from Indonesia showed that the size of this difference between boys and girls increased up to the age of 35 months [18]. It is still not known whether this greater difference persists until the final height has been attained, or whether there will still be a catch-up growth in adolescence.

The overall prevalence of wasting was almost one-quarter that of stunting. Unlike stunting, there was no significant difference in the prevalence of wasting between children of different socioeconomic status. Studies from other areas yielded variable findings [13–15]. Stunting, which occurs mostly in the first three years of life, reflects long-term undernutrition and poor health, whereas wasting is more a reflection of recent energy imbalance. Our study seems to suggest that the problems of undernutrition are important in the poorer segment of the population, especially in the early years of life [2, 3, 11].

The prevalence of overweight, based on either the IOTF or the WHO-NCHS references, was, on average, four to five times higher in nonpoor urban children than in rural children or poor urban children, as was the prevalence of obesity. A higher prevalence of obesity in the higher socioeconomic portion of the population has been found in other studies in developing countries [13–15]. A study of schoolchildren in Manila found that children from higher socioeconomic groups tended to consume more food, including animal food, fats and oils, and beverages, resulting in higher intake of calories. Moreover, children from high socioeconomic groups were apparently less physically active, were more likely to be driven to school instead of walking, and were more likely to prefer television and computer games over outdoor games [19].

In industrialized countries, and increasingly in developing countries, wealth has been associated with diets high in fat in combination with a sedentary lifestyle. But as global income rises and luxuries become affordable to most people in developed and middle-income countries, the pattern is changing [20]. In most developed countries, obesity is now associated with low income and social class [21–24]. Studies in developed countries have shown that children from lower-income families consume more energy-dense but inexpensive foods than those from higher-income families. These children also engage in less physical activity either because there is no safe place to play outdoors or because there is no money to pay for safe indoor facilities [25–27].

Nonpoor urban boys had significantly higher odds ratios for obesity than nonpoor urban girls. Similar findings were reported from the cities of Jakarta, Manila, and Kuala Lumpur [13–15]. Two studies in the United States found a higher prevalence of obesity in younger school-aged boys compared with girls, followed by an increasingly higher prevalence in girls compared with boys, as they approached adolescence [25, 28]. Other studies in similar age groups in South Africa, France, Russia, and China produced variable results in the prevalence of obesity between boys and girls in different age groups. [3, 16, 29, 30].

There is no clear explanation for this gender difference in susceptibility to obesity across race and age groups. The difference may be due to the variability of age range between studies, which, combined with the variability of the timing of maturation and body composition across race and gender, may lead to apparent differences in the prevalence of obesity. This assumption needs further study to be verified.

Unlike the study by Popkin et al. [3], our study did not indicate any association between stunting and overweight or obesity. Stunted children had a significantly lower mean BMI and WHZ, irrespective of socioeconomic status. It is possible that short children were at higher risk for later obesity during adolescence or adulthood, but further investigation is needed to determine whether this is the case.

In summary, our study indicates that poorer segments of the population in Indonesia still face the problem of undernutrition and will benefit from intervention to improve the quantity and quality of their food intake, especially in the early years of life. This study also shows that children from higher socioeconomic groups will benefit from programs to reduce the risk of obesity, such as public health campaigns on healthful food and encouragement to increase physical activity. However, one of the limitations of our study is that it did not assess some important predictors of height and obesity, such as parental height and obesity status, as well as lifestyle factors, such as diet and physical activity [22, 24, 31, 32].

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Donated fortified cereal blends improve the nutrient density of traditional complementary foods in Haiti, but iron and zinc gaps remain for infants

Marie T. Ruel, Purnima Menon, Cornelia Loechl, and Gretel Pelto

Abstract

This research assesses whether fortified cereal blends such as corn-soy blend (CSB) or wheat-soy (WSB) blend can significantly contribute to improving the quality of the diet of infants and young children 6 to 23 months of age. A series of participatory recipe trials was conducted to assess current complementary feeding practices in the Central Plateau of Haiti and to develop new, improved recipes by using a combination of locally available ingredients and foods and donated fortified cereal blends. Our findings show that it is feasible to improve the nutritional quality of complementary foods in poor rural areas of Haiti, using locally available ingredients and fortified cereal blends. Significant improvements in the concentrations of vitamin A could be obtained by including acceptable and affordable amounts of locally available vitamin A-rich foods such as pumpkin or eggs. Only preparations using CSB, however, could achieve the recommended concentrations of iron and zinc in complementary foods, and even this was achievable only for 12- to 23-month-old children. For infants, and especially those between 6 and 8 months of age, the high requirements of 7.7 mg of iron and 1.6 mg of zinc per 100 kcal of complementary foods could not be met, even with a combination of fortified CSB and other locally available, acceptable, and affordable foods. The same was true for the zinc density of complementary foods among 9- to 11-month-old children, which could not be achieved even with fortified CSB. Thus, in this population, fortified cereal blends were key to achieving the recommended iron and zinc densities of complementary foods for children 12 to 23 months of age, but they were not sufficient for infants. Complementary approaches, such as improving the availability, access, and intake of animal-source foods or the use of home fortification techniques (using spreads, sprinkles, or dispersible tablets), are needed to ensure adequate iron and zinc density of complementary foods for infants younger than 12 months in resource-constrained environments such as rural Haiti.

Key words: complementary foods, corn-soy blend, food aid, Haiti, iron, micronutrient deficiencies, recipe trials, vitamin A, zinc

Introduction

Infants and young children in their first two years of life have particularly high energy and nutrient requirements, while at the same time having limited gastric capacity and motor skills. Thus, they require special foods of adequate nutrient density, consistency, and texture, and they need to be fed more often than adults. In resource-constrained populations, diets consist mainly of cereal-based staple foods, and access to nutrient-rich foods such as animal products, fruits, and vegetables is limited. Young children living in these conditions are at particularly high risk of micronutrient deficiencies, including those of iron, zinc, and vitamin A.

Current child-feeding recommendations state that children 6 to 23 months of age should be fed animal-source foods daily, especially if they do not have access to fortified foods or vitamin and mineral supplements [1]. Unfortunately, the families that cannot afford to feed their children animal-source foods on a regular basis are also the ones that have limited access to fortified foods or vitamin and mineral supplements.

A number of Maternal and Child Health programs targeted to poor families in the developing world

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

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include a food aid component. In addition to their preventive health and nutrition activities, these programs distribute monthly take-home rations of fortified cereal blends, such as wheat-soy blend (WSB), corn-soy blend (CSB), and soy-fortified bulgur (SFB). These cereal blends are fortified with several vitamins and minerals (see Appendix 1 for nutrient composition) and are usually targeted to pregnant and lactating women and malnourished children under the age of five years. The World Vision, US Agency for International Development (USAID)-funded Title II Program in Haiti is one such program, which currently provides direct monthly food rations to malnourished children (8 kg of WSB or CSB and 2 kg of oil*) and to pregnant or lactating women (5 kg of SFB, 1.5 kg of oil, and 2 kg of lentils). In addition, the program provides one indirect food ration to families of beneficiaries to compensate for some of the intrahousehold sharing of commodities that naturally occurs with take-home rations.**

In spite of the popularity of Maternal and Child Health food aid programs in the developing world, the contribution of donated fortified cereal blends to the quality of young children's diets has rarely been assessed. The question addressed in this article is whether the donated fortified cereals provided as take-home rations by the World Vision Program can help infants and young children meet their daily nutrient requirements by significantly improving the nutrient density of their diet. In order to answer this question, we conducted a series of participatory recipe trials to assess current complementary feeding practices in one of the areas targeted by the program (the Central Plateau) and to develop new, improved recipes using a combination of locally available ingredients and foods, and donated fortified cereal blends.

Methods

Study area

This study was conducted in a total of 11 communities in the Central Plateau region of Haiti, comprising 6 lowland communities and 5 in mountainous areas. The regions and communities were selected to represent the different areas covered by a larger program evaluation, of which this substudy was a part [2]. All study communities were primarily rural. The lowland communities were generally accessible by road, and all were within 6 km from the main road. The main crops cultivated in these areas were staples such as corn, sorghum, beans, cassava, and sweet potatoes. The highland communities, on the other hand, were less accessible by road, more remote, and less densely populated and had more limited access to water and health services. Vegetable production was more common than staple food cultivation in the mountain areas. Our baseline survey in the intervention area revealed that 23% of children were stunted, 21% were underweight, and 5% were wasted [2].

Recipe trials

Recipe trials are participatory cooking sessions conducted with small groups of mothers and their children with the aim of developing special complementary foods for infants and young children. Specifically, recipes are prepared, tasted, and discussed to evaluate their acceptability, feasibility, and affordability for inclusion in the diets of young children [3]. This technique of developing enriched complementary foods that are based on locally known recipes as well as local ingredients has been used in a number of countries, with adaptations to each context [4–6].

In our study, the recipe trials were used to document the types of complementary foods usually prepared for young children in this population, their ingredients, and the mode of preparation. Thus, the recipe trials began with a recipe demonstration, conducted by the participants for the research team, to learn how infant foods were usually prepared. A group of mothers used their traditional preparation methods to demonstrate current recipes for various foods that had been previously identified as widely fed complementary foods: salt cracker gruel, bread soup, mashed plantain with fish sauce, and wheat flour gruel. This was followed by a three-step participatory process, which included the following activities:

1. *A first visit to prepare the trial with the group.* Specific activities included exploring potential improvements in currently fed complementary foods and discussing an array of suggested ingredients to enrich the complementary foods, creating new recipes, and preparing for the actual recipe trial. Public health programs in Haiti have traditionally used the concept of food groups to discuss dietary quality, and therefore this was a familiar concept for the participants in the recipe trial. The concept of "enrichment" of traditional recipes was also used to aid the discussion of potential candidate ingredients for improving the nutrient value of the traditional recipes.
2. *The recipe trial itself*, followed by a tasting session and feedback on the recipes, techniques of preparation,

* Donated oil is also fortified with vitamin A and E (see Appendix 1).

** The indirect food ration differs depending on whether the beneficiary is a malnourished child or a pregnant or lactating woman. When the beneficiary is a child, the indirect ration for the family includes 10 kg of WSB and 2.5 kg of lentils. When the beneficiary is a pregnant or lactating woman, the indirect ration includes 5 kg of WSB, 1.5 kg of oil, and 2 kg of lentils. When a family has two beneficiaries, only one indirect ration is provided, and the ration provided includes 10 kg of WSB and 2.5 kg of lentils.

perceived feasibility, and affordability.

3. *Follow-up visits* for feedback on home-based preparation of the improved recipes and the experience of feeding the improved recipes to children and other family members.

The complete three-step process was carried out in three project areas.* Specific question guides were developed to facilitate the collection and organization of information at each stage. The ingredients were either purchased by the participants in quantities they normally used and with cash assistance from the research team, brought from the participants' home gardens, or bought from local markets by the research team. In addition to bringing ingredients for the recipe trials, the participants provided other types of support, such as hosting the activity or providing the fuel and cooking utensils to prepare the recipes. The arrangements for these logistical issues were worked out by the participants themselves at step 1 of the recipe trials in each zone. Thus, the entire process was highly participatory and was owned by the women themselves. The research team served mainly to facilitate the process of development and discussion and to ensure that all steps were documented.

At the end of each recipe trial session, the participants and their children tasted the recipes that were prepared. Only children older than six months were included in the tasting sessions. Often, other neighbors and children assisted in the tasting sessions. Specific issues related to the acceptability of the recipe, the feasibility of home preparation under daily conditions, and the affordability of the recipe were explored by feedback interviews conducted at the end of the tasting session.

The final step of the recipe trials included a set of follow-up interviews with each group of participants, usually about two or three weeks after the recipe trial session (step 3). These interviews gathered data on which of the recipes had been prepared at home between the time of the recipe trial and the follow-up visit. The interviews explored the feasibility and affordability of the recipes as well as any problem that may have come up during the preparation or consumption of the recipes in the home setting of each participant. The interviews were also used to assess whether participants had adhered to the originally developed recipe or had made any further modifications to the recipes.

Finally, the data from all the recipe trials were combined for analysis of the feasibility, acceptability, and affordability of the various recipes developed by the group trials. The cost and nutrient content of each recipe were assessed, and the information was used to identify a list of promising recipes for promotion in the behavior change and communication (BCC) program. Analysis of the nutrient composition of the foods was performed with a software program called Food Processor 7.1 (ESHA) and utilized US Department of Agriculture food-composition values.

The protocol of the study was approved by the Cornell University Committee on Human Subjects.

Results

Complementary foods commonly fed to infants and young children

The mothers in our study traditionally prepared three types of complementary foods: cereal gruels with some type of fat (salt cracker gruel, and bread soup), cereal gruels with sugar but no fat (wheat flour gruel), and mashed plantain or manioc with a fish sauce. The main ingredients included in these gruels are presented in table 1. Two of the gruels were selected for modification during the recipe trials: the wheat flour gruel and the mashed plantain with fish sauce. The main reasons for choosing these two recipes were that they seemed more appropriate for enrichment because they already contained some basic energy- or nutrient-rich foods (such as fish or oil) or they were based on wheat flour, which could be replaced by donated fortified cereal blends such as WSB or CSB. The salt cracker and bread

* The three-step recipe trial process was conducted in the following rural zones of the Central Plateau of Haiti: Bassin Zim, with a group of two mothers and three grandmothers and their children and grandchildren (1–36 months old); Tierra Muscadi, with a mixed group of five mothers and three fathers and their children (1.5–11 months old); and Marmont, with a group of five mothers and their children (8–11 months old).

TABLE 1. Types of complementary foods traditionally fed to infants and young children in the Central Plateau of Haiti

Food	Main ingredients
Cereal gruels or soups with source of fat	
Salt cracker gruel (*bouillie de bon bon sel*)	Water, salt crackers, butter, sugar, salt
Bread soup (*soupe de pain)*	Water, bread, oil, spices, vegetables, salt
Cereal gruels with sugar, no fat	
Wheat flour gruel (*bouillie de farine France)*	Water, wheat flour, sugar, flavorings (vanilla or cinnamon)
Mashed plantain or manioc gruel with fish and fat (*banane écrasée, bouillie de manioc)*	Mashed plantain or manioc gruel with fish sauce (made with small amount of dried fish cooked in oil and water)

soups were not considered for modification, although they had high energy density, because they appeared to have very low nutrient density and offered little potential for improvement.

Modified recipes developed during the recipe trials

A total of 11 modified recipes were developed during the recipe trials. Table 2 summarizes information on the acceptability, perceived feasibility of preparation, and cost of the recipes, and the results of the follow-up interviews conducted to assess whether mothers had prepared the recipes at home. The most promising recipes from the point of view of cost, acceptability, and feasibility were gruels made from the fortified cereal blends with added fish or dry milk (table 2, recipes 8 and 9), or gruels made from wheat flour and enriched with the addition of beans and dried fish (recipe 3), beans and sugar (recipes 4 and 5), a beaten egg (recipe 10), or expressed breastmilk (recipe 11).

Mashed plantain preparations with pumpkin and fish sauce (recipes 6 and 7) were also well accepted, but they were among the most expensive recipes. When plantains are in season, however, the cost of these recipes is reduced by at least 7 gourdes (US$0.25)* for families who grow them, and thus the recipes become much more affordable.

The use of beans in the recipes, although culturally and nutritionally desirable, adds considerably to the number of preparation steps and the time involved, because beans need to be processed by roasting, removing the skin, and powdering. This may considerably reduce the likelihood that mothers will prepare these recipes daily. However, because they were very popular in terms of taste and child acceptance, they can still be promoted for preparation, albeit on a less frequent basis.

On the whole, the improved recipes required approximately the same preparation time as the traditional recipes (the wheat-based and plantain-based traditional recipes took 25 and 35 minutes to prepare, respectively). As expected, both traditional recipes were cheaper than most of the improved recipes, because they included less ingredients: the wheat-based traditional recipes cost about 5.35 gourdes (US$0.19) and the plantain-based recipes 11 gourdes (US$0.39).** The cost of the improved CSB-based recipes, however, was very similar to the cost of the traditional wheat-based preparations and almost half the cost of the traditional mashed plantain-based recipes (for households that had to purchase the plantains).

One potential constraint on the sustained use of most enriched recipes is that these gruels are generally prepared for the entire family, and therefore, preparing an enriched product entails a much higher cost than simply adding small amounts of high-quality foods to the child's portion. The option of adding ingredients such as an egg, powdered milk, or expressed breastmilk to the child's gruel seems a good alternative, and women responded positively to the suggestion to prepare these enriched porridges only for the youngest members of the family.

With regard to cost, the cheapest improved preparations are, as expected, those based on the use of donated cereal blends, because the main ingredients (the flours and the oil) are donated by the program. The next cheapest preparation is the wheat flour gruel with an added egg. This preparation is cheaper than wheat flour gruel with black beans and dried fish, or black beans and sugar, and is clearly cheaper than all preparations that include a source of fish. In terms of acceptance and energy density, this preparation is also a good choice (see below). Even if the fish preparations are more expensive, the unique nutrient composition of fish is worth the effort of trying to promote its consumption at least once or twice a week if families can afford it.

Nutritional quality of the complementary foods

Our analysis of the nutritional quality of the currently fed complementary foods and the modified recipes is based on the assessment of their energy and micronutrient density, according to current World Health Organization (WHO) recommendations for complementary feeding of the breastfed child [1, 7]. Thus, the ability of the complementary foods to help children meet their requirements of energy and selected micronutrients (iron, zinc, and vitamin A) at different ages was assessed by comparing the energy and nutrient content of selected complementary foods with current recommendations.***

Energy density

The current WHO recommendations suggest that infants between 6 and 8 months of age should receive at least 200 kcal/day from complementary foods [1]. For 9- to 11-month-old infants, the amount of energy from complementary foods should be 300 kcal/day,

* At the time of the study, the exchange rate was 28 gourdes—US$1.00.

** The per capita gross domestic product in Haiti in 2001 was estimated at $447 (http://unstats.un.org/unsd/demographic/social/inc-eco.htm; accessed September 12, 2004).

*** For wheat flour, we used the nutrient composition values for nonfortified wheat flour, because our interviews at the main flour mill in Port-au-Prince, which controls 80% of the market in Haiti, indicated that fortification was irregular. When fortified, wheat flour should contain 3.7 mg of iron/100 g of flour. Information about the type of iron fortificant used was not available, however, and thus the bioavailability of iron in the fortified flour is unknown.

TABLE 2. Improved recipes tested in recipe trials

No.	Name	Comments on recipe: From discussion after recipe trial — Acceptability	Feasibility (no. of steps, preparation time)	Cost (gourdes)[a]	From follow-up interviews — Whether the recipe was actually tried at home, and feasibility of sustained preparation
			Millet-based		
1	Millet gruel with black beans and groundnuts	Very good	10 steps, 45 min	11.5	Yes. However, cost of beans and time-consuming recipe were constraints
			Wheat flour-based		
2	Wheat flour gruel with black beans and groundnuts	Very good	7 steps, 25 min	11	No. Cost of beans and time-consuming recipe were constraints
3	Wheat flour gruel with black beans and dried fish	Less liked than sweet version; considered too thick for a 6-month-old	4 steps, 35 min	9.25	Yes. All women tried it. However, they felt that the children liked the sweet version more
4	Wheat flour gruel with black beans and sugar	Good; considered too thick for a 6-month-old	4 steps, 35 min	8.25	Yes. All women tried it. Well accepted by children
5	Wheat flour gruel with black beans, sugar, and oil	Good, consistency fine too	4 steps, 35 min	11.25	Only 2 of 5 women tried it. Lack of money to buy beans and time for preparation
			Mashed plantain-based		
6	Mashed plantain with pumpkin and fish sauce	Good	2 steps, 35 min	13	Yes. All women tried it. Well accepted by children.
7	Mashed plantain with pumpkin and fish sauce	Excellent	2 steps, 35 min	17.5	3 of 5 women tried it. Well liked. Lack of availability of pumpkin in market was a constraint; can be prepared when pumpkins are available in gardens
			CSB-based		
8	CSB gruel with dried fish	Good	2 steps, 20 min	6	Follow-up interviews not done, but can be considered feasible because major ingredients (CSB/WSB and oil) are donated by the program
9	CSB gruel with dried milk and sugar	Very good	1 step, 15 min	6	
			Other recipes		
10	Addition of an egg to the wheat flour gruel	Good	1 step, 35 min	6.25	2 of 5 women tried it. Well liked by children
11	Addition of expressed breastmilk to the gruel	No information	Depends on which gruel	Cost of gruel	All lactating women in the group tried it. Well liked by children

a. 28 gourdes = US$1.00.

and for 12- to 23-month-old children, it should be 550 kcal/day. These guidelines are based on children with average energy requirements receiving average amounts of breastmilk at each age [7]. If infants and young children consume more or less breastmilk than average, the amount of energy required from complementary foods will differ accordingly. These recommendations also assume good maternal nutritional status and adequate breastmilk intake and composition of breastmilk.

The number of times infants and young children should be fed complementary foods depends on the average energy density of their diet (kilocalories per gram of main complementary food) and the amount they consume at each meal. The recently developed *Guiding Principles for Complementary Feeding of the Breastfed Child* [1] recommends that complementary foods have a minimum energy density of 0.8 kcal/g and that they be fed two or three times a day to infants 6 to 8 months of age, and three or four times a day to infants and children 9 to 11 months and 12 to 24 months.

Table 3 presents the energy density (kcal/g) of the currently fed complementary foods as well as of the modified recipes developed during the recipe trials. Also, using information on average serving sizes used at different ages, as assessed during the discussions that followed each recipe trial,* the table presents the number of servings of each of the gruels that would be needed to meet the energy needs of children in different age groups.

Note that all recipes, including the traditional ones, meet the minimum requirement of 0.8 kcal/g. The salt cracker gruel has the highest energy density of all complementary foods, whereas the bread soup, wheat flour gruel, and improved mashed plantain preparations have the lowest energy densities. It is interesting to note that the original preparation of mashed plantain with fish sauce is actually more energy dense than the modified recipes. This is because of the larger amount of vegetable oil used to prepare the accompanying fish sauce in the original preparation in one area (Bassin Zim), compared with the modified recipes of the same dish prepared in other areas (Marmont and Tierra Muscadi). It may be advisable to retain the amount of fat used in the original recipe to increase the energy density of the improved preparation. It is important to remember, however, that higher energy density resulting from additional oil results in lower density of protein and micronutrients, and therefore the approach should be used cautiously.

The last three columns of table 3 present the number of servings of each complementary food that would be required to meet the daily energy needs of infants and children 6 to 8, 9 to 11, and 12 to 23 months old.

* Mothers reported that on average 6- to 8-month-old infants usually consumed ½ cup of the gruels or mashed plantain or manioc preparations, 9- to 11-month-old infants about ¾ cup, and 12- to 23-month-old children 1 cup. Based on these serving sizes and the energy densities of the different complementary foods, we computed the number of servings of each preparation that would need to be consumed by children of different ages in order to meet their daily energy requirements [7].

TABLE 3. Energy density of traditional and modified recipes, and number of daily servings required to meet breastfed children's daily energy requirements

No.	Name	Energy density (kcal/g)[a]	No. of daily servings[b] required according to age		
			6–8 mo	9–11 mo	12–23 mo
	Traditional recipes				
1	Salt cracker gruel	2.40	0.7	0.7	0.9
2	Bread soup	0.87	1.9	1.9	2.6
3	Wheat flour gruel	0.90	1.9	1.9	2.6
4	Mashed plantain with fish sauce	2.10	0.9	0.9	1.2
	Modified recipes				
1	Millet gruel with black beans and groundnuts	0.96	1.6	1.6	2.2
2	Wheat flour gruel with black beans and groundnuts	0.97	1.6	1.6	2.2
3	Wheat flour gruel with black beans and dried fish	1.55	1.0	1.0	1.4
4	Wheat flour gruel with black beans and sugar	1.28	1.2	1.2	1.7
5	Wheat flour gruel with black beans, sugar, and oil	1.11	1.4	1.4	1.9
6	Mashed plantain with pumpkin and fish sauce	0.80	2.1	2.1	2.9
7	Mashed plantain with pumpkin and fish sauce	0.87	1.8	1.8	2.5
8	CSB gruel with dried fish	1.25	1.2	1.2	1.7
9	CSB gruel with dried milk and sugar	1.44	1.0	1.0	1.4
10	Addition of an egg to the wheat flour gruel	1.36	1.0	1.0	1.3

a. The minimum energy density recommended for complementary foods for breastfed children 6–23 months of age is 0.08 kcal/g [1].
b. The average serving sizes for children 6–8, 9–11, and 12–23 months were estimated during recipe trials to be ½ cup, ¾ cup, and 1 cup, respectively. The number of servings recommended at 6–8, 9–11, and 12–23 months are: 2–3, 3–4, and 3–4, respectively [1].

Note that all calculations presented in this table are based on assumptions of *average* energy intake from breastmilk and average energy requirements [7]. As expected, gruels of greater energy density would require a smaller number of feedings per day, whereas the lower-density preparations would require greater feeding frequency. The salt cracker gruel, for example, which has the highest energy density, would need to be fed about once daily (0.7–0.9 servings, depending on age), whereas the bread soup, wheat flour gruel, and improved mashed plantain preparations, which are of lower energy density, would have to be fed two or three times daily. Table 3 shows that, across all age groups, none of the preparations exceed the recommended feeding frequency, suggesting that in general the feeding frequencies required for children given the traditional or improved preparations are not excessive. Thus, it appears that the energy densities of commonly fed complementary foods in this population are generally acceptable.

Vitamin A, iron, and zinc density

Vitamin A, iron, and zinc are critical micronutrients for the growth, development, immunity, and health of infants and young children and are known to be limiting nutrients in the diets of infants and young children [7]. The micronutrient density of complementary foods is usually expressed in terms of the amount of the nutrient per 100 kcal of the complementary food. Table 4 shows the average densities of vitamin A, iron, and zinc in the traditional and improved recipes, compared with the average recommended micronutrient densities of complementary foods at specific ages (see table headers). Note that the recommended densities for all three micronutrients decrease markedly as the infant becomes older and enters the second year of life; this is especially true for iron. The recommended iron density of complementary foods for infants 6 to 8 months of age is 7.7 mg/100 kcal for diets of low iron bioavailability, compared with 4.6 mg/100 kcal and 1.6 mg/100 kcal for children 9 to 11 and 12 to 23 months of age, respectively. Note also that the recommended iron density of complementary foods is, as expected, lower for diets in which the bioavailability of iron is average than in those in which iron bioavailability is low (see numbers in parentheses in table headers). In this analysis, we consider all recipes to have low iron bioavailability, unless they include fish (traditional recipe 4 and modified recipes 3, 6, and 7) and/or CSB, which contains vitamin C, a promoter of iron absorption (modified recipes 8 and 9), in which case they are considered to have average iron bioavailability.

The data show that none of the traditional recipes met the recommended nutrient densities for vitamin A, iron, or zinc. The improved preparations that contained even small amounts of pumpkin or an egg, however, achieved higher vitamin A densities than those recommended for all three age groups (see bolded numbers in table 4). The use of CSB, which is fortified with vitamin A, was also an excellent alternative to increase the vitamin A density of the recipes. As shown in table 4, both recipes containing CSB had vitamin A densities more than three times higher than current recommendations.*

The densities of iron and zinc, which are considered “problem” nutrients in infants and young children in developing countries who do not receive fortified foods, are tremendously inadequate for the 6- to 8-month age group in all our recipes, whether traditional or improved [1]. Although adding an egg to the wheat flour gruel almost doubled the iron and zinc content of the usual recipes, and adding dried fish to the wheat flour and bean gruel increased their zinc density, all modified recipes still had grossly inadequate iron and zinc densities for 6- to 8-month-old infants. The complementary foods made with CSB (the fortified food aid commodity) had significantly more iron and zinc than the other recipes. Moreover, the bioavailability of iron can be assumed to be average, as opposed to low, for these recipes (8 and 9), because CSB is also fortified with vitamin C. Even with average bioavailability, which decreases the recommended iron density of complementary foods to 4 mg/100 kcal for 6- to 8-month-old children, and with the addition of feasible and acceptable levels of fish in recipe 8, the CSB-based recipes still did not reach the recommended iron density of complementary foods for this age group. The same was true for zinc density, which was only about half the recommended density for this age group in both preparations that included CSB. Zinc densities in the gruels prepared with CSB were also too low for 9- to 11-month-old children, although iron densities were adequate for this age group if the assumption of average iron bioavailability was used.

The situation was markedly different for children in their second year of life; for these children, the two CSB-based recipes achieved appropriate iron and zinc density, and for iron, this was true whether low or average bioavailability was assumed. The recommended iron densities for 12- to 23-month-old children are 1.6 and 0.8 mg/100 kcal for low and average iron bioavailability, respectively; the CSB gruels contained 3.20 mg of iron per 100 kcal (recipe 8 containing fish) and 2.5 mg of iron per 100 kcal (recipe 9 containing dry milk).

Thus, fortified cereal blends such as CSB could contribute significantly to improving the quality of the complementary foods given to Haitian children

* Although the donated oil is fortified with vitamins A and E, we used the nutrient composition of nonfortified oil in our calculations of the nutrient density of the preparations. This is because the donated oil constitutes only a small proportion of all the oil used by families, and other oils available in the market are not fortified.

in their second year of life. The use of CSB was key to allowing the diets of 12- to 23-month-old children to reach the recommended densities of three main problem nutrients: vitamin A, iron, and zinc. This was not the case for children under one year of age, who would need complementary interventions to help them meet their iron and zinc requirements.

In the following section, we assess the potential contribution and feasibility of one such strategy—using red meat or liver—to complement the diets of six- to eight-month-old infants and to help them fill their iron and zinc gaps.

Cost and feasibility of using red meat or liver in the diets of six- to eight-month-old infants

To determine whether it would be feasible to promote increased intake of red meat (beef) or liver to fill the

TABLE 4. Summary of the vitamin A, iron and zinc densities of traditional and enriched recipes

No.	Name	Density (amount /100 kcal of recipe)		
		Vitamin A (μg RE) *Recommended densities*[a] 6-8 mo: 31; 9–11 mo: 30; 12–23 mo: 23	**Iron** (mg) *Recommended densities*[a] 6–8 mo: 7.7^b $(4.0)^c$; 9–11 mo: 4.6^b $(2.4)^c$; 12–23 mo: 1.6^b $(0.8)^c$	**Zinc** (mg) *Recommended densities*[a] 6–8 mo: 1.6; 9–11 mo: 1.1; 12–23 mo: 0.6
Traditional recipes				
1	Salt cracker gruel	0	0.93	0.14
2	Bread soup	13.02	0.72	0.05
3	Wheat flour gruel	0.03	0.41	0.13
4	Mashed plantain with fish sauce	0.66	0.16	0.05
Modified recipes				
1	Millet gruel with black beans and groundnuts	0.12	1.35	0.18
2	Wheat flour gruel with black beans and groundnuts	0.12	0.50	0.26
3	Wheat flour gruel with black beans and dried fish	0.19	0.61	0.35
4	Wheat flour gruel with black beans and sugar	0.17	0.68	0.28
5	Wheat flour gruel with black beans, sugar, and oil	0.21	0.73	0.31
6	Mashed plantain with pumpkin and fish sauce	**46.20**[d]	0.49	0.17
7	Mashed plantain with pumpkin and fish sauce	**40.55**	0.49	0.24
8	CSB gruel with dried fish	**140.50**	3.20	0.90
9	CSB gruel with dried milk and sugar	**111.00**	2.50	0.70
10	Addition of an egg to the wheat flour gruel	**42.55**	0.86	0.34

a. Recommended nutrient densities are for infants who consume average amounts of breastmilk [7].
b. Assuming low bioavailability of iron [19].
c. Assuming medium bioavailability of iron (numbers in parentheses) [19].
d. Boldface numbers indicate that the recipe meets the recommended nutrient density for all three age groups.

iron and zinc gaps, we calculated the amounts of these products that would be required to enable young infants six to eight months old to meet their daily requirements of these nutrients. We assumed that the infants were consuming gruels twice a day, which is the minimum recommended feeding frequency for this age group. We used the WHO recommended daily intakes of iron and zinc for infants obtaining the average amount of energy from breastmilk [8]. The *absorbed* iron requirements of infants between six and eight months are estimated to be about 1 mg/day, and the recommended intake of iron varies, depending on the bioavailability of the sources of iron in the diet [7]. The recommended zinc intake for the same age group is 4.1 mg/day (no correction for bioavailability is available). Since meats contain heme iron, which is highly bioavailable compared with the iron in cereals, calculating the amount of meat needed to fill the iron gap requires consideration of the difference between the amount of iron absorbed from meat and the amount absorbed from cereal-based gruels.

Table 5 presents the amounts of beef and beef liver that would be needed to fill the iron gap that remains after children have been fed the enriched gruels made with either fortified food aid commodities or unfortified wheat flour. The calculations are made separately, depending on whether the meat products are fed at the same meal as the gruel or not. The reason for making this distinction is that meat products have been shown to enhance absorption of the nonheme iron contained in plant-based foods when consumed at the same meal [9, 10].

In all calculations, we use an iron requirement of 1 mg of *absorbed* iron [7]. We assume a high bioavailability of iron from beef and liver (15%), a medium bioavailability of iron from gruel consumed at the same

TABLE 5. Amounts and price of beef and beef liver that would have to be consumed by children six to eight months old to complement selected gruels fed twice a day to fulfill their requirements for iron[a]

Beef or beef liver is eaten at a different meal from the gruel					
		Beef		Beef liver	
Gruel	Iron absorbed from gruel[b] (mg)	Amount needed (g)	Price (gourdes)	Amount needed (g)	Price (gourdes)
CSB gruel with dried fish	0.88	20	2	16	2
CSB gruel with sugar and milk	0.59	56	5.5	45	6
Wheat flour gruel with beans and fish	0.20	102	10	83	12
Wheat flour gruel with beans and sugar	0.13	110	11	90	13
Beef or beef liver is eaten at the same meal as the gruel					
		Beef		Beef liver	
Gruel	Iron absorbed from gruel[c] (mg)	Initial amount + additional amount needed (g)	Price of total amount[d] (gourdes)	Initial amount + additional amount needed (g)	Price of total amount[d] (gourdes)
CSB gruel with dried fish (salty)	1.56	20 + 0	2	20 + 0	3
CSB gruel with sugar and milk (sweet)	1.10	20 + 0	2	20 + 0	3
Wheat flour gruel with beans and fish	0.36	20 + 43	6	20 + 18	5.6
Wheat flour gruel with beans and sugar	0.25	20 + 57	8	20 + 30	7

CSB, Corn-soy blend.

a. Absorbed iron requirements for infants 6–8 months old = 1.05 mg (calculated from iron intake requirements) [7]. Exchange rate at the time of the study: 1 US$ = 28 gourdes.

b. Assuming that 10 g of beef or beef liver is fed twice daily at a different meal than the gruel. Bioavailability assumptions: low (6%) for sweet CSB and wheat flour gruels; low to medium (8.5%) for CSB and wheat flour gruels containing dried fish.

c. Assuming that 10 g of beef or beef liver is fed twice daily along with ½ cup of gruel. Assumptions about *increase* in bioavailability with addition of red meat: Increase from low (6%) to medium (11%) with addition of red meat to low-bioavailability gruels, increase from low-medium (8.5%) to high (15%) with the addition of red meat to low- to medium-bioavailability gruels [10].

d. The total price of beef/beef liver here includes the price of the 20 g fed at the same meals as the gruel + the cost of the additional beef or beef liver needed to close the iron gap.

time as meat (11%), and a low bioavailability of iron from gruel consumed without meat (6%) (see details of calculations in Appendix 2).

The findings presented in table 5 show that infants fed improved gruel recipes made of fortified CSB would still need between 20 and 60 g/day of beef or between 15 and 45 g/day of beef liver in order to close their iron gap (assuming that meat is *not* consumed at the same meal as gruels), depending on whether the gruels consumed included dried fish or not. If nonfortified cereals such as wheat flour were used to prepare the gruels, almost twice that amount of meat or liver, i.e., about 100 g, would be required for infants to meet their daily requirements of absorbable iron.

By contrast, even as little as 10 g of beef or liver, if consumed at the same time as each serving of the fortified gruel—for a total of 20 g of beef or beef liver per day—would be sufficient to completely close the iron gap for infants in this age range who consume CSB-containing gruels. It is important to remember, however, that these amounts of meat or liver would have to be consumed by the six- to eight-month-old infant in addition to the two servings per day of ½ cup of enriched porridges, some of which already contain fish. It may be impossible to feed such large amounts of food to young infants, who have limited gastric capacity. The organoleptic characteristics of meals containing meats and gruels are also an issue of concern. Finally, the cost of meat products may be prohibitive in the long run for poor Haitian families. Even if mothers were to purchase only the amounts required for a six- to eight-month-old infant, the cost of beef or beef liver would range from 2 to 14 gourdes (US$0.07–0.50). This may be affordable on an occasional basis, but certainly not on a daily basis in a situation where the average income is under a dollar a day. Consuming the meat products at the same meal as other sources of nonheme iron would slightly reduce the cost, especially if donated fortified cereal blends were used (these have the double advantage of being fortified and free). This option may therefore be more feasible for beneficiary families, but again, only under the conditions that meat and organ meats are readily available in the markets, mothers are able to purchase them in small quantities, and mothers are willing and able to use them only for their young infants.

Meeting zinc requirements by the addition of some animal products to the diet seems more feasible than meeting iron requirements in this way, both in terms of the amounts required and the cost (the amounts range between 19 and 55 g and the costs between 2 and 5.5 gourdes, or US$0.10–0.20) (results not shown). These costs, however, are still significant for poor families, and thus, alternative or complementary solutions to enhance the iron and zinc content of young children's diets should be given serious consideration.

Program implications

Summary of findings

Our research shows that it is feasible to markedly improve the nutritional quality of complementary foods in poor rural areas of Haiti by using a combination of donated fortified cereal blends and locally available foods. Significant improvements in the concentrations of vitamin A and zinc could be obtained by including CSB and/or acceptable and affordable amounts of black beans, groundnuts, pumpkin, dried fish, milk, or eggs in the preparations. Only preparations containing CSB, however, could achieve the recommended concentrations of iron and zinc in complementary foods, and even this was achievable only for 12- to 23-month-old children. For infants, and especially those between 6 and 8 months of age, the high densities of iron and zinc recommended in complementary foods for this age group could not be achieved, even when fortified CSB and other locally available, acceptable, and affordable foods were combined. The same was true for the recommended zinc density of complementary foods among 9- to 11-month-old children, which could not be fully achieved even with fortified CSB.

It is important to note that these findings probably represent a "worst-case scenario," because we generally used conservative bioavailability assumptions for iron, and we did not correct for the fact that iron absorption increases with poor iron status. The recent Demographic and Health Survey in Haiti indicates that approximately 50% of children in this age group are anemic; thus, we can assume that a large proportion of children are iron deficient and likely to absorb more iron than non-iron-deficient children.

Using our conservative assumptions for iron bioavailability, our findings show that in this population, fortified cereal blends were key to achieving the recommended vitamin A, iron, and zinc densities of complementary foods for children 12 to 23 months of age, but they were not sufficient for infants. Among infants under one year of age, the presence of CSB brought the density of vitamin A in complementary foods to the recommended levels, but did not do the same for zinc and iron. Thus, complementary approaches are needed to ensure the adequate iron and zinc density of complementary foods for infants younger than 12 months in resource-constrained environments such as rural Haiti.

One such strategy, which was explored in the present study, is to complement the diet with animal flesh foods such as red meat or liver. The need to use animal-source foods to improve the nutritional quality of complementary foods, however, immediately raises concerns about the availability and access of poor rural families to these products. Our research suggests that although cultural factors do not seem to be a constraint to including animal-source foods in young children's diets in this population [11], economic barriers are fundamentally limiting. Families may have difficulty purchasing even the relatively small amounts of meat products required to feed their young infants on a regular basis, let alone the amounts that would be required if they were to use meat products in food preparation for the whole family. As is the case in many cultures, Haitian mothers cannot conceive of purchasing special nutrient-rich (and expensive) foods only for their young children, especially when they have several other children who would benefit from improved dietary quality. Moreover, even if a mother could be persuaded to purchase small amounts of meat products for her youngest, most vulnerable child, our market study showed that liver, in particular, is largely unavailable for sale in small quantities in local markets [11].

Finally, an additional constraint to using animal-source foods to improve young children's intakes of bioavailable iron and zinc is the issue of feasibility, i.e., whether young children can actually consume the required amounts of meat products at the required frequency. Infants and young children have limited gastric capacity as well as developmental constraints that may prevent them from being able to consume meat products, especially in environments where food processors or other tools to make pureed foods are unavailable. Furthermore, there could be organoleptic constraints to feeding gruels and beef or liver at the same time, particularly at an age when infants are only beginning to experience different tastes and textures. Thus, although meat products can significantly contribute to improving the quality of young children's diets, especially with regard to bioavailable iron and zinc, it is important to recognize their limitations.

In summary, our results confirm that both donated fortified cereal blends and meat products have great potential to improve the nutritional quality of complementary foods. For infants 6 to 11 months of age, however, neither one of these approaches is sufficient. The fortified cereals do not have sufficiently high levels of iron and zinc fortificants to completely close the iron and zinc gaps in these young children, and the regular use of meat products is likely to be economically and practically unfeasible in poor environments. Combining the two approaches is clearly worth exploring, but additional recipe trials will be needed to explore the possibility of developing complementary foods based on fortified cereal blends and meat or organ meat for this age group, in different cultures.

Iron and zinc fortification levels of donated fortified cereal blends

The nutrient composition of donated fortified cereal blends used in the World Vision-Haiti Program is presented in Appendix 1. Compared with other processed complementary foods designed for infants and young children in Latin America, the iron content of WSB and CSB (17.5–18 mg/100 g) is average, while the zinc content (5.5–5 mg/100 g) is low [12]. For instance, in the nine products compared by Lutter [12], the iron concentration ranged from 10 to 23 mg/100 g of dry products, whereas the zinc concentration ranged from 5 (in CSB) to 23 mg/100 g (in a product developed in Mexico). Unfortunately, the table comparing the nine products does not include any information on the iron compound used in the fortification process, and thus it is impossible to assess the bioavailability of iron in these foods.

For CSB and WSB, the iron fortificant is ferrous fumarate [13], which has good bioavailability (as high as that of ferrous sulfate) [14]. Corn-soy blend and WSB also contain 40 mg of vitamin C per 100 g, which increases the absorption of nonheme iron. It is not clear, however, how much of this vitamin C remains after the CSB has been cooked and, therefore, what its ultimate contribution to increasing nonheme iron bioavailability is. For zinc, although the levels are lower than the levels found in other complementary foods in Latin America [12], they are consistent with current recommendations for processed complementary foods of 4 to 5 mg per 100 g of dried product [15]. Overall, it appears that the current iron and zinc fortification levels of CSB (and WSB) are generally acceptable, and our findings confirm that they are sufficient for children in their second year of life, who consume them in the recommended frequency and quantity. For infants, however, these levels are still too low, and therefore complementary strategies need to be considered, such as the use of supplements or home fortification with micronutrient sprinkles, spreads, or dispersible tablets. Increasing the fortification levels of cereal blends could also be an option, but potential toxicity or negative interactions between micronutrients has to be carefully considered before implementing such measures. It is also important to recognize that donated cereal blends are not used only as complementary foods—on the contrary, they are often widely shared among all family members—and therefore their fortification levels have to be safe for all age groups, including those who may consume relatively large amounts of the products. Combining approaches—such as using donated fortified foods, including some amounts of meat in the diet, and possibly using home fortification methods such as sprinkles, spreads, or dispersible tablets—will be necessary to ensure that the iron and zinc requirements of infants and young children are met.

Size of the monthly rations

We calculated the amount of CSB that would be required on a monthly basis to feed children under 24 months of age the average age-specific amount of the gruel twice a day. For infants 6 to 8 months old who usually consume approximately ½ cup of the gruel per serving, approximately 1.7 kg/month would be needed, whereas for 12- to 23-month-old children who consume on average one cup per serving, 3.4 kg/month would be required. Thus, the current amount of WSB of 8 kg/month (similar to CSB) for the direct ration is largely sufficient to cover the energy requirements of the target child, on the assumption that families also invest in additional ingredients to complement the energy content of the gruels. Clearly, continued efforts should be made to ensure that the WSB or CSB commodities are used primarily for the target children, although some sharing among family members would be acceptable in the case of the World Vision Program, because the size of the monthly ration is more than twice the amount required for a child under two years of age.

Recommendations for food aid programs

One of the key objectives of food aid programs targeted to young children is to reduce childhood malnutrition. In order to achieve this objective, packages of integrated nutrition and health interventions have been developed, which usually include several preventive interventions such as immunization, selected micronutrient supplementation, deworming, distribution of oral rehydration salts, and health and nutrition education, in addition to the distribution of food aid commodities. Food is used in these programs as a means to help alleviate one of the main constraints to adequate child-feeding practices, household food insecurity. Food rations, however, are but one of several approaches needed to improve complementary feeding practices. At least equally important is to teach families how to use the food supplements for the targeted beneficiaries, and our study is an example of how this can be done using participatory research methods. Based on our experience, we offer the following recommendations to food aid programs:

1. Food aid programs should conduct participatory, context-specific research to develop feasible, affordable, and culturally acceptable recipes using the food aid commodities distributed, combined with other locally available and affordable foods and ingredients.

The recipes should be developed on the basis of existing cultural patterns and the types of preparations used locally. The recipes should also be developed specifically for the age group targeted, e.g., infants and young children, or pregnant or lactating women. Within a country, the recipe trials should be conducted in different ecological zones with varying food systems as well as among populations with different dietary patterns. Well-designed and detailed step-by-step written materials are available to guide the design of formative research to assess current practices and the development of improved complementary feeding practices using methods such as focused ethnographic studies [16] and Trials of Improved Practices [3]. Successful programmatic experience with adapting these techniques to develop enriched complementary foods based on locally known recipes and locally available ingredients has also been documented in a number of countries [4–6].

2. Food aid programs should include intense promotional and educational efforts to ensure that the specially fortified cereal blends, such as CSB and WSB, are used primarily for the targeted beneficiaries (e.g., infants and young children, or pregnant or lactating women) who have higher nutrient requirements than other members of the household.

There is ample, although largely anecdotal, evidence that sharing of donated food commodities among family members is an unavoidable scenario in food aid programs. Some programs, such as World Vision in Haiti, have attempted to address this by providing an indirect food ration to be shared among family members, in addition to the direct food ration for the targeted beneficiary. At a given level of resources, this approach involves providing significantly larger amounts of food to a smaller number of beneficiaries and their families, and thus results in lower coverage. The approach, however, may still be more cost-effective than providing a single direct ration if leakage among family members is unavoidable, because it may ensure that the targeted beneficiary actually receives a greater share of the donated food commodities.

An additional approach used by the World Vision Program in Haiti is to provide different food commodities in the direct and indirect rations. More highly fortified products, such as CSB and WSB, are intended for the beneficiary child or mother, whereas other less fortified (or nonfortified) products, such as SFB and lentils, are provided for other family members. Although a theoretically sound approach, it is unlikely to be successful if the program does not include a strong educational intervention to teach recipients about the appropriate use of the different commodities for different household members.

Thus, in programs where both direct and indirect rations are used, and especially where higher-quality foods are provided for targeted beneficiaries, recipe trials and promotional efforts should focus on developing special preparations for the targeted beneficiaries using these products. This would ensure that the program achieves its objective of enhancing the nutrient intake and dietary quality of these more vulnerable household members. In the case of Haiti, for example, mothers should be sensitized to the fact that the WSB and CSB are intended for use as "special foods" for the young targeted child, while the other food commodities are provided specifically to complement the diets of other family members. Clearly, these concepts may be culturally unacceptable and impractical for mothers who have many mouths to feed and little time to do so. However, given the potentially important nutritional contribution of WSB and CSB at their current levels of fortification, it is crucial that programs ensure the appropriate use of these commodities in order to achieve a nutritional impact on their primary target. To our knowledge, no information is available on the effectiveness of such promotional efforts, but our evaluation of the World Vision Program in Haiti should shed some light on these issues.

3. Programs need to develop links with other types of interventions to improve the micronutrient density of complementary foods, and especially their iron and zinc concentrations. These include linking up with new initiatives, such as the promotion of increased availability, access, and intake of animal-source foods, or the use of home fortification with micronutrient sprinkles, spreads, or dispersible tablets.

As indicated previously, most maternal and child health programs with a food aid component provide a number of preventive nutrition and health interventions, including vitamin A and/or iron supplementation programs. Links with other, possibly more sustainable approaches, such as promoting greater intake of animal-source foods by young children, should also be established. In order to be successful, however, economic, cultural, and child developmental constraints to increasing the intake of animal-source foods among young children must be understood, and effective interventions to alleviate them should be designed. New initiatives are currently under way to develop strategies to improve household availability and access to animal-source foods and to promote their use in complementary foods for infants and young children. Simple technologies and tools to process meat products into purees in resource-constrained environments also need to be developed to facilitate their incorporation in young children's diets.

Finally, "home fortification," which consists of the direct addition of micronutrient sprinkles, spreads, or dispersible tablets to fortify young children's foods, is becoming increasingly popular. Although the efficacy of these approaches has been demonstrated in a few studies [17, 18], more research is needed to document their feasibility and effectiveness. The feasibility and acceptability of distributing micronutrient sprinkles for children 6 to 23 months of age along with the food rations in the World Vision-Haiti Program is currently being explored.

Conclusions

Poor complementary feeding practices continue to be a major bottleneck to reducing malnutrition in developing countries. It is thus imperative that existing resources, such as fortified food aid commodities, be used more effectively to contribute to improving the overall quality—and not only the quantity—of complementary foods for infants and young children. To achieve this, food aid programs should prioritize and strengthen their promotional and educational strategies to better educate program recipients in the optimal use of fortified food commodities, especially for targeted beneficiaries, i.e., pregnant or lactating women and infants and young children who have high nutrient requirements. Food aid programs should also strengthen their links with other initiatives to improve complementary feeding practices, including programs for the control of micronutrient deficiencies and interventions to improve the availability of and access to nutrient-rich foods. Finally, the vulnerability and excessively high nutrient requirements of infants in their first year can never be overemphasized, and packages of complementary interventions should be implemented in a timely manner to effectively reach infants during these critical few months of their life.

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APPENDIX 1. Nutrient composition of donated commodities per 100 g

Nutrient	WSB	CSB	SBF	Oil
Water (g)	8.8	9.7	8.7	
Energy (kcal)	354.5	375.7	33.9.8	884
Protein (g)	21.5	17.2	18.2	
Total lipids (g)	5.9	6.9	1.3	100
Carbohydrates (g)	46.9	61.7	69.6	
Fiber, total dietary (g)	13.18	9	18.18	
Ash (g)	2.0	1.8	2.2	
Calcium (mg)	842	831	110	
Iron (mg)	17.85	17.49	2.90	0.02
Magnesium (mg)	227.26	173.8	182.90	0.03
Phosphorus (mg)	294	206	356	
Potassium (mg)	694	634	706	
Sodium (mg)	13.8	7.3	17.5	
Zinc (mg)	5.5	5.0	2.0	
Copper (mg)	1.0	0.9	0.9	
Manganese (mg)	2.2	0.7	3	
Selenium (μg)	2.0	6.0	2.0	
Vitamin C (mg)	40	40	0	
Thiamine (mg)	0.54	0.53	0.44	
Riboflavin (mg)	0.50	0.48	0.26	
Niacin (mg)	8.19	6.23	3.53	
Pantothenic acid (mg)	3.7	3.4	1.2	
Vitamin B_6 (mg)	0.47	0.5	0.4	
Folate (μg)	275	300	150	
Vitamin B_{12} (μg)	1	1	0	
Vitamin A (IU)	2,323	2,612	2,205	6,000
Vitamin E (mg)	8.3	8.7	0.1	18.2
Vitamin D (IU)	198	198		
Iodine (μg)	56.88	56.9		

WSB, Wheat-soy blend; CSB, corn-soy blend; SFB, soy-fortified bulgur.
Source: www.usaid.gov/hum_response/crg/fswheatsoyblend.htm. Accessed September 12, 2004.

APPENDIX 2. Estimation of the amounts of beef and beef liver needed to close the iron gap for infants between six and eight months of age who are fed enriched gruels

TABLE A1. Requirements for absorbable iron [7]

Bioavailability	% absorption	Recommended iron intake (mg)	Absorbed iron requirements (mg) = recommended intake * % absorption
High	15%	7.0	1.05
Medium	10%	10.9	1.09
Low	5%	20.8	1.04

TABLE A2. Example of calculations of the amounts of beef that would need to be consumed by children six to eight months old to complement selected gruels fed twice a day in order to fulfill their requirements for iron

Amount of beef required if beef is not eaten at the same meal as gruel					
	Iron content (mg)	Iron absorbed[a] (mg)	Absorbed iron gap (mg)	Additional iron intake needed from beef (mg)	Beef needed to provide extra iron (g)
Gruel	(A)	(B) = (A)* bioavailability	(C) = 1.05–(B)	(D) = (C)/0.25	[(D)/3.33]*100
CSB gruel with dried fish	10.4	0.884	0.166	0.66	19.94
CSB gruel with beans and sugar	9.8	0.588	0.462	1.85	55.50
Wheat flour gruel with beans and dried fish	2.4	0.204	0.846	3.38	101.62
Wheat flour gruel with beans and sugar	2.24	0.1344	0.9156	3.66	109.98
Amount of beef required if 20 g of beef is eaten at the same meal as gruel[b]					
	Iron content (mg)	Gruel iron absorbed with added 20 g of beef (mg)	Absorbed iron provided by beef (mg)[c] (estimated to be 25%)	Absorbed iron gap (mg)	Additional beef needed to close absorbed iron gap (g)
Gruel (g)	(A)	(B) = (A)* bioavailability	(C) = (3.33*0.25)/5	(D) = 1.05-(B+C)	[(D)/(3.33*0.25)] *100
CSB gruel with dried fish	10.4	1.56	0.17	–0.68	–81.26
CSB gruel with beans and sugar	9.8	1.078	0.17	–0.19	–23.36
Wheat flour gruel with beans and dried fish	2.4	0.36	0.17	0.52	62.88
Wheat flour gruel with beans and sugar	2.24	0.2464	0.17	0.64	76.53

a. Assumptions about bioavailability: low (6%) for sweet CSB and wheat flour gruels, low-medium (8.5%) for CSB and wheat flour gruels containing dried fish.

b. Assumptions about *increase* in bioavailability with addition of red meat: Increase from low (6%) to medium (11%) for sweet CSB and wheat flour gruels, and increase from low-medium (8.5%) to high (15%) for CSB and wheat flour gruels containing dried fish [10].

c. Nutrient composition values for beef were obtained from the USDA National Nutrient Database for Standard Reference Release 15 (available at http://www.nal.usda.gov/fnic/foodcomp/Data/SR15/sr15.html). Accessed September 29, 2004.

WHO Technical Background Paper

Feeding of nonbreastfed children from 6 to 24 months of age in developing countries

Kathryn G. Dewey, Roberta J. Cohen, and Nigel C. Rollins

1. Introduction

Although breastfeeding is recommended for two years or more [1], there are circumstances under which this is not possible or desirable. In particular, the current epidemic of HIV/AIDS in parts of the developing world has forced policy makers to evaluate what type of infant-feeding recommendations to make to HIV-positive mothers, who may transmit the virus to their infants via breastmilk. The most recent international guidelines state that "when replacement feeding is acceptable, feasible, affordable, sustainable and safe, avoidance of all breastfeeding by HIV-infected mothers is recommended" [2]. When these conditions cannot be met, it is recommended that mothers breastfeed exclusively for the first few months and stop as soon as alternative feeding options become feasible. Other circumstances that may prevent a child from being breastfed include death or severe illness of the mother, or inability or lack of desire by the mother to breastfeed. Guidelines regarding replacement feeding from birth to six months for infants of HIV-positive mothers have been published elsewhere [2]. After the first six months, however, there is little information on how to construct a nutritionally adequate diet for the nonbreastfed child.

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This paper was written as the Technical Background Paper for an informal meeting in Geneva (March 8–10, 2004) to discuss feeding of nonbreastfed children 6 to 24 months of age in developing countries, organized by the Department of Child and Adolescent Health and Development and the Department of Nutrition for Health and Development of the World Health Organization.

The age range from 6 to 24 months is a critical period, when malnutrition and infection are particularly common in developing countries. For breastfed children, a set of recommendations in the form of 10 Guiding Principles was recently issued regarding complementary feeding within this age range [3]. Many of these Guiding Principles can also be applied to nonbreastfed children (Nos. 3, 4, 6, and 10). Others, however, need to be revised for nonbreastfed infants.

This document will cover appropriate feeding of nonbreastfed children from 6 to 24 months of age, with a focus on developing-country populations. The Guiding Principles that will be addressed include No. 5 (amount of food needed), No. 7 (meal frequency and energy density), No. 8 (nutrient content of foods), and No. 9 (use of vitamin-mineral supplements or fortified products). To address Nos. 8 and 9, linear programming (LP) techniques were used to develop diets that can meet nutrient requirements within this age range.

2. Use of animal milk for infants between 6 and 12 months of age

The issue of whether to include animal milk in the diet of infants under 12 months of age has been debated for decades. Most of the debate has focused on the use of whole cow's milk. The three main concerns are that cow's milk is low in iron (and the iron is not very well absorbed because milk also contains large amounts of bovine proteins and calcium, which inhibit nonheme iron absorption), can cause occult blood loss from the gastrointestinal tract, and has a high potential renal solute load (PRSL) [4, 5]. In the earlier part of the twentieth century, the use of whole cow's milk during infancy, even during the first four months of life, was common in the United States [5]. By the 1960s, concerns were raised by studies showing that cow's milk could cause occult gastrointestinal blood loss in infants with iron-deficiency anemia. The Committee on Nutrition of the American Academy of Pediatrics (CON-AAP) [6] stated in 1976 and 1983 that for nonbreastfed infants more than six months old, iron-fortified formula was the most convenient source of iron, but cow's milk together with regular use of iron-fortified cereals was acceptable. However, subsequent studies showing that blood loss could occur even in nonanemic infants, along with the recognition that the electrolytic iron in iron-fortified cereals is probably of low bioavailability, prompted the CON-AAP to recommend in 1992 that nonbreastfed infants be given iron-fortified formulas throughout the first year of life.

More recent papers on occult blood loss suggest that in the older infant the losses are very minor and not likely to affect iron status [7, 8]. The gastrointestinal response to cow's milk that causes blood loss decreases with age and disappears by 12 months [8]. Furthermore, there appears to be a dose-response relationship between the quantity of cow's milk and the amount of blood lost, such that only large volumes of milk would pose a significant risk between 6 and 12 months. Heat-treated cow's milk does not provoke blood loss [9], so use of boiled or evaporated milk would eliminate this risk. Thus, the risk of iron deficiency provoked by occult blood loss appears to be low and can be further reduced by heat treatment or restrictions on the amount of milk consumed. Although the low iron content and bioavailability of cow's milk can contribute to anemia, iron deficiency can be avoided by using iron supplements or fortified foods with adequate bioavailability.

The remaining issue is the potential renal solute load (PRSL) of cow's milk, which is considerably higher than that of breastmilk because of the higher content of protein and several minerals (sodium, chloride, potassium, and phosphorus). PRSL refers to the solutes coming from the diet that must be excreted by the kidney if none are used for growth and none are lost through nonrenal routes [4]. A high PRSL can lead to hypernatremic dehydration under conditions of water stress.

The potentially adverse consequences of feeding undiluted cow's milk to young infants have been recognized for more than 100 years [5]. This recognition led to various recipes for formulas that involved the addition of water and carbohydrate to the milk (for example, a typical evaporated milk formula used in the United States in the 1940s consisted of one can (13 ounces) of evaporated milk, 19 fluid ounces of water, and approximately 1 ounce of carbohydrate such as corn syrup) [5]. Over time, commercially prepared infant formulas were developed that came closer to approximating the nutritional composition of human milk, and these have become the standard for nonbreastfed infants in industrialized countries.

During the first six months of life, when infants usually receive nearly all of their nutrients from a single source (breastmilk or formula), it is important to ensure that the PRSL of that product is appropriate. However, when infants begin to consume a mixed diet, the risks of providing a product with a relatively high PRSL, such as undiluted cow's milk, can be avoided if a sufficient amount of fluid is included in the overall diet. The greatest danger from a high PRSL occurs when the child has diarrhea and is losing far more water than usual. Continued use of cow's milk (or other foods with a high PRSL) during diarrhea, without providing extra fluids, can exacerbate the situation. Thus, if cow's milk is a significant part of the diet, special attention needs to be paid to ensuring adequate hydration during illness. In section 3.6, this issue is revisited using information on the PRSL of the diets generated by LP.

3. Using linear programming (LP) to design diets for nonbreastfed children

3.1 LP

LP is a technique that can be used to develop diets that meet nutritional requirements at the lowest possible cost [10–12]. It has been used for decades for feeding domestic animals, but only recently has the technique been applied to human diets. Briefly, LP allows one to minimize any linear function of a set of variables (e.g., cost) while fulfilling numerous constraints (e.g., energy and nutrient requirements, maximum amount of each food that can feasibly be consumed). The solver function in Microsoft Excel can be used to run the program. For a given population, the only information needed is the list of locally available foods and their costs, and the typical amounts of each food consumed by children in the designated age range. In this report, the age ranges used for the LP analyses were 6 to 9, 9 to 12, and 12 to 24 months.

3.2 Methods used in this report

3.2.1 Food-availability scenarios

To develop dietary recommendations that could be applied under a wide range of circumstances, the LP analyses were conducted assuming several different scenarios regarding the availability and affordability of milk products:

» Commercial infant formula available
» Animal milk products available, but not infant formula
» No animal milk products available

Within each of these scenarios, LP runs were conducted both with and without the inclusion of other types of animal-source foods, such as eggs, chicken, meat, chicken liver, and fish. In all runs, iron, zinc, and calcium supplements were allowed to enter the solution if necessary (i.e., if no solution could be found without one or more of those supplements). The costs of these supplements were set artificially high in order to "force" the program to choose foods whenever possible, rather than supplements. In two other sets of runs (sections 3.5.2 and 3.5.3), a fortified, fat-based complementary food supplement (Nutributter) or a fortified corn-soy blend (CSB) flour was allowed to enter the solution. The composition of Nutributter and CSB used in these analyses is shown in table 1. In these runs, the cost of Nutributter was set somewhat high (US$0.10 per 20-g dose) to minimize the amount of Nutributter that was chosen. The cost of CSB was estimated to be US$0.04 per 100 g. In another set of runs (section 3.5.4), three different complementary food supplements—Nutributter; Foodlets, a multiple micronutrient developed by UNICEF; and Sprinkles—were each allowed to enter the solutions one at a time (the composition of each of these products is shown in table 1). In these runs, more realistic cost estimates for these supplements were used (US$0.06 per 20 g of Nutributter; US$0.03 per dose of Foodlets or Sprinkles) [13] so that an overall cost comparison of the resulting diets, and of the diets with CSB, could be made (it should be noted, however, that these three complementary food supplements are still undergoing research testing and are not yet widely available, and CSB is generally available only through food aid programs). Finally, in another set of runs (section 3.5.5), heat-treated expressed breastmilk was substituted for cow's milk to determine the nutritional feasibility of this option for HIV-positive mothers.

3.2.2 Datasets used to develop food lists and maximum amounts consumed

Datasets on the dietary intake of children between 6 and 15 months of age were available from five countries: Bangladesh [15], Ghana [16], Guatemala [17], Honduras [18], and Peru [19] (see details in table 2). The information from the latter three countries was combined to represent the Latin America region.

These datasets were used to determine the foods consumed most often by infants in that population and the maximum amount of each food ever consumed by any child in each of the countries. This information was used to develop the food lists to be used in the LP runs. To maximize the possibility of developing nutritionally adequate diets using local foods, nutrient-dense foods such as meat, chicken liver, and eggs were added to the food lists, even if they were only rarely consumed by a given population. Table 3 shows the food lists for each of the three regions represented. In general, the maximum amount of each food that was allowed to enter the LP solution was set at 90% of the maximum amount ever consumed by any child in any of the five countries. However, for some foods the maximum amount ever consumed was very low (< 20 g), so in these cases the maximum for the LP runs was set at 20 g. For eggs, the maximum was set at 50 g (one egg), given that it would not be feasible to recommend more than one egg per day in most circumstances.

Information on the costs of local foods in each country was also obtained (table 3). The LP runs were set up to minimize the total cost of each diet, using this cost information.

3.2.3 Food-composition data and bioavailability assumptions

Food-composition data were taken from the International Minilist [20] whenever possible. This database includes information on phytate content, which was used for estimating zinc bioavailability. When a given food was not available in the International Minilist, data were obtained from US Department of Agriculture (USDA) food-composition tables or the World Food Program [20]. For Ghana, the nutrient content of various recipes typically used for infant feeding was calculated using the USDA food-composition data.

The LP runs were structured to take into account the estimated bioavailability of iron, zinc, and calcium from the foods in each diet. The absorption of iron was assumed to be 6% from plant-source foods, 11% from animal-source foods (including milk, in which the bioavailability of iron is lower than in meats), and 8.5% from iron supplements. Zinc absorption was estimated based on the phytate-to-zinc ratio of the diet, using a nonlinear regression to smooth out the step function published by the Food and Agriculture Organization/World Health Organization/International Atomic Energy Agency (FAO/WHO/IAEA) [21]. The absorption of calcium was assumed to be 25% for legumes, roots or tubers, and grains, 5% for foods with high oxalate content (e.g., spinach), 45% for other fruits and vegetables, 32% for all other foods (including dairy products), and 30% for calcium supplements [22].

3.2.4 Constraints on nutrient intake

In each LP run, the solution had to meet several constraints regarding nutrient intake. First, the total energy content of the diet had to be equal to the energy requirements for each age range (615 kcal/day for 6–9 months, 686 kcal/day for 9–12 months, and 894 kcal/day for 12–24 months) [23]. Second, the fat content of the diet had to provide at least 30% of the energy. Third, each solution had to meet or exceed the recommended nutrient intake (RNI) for protein and nine selected micronutrients (vitamin A, thiamine, riboflavin, vitamin B_6, folate, vitamin C, calcium, iron, and zinc). These nine nutrients were selected because they were identified as potential "problem nutrients" for children 6 to 24 months of age [23]. Niacin was also identified as a potential problem nutrient, but it was not included as a constraint in the LP runs because of the difficulty of estimating the amount of niacin available via the conversion from tryptophan.

The RNI values chosen for this analysis were based on the latest WHO/FAO or Institute of Medicine (IOM) Dietary Reference Intakes recommendations

TABLE 1. Composition of complementary food supplements and corn-soy blend

Nutrient	Nutributter[a] (per 20 g)	Foodlets (per one dose)[b]	Sprinkles (per one dose)[c]	CSB[d] (per 100 g)
Energy (kcal)	108	0	0	376
Protein (g)	2.5	0	0	17.2
Fat (g)	7	0	0	6.9
Vitamin A (μg RE)	400	375	300	784
Thiamine (mg)	0.3	0.5	0	0.5
Riboflavin (mg)	0.4	0.5	0	0.5
Niacin (mg)	4	6	0	6
Vitamin B_6 (mg)	0.3	0.5	0	0.5
Vitamin B_{12} (μg)	0.5	0.9	0	1.0
Folic acid (μg)	80	150	150	300
Pantothenic acid (mg)	1.8	0	0	3.4
Vitamin C (mg)	30	35	50	40
Vitamin D (μg)	0	5	7.5	5
Vitamin E (mg)	0.4	6	0	8.7
Calcium (mg)	100	0	0	831
Copper (mg)	0.2	0.6	0	n/a
Iodine (μg)	90	50	0	57
Iron (mg)	9	10	12.5	17.5
Magnesium (mg)	16	0	0	174
Manganese (mg)	0.08	0	0	n/a
Phosphorus (mg)	82	0	0	206
Potassium (mg)	152	0	0	n/a
Selenium (μg)	10	0	0	n/a
Zinc (mg)	4	10	5	5
Phytate (mg)	83	0	0	877

RE, Retinol equivalent; n/a, not available.

a. Nutributter is a fortified, fat-based spread produced by Nutriset (Malauney, France). The composition shown here is for a version used in a trial on complementary feeding in Ghana, 2003-04. The ingredients include vegetable fat, peanut paste, dry skimmed milk powder, dry whey, maltodextrin, sugar, and vitamin/mineral complex.

b. As shown in Nestel et al. [13].

c. Current formulation (S. Zlotkin, personal communication).

d. Corn-soy blend [14].

TABLE 2. Studies from which dietary data were available for the linear programming runs

Country	Age range (mo)	*N*	No. of records/ child	Total no. of records	Dietary data collection
Bangladesh [15]	6–12	126	1	126	Weighed intake (by observer)
Ghana [16]	6–12	190	1–5	501	Weighed intake (by observer)
Guatemala [17]	6–15	305	1–6	1,552	Weighed intake (by observer)
Honduras [18]	6–9	127	1–6	706	Maternal recall
Peru [19]	6–12	127	1–6	739	Weighed intake (by observer)

[23], whichever was lower for a given nutrient (for the 6- to 12-month age interval). The lower value was chosen because most of the RNI values are based on “adequate intake” estimates, which may overestimate actual nutrient needs. Choosing the lower values also maximized the chance of finding a solution that met nutrient needs using local foods. To estimate the recommended amount of *absorbed* iron, zinc, and calcium, the relevant RNIs were multiplied by 0.1, 0.33, and 0.3, respectively (the bioavailability factors used in calculating the RNIs). Thus, the amounts of these nutrients to be provided by the LP solutions at 6 to 12 months were 0.93 mg of absorbed iron, 1.0 mg of absorbed zinc, and 81 mg of absorbed calcium. At 12 to 24 months, the respective amounts were 0.58, 1.0, and 150 mg.

TABLE 3. Foods included for each region, 90% of maximum amount consumed in grams in each region (90% max.), and costs used in linear programming runs

No.	Latin America	90% max.	$US/ 100 g	Bangladesh	90% max.	$US/ 100 g	Ghana	90% max.	$US/ 100 g
1.	Banana, raw, ripe	115	0.05	Banana (ripe)	115	0.03			
2.	Beef, medium fat	40	0.58				Beef, thin, roasted	40	0.19
3.	Bread, wheat, white	75	0.03	Bread	75	0.48	Bread, wheat, white	75	0.17
4.	Cassava root, white boiled	185	0.14				Cassava root, white boiled	185	0.09
5.	Chicken, mature, meat	95	0.59	Chicken	95	0.73	Chicken, mature, meat	95	0.65
6.	Crackers, salty or savory	20	0.48	Crackers	20	0.05			
7.	Egg, chicken, raw or cooked	50	0.20	Egg	50	0.10	Egg, chicken, raw or cooked	50	0.34
8.	Halibut, cooked, dry heat	75	0.37	Fish	75	0.22	Fish, smoked tuna	75	0.18
9.	Infant formula, lactogen, dry	140	3.00	Infant formula, dry	140	3.00	Infant formula, lactogen, dry	140	3.00
10.	Kidney bean, mature boiled	80	0.03	Lentil-cooked (dal)	80	0.05	Soybean, mature boiled	20	0.04
11.	Liver, chicken	35	0.59	Liver, chicken	35	0.83	Liver, chicken	35	0.18
12.	Mango, ripe, raw	80	0.03	Mango	80	0.17			
13.	Milk (cow), whole, not fortified	1,000	0.05	Milk (cow)	1,000	0.05	Milk (cow), whole, not fortified	1,000	0.05
14.				Onion	20	0.03	Onion, bulb, raw or boiled	20	0.06
15.	Orange, raw	180	0.07	Orange juice	180	0.11	Orange juice	180	0.03
16.	Papaya, ripe, raw	155	0.11	Papaya	155	0.13	Papaya, ripe, raw	155	0.12
17.	Pasta, wheat, white, cooked	70	0.03	Vermicelli	70	0.10			
18.	Peas, green, boiled	20	0.08				Cowpea, mature boiled	80	0.04
19.	Plantain, cooked	180	0.05				Plantain, cooked	180	0.05
20.	Potato, baked or boiled	125	0.07	Potato	125	0.02			
21.	Rice, white, unenriched, cooked	195	0.02	Rice (cooked)	195	0.03	Rice, white, unenriched, cooked	195	0.06
22.	Soybean oil	35	0.37	Oil	35	0.07	Palm oil, red, fresh	35	0.12
23.	Spinach, boiled	40	0.13	Spinach	40	0.02	Leaf, taro	40	0.06
24.	Squash, winter, yellow, cooked	130	0.09	Pumpkin	130	0.03			
25.	Sweet potato, tuber, orange	80	0.11				Yam, white, tuber, cooked	60	0.10
26.	Tomato, ripe or green	65	0.30				Tomato, ripe or green	65	0.06
27.	Tortilla, maize, lime-treated	75	0.07	Ruti (wheat tortilla)	75	0.03			
Region-specific foods									
28.	Apple, raw	65	0.27				Banku	295	0.03
29.	Avocado	30	0.14				Corn dough	130	0.03
30.	Cabbage, boiled	55	0.07	Coconut (dry)	20	0.04	Fish, fresh mackerel	75	0.15
31.	Cantaloupe, raw	80	0.05	Guava	25	0.05	Groundnut soup	100	0.03

continued

TABLE 3. Foods included for each region, 90% of maximum amount consumed in grams in each region (90% max.), and costs used in linear programming runs *(continued)*

No.	Latin America	90% max.	$US/ 100 g	Bangladesh	90% max.	$US/ 100 g	Ghana	90% max.	$US/ 100 g
32.	Carrots, raw or boiled	85	0.08	Gur (cane sugar, brown)	20	0.03	Kenkey	100	0.03
33.	Cheese, hard, whole milk	20	0.35	Semolina	20	0.05	Kontomire stew	125	0.04
34.	Oats, rolled or meal, cooked	270	0.04				Koose	140	0.07
35.	Pineapple, raw	60	0.10				Okra soup (fresh or dried)	180	0.03
36.	Shortening, hydrogenated vegetable	35	0.10				Palm soup	160	0.03
37.	Squash, summer, cooked (fruit)	70	0.09				Sugar, white	45	0.03
38.							Tomato stew	100	0.03
39.							TZ (corn and millet porridge)	405	0.04

3.3 Results of initial LP runs with no limits on food choices

The initial set of LP runs was conducted without any limits on the number or types of different foods that could be included in a solution, focusing first on the age range from six to nine months. This was done for each of the three regions represented, and for each scenario described in section 3.2.1 (six combinations: formula + other animal-source food; formula but no other animal-source food; milk + other animal-source food; milk but no other animal-source food; no milk, but other animal-source food available; and no milk or other animal-source food). Micronutrient supplements were allowed, but these runs did not include Nutributter as an option. In Latin America and Bangladesh, solutions that did not include micronutrient supplements were possible only when formula was included. In Ghana, it was possible to get a solution that did not include micronutrient supplements if both milk and other animal-source foods were included. However, the solution had three different types of animal-source foods (besides milk): chicken liver, beef, and fish. This diet and most of the other diets that resulted from these initial LP runs were considered impractical because they generally incorporated multiple types of animal-source foods and a large number of different types of fruits and vegetables to be consumed all on the same day. In addition, many of these solutions included trivial amounts (< 5 g) of some foods, and did not include any of the staple foods for the region (e.g., no rice was included in the solutions for Bangladesh). Therefore, the programs were rerun after imposing additional constraints on the food choices.

3.4 Additional constraints on food choices

To achieve solutions that were more practical for translating into daily dietary recommendations, the following additional constraints were imposed:

Other than egg, only one other nonmilk animal-source food (meat, chicken, fish, or chicken liver) at a time was allowed. Thus, for solutions that included nonmilk animal-source foods, there were five options: egg only, egg + beef, egg + chicken, egg + fish, and egg + chicken liver. These five options were run both with and without the inclusion of infant formula or milk products. All resulting combinations were also run both with and without the inclusion of Nutributter.

The number of different fruits and vegetables allowed in a solution was restricted to two types of fruit and three types of vegetables at a time. These runs used the following choices: For Latin America, banana, papaya, spinach, avocado, and carrot in the first set of runs; in later runs, melon, mango, cabbage, and winter squash were substituted one at a time for banana, papaya, spinach, and carrot, respectively. For Bangladesh, guava, papaya, spinach, and pumpkin in the first set of runs; in later runs, banana was substituted for guava and mango was substituted for papaya. For Ghana, papaya, orange juice, tomato, taro leaf, onion, and okra soup.

If a solution included less than 5 g of any individual food, that food was deleted and the LP analysis was rerun. The only exception was oil, in which case the minimum was set to 5 g any time oil entered the solution.

The minimum amount of staple food was set at 30 g. The staple food was defined as rice (or rice products) in Bangladesh, TZ (a maize and millet porridge) in Ghana, and tortilla (or maize products) in Latin

America. In later runs in Latin America, bread or rice was substituted for tortilla as the "staple food" (i.e., a minimum of 30 g was imposed).

For options in which animal milk was included, the minimum amount of milk was set at 200 g.

Sugar was deleted as a food choice in all regions. Coconut was deleted as a food choice in Bangladesh (because its fibrous consistency may be inappropriate for infants), and oatmeal was deleted in Latin America (because oats are usually imported).

3.5 Results of LP runs with limits on food choices

3.5.1 Without complementary food supplements or fortified corn-soy blend (CSB)

When infant formula was allowed into the solution at 6 to 9 months and 9 to 12 months, the amount that entered ranged from 279 to 486 ml/day when other animal-source foods were included (except when chicken liver was part of the diet, when the amount of formula that entered decreased to 100 to 186 ml/day). When no other animal-source foods were included, the amount of formula selected was 407 to 543 ml/day.

When no infant formula was allowed into the solution, the results varied greatly, depending on the other foods in the diet. Tables 4 to 12 show the amounts of foods in each solution for six different scenarios: (1) dairy products (whole cow's milk, and in Latin America, cheese) + egg + one other animal-source food; (2) dairy products + egg but no other animal-source food; (3) dairy products but no other animal-source food; (4) no animal-source food; (5) no animal-source food, but Nutributter included; and (6) no animal-source food, but CSB included. Each table represents a different region and one of the three age intervals. The first column shows the foods permitted to enter the solution, and the second column shows the maximum quantity that was allowed to enter (in grams of cooked food except for CSB, which is shown as the dry amount). The remaining six columns show the amounts of each food that entered the solution for each of the six scenarios above. This section will discuss the first four scenarios.

At six to nine months (tables 4–6), no solution was possible without the inclusion of an iron supplement. The amount of supplemental iron required ranged from 1.2 to 7.8 mg/day, depending on the amount and type of animal-source foods in the diet. When there was no animal-source food in the diet (scenario 4), supplemental calcium (19–113 mg/day) and zinc (0.6–1.5 mg/day) were also needed. The amount of supplemental calcium required depended on the region and the type of staple food chosen for Latin America (less calcium was required when tortillas were included, because the maize is treated with lime). When other animal-source foods were in the diet (scenarios 1 and 2), the amount of milk in the solution was approximately 200 ml/day (the imposed minimum) in Bangladesh, 200 to 345 ml/day in Ghana (the higher amount was needed for scenario 2), and 200 to 369 ml/day in Latin America (less milk was required when bread was the staple than when tortillas or rice were the staple). When no other animal-source foods were in the diet (scenario 3), the amount of milk in the solution was 340 ml/day in Bangladesh, 490 ml/day in Ghana, and 399 to 496 ml/day in Latin America. When egg was allowed (scenarios 1 and 2), the amount that entered was the maximum (50 g), except in Ghana when beef was included. The amount of meat, chicken, fish, or chicken liver in scenario 1 ranged from 30 to 75 g/day. For beef, fish, and chicken liver, the amount that entered the solution was generally the maximum allowed (40, 75, and 35 g/day, respectively). Grain products were "forced" into all solutions at a minimum of 30 g/day, but the amount that entered varied depending on the other foods in the diet. Legumes entered all solutions. Up to seven additional foods entered the solutions, usually including one fruit and one to three vegetables. Oil was added to almost all diets in Bangladesh but was required only for scenario 4 (no animal-source food) in Latin America and Ghana.

At 9 to 12 months (tables 7–9), the situation was similar. No solution was possible without the inclusion of an iron supplement. The amount of supplemental iron required ranged from 0.7 mg/day (in Ghana, scenario 1 with chicken liver) to approximately 5 to 7 mg/day (scenarios 2–4). When there was no animal-source food in the diet, supplemental calcium (5–117 mg/day) and zinc (0.7–1.5 mg/day) were also needed (except in Bangladesh, where no solution for scenario 4 was possible unless the maximum amount of spinach allowed was increased to 100 g; in this situation no supplemental zinc was needed). When other animal-source foods were in the diet, the amount of milk in the solution was approximately 200 ml/day in Bangladesh, 200 to 337 ml/day in Ghana, and 200 to 365 ml/day in Latin America. When no other animal-source foods were in the diet (scenario 3), the amount of milk in the solution was 339 ml/day in Bangladesh, 483 ml/day in Ghana, and 375 to 516 ml/day in Latin America. When egg was allowed, the maximum amount (50 g) always entered (except in Ghana when beef was included). The amount of meat, chicken, fish, or chicken liver in scenario 1 ranged from 28 to 75 g/day. Legumes entered all solutions. Oil was added to almost all diets in Bangladesh and Ghana, but was required only for scenario 4 (no animal-source food) in Latin America.

At 12 to 24 months (tables 10–12), iron supplements were not required in Ghana but were required for scenarios 2 to 4 in Latin America and all scenarios in Bangladesh except when chicken liver was included. The amount of supplemental iron required in those two regions was approximately 1 to 3 mg/day, considerably less than at 6 to 12 months. When there was no animal-source food in the diet, supplemental calcium (210–330 mg/day) and zinc (0.3–1.3 mg/day) were also needed. In Bangladesh, no solution for scenario 4 (no animal-source food) was possible unless the maximum amount of spinach was increased to 120 g. In Ghana, nonmilk animal-source foods did not enter the solutions (except when chicken liver was the option), but the amount of milk included in scenarios 1 to 3 was 339 to 351 ml/day. In Latin America and Bangladesh, the amount of milk in the solution was 200 to 352 ml/day when other animal-source foods were in the diet and 376 to 439 ml/day when no other animal-source foods were allowed. When egg was allowed, none entered in Ghana, but the maximum amount (50 g) entered in Latin America and Bangladesh except when chicken liver was included. The amount of meat, chicken, fish, or chicken liver in scenario 1 for Latin America and Bangladesh ranged from 20 to 75 g/day. Legumes entered all solutions. Oil was required for most scenarios in Bangladesh and for certain diets in scenarios

TABLE 4. Solutions for Latin America, 6–9 months

Food type	Max. grams per day	Dairy + egg + M, P, F, or L	Dairy + egg	Dairy, no egg or M, P, F, or L	No ASF	No ASF; Nutributter added	No ASF; CSB added
Milk	1,000	200–236	249–369	399–496	—	—	—
Cheese	20	0 (MPL) 20 (F)	20	20	—	—	—
Egg	50	50	50		—	—	—
M, P, F, L							
Beef	40	40	—	—	—	—	—
Chicken	95	or 51–69	—	—	—	—	—
Fish	75	or 75	—	—	—	—	—
Liver (chicken)	35	or 35	—	—	—	—	—
Grains							
Tortilla	75	0–61	0–30	0–30	75	75	30
Bread	75	0–30	0–31	0–30	0–30	41	14
Rice	195	0–30	0–31	0–30	0–30	0	0
Crackers	20	0	0	0	0–18	0	0
Pasta	70	0	0	0	0	0	0
Legumes							
Red beans	80	55–80	68–80	64–80	0–39	80	80
Roots/tubers/plantain/cassava							
Plantain	180	0–24	0	0	0–6	0	0
Sweet potato	80	0–34	0	0	80	0	0
Cassava	185	0	0	0	0	0	0
Potato	0	0	0	0	0	0	0
Spinach	40	40	40	40	40	0	40
Other vegetables							
Avocado	30	0–26	29–30	0–18	30	0	30
Carrot	85	85	85	85	85	83	76
Fruits							
Papaya	155	14 –35	0–32	28–30	155	0	0
Banana	115	0	0	0	0	0	0
Oil	35	0	0	0	12–13	10	11
Fe supplement (mg)		2.2–5.8	6.3–6.4	7.0–7.1	7.3–7.8	0	0
Ca supplement (mg)		0	0	0	9–28	0	0
Zn supplement (mg)		0	0	0	1.3–1.5	0	0.5
Nutributter	20	—	—	—	—	20	—
CSB	60	—	—	—	—	—	60

M, meat; P, poultry; F, fish; L, liver (chicken); ASF, animal-source foods; CSB, corn-soy blend. Amounts shown are per gram of cooked food, except for CSB, which is the dry amount. Food minimums: milk—200 g; tortilla, rice, or bread—30 g (only one of these three foods was forced per run). Food limits: fruits—only banana and papaya; vegetables—only spinach, carrots, and avocado.

1, 3, and 4 in Latin America.

In Ghana, the solutions included three different types of legumes (groundnuts, soybeans, and cowpeas), whereas there was only one source of legumes in the diets for Latin America and Bangladesh. This may explain why nonmilk animal-source foods generally did not enter the solutions at 12 to 24 months in Ghana. With fewer types of legumes available, nonmilk animal-source foods would be needed at this age in Ghana.

One important consideration in the above LP analyses is the conversion factor used to estimate the amount of vitamin A obtainable from β-carotene in plant foods. The food-composition tables use a ratio of 6:1 for the conversion of β-carotene to retinol equivalents (RE), but recent data indicate that a ratio of 12:1 is more appropriate [24]. Thus, if all of the vitamin A in the LP solutions came from plant sources, the actual amount of usable vitamin A would be approximately half of the amount estimated by the program. This was not a concern for the LP solutions for Latin America or Bangladesh, because all of them (even those with no animal-source foods) included more than 800 RE of vitamin A (twice the RNI of 400 RE), and thus would have been adequate even if a ratio of 12:1 had been used. For Ghana, most of the LP solutions had less than

TABLE 5. Solutions for Bangladesh, 6–9 months

Food type	Max. grams per day	Dairy + egg + P, F, or L[a]	Dairy + egg	Dairy, no egg or P, F, or L	No ASF	No ASF; Nutributter added	No ASF; CSB added
Milk	1,000	200	204	340	—	—	—
Egg	50	50	50	—	—	—	—
P, F, L							
Chicken	95	34	—	—	—	—	—
Fish	75	or 73	—	—	—	—	—
Liver (chicken)	35	or 35	—	—	—	—	—
Grains							
Bread	75	0	0	0	0	0	16
Rice	195	30	30	30	30	30	30
Crackers	20	0	6	0	20	20	0
Semolina	20	0	0	0	0	0	0
Pasta	70	0	0	5	0	0	0
Legumes							
Lentils	80	80	80	80	80	80	80
Roots/tubers/plantain/cassava							
Potato	125	72–125	125	125	100	64	0
Spinach	40	40	40	40	100[b]	40	40
Other vegetables							
Pumpkin	130	130	130	130	130	130	130
Onion	20	0	20	20	20	20	20
Fruits							
Papaya	155	0	0	0	155	155	0
Guava	25	0	25	25	25	25	25
Oil	35	0–5	5	6	17	10	15
Fe supplement (mg)		2.5–5.7	6.2	6.9	5.6	0	0
Ca supplement (mg)		0	0	0	113	28	0
Zn supplement (mg)		0	0	0	0.6	0	0
Nutributter	20	—	—	—	—	20	—
CSB	60	—	—	—	—	—	60

P, Poultry; F, fish; L, liver (chicken); ASF, animal-source foods; CSB, corn-soy blend. Amounts shown are per gram of cooked food, except for CSB, which is the dry amount. Food minimums: milk—200 g; rice—30 g. Food limits: fruits—only guava and papaya; vegetables—only spinach, pumpkin, and onions.

a. Meat was not included because it was never consumed by young children in the study population.

b. Riboflavin limiting, no solution possible unless spinach maximum is increased.

800 RE of vitamin A. To evaluate actual vitamin A adequacy, the Ghana analyses were rerun after multiplying the vitamin A content of the plant source foods by 0.5. All of the solutions yielded identical diets to those shown in tables 10 to 12 and had more than 400 RE of vitamin A (adjusted). Thus, the diets in tables 4 to 12 are adequate in vitamin A even if a 12:1 conversion ratio for β-carotene is utilized.

Another important consideration in these analyses is the maximum amount of nonmilk animal-source foods allowed in scenarios 1 and 2. To optimize the ability to meet nutrient needs from local foods, the maximum amounts chosen (90% of the maximum amount consumed in any of the sites) were relatively high (40 g of beef, 75 g of fish, 95 g of chicken, 35 g of chicken liver, and 50 g of egg). Most infants in devel-

TABLE 6. Solutions for Ghana, 6–9 months

Food type	Max. grams per day	Dairy + egg + M, P, F, or L	Dairy + egg	Dairy, no egg or M, P, F, or L	No ASF	No ASF; Nutributter added	No ASF; CSB added
Milk	1,000	200	345	490	—	—	—
Egg	50	0 (M) 50 (PFL)	50	—	—	—	—
M, P, F, L							
Beef	40	40	—	—	—	—	—
Chicken	95	or 30	—	—	—	—	—
Fish	75	or 75	—	—	—	—	—
Liver (chicken)	35	or 35	—	—	—	—	—
Grains							
Bread	75	0	0	0	0	0	0
Rice	195	0	0	0	0	0	0
TZ	405	59–129	94	87	32	30	30
Corn dough	130	0	0	0	0	0	20
Banku /kenkey	295	0	0	0	0	0	0
Legumes							
Cowpeas	80	80	80	80	80	80	80
Groundnut soup	100	0–39	0	0	100	100	100
Soybeans	20	20	20	20	20	20	20
Roots/tubers/ plantain/cassava							
Cassava	185	0	0	0	0	20	0
Yam	60	0	7	0	0	0	0
Plantain	180	0	0	0	0	0	0
Taro leaf	40	40	40	40	40	40	22
Other vegetables							
Onion	20	0	0	0	20	20	0
Okra soup	180	0–21	0	0	180	20	47
Fruits							
Papaya	155	0	0	0	155	155	0
Orange juice	180	0	0	0	180	180	0
Tomato	65	65	65	65	65	0	0
Oil	35	0–5	0	0	5	0	1
Fe supplement (mg)		1.2–4.7	5.1	5.8	5.9	0	0
Ca supplement (mg)		0	0	0	39	0	0
Zn supplement (mg)		0	0	0	0.8	0	0
Nutributter	20	—	—	—	—	20	—
CSB	60	—	—	—	—	—	60

M, Meat; P, Poultry; F, fish; L, liver (chicken); ASF, animal-source foods; CSB, corn-soy blend. Amounts shown are per gram of cooked food, except for CSB, which is the dry amount. Food minimums: milk—200 g; TZ (corn and millet porridge)—30 g. Food limits: fruits—only orange juice, papaya, and tomato; vegetables—taro leaf, onion, and okra soup.

oping countries do not consume these quantities of animal-source foods. Among children under two years of age in the United States who consume these foods, the mean consumption of red meat (35 g), eggs (46 g), and organ meats (66 g) is similar to or greater than the maximum amounts allowed in the LP analyses, but the mean consumption of poultry (45 g) and fish (40 g) is considerably lower than the maximum allowed [25]. Thus, the diets for scenarios 1 and 2 may be unrealistic and might lead to an underestimation of the amount of milk needed if consumption of animal-source foods is less than the amounts that entered each solution. To evaluate this possibility, the LP analyses for these two scenarios were rerun using maximum amounts for nonegg animal-source foods set at the 75th percentile of consumption (for the site with the highest consumption of that food). These maximums were 14 g of beef, 38 g of fish, 20 g of chicken, and 21 g of chicken

TABLE 7. Solutions for Latin America, 9–12 months

Food type	Max. grams per day	Dairy + egg + M, P, F, or L	Dairy + egg	Dairy, no egg or M, P, F, or L	No ASF	No ASF; Nutributter added	No ASF; CSB added
Milk	1,000	200–300	200–365	375–516	—	—	—
Cheese	20	0 (MPL)14–20 (F)	20	20	—	—	—
Egg	50	50	50	—	—	—	—
M, P, F, L							
Beef	40	40	—	—	—	—	—
Chicken	95	or 48–78	—	—	—	—	—
Fish	75	or 75	—	—	—	—	—
Liver (chicken)	35	or 35	—	—	—	—	—
Grains							
Tortilla	75	0–71	0–30	0–52	75	75	30
Bread	75	0–30	0–30	0–30	0–30	63	39
Rice	195	0–30	0–30	0–30	0–30	0	0
Crackers	20	0	0	0–20	0–20	0	0
Pasta	70	0	0	0	0	0	0
Legumes							
Red beans	80	77–80	80	80	29–80	80	80
Roots/tubers/ plantain/cassava							
Plantain	180	0–90	0–49	0–64	0	0	0
Sweet potato	80	0–31	0–56	0–52	59–80	0	0
Cassava	185	0–7	0	0	0	0	0
Potato	0	0	0	0	0	0	0
Spinach	40	4 0	40	40	40	0	40
Other vegetables							
Avocado	30	0–3	30	0–30	30	0	30
Carrot	85	85	85	85	85	79	55
Fruits							
Papaya	155	16–35	0–23	0–12	155	0	0
Banana	115	0	0	0	0	0	0
Oil	35	0–5	0	0	13–15	12	12
Fe supplement (mg)		2.2–5.5	5.9–6.0	6.6–6.7	6.5–7.4	0	0
Ca supplement (mg)		0	0	0	5–18	0	0
Zn supplement (mg)		0	0	0	1.4–1.5	0	0.5
Nutributter	20	—	—	—	—	20	—
CSB	60						60

M, meat; P, poultry; F, fish; L, liver (chicken); ASF, animal-source foods; CSB, corn-soy blend. Amounts shown are per gram of cooked food, except for CSB, which is the dry amount. Food minimums: milk—200 g; tortilla, rice, or bread—30 g (only one of these three foods was forced per run). Food limits: fruits—only banana and papaya; vegetables—only spinach, carrots, and avocado.

liver. The maximum for eggs was kept at 50 g because that amount is equivalent to approximately one egg. In these reanalyses, the amount of milk that entered remained approximately the same in Bangladesh, but there were changes in the amounts of some of the non-animal-source foods and a slight increase in the amount of iron supplement required. For Ghana, there was also very little change in the amount of milk that entered, but the amount of iron supplement required increased slightly. For Latin America, there was a small increase in the amount of milk (a difference of 0–81 ml, depending on which animal-source food was allowed), but the amount did not exceed 350 ml in any of the solutions; the amount of iron supplement required also increased slightly. The full amount of egg allowed (50 g) entered most of the solutions, so it could still be argued that these diets contain more animal-source foods than is realistic for developing countries. For this reason, scenarios 3 to 6 in tables 4 to 12 may be more appropriate in most circumstances.

3.5.2 With Nutributter

The LP runs that included Nutributter (at US$0.10 per 20 g) were done both with and without imposing the additional constraints described in section 3.4. Infant formula did not enter any of the solutions at any age.

TABLE 8. Solutions for Bangladesh, 9–12 months

Food type	Max. grams	Dairy + egg + P, F, or L[a]	Dairy + egg	Dairy, no egg or P, F, or L	No ASF	No ASF; Nutributter added	No ASF; CSB added
Milk	1,000	200	203	339	—	—	—
Egg	50	50	50	—	—	—	—
P, F, L							
Chicken	95	44	—	—	—	—	—
Fish	75	or 75	—	—	—	—	—
Liver (chicken)	35	or 35	—	—	—	—	—
Grains							
Bread	75	0	5	0	75	0	9
Rice	195	30	30	30	30	30	30
Crackers	20	0–12	20	18	20	20	0
Semolina	20	0–9	0	0	0	0	0
Pasta	70	0–9	0	0	0	0	53
Legumes							
Lentils	80	80	80	80	39	80	80
Roots/tubers/ plantain/cassava							
Potato	125	121–125	125	125	6	122	0
Spinach	40	40	40	40	100[b]	40	40
Other vegetables							
Pumpkin	130	130	130	130	130	130	130
Onion	20	0–12	20	20	20	20	20
Fruits							
Papaya	155	0	0	0	155	155	0
Guava	25	25	25	25	25	25	25
Oil	35	0–6	5	6	17	12	17
Fe supplement (mg)		2.3–5.4	6.1	6.7	6.5	0	0
Ca supplement (mg)		0	0	0	117	25	0
Zn supplement (mg)		0	0	0	0	0	0
Nutributter	20	—	—	—	—	20	—
CSB	60	—	—	—	—	—	60

P, Poultry; F, fish; L, liver (chicken); ASF, animal-source foods; CSB, corn-soy blend. Amounts shown are per gram of cooked food, except for CSB, which is the dry amount. Food minimums: milk—200 g; rice—30 g. Food limits: fruits—only guava and papaya; vegetables—only spinach, pumpkin, and onions.

a. Meat was not included because it was never consumed by young children in the study population.

At 6–9 and 9–12 months, the amount of Nutributter that entered was close to the maximum allowed (19–20 mg/day). At 12 to 24 months, only 9 to 10 mg of Nutributter entered when milk products were allowed. When milk was allowed but no minimum amount was set, the amount of milk included in the solutions for Ghana was 121 ml at 6–9 and 9–12 months, and 343 ml at 12–24 months. For Latin America, the amount of milk included was 0 ml at 6–9 months, 36 ml at 9–12 months, and 259 ml at 12–24 months. For Bangladesh, the amount of milk included was 108 ml at 6–9 months, 111 ml at 9–12 months, and 335 ml at 12–24 months. Other animal-source foods did not enter the solutions when Nutributter was included (except for 7 g of cheese in Latin America at 6–9 months).

The second-to-last column of tables 4 to 12 shows

TABLE 9. Solutions for Ghana, 9–12 months

Food type	Max. grams per day	Dairy + egg + M, P, F, or L	Dairy + egg	Dairy, no egg or M, P, F, or L	No ASF	No ASF; Nutributter added	No ASF; CSB added
Milk	1,000	200	337	483	—	—	—
Egg	50	12–50	50	—	—	—	—
M, P, F, L							
Beef	40	40	—	—	—	—	—
Chicken	95	or 28	—	—	—	—	—
Fish	75	or 75	—	—	—	—	—
Liver (chicken)	35	or 35	—	—	—	—	—
Grains							
Bread	75	0	0	0	0	0	0
Rice	195	0	0	0	0	0	0
TZ	405	94–161	115	107	30	30	30
Corn dough	130	0	0	0	0	44	56
Banku /kenkey	295	0	0	0	0	0	0
Legumes							
Cowpeas	80	80	80	80	80	80	75
Groundnut soup	100	0–52	0	40	100	100	96
Soybeans	20	20	20	20	20	20	20
Roots/tubers/ plantain/cassava							
Cassava	185	0	0	0	57	0	0
Yam	60	0–19	7	0	0	0	0
Plantain	180	0	0	0	0	0	0
Taro leaf	40	40	40	0	40	40	0
Other vegetables							
Onion	20	0	0	0	20	14	0
Okra soup	180	0–21	0	0	180	180	0
Fruits							
Papaya	155	0	0	0	155	0	0
Orange juice	180	0	0	0	180	180	0
Tomato	65	65	65	65	65	0	0
Oil	35	0–5	5	5	5	0	6
Fe supplement (mg)		0.7–4.5	4.9	5.6	5.6	0	0
Ca supplement (mg)		0	0	0	30	0	0
Zn supplement (mg)		0	0	0	0.7	0	0
Nutributter	20	—	—	—	—	20	—
CSB	60	—	—	—	—	—	60

M, Meat; P, Poultry; F, fish; L, liver (chicken); ASF, animal-source foods; CSB, corn-soy blend. Amounts shown are per gram of cooked food, except for CSB, which is the dry amount. Food minimums: milk—200 g; TZ (corn and millet porridge)—30 g. Food limits: fruits—only orange juice, papaya, and tomato; vegetables—taro leaf, onion, and okra soup.

the solutions when Nutributter was included in a diet with no animal-source foods, applying the constraints described in section 3.4. At all ages, solutions were obtained without the need for additional iron or zinc supplements. Because the formulation of Nutributter used in these analyses included only a modest amount of calcium (100 mg per 20 g), in some situations the solution included additional calcium. At 6–9 and 9–12 months, this was necessary only in Bangladesh, where a small amount (25–28 mg) of additional calcium was included in the solution. At 12 to 24 months, it was necessary in all sites (115–249 mg of additional calcium), because the RNI for calcium at that age is much higher than at 6 to 12 months (500 vs. 270 mg).

The diets shown in the second-to-last column of tables 4 to 12 generally contain one or two types of grain products, legumes, occasionally tubers, one to three vegetables, zero to three fruits, and usually some additional oil. It should be noted that the maximum amount of Nutributter allowed (20 g) is a modest

TABLE 10. Solutions for Latin America, 12–24 months

Food type	Max. grams per day	Dairy + egg + M, P, F, or L	Dairy + egg	Dairy, no egg or M, P, F, or L	No ASF	No ASF; Nutributter added	No ASF; CSB added
Milk	1,000	200–230	277–312	423–439	—	—	—
Cheese	20	0–20 (all)	0–20	15–20	—	—	—
Egg	50	0 (L) 50 (MPF)	50		—	—	—
M, P, F, L							
Beef	40	40	—	—	—	—	—
Chicken	95	or 76–88	—	—	—	—	—
Fish	75	or 75	—	—	—	—	—
Liver (chicken)	35	or 24–25	—	—	—	—	—
Grains							
Tortilla	75	5–75	0–30	0–33	75	75	30
Bread	75	0–75	0–30	0–30	0–30	0	75
Rice	195	0–30	0–30	0–30	0–30	0	0
Crackers	20	0	0	0	20	20	0
Pasta	70	0–70	0–40	0–70	0	0	70
Legumes							
Red beans	80	80	80	80	80	80	0
Roots/tubers/ plantain/cassava							
Plantain	180	0–180	178–180	130–180	0	0	0
Sweet potato	80	0	0	0	80	80	0
Cassava	185	0–114	0	0	16–64	0	0
Potato	0	0	0	0	0	0	0
Spinach	40	40	40	40	40	40	40
Other vegetables							
Avocado	30	0–30	30	30	30	30	0
Carrot	85	0– 85	85	85	85	83	31
Fruits							
Papaya	155	0–34	0	0	155	155	0
Banana	115	0	0	0	0–45	0	90
Oil	35	0–11	0	0–5	19–20	13	22
Fe supplement (mg)		0–0.5	1.0–1.1	1.7–2.0	1.8–2.0	0	0
Ca supplement (mg)		0	0	0	210–216	115	0
Zn supplement (mg)		0	0	0	1.3	0	0
Nutributter	20	—	—	—	—	20	—
CSB	60	—	—	—	—	—	60

M, meat; P, poultry; F, fish; L, liver (chicken); ASF, animal-source foods; CSB, corn-soy blend. Amounts shown are per gram of cooked food, except for CSB, which is the dry amount. Food minimums: milk—200 g; tortilla, rice, or bread—30 g (only one of these three foods was forced per run). Food limits: fruits—only banana and papaya; vegetables—only spinach, carrots, and avocado.

amount and could be increased, especially in the second year of life. In addition, the amount of calcium included in the product could be increased. This has the potential to simplify the diets further.

3.5.3 With CSB

The LP runs with CSB allowed for a maximum of 60 g of this product, a typical ration size in feeding programs for infants and young children. The additional constraints described in section 3.4 were also imposed. In all sites, at all ages, the maximum amount of CSB entered the solutions. When milk was allowed, no more than the minimum amount of 200 ml of milk entered. When other animal-source foods were allowed, egg entered most of the solutions in Bangladesh (8–38 g) and Latin America (10–50 g), but not in Ghana. Other animal-source foods rarely entered in Bangladesh or Ghana, but cheese, fish, or chicken liver sometimes entered in Latin America. The last column of tables 4 to 12 shows the solutions when no animal-source food was allowed. In Latin America, these were generally similar to the solutions using Nutributter, except

TABLE 11. Solutions for Bangladesh, 12–24 months

Food type	Max. grams	Dairy + egg + P, F, or L[a]	Dairy + egg	Dairy, no egg or P, F, or L	No ASF	No ASF; Nutributter added	No ASF; CSB added
Milk	1,000	273–352	310	376	—	—	—
Egg	50	22(L) 50 (P,F)	50	—	—	—	—
P, F, L							
Chicken	95	46	—	—	—	—	—
Fish	75	or 75	—	—	—	—	—
Liver (chicken)	35	or 20	—	—	—	—	—
Grains							
Bread	75	0–69	41	67	55	44	0
Rice	195	30	30	30	30	30	78
Crackers	20	20	20	20	20	20	20
Semolina	20	0–20	20	15	0	0	0
Pasta	70	0	0	0	70	70	0
Legumes							
Lentils	80	80	80	80	80	80	80
Roots/tubers/ plantain/cassava							
Potato	125	125	125	125	125	125	125
Spinach	40	40	40	40	120[b]	40	40
Other vegetables							
Pumpkin	130	0–130	130	130	130	130	130
Onion	20	0–20	20	20	20	20	20
Fruits							
Papaya	155	0–20	0	0	155	155	0
Guava	25	0–25	25	25	25	25	19
Orange juice	180	—	—	—	—	—	0
Banana	115	—	—	—	—	—	0
Oil	35	0–5	5	5	21	14	21
Fe supplement (mg)		0–0.9	1.6	2.2	0.5	0	0
Ca supplement (mg)		0	0	0	330	249	0
Zn supplement (mg)		0	0	0	0.3	0	0
Nutributter	20	—	—	—	—	20	—
CSB	60	—	—	—	—	—	60

P, Poultry; F, fish; L, liver (chicken); ASF, animal-source foods; CSB, corn-soy blend. Amounts shown are per gram of cooked food, except for CSB, which is the dry amount. Food minimums: milk—200 g; rice—30 g. Food limits: fruits—only guava and papaya; vegetables—only spinach, pumpkin, and onions.

a. Meat was not included because it was never consumed by young children in the study population.

b. Riboflavin limiting, no solution possible unless spinach maximum is increased.

that the CSB substituted for some of the other grain products (and legumes at 12–24 months), spinach and avocado were added, and the CSB diets at 6–9 and 9–12 months required the addition of 0.5 mg of zinc. In Bangladesh, the solutions using CSB required fewer foods than the solutions using Nutributter (e.g., potato was deleted at 6–9 and 9–12 months, and papaya was deleted at all ages), but were otherwise similar. In Ghana, the solutions using CSB required less taro leaf, onion, okra soup, and orange juice than the solutions using Nutributter.

3.5.4 Cost comparisons with three different complementary food supplements and CSB

Nutributter is not the only product that could be added to home-produced foods to boost the nutritional

TABLE 12. Solutions for Ghana, 12–24 months

Food type	Max. grams per day	Dairy + egg + M, P, F, or L	Dairy + egg	Dairy, no egg or M, P, F, or L	No ASF	No ASF; Nutributter added	No ASF; CSB added
Milk	1,000	339–351	339	339	—	—	—
Egg	50	0	0	—	—	—	—
M, P, F, L							
Beef	40	0	—	—	—	—	—
Chicken	95	0	—	—	—	—	—
Fish	75	0	—	—	—	—	—
Liver (chicken)	35	or 14	—	—	—	—	—
Grains							
Bread	75	0	0	0	0	0	0
Rice	195	0	0	0	0	0	0
TZ	405	67–185	185	185	157	30	30
Corn dough	130	53–130	53	53	0	0	130
Banku/kenkey	295	0	0	0	0	0	0
Legumes							
Cowpeas	80	80	80	80	80	80	0
Groundnut soup	100	92–100	92	92	100	100	100
Soybeans	20	20	20	20	20	20	20
Roots/tubers/ plantain/cassava							
Cassava	185	0	0	0	48	135	0
Yam	60	0	0	0	0	0	0
Plantain	180	0	0	0	0	0	0
Taro leaf	40	0–40	40	40	40	40	6
Other vegetables							
Onion	20	0	0	0	20	20	0
Okra soup	180	0	0	0	180	180	105
Fruits							
Papaya	155	0	0	0	155	155	0
Orange juice	180	15–34	15	15	180	180	0
Tomato	65	0	0	0	65	65	0
Oil	35	0	0	0	7	5	17
Fe supplement (mg)		0	0	0	0	0	0
Ca supplement (mg)		0	0	0	251	147	0
Zn supplement (mg)		0	0	0	0.5	0	0
Nutributter	20	—	—	—	—	20	—
CSB	60	—	—	—	—	—	60

M, Meat; P, Poultry; F, fish; L, liver (chicken); ASF, animal-source foods; CSB, corn-soy blend. Amounts shown are per gram of cooked food, except for CSB, which is the dry amount. Food minimums: milk—200 g; TZ (corn and millet porridge)—30 g. Food limits: fruits—only orange juice, papaya, and tomato; vegetables—taro leaf, onion, and okra soup.

content of diets for infants and young children. Other options include crushable micronutrient tablets (called "Foodlets" by UNICEF) and Sprinkles, both of which can be mixed with foods for infants [13]. To compare these options, the LP runs were conducted with these three complementary food supplements allowed one at a time, using the cost estimates described in section 3.2.1. Table 13 summarizes the food costs for these diets and for the CSB diets in Latin America, Bangladesh, and Ghana using two scenarios: including milk (minimum of 200 ml/day) but no other animal-source food, and without any animal-source food. In the latter scenario, calcium and zinc supplements were allowed to enter the solution if needed, but the cost of these additional nutrients was not included.

When milk was included, the total cost of the diet was similar across the four options (Nutributter, Sprinkles, Foodlets, or CSB) at 6–9 and 9–12 months in Bangladesh and Ghana, ranging from US$0.18 to 0.24 per day, whereas in Latin America, the CSB option was more costly (US$0.31–0.33) than the other three options (US$0.24–0.26) at these ages. When no animal-source food was allowed, the total cost of the diet at 6–9 and 9–12 months was lowest with the Nutributter option in Latin America (US$0.26–0.27 vs. US$0.27–0.65 for the other options), but in the other two sites it was lowest with the CSB option (US$0.14–0.24 vs. US$0.30–0.54 for the other options). At 12 to 24 months, the CSB option was less expensive (US$0.17–0.29) than the other three options (US$0.29–0.83) in all sites, regardless of whether milk was included. It should be noted that in Bangladesh, no solution could be reached for the "no animal-source food" scenario with the Sprinkles or Foodlets options unless the maximum amount of spinach allowed was increased to 100 g (this was not the case for the Nutributter or CSB options). It should also be kept in mind that the costs shown in table 13 are rough estimates and could vary greatly depending on changes in local food costs. The choice of which option is most appropriate in a given situation will depend not only on cost, but also on availability and acceptability.

3.5.5 LP runs with heat-treated expressed breastmilk

For HIV-positive mothers, one option is to express their breastmilk, use heat treatment to inactivate HIV, and feed the treated milk to their infants. This may be a more practical option after six months, when milk is no longer the sole source of nutrients, than during the first six months, when sustained expression of sufficient quantities of milk may be difficult. Expressed breastmilk is a readily available, less costly option than commercial infant formula or cow's milk. To evaluate the types of foods that would be needed to complement expressed breastmilk, the LP runs for 6–9 and 9–12 months were repeated with heat-treated breastmilk as an option instead of cow's milk. The nutrient composition of human milk may be altered by heat treatment, but preliminary data suggest that the changes are minor except for vitamin C concentration, which appears to be reduced by about 20% [26]. Thus, for these LP runs, the composition of the human milk was assumed to be similar to that of milk from well-nourished women [27], but with the concentration of vitamin C reduced by 20%. The cost of human milk was set at US$0.01 per 100 ml, to allow for fuel costs for heat treatment (by comparison, the cost of cow's milk was US$0.05 per 100 ml). The amount of expressed breastmilk allowed into the LP solution was constrained by using a minimum of 200 ml/day and a maximum of 400 ml/day.

The results of these LP runs were similar to those using cow's milk, although different foods were sometimes chosen and the amounts varied somewhat. The amount of supplemental iron required was somewhat higher with breastmilk than with cow's milk, due to the lower iron content of human milk (0.3 mg/L, compared with 1.0 mg/L for cow's milk). Similarly, for scenarios that included little or no other animal-source food, some of the solutions included a small amount of zinc or calcium supplement when breastmilk was used but not when cow's milk was used. This is because the zinc and calcium concentrations in human milk are lower than those in cow's milk (zinc 0.9 vs. 4.0 mg/L, and calcium 280 vs. 1,150 mg/L, respectively). The amount of breastmilk that entered was approximately 200 ml in Latin America, 300 to 400 in Bangladesh, and 200 to 300 in Ghana. In Latin America less breastmilk than cow's milk entered the solutions for the scenarios that included no other animal-source food or egg as the only other animal-source food, whereas in Bangladesh more breastmilk than cow's milk was used for most options. In Ghana, the amount of breastmilk that entered varied depending on the dietary scenario.

Thus, a nutritionally adequate diet can be designed using heat-treated expressed breastmilk and appropriate complementary foods plus an additional source of iron (as is true for diets that include cow's milk). Although these LP runs do not demonstrate an advantage of breastmilk over cow's milk at this age with regard to the 12 nutrients considered in these analyses, they do not take into account all of the nutritional differences that may have functional consequences (e.g., certain fatty acids), nor the non-nutritive benefits of human milk (e.g., anti-infective properties, although there is little information on whether, or the extent to which, breastmilk from an HIV-infected woman protects her child from other infections) [28]. The cost of the overall diet is likely to be considerably lower if expressed breastmilk is used in place of cow's milk, and if no animal milk is available at all, the inclusion of expressed breastmilk is likely to significantly enhance dietary quality.

TABLE 13. Cost comparisons of diets including Nutributter, Sprinkles, Foodlets or corn-soy blend (US$)

Location	Nutributter	Sprinkles	Foodlets	Corn-soy blend
6–9 mo				
With milk				
Latin America	0.25	0.24	0.24	0.31
Bangladesh	0.24	0.20	0.18	0.21
Ghana	0.23	0.21	0.21	0.20
Without milk				
Latin America	0.26	0.65	0.65	0.27
Bangladesh	0.40	0.40	0.38	0.22
Ghana	0.47	0.49	0.49	0.14
9–12 mo				
With milk				
Latin America	0.26	0.26	0.25	0.33
Bangladesh	0.22	0.21	0.19	0.21
Ghana	0.23	0.22	0.22	0.21
Without milk				
Latin America	0.27	0.65	0.65	0.49
Bangladesh	0.41	0.42	0.42	0.24
Ghana	0.30	0.54	0.54	0.12
12–24 mo				
With milk				
Latin America	0.32	0.40	0.37	0.25
Bangladesh	0.29	0.33	0.33	0.19
Ghana	0.30	0.34	0.33	0.21
Without milk				
Latin America	0.79	0.82	0.83	0.29
Bangladesh	0.49	0.54	0.50	0.19
Ghana	0.64	0.62	0.60	0.17

3.6 Evaluation of potential renal solute load (PRSL) and extra fluid needed

The diets resulting from each of the LP solutions described in sections 3.5.1 and 3.5.2 were evaluated further for their PRSL and water content. PRSL was calculated using the following equation [4]:

$$\text{PRSL} = \text{Na} + \text{Cl} + \text{K} + \text{P} + (\text{protein} / 175)$$

(PRSL in milliosmoles; Na, Cl, K, and P in millimoles; protein in milligrams)

Because the Cl content of most foods is not listed in food-composition tables, Cl was estimated by multiplying the Na content by 1.5.

Across all age groups and sites, PRSL ranged from a low of 124 mOsm to a high of 461 mOsm, and was generally higher for diets that included nonmilk animal-source food. By making certain assumptions about urine concentration and the amount of nonrenal water loss expected, these PRSL values can be used to estimate the amount of water required from the total diet. These calculations are based on the following equation [4]:

$$C_{\text{urine}} = \text{RSL}_{\text{est}} / [W_f - W_e]$$

where C_{urine} is urinary concentration (mOsm/L), RSL_{est} is renal solute load (mOsm/day), W_f is water intake (L/day), and W_e is extrarenal water loss (L/day). RSL is generally less than PRSL because of the use of solutes for growth. To be conservative, PRSL was substituted for RSL in the above equation when solving for W_f. This results in the following equation:

$$W_f = [\text{PRSL}/C_{\text{urine}}] + W_e$$

The renal concentrating ability (C_{urine}) of an infant at about nine months of age is estimated to be 1,100 mOsm/L [4], but to allow for a margin of safety a value of 700 mOsm/L was used. Thus, the first part of the above equation [$\text{PRSL}/C_{\text{urine}}$] would range from 0.18 to 0.66 L/day (180–660 ml/day) for the range of PRSL values observed. W_e can be calculated based on assumed body weight. Under normal climatic conditions, W_e is about 60 ml/kg/day [4]. Based on estimated body weights of 7.5 kg at 6 months, 8.5 kg at 9 months, 9.75 kg at 12 months, and 12.3 kg at 24 months, W_e would be 480 ml/day at 6–9 months, 548 ml/day at 9–12 months, and 662 ml/day at 12–24 months.

Using the above equation, table 14 shows the estimated total water needs of nonbreastfed children in each age interval, based on either a low- or a high-PRSL diet. Under normal climatic conditions, total water needs are 690 to 900 ml/day with a low-PRSL diet and 1,010 to 1,210 ml/day with a high-PRSL diet. The amount of fluid coming from the diet can be subtracted from the total amount of water needed (based on each diet's PRSL) to estimate the amount of extra fluids required in each dietary scenario. The water content of these diets was 220 to 560 ml/day for the low-PRSL diets and 510 to 740 ml/day for the high-PRSL diets. The estimated net amount of extra water needed is 470 to 500 ml/day at 6–9 months, 450 to 530 ml/day at 9–12 months, and 340 to 470 ml/day at 12–24 months. This fluid can be provided as plain water or other beverages, or it can be used to make a porridge from the rice and/or other foods in the solution.

Under hot conditions, extrarenal water losses increase. If we assume that they are doubled under tropical conditions, the above equation can be applied using a value for W_e of 960 ml/day at 6–9 months, 1,096 ml/day at 9–12 months, and 1,324 ml/day at 12–24 months. This results in an estimate of the extra fluid to be incorporated into the diet of 950 to 980 ml/day at 6–9 months, 990 to 1,080 ml/day at 9–12 months, and 1,000 to 1,130 ml/day at 12–24 months (table 14).

Extrarenal water losses during diarrhea can be two to three times greater than normal, with the resulting total water need being increased accordingly. Fever can also increase extrarenal water losses. In such circumstances, it is essential that extra fluids be provided in addition to the water that would be coming from the normal diet. If the infant refuses the quantity of water needed, it may be necessary to restrict the intake of foods that are high in PRSL during illness. The foods with the highest PRSL in these sites were fish, cheese, chicken, beef, and chicken liver.

3.7 Evaluation of protein quality

Although the LP analyses were set up to ensure that the total amount of protein in each solution was adequate, they did not include individual amino acid requirements. This is partly because of uncertainty about amino acid requirements during infancy and early childhood [29]. For the diets in tables 4 to 12 that included animal-source foods (scenarios 1–3), the total amount of protein ranged from 24 to 52 g/day (14%–30% of energy), which is approximately two to five times the amount needed. Given that these diets included animal protein and that the total amount of protein was generous, there is very little risk of inadequate intake of individual amino acids.

The diets that could be more problematic are those without animal-source foods (scenarios 4–6 in tables 4–12). The total amount of protein in these diets ranged from 14 to 26 g/day. All of these diets included both grains and legumes, which enhances protein quality. Nonetheless, it is possible that some of them would provide less than the desired amounts of certain essential amino acids. Inspection of these diets suggested that the potentially limiting amino acids are lysine, sulfur-containing amino acids (methionine + cysteine), and tryptophan. To evaluate amino acid adequacy, the total amounts of these amino acids provided by each of the diets lacking animal-source foods were calculated and compared with recommended amino acid intakes for each age interval [30]. The results indicated that all of the diets were adequate in these amino acids, with one exception: the "no animal-source food" (without Nutributter) option for Latin America at six to nine months, which was short in lysine (630 mg/day, with tortillas as the staple grain, compared with the recommended amount of approximately 676 mg/day). This diet was also the lowest in total protein (14 g/day), with all other diets containing at least 17 g/day. Thus, nearly all of the options presented in tables 4 to 12 have adequate protein quality.

TABLE 14. Estimated water needs of nonbreastfed children (ml/day)

		Normal climate			Hot climate		
Age (mo)	PRSL[a]	Total water needed	Amount from foods	Extra water needed	Total water needed	Amount from foods	Extra water needed
6–9	Low[b]	690	220	470	1,170	220	950
	High[c]	1,010	510	500	1,490	510	980
9–12	Low[b]	760	310	450	1,300	310	990
	High[c]	1,080	550	530	1,630	550	1,080
12–24	Low[b]	900	560	340	1,560	560	1,000
	High[c]	1,210	740	470	1,870	740	1,130

a. PRSL, Potential renal solute load.
b. Based on the average of the lowest PRSL observed in each site at this age.
c. Based on the average of the highest PRSL observed in each site at this age.

4. Meal frequency and energy density

The number of feedings required depends on the overall energy density of the diet. Theoretical estimates of required meal frequency and energy density can be calculated from the total amount of energy required, assuming a gastric capacity of 30 g/kg body weight/day [23]. To meet the needs of nearly all children, 2 SD is added to the average age-specific total daily energy requirements. Table 15 shows the minimum number of meals required with three different estimates of energy density (0.6, 0.8, and 1.0 kcal/g). At the lowest energy density (0.6 kcal/g), five or six meals per day would be needed. This decreases to approximately four meals per day when energy density is at least 0.8 kcal/g, and to approximately three meals per day when energy density is at least 1.0 kcal/g. If a child typically consumes amounts that are less than the assumed gastric capacity at each meal, meal frequency would need to be higher than the values in table 15.

Conversely, the minimum dietary energy density required depends on meal frequency. Table 15 shows that the minimum energy density is about 0.65 kcal/g when there are five meals per day, 0.75 kcal/g when there are four meals per day, and 1.0 kcal/g when there are three meals per day.

These estimates provide a margin of safety because 2 SD has been added to the average energy requirement. Thus, not all children will need the number of meals shown in table 15. Since it is not possible to know which children have higher or lower energy requirements, caregivers should be attentive to the child's hunger cues when judging how often and how much to feed the child.

5. Review of experience with feeding nonbreastfed children

5.1 Replacement feeding of infants of HIV-positive mothers

Recent experience with replacement feeding of infants of HIV-positive mothers has reinforced concerns about the risks associated with bottle feeding of animal milks or infant formulas in developing countries. For example, in a study of 148 infants of HIV-positive mothers in India [31], the hospitalization rate during the follow-up period from birth to about 13 weeks was 0 among breastfed infants vs. 0.093 per 100 person-days in the replacement-fed infants ($p < .0001$). Four infants died, all of whom were replacement fed. In that setting, replacement feeding usually consisted of "top feeding," which is done with animal milk (cow, goat, or buffalo) diluted with water. Provision of ready-to-feed infant formula and instructions in its use could certainly reduce the risk of contamination and associated morbidity and mortality. However, in most situations contamination of milk fed by bottle is widespread. In periurban Peru, for example, 35% of bottle nipples tested positive for *Escherichia coli* [32], and in a semiurban slum in India, 54% of milk samples were contaminated by bacteria [33].

Aside from the issue of contamination, there has been concern about the nutritional adequacy of replacement diets. In formative research in Zambia to develop recommendations on replacement feeding, it was found that diets for infants over six months of age were nutritionally inadequate, even with breastmilk included, and that removing breastmilk would worsen the situation (E. Piwoz, personal communication).

Although some clinical and operational research

TABLE 15. Energy requirements, minimum meal frequency, and minimum dietary energy density for nonbreastfed children 6–24 months of age

Requirement	6–9 mo	9–12 mo	12–24 mo
Average energy requirement (kcal/day)	615	686	894
Energy requirement + 2 SD (+ 25%)	769	858	1,118
Functional gastric capacity (g/meal), based on 30 g/kg body weight	249	285	345
Number of meals required for given energy density			
0.6 kcal/g	5.1	5.0	5.4
0.8 kcal/g	3.9	3.8	4.1
1.0 kcal/g	3.1	3.0	3.2
Minimum energy density (kcal/g) required for given daily meal frequency			
3/day	1.03	1.00	1.08
4/day	0.77	0.75	0.81
5/day	0.62	0.60	0.65

studies have described the difficulties associated with implementing replacement feeding, few have reported on the micronutrient status of infants and young children in these studies or the association between nutritional status and the type of replacement feeding adopted. Nor is there clarity regarding the provision of micronutrient supplements to children in programs for the prevention of postnatal mother-to-child transmission of HIV infection (PMTCT).

To gather information on these issues, 10 research groups that are either involved with clinical PMTCT studies or are supporting operational programs in some capacity in eight countries in sub-Saharan Africa (Botswana, Côte d'Ivoire, Kenya, Malawi, South Africa, Uganda, Zambia, and Zimbabwe), were asked four questions regarding their study or program protocols:

» What replacement milk or food is recommended as an initial alternative to breastfeeding or after breastfeeding stops (especially after six months of age), and what support is offered?
» Are micronutrients offered to any children in the PMTCT study or program, and if so, what criteria are used to indicate that a child should receive supplements?
» What is the composition of the supplement, and how was this supplement chosen?
» What are the study or program recommendations regarding iron supplements for HIV-exposed infants, and what protocols are used for managing anemia?

The information obtained from those who responded (see Acknowledgments) is summarized below.

5.1.1 Replacement milk or food recommended and support offered

Research groups in Botswana, Côte d'Ivoire, Kenya, South Africa, and Zambia recommended and provided commercial infant formula as a breastmilk substitute for infants up to 12 months; some groups also provided bottles and teats or cups and also pots for sterilizing bottles. The national PMTCT programs in Botswana and South Africa provide infant formula to HIV-infected women for 12 and 6 months, respectively. In South Africa, a mother can avail herself of this supply any time in the child's first year of life, so that she may consider a period of exclusive breastfeeding and then use commercial infant formula to facilitate the transition from breastfeeding. In contrast to the national PMTCT programs, research groups in Côte d'Ivoire, Kenya, and Zambia provide free infant formula for varying periods. In Zambia, mothers participating in a study specifically designed to investigate the feasibility and the nutritional and morbidity consequences of early and abrupt cessation of breastfeeding are given infant formula along with a locally developed, nutrient-enriched cereal blend for three months to provide a nutritious diet when infants are weaned from breastmilk around four months of age.

In Malawi, Uganda, and Zimbabwe, research groups generally followed the national PMTCT protocols, which advocated exclusive breastfeeding unless the mother is able to purchase commercial infant formula herself and has the additional resources to safely prepare and store milk. After the infant is six months of age, full-cream unmodified cow's and goat's milk are also recommended. In Malawi, mothers participating in the research study are provided with the equivalent of 75 g/day of a locally produced, nutrient-fortified, ready-to-use food for infants made from peanuts, powdered milk, cooking oil, sugar, and a micronutrient premix.

Specific counseling on infant-feeding practices, including appropriate complementary feeding, is provided by all groups and programs. The quality, focus, and intensity of this counseling vary greatly, however, depending on the resources available.

5.1.2 Use of micronutrient supplements in PMTCT programs

National PMTCT protocols in each of the countries recommend vitamin A supplements every six months to all infants as part of the Integrated Management of Childhood Illness (IMCI) program. The South Africa PMTCT program also provides a multivitamin supplement containing vitamin A (900 µg), vitamin C (30 mg), vitamin B_1 (1.65 mg), vitamin B_2 (1.32 mg), vitamin B_6 (1 mg), niacin (11 mg), and vitamin D (300 IU/5 ml) to all HIV-exposed infants. The rationale for this was that infected infants would probably benefit, although there was no evidence base for this recommendation and there are no explicit recommendations regarding nonbreastfed infants, especially after six months of age. In a research program in Botswana to study the effect of an antiretroviral regimen given to breastfed infants, a comparable multivitamin preparation (vitamin A 2,330 IU, vitamin D 200 IU, thiamine 1 mg, riboflavin 1.2 mg, pyridoxine 0.5 mg, nicotinamide 5 mg, vitamin C 35 mg, and vitamin B_{12} 2.5 µg/5 ml) is recommended for all breastfed infants to avoid nutritionally related hematological abnormalities that might otherwise be attributed to the antiretroviral regimen.

In a research program in Malawi also investigating the effect of an antiretroviral regimen for HIV-infected mothers and/or their infants, a nutrient-rich, ready-to-use food is provided to infants who are rapidly weaned. The daily quantity of this food is designed to provide vitamin A (683 µg), vitamin C (40 mg), vitamin B_1 (0.5 mg), vitamin B_2 (1.4 mg), vitamin B_6 (0.5 mg), vitamin B_{12} (1.4 µg), folic acid (158 µg), pantothenic acid (2.3 mg), and niacin (4.0 mg), as well as Ca (240 mg), P (296 mg), K (833 mg), Mg (69 mg), Zn (10.5 mg), Cu (1.3 mg), and Fe (8.6 mg). For most nutrients, this formulation was based on replacing the nutrients that breastmilk would otherwise provide to infants 6 to 12 months of age. The product was already available in Malawi and had been formulated as part of the protocol for the treatment of children with severe malnutrition. It had been found to be well tolerated and safe in this setting.

In Zimbabwe, the PMTCT protocol advocates providing “multivitamins” to nonbreastfed infants receiving modified animal milk. However, these are not generally available, and locally manufactured, commercially available multivitamin preparations contain only vitamin A (2,000 IU), vitamin B_1 (1 mg), vitamin B_2 (1 mg), vitamin C (30 mg), and nicotinamide (7 mg/5 ml). Externally supported programs provide the same preparation to infants found to have growth faltering. In the Zambia Exclusive Breastfeeding study, micronutrients are provided via commercial infant formula and by a nutrient-enriched cereal blend containing vitamin A, vitamin E, vitamin C, vitamin D, vitamin B_1, vitamin B_2, vitamin B_3, vitamin B_6, folate, vitamin B_{12}, zinc sulfate, ferrous fumarate, magnesium, and iodine. This was developed by the Zambian National Institute for Scientific and Industrial Research in collaboration with the US Department of Agriculture as a complete replacement diet and is made from locally available foods. It is reportedly highly acceptable to mothers and is easy to prepare. No other supplements are provided in the national PMTCT program.

5.1.3 Use of iron supplements for HIV-exposed infants and management of anemia

None of the PMTCT protocols had an explicit recommendation for iron supplementation before or after the age of six months, regardless of whether the child had been breastfed, abruptly changed from breastmilk to another replacement feed, or replacement fed from birth; each deferred to national protocols or made no comment at all. In the Malawi research project, hemoglobin is tested at all follow-up visits, and adverse events are graded according to age (< 3, 3, or > 3 months) and severity. Iron supplements are not routinely given, since the ready-to-use food (RTUF) is fortified with iron.

National protocols generally recommended oral iron (6 mg of elemental iron/kg/day) with or without folate or multivitamins for treating mild to moderate clinical anemia, preferably with biochemical evidence of iron deficiency; transfusion is generally recommended if hemoglobin drops below 60 g/L. In Zimbabwe, preterm or low-birthweight infants are supposed to receive vitamin D and folate for three months from birth, and iron supplements from one to three months of age. Other countries reported using IMCI guidelines, which include dietary recommendations to improve iron intake and prevention of malaria; prophylactic iron supplementation is recommended in Uganda, though implementation is not always effective.

5.1.4 Need for consistent guidelines and further research

Respondents to the above questions were uniformly interested in learning about the approach of other groups. The WHO technical group on HIV and Nutrition highlighted the need to identify the daily requirements and safe limits for micronutrients in HIV-infected adults and children [34]. Even if a child is not infected with HIV, the likelihood of micronutrient deficiencies during this age period is high. Thus, there is a need for consistent guidelines regarding the types and amounts of fortified products or supplements that are recommended for nonbreastfed children. Research on products that are safe to use in developing-country settings is particularly important. For example, a South African food that may be useful in feeding nonbreastfed infants is a fermented cow’s milk product that does not require refrigeration. Although milk products are generally low in iron, it may be possible to fortify such a product for use as a lower-cost, potentially safer alternative to commercial infant formula.

5.2 Adaptation of products used for malnourished children

Although there are published guidelines and formula recipes (e.g., F100 for feeding children with serious infections or severe malnutrition [35]), these are not directly applicable to nonbreastfed children in general. This is because the energy and protein needs of recovering severely malnourished children are much higher than normal, and those who are recovering from serious infections need special diets to minimize adverse reactions such as diarrhea induced by temporary lactose intolerance. Furthermore, the formulas recommended, such as F100, are not as useful for home-based feeding in contaminated environments because they provide an excellent growth medium for pathogenic bacteria.

An earlier version of the Nutributter product described herein (called ready-to-use food, RTUF) was originally developed as an alternative to the F100 formula for rehabilitation of severely malnourished children (after the initial phase of treatment). The advantages of RTUF are that it is resistant to bacterial contamination because it contains no water, can be eaten directly by the child without the addition of water, and has a very high energy and nutrient density. In a recent randomized trial comparing the efficacy of RTUF with that of the F100 formula fed to malnourished children 6 to 36 months of age in a clinical setting in Senegal, the RTUF group had significantly greater daily energy intake and weight gain and a shorter duration of rehabilitation than the F100 group [36]. This demonstrated that a product such as Nutributter can be successfully used to promote weight gain. The RTUF product is now being used for malnourished children in Malawi, and as mentioned above, the same program recently began trying it for children of HIV-positive mothers in the community, because infant formula is considered too risky. So far, there have been no major logistical or acceptability problems in using it, even for children younger than 12 months. A peanut-free version is now ready for field testing (André Briend, personal communication).

In the above trials, a relatively large amount of RTUF was fed, and it was consumed directly from the sachet rather than being mixed with other foods. For severely malnourished children who require very high energy intake, this may be the best strategy, but for nonbreastfed children in general, it would be less expensive to use a small amount of the product as a supplement (either eaten alone or mixed with other foods). The LP runs described in section 3.5.2 indicate that 20 g of Nutributter is generally sufficient in a diet that does not contain animal-source foods, as long as other nutritious foods, such as fruits and vegetables, are available. When the types of foods are even more limited, a larger quantity of Nutributter can be used to satisfy nutrient needs.

The total fluid needs of children fed RTUF or Nutributter should be kept in mind, since the product does not contain water. Fluid needs can be partially satisfied by including animal milks (with due attention to hygiene), but they can also be met by providing plain boiled water or preparing porridges or soups from the foods listed in the diets shown in tables 4 to 12.

6. Conclusions and limitations

The literature reviewed and the results of the LP runs described above suggest the following conclusions:

1. Animal milk, such as undiluted whole cow's milk, can be fed to infants after six months of age, provided that iron supplements or iron-fortified foods with adequate bioavailability are consumed and the amount of fluid in the overall diet is adequate (see section 3.6). Animal milk, such as cow's milk, is a good source of several key nutrients. When the diet does not include fortified foods or supplements, the amounts of milk needed daily range from less than 200 to approximately 370 ml if other animal-source foods are included in the diet, and from approximately 300 to 500 ml if they are not. Raw milk (i.e., not boiled or pasteurized) should be avoided because of the risk of disease transmission. Fermented milk products (e.g., yogurt) hold promise for reducing the risk of illness due to contamination, since they are more resistant to bacterial growth and can be fed more easily by spoon or cup rather than by bottle, as compared with nonfermented liquid milk. Commercial infant formula is an option when it is available and affordable, can be safely used, and provides a nutritional or other advantage over animal milk (e.g., when fortified food products or supplements are not available or are more expensive). In these circumstances, the daily amount of formula needed at 6 to 12 months of age is approximately 280 to 500 ml if other animal-source foods are included in the diet and approximately 400 to 550 ml if they are not.

2. To meet nutrient needs, animal-source foods other than milk are also needed unless multiple micronutrient supplements or fortified products are provided. The daily amounts included in the LP analyses were 50 g of egg (one egg) and 14 to 75 g of meat, poultry, fish, or chicken liver.

3. Iron supplements or fortified products are needed in nearly all situations, in daily amounts ranging from 1 to 8 mg Fe, depending on the age range and other foods in the diet. If animal-source foods are not available, supplements of zinc (0.3–1.5 mg/day) and calcium (5–117 g/day at 6–12 months, 210–330 g/day at 12–24 months) are also needed.

4. Grain products, legumes, fruits, and vegetables should also be included in the diet. If milk and other animal-source foods are not consumed in adequate amounts, both grains and legumes should be consumed daily, if possible within the same meal, to ensure adequate protein quality. In general, one or two types of fruit and one to three types of vegetables per day can be recommended. The amounts included in the LP analyses can be found in tables 4 to 12. These are meant to be examples of the types and amounts of foods to include, not explicit dietary guidelines. Such guidelines need to be created at the local level, based on the types of foods available in the area and at different seasons of the year.

5. If fortified products such as Nutributter, Sprinkles, Foodlets, or CSB are available, there is no need for commercial infant formula, and nonmilk animal-source foods are optional. With adequate levels of micronutrients in the product, there is also no need for additional supplements. If milk is included in the diet, the amount needed is generally less than when fortified products are not included. If milk is not included in the diet, calcium needs may not be completely met (because some of the products contain little or no calcium), and the product would need to contain vitamin B_{12} if there are no other animal-source foods in the diet. Fortified products allow for a simpler and presumably more affordable diet, depending on local food composition and costs.

6. Cost comparisons of three different complementary food supplements (Nutributter, Foodlets, and Sprinkles) and CSB indicate that at 6 to 12 months, the Nutributter or CSB options resulted in lower-cost diets in some situations, but otherwise the costs were similar. At 12 to 24 months, the CSB option was least

expensive. Because it is difficult to incorporate all of the essential micronutrients into Foodlets or Sprinkles, the diets using those options sometimes required a wider variety or larger quantities of fruits and vegetables than the diets based on the Nutributter or CSB options. Nonetheless, the choice of which type of product to use will depend on local circumstances. There is limited experience with the use of complementary food supplements in community settings, but preliminary evidence indicates that they are acceptable to mothers and infants.

7. If animal-source foods are not consumed regularly, 10 to 20 g of added fats or oils are needed unless a fat-rich food is given (such as foods or pastes made from groundnuts, other nuts, and seeds). If animal-source foods are consumed, up to 5 g of additional fats or oils may be needed in some circumstances. Good sources of essential fatty acids (e.g., fish, avocado, nut pastes, and most vegetable oils) should be included.

8. Nonbreastfed infants need at least 400 to 600 ml/day of water (in addition to water contained in foods, including milk) in a temperate climate, and 800 to 1200 ml/day in a hot climate. This water can be incorporated into porridges or other foods, but plain, clean (boiled, if necessary) water is less prone to contamination and should be offered several times per day to ensure that the infant's thirst is satisfied.

9. The number of meals required by nonbreastfed children depends on the energy density of the local foods and the usual amounts consumed at each feed. When the energy density is at least 0.8 kcal/g and children are fed to satiety, four or five meals per day are needed (meals include milk-only feeds, other foods, and combinations of milk feeds and other foods). If the energy density or the amount of food per meal is low, more frequent meals may be required. In all situations, responsive feeding practices that are sensitive to the child's hunger and satiety cues are advisable [3].

It is important to keep in mind that there are several limitations to the LP analyses described here.

First, the analyses are based on meeting the needs for selected nutrients (energy, fat, protein, vitamin A, thiamine, riboflavin, vitamin B_6, folate, vitamin C, calcium, iron, and zinc), not for all of the essential nutrients. Although these are the nutrients considered to be most limiting at this age, the results could be different if other micronutrients were included, such as vitamin E, iodine, phosphorus, selenium, or essential fatty acids. Unfortunately, there is inadequate or unreliable information on the content of these nutrients in many foods, precluding their inclusion in the LP analyses.

Second, there is still uncertainty about the RNI values during infancy, as explained in section 3.2.4, so the results could differ if better estimates were available.

Third, the food-composition data used are subject to error, and there is considerable variability in nutrient content due to local conditions, such as soil, cultivar, processing, etc.

Fourth, although the LP analyses take the bioavailability of iron, zinc, and calcium into account, the calculations are based on the entire day's diet, not the bioavailability of the food in each individual meal. This introduces some unavoidable error into the results.

Fifth, the maximum amounts of individual foods allowed in these analyses were based on a limited number of dietary studies, mostly of breastfed infants under 12 months of age. There was little information on the quantities that could be consumed in the second year of life. As a result, the solutions for children from 12 to 24 months may have been overly constrained by the limitations imposed on food quantity.

Finally, the food cost estimates used in specific LP analyses could be incorrect, and will certainly vary by region and across time. Use of different food costs can greatly alter the types and amounts of foods that appear in the LP solutions.

Several of the above limitations can be overcome by running the LP analyses using locally available data specific to the region of interest. It is important to note that tables 4 to 12 in this report are intended to be an overall guide, not recommendations to be applied to all settings. If local food composition and cost information is available, local authorities can conduct their own assessment of dietary needs for nonbreastfed children in their area. This may yield solutions that differ somewhat from those shown in this report. For example, dietary data from a research study of 242 children 6 to 23 months of age in Malawi (representing 320 dietary records) were obtained [37] (Dr. Christine Hotz, personal communication) and run through the same LP analyses as described here. The resulting solutions were similar to those for Ghana, but because the maximum amounts of certain foods consumed were greater in Malawi than in Ghana (e.g., green leafy vegetables, beans, and pumpkin), the diets included more of these foods and fewer animal-source foods (though iron supplements were still needed). Once a local assessment is completed using LP, further work is needed to develop recipes and dietary guidelines that can be used by caregivers. This will need to include careful attention to the amount of fluid needed in the overall diet, as explained in section 3.6.

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Feeding of nonbreastfed children from 6 to 24 months of age

Conclusions of an informal meeting on infant and young child feeding organized by the World Health Organization, Geneva, March 8–10, 2004

Informal Working Group on Feeding of Nonbreastfed Children

According to current United Nations recommendations, infants should be exclusively breastfed for the first six months of life and thereafter should receive appropriate complementary feeding with continued breastfeeding up to two years or beyond. However, there are a number of infants who will not enjoy the benefits of breastfeeding in the early months of life or for whom breastfeeding will stop before the recommended period of two years or beyond. A group that calls for particular attention consists of the infants of mothers who are known to be HIV positive. To reduce the risk of HIV transmission, it is recommended that when it is acceptable, feasible, affordable, sustainable, and safe, these mothers give replacement feeding from birth. Otherwise, they should breastfeed exclusively and stop as soon as alternative feeding options become feasible. Another group includes those infants whose mothers have died, or who for some reason do not breastfeed.

Recommendations for appropriate feeding of breastfed infants from six months onwards have been summarized by the Pan American Health Organization (PAHO) in the publication *Guiding Principles for Complementary Feeding of the Breastfed Child* [1]. Some of these Guiding Principles are not applicable to nonbreastfed children, whereas others need adaptation. The World Health Organization (WHO) convened this informal meeting to identify an analogous set of guiding principles for feeding nonbreastfed children after six months of age.

The outline of the adapted Guiding Principles is presented in Box 1. These guidelines were developed on the basis of the evidence presented in the background document published in this issue of the *Food and Nutrition Bulletin* [2] and developed based on consensus by participants in the meeting [3].

Beyond the development of these Guiding Principles, the following points were discussed:

Duration of exclusive breastfeeding in the context of HIV

A previous meeting examined the issue of infant feeding in the context of HIV/AIDS and concluded that when breastmilk substitutes were not acceptable, feasible, affordable, sustainable, and safe, then exclusive breastfeeding (breastmilk only, with no other food or drink except vitamin and mineral drops, not even water) should be recommended for the first few months [4]. In the present meeting, it was also acknowledged that the precise timing of breastfeeding cessation should be determined after examining the risks attached to early cessation and continuation of breastfeeding. It was confirmed that the optimal time of breastfeeding cessation varies according to individual circumstances. Attention was drawn to the risk of recommending complete early cessation of breastfeeding for mothers with no safe option for infant feeding after that time.

Expressing and heat-treating breastmilk to reduce the risk of HIV transmission

Boiling breastmilk may damage some of its nutrients and does not seem an acceptable option. An adapted method of breastmilk pasteurization developed in Pretoria seems more suitable: boiling a pan of water, removing it from the heat source, and immediately placing a covered glass jar of breastmilk in the water for 20 minutes was shown in two studies to eliminate HIV [5, 6]. Heating a pan of water with a jar of breastmilk in it until the water begins to boil, and then immediately removing the jar from the water, eliminated the virus in another study [7]. The safety of these approaches

The members of the Informal Working Group are listed at the end of the text of this article. Please direct queries to: Dr André Briend (brienda@who.int) or Dr. Peggy Henderson (hendersonp@who.int) at the World Health Organization Department of Child and Adolescent Health and Development, Geneva.

BOX 1. Summary of Guiding Principles for feeding nonbreastfed children 6 to 24 months of age

1. Amount of Food Needed

Guideline: Ensure that energy needs are met. These needs are approximately 600 kcal/day at 6–8 months of age, 700 kcal/day at 9–11 months of age, and 900 kcal/day at 12–23 months of age.

2. Food Consistency

Guideline: Gradually increase food consistency and variety as the infant gets older, adapting to the infant's requirements and abilities. Infants can eat puréed, mashed, and semisolid foods beginning at 6 months. By 8 months most infants can also eat "finger foods" (snacks that children can eat on their own). By 12 months, most children can eat the same types of foods as consumed by the rest of the family (keeping in mind the need for nutrient-dense foods; see #4 below). Avoid foods in a form that may cause choking (i.e., items that have a shape and/or consistency that may cause them to become lodged in the trachea, such as nuts, grapes, raw carrots). Such foods should be mashed, puréed, or juiced before being fed to young children.

3. Meal Frequency and Energy Density

Guideline: For the average healthy infant, meals should be provided 4–5 times per day, with additional nutritious snacks (such as pieces of fruit or bread or chapatti with nut paste) offered 1–2 times per day, as desired. The appropriate number of feedings depends on the energy density of the local foods and the usual amounts consumed at each feeding. If energy density or amount of food per meal is low, more frequent meals may be required.

4. Nutrient Content of Foods

Guideline: Feed a variety of foods to ensure that nutrient needs are met.

» Meat, poultry, fish, or eggs should be eaten daily, or as often as possible, because they are rich sources of many key nutrients such as iron and zinc. Milk products are rich sources of calcium and several other nutrients. Diets that do not contain animal-source foods (meat, poultry, fish, or eggs, plus milk products) cannot meet all nutrient needs at this age unless fortified products or nutrient supplements are used.

» If adequate amounts of other animal-source foods are consumed regularly, the amount of milk needed is ~200–400 ml/d; otherwise, the amount of milk needed is ~300–500 ml/d. Acceptable milk sources include full-cream animal milk (cow, goat, buffalo, sheep, camel), ultra-high temperature (UHT) milk, reconstituted evaporated (but not condensed) milk, fermented milk or yogurt, and expressed breast milk (heat-treated if HIV-positive).

» If milk and other animal-source foods are not eaten in adequate amounts, both grains and legumes should be consumed daily, within the same meal if possible, to ensure adequate protein quality.

» Dairy products are the richest sources of calcium. If dairy products are not consumed in adequate amounts, other foods that contain relatively large amounts of calcium, such as small fish that include the bones (dried or fresh, with the bones crushed or otherwise processed so that they are safe to eat) and lime-treated maize tortillas, can fill the gap. Other foods such as soybeans, cabbage, carrots, squash, papaya, green leafy vegetables, guava, and pumpkin are useful additional sources of calcium.

» The daily diet should include vitamin A-rich foods (e.g., dark-colored fruits and vegetables, red palm oil, vitamin A fortified oil or foods); vitamin C rich foods (e.g., many fruits, vegetables, and potatoes) consumed with meals to enhance iron absorption; and foods rich in the B vitamins, including riboflavin (e.g., liver, egg, dairy products, green leafy vegetables, soybeans); vitamin B6 (e.g., meat, poultry, fish, banana, green leafy vegetables, potato and other tubers, peanuts); and folate (e.g., legumes, green leafy vegetables, orange juice).

» Provide diets with adequate fat content. If animal-source foods are not consumed regularly, 10–20 g of added fats or oils are needed unless a fat-rich food is given (such as foods or pastes made from groundnuts,

continued

needs further evaluation. Their acceptability remains an open question.

Use of plain cow's milk for feeding nonbreastfed children

The use of plain cow's milk raises some concerns because of the low content and bioavailability of iron in cow's milk, possible occult gastrointestinal blood loss, and high potential renal solute load. These concerns should not prevent the use of cow's milk after the age of six months. Iron deficiency can be prevented by adequate supplementation. Occult blood loss decreases with age and usually disappears by the age of 12 months. Heat-treated cow's milk does not provoke blood loss. The potential renal solute load of cow's milk is indeed higher than that of breastmilk but this does not seem to be a problem in children more than six months of age, who have a more mature kidney function, provided the child is regularly offered plain water [2].

Support for replacement feeding after six months

In resource-poor settings, families may require extra support to appropriately feed infants after early cessation of breastfeeding. Several alternative ways of achieving this were discussed in the meeting. The World Food Program is developing a strategy to integrate food aid with programs for Prevention of

BOX 1. Summary of Guiding Principles for feeding nonbreastfed children 6 to 24 months of age *(continued)*

other nuts, and seeds). If animal-source foods are consumed, up to 5 g of additional fats or oils may be needed.

» Avoid giving drinks with low nutrient value, such as tea, coffee, and sugary soft drinks. Limit the amount of juice offered, to avoid displacing more nutrient-rich foods.

5. Use of Vitamin-Mineral Supplements or Fortified Products
Guideline: As needed, use fortified complementary foods or vitamin-mineral supplements (preferably mixed with or fed with food) that contain iron (8–10 mg/day at 6–12 months, 5–7 mg/day at 12–24 months). If adequate amounts of animal-source foods are not consumed, these fortified foods or supplements should also contain other micronutrients, particularly zinc, calcium, and vitamin B12. In countries where vitamin A deficiency is prevalent or where the under-five mortality rate is more than 50 per 1000, it is recommended that children 6–24 months old receive a high-dose vitamin A supplement (100,000 IU once for infants 6–12 months old and 200,000 IU biannually for young children 12–23 months old).

6. Fluid Needs
Guideline: Nonbreastfed infants need at least 400–600 ml/day of extra fluids (in addition to the 200–700 ml/day of water estimated to come from milk and other foods) in a temperate climate, and 800–1200 ml/day in a hot climate. Plain, clean (boiled, if necessary) water should be offered several times per day to ensure that the infant's thirst is satisfied.

7. Safe Preparation and Storage of Foods
Guideline: Practice good hygiene and proper food handling by a) washing caregivers' and children's hands with soap before food preparation and eating, b) storing foods safely and serving foods immediately after preparation, c) using clean utensils to prepare and serve food, d) using clean cups and bowls when feeding children, and e) avoiding the use of feeding bottles, which are difficult to keep clean (for additional details, see WHO Complementary Feeding: Family foods for breastfed children, 2000 and Five Keys to Safer Food http://www.who.int/foodsafety/publications/consumer/5keys/en/).

8. Responsive Feeding
Guideline: Practice responsive feeding, applying the principles of psychosocial care. Specifically, feed infants directly and assist older children when they feed themselves, being sensitive to their hunger and satiety cues; feed slowly and patiently, and encourage children to eat, but do not force them; if children refuse many foods, experiment with different food combinations, tastes, textures, and methods of encouragement; minimize distractions during meals if the child loses interest easily; and remember that feeding times are periods of learning and love — talk to children during feeding, with eye-to-eye contact.

9. Feeding During and After Illness
Guideline: Increase fluid intake during illness and encourage the child to eat soft, varied, appetizing, favorite foods. After illness, give food more often than usual and encourage the child to eat more.

Mother-to-Child Transmission (PMTCT) of HIV, and hence could target infants and young children of HIV-positive mothers with supplementary foods such as corn-soya blend or an equivalent alternative after the cessation of breastfeeding. These fortified foods were not initially designed for replacement feeding but may be useful additional sources of micronutrients to supplement the diet of nonbreastfed children. The Food and Agriculture Organization (FAO) is supporting an approach that involves strengthening of livelihoods and food security for individuals and households infected and affected by HIV/AIDS. Linkage of these efforts with PMTCT programs offers the potential for providing support to increased household food production at an early stage, during pregnancy and in the postpartum period. As an alternative option, the participants discussed the provision of free formula as a supplement to the local diet after early cessation of breastfeeding. Substantial experience has been gained in this field by UNICEF and some governments that supported the provision of free formula to HIV-positive women starting from birth as part of PMTCT programs. There are obvious health risks associated with formula feeding if the formula is not prepared and given safely, as well as the potential of spillover to the general population. The participants agreed that if free formula were to be considered, mothers should be guided by skilled counselors. Free distribution should also comply with the provisions laid down in the International Code of Marketing of Breast-Milk Substitutes and subsequent World Health Assembly resolutions [8].

Next steps

The Guiding Principles for feeding nonbreastfed children 6 to 24 months of age, together with their rationale, will be presented in an official WHO document currently under preparation. For further details, kindly consult the following websites: http://www.who.int/child-adolescent-health/ and http://www.who.int/nut. Accessed September 12, 2004.

Participants in the meeting who formed the informal working group were Rajiv Bahl, Peter Ben Embarek, Bruno de Benoist, Nita Bhandari, André Briend, Bernadette Daelmans, Kathryn Dewey, Ruskshana Haider, Peggy Henderson, Sultana Khanum, Sophie Leonard, Chessa Lutter, Jose Martines, Mirella Mokbel

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Future challenges

E-Siong Tee, Marie Claude Dop, and Pattanee Winichagoon

Abstract

The workshop "Food-consumption surveys in developing countries: Future challenges," held in Chiang Rai, Thailand, January 25–26, 2003, brought together 30 nutritionists and food safety experts from 10 Southeast Asian countries as well as from countries outside the region. It provided a forum for sharing information and experiences relating to food-consumption survey methodology. It enabled detailed discussions of the gathering of food-consumption data in developing countries for purposes of nutrition assessment, exposure assessment, and studies of diet-disease relationships. The workshop participants emphasized the need to obtain the support of policy and decision makers to establish a mechanism for conducting regular coordinated food-consumption surveys to meet these needs. The participants emphasized the importance of identifying all relevant stakeholders and involving them in the planning and conduct of these surveys. A number of technical issues related to food-consumption surveys were discussed, including food-intake methodologies. It was felt that surveys on individuals are preferred, and a combination of 24-hour recall and food-frequency questionnaire would most likely provide the required data. The workshop emphasized the need to develop, maintain, and update databases at the national and regional levels for nutrients and non-nutrients as well as contaminants and food additives. To ensure that surveys are conducted regularly and professionally, the importance of having qualified and trained personnel was emphasized. Several issues related to reports of food-consumption data were discussed, including timely reporting, effective dissemination, and appropriate usage. The participants unanimously recommended the organization of further technical meetings or workshops to follow up on recommended activities and enable continuing regional collaboration on food-consumption surveys.

Key words: food consumption surveys, nutrition assessment, exposure assessment

Background

Food-consumption surveys are indispensable tools for assessing nutrient intake. In developing countries, their traditional goal has been to assess the prevalence of inadequate intakes and trends in food consumption, mostly through large national or subnational nutrition surveys. Food-consumption data are needed to develop appropriate Food-Based Dietary Guidelines and to monitor changes in dietary behaviors and patterns. With rapid social and economic development, assessing non-nutrient intakes and exposure to additives and contaminants, as well as establishing diet-disease relationships, are becoming important additional goals of food-consumption surveys in developing countries.

The first effort in regional collaboration in food-consumption surveys was a seminar on nutrition assessment methods for National Nutrition Surveys held in Kuala Lumpur in 1997, initiated by the Institute for Medical Research (IMR) [1]. In September 2000, the International Life Sciences Institute Southeast Asia Region (ILSI SEAsia), with the support of the IMR

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Proceedings of a Workshop jointly organized by the Food and Agriculture and Organization of the United Nations (FAO), the International Life Sciences Institute (ILSI) SouthEast Asia Region, and the Institute of Nutrition, Mahidol University (INMU), Thailand, January 25–26, 2003, Chiang Rai, Thailand, as a satellite meeting of the 5th International Conference on Dietary Assessment Methods.

and of the Nutrition Society of Malaysia, organized a follow-up workshop in Kuala Lumpur.* In October of that year, another workshop was held in Beijing in conjunction with the Third Asian Conference on Food Safety.** As a follow-up to these previous meetings, a workshop on food-consumption surveys was organized on January 25–26, 2003, as a satellite meeting of the Fifth International Conference on Dietary Assessment Methods held in Chiang Rai, Thailand.

This report contains a summary of the proceedings, including information on the organizers and participants, workshop highlights (comprising opening remarks and summaries of the two keynote lectures and six country reports), and workshop discussions and recommendations. The full text of the two keynote lectures is presented in this issue of the *Food and Nutrition Bulletin*, pages 317–329.

Organizers and participants

The Food and Agriculture Organization (FAO) of the United Nations, the International Life Sciences Institute (ILSI) Southeast Asia Region, and the Institute of Nutrition, Mahidol University, Thailand, jointly organized the workshop.

Some 30 nutritionists responsible for national or large-scale nutrition/food-consumption surveys and food safety officers from developing countries participated in the workshop. They came from all 10 Southeast Asian countries as well as from outside the region, from Burkina Faso, China, Iran, and Mexico. Experts from five other countries—France, Italy, New Zealand, Japan, and the United States—acted as resource persons. In addition, relevant key officials from FAO and ILSI SEAsia Region participated in the meeting.

Workshop highlights

Opening remarks

Dr. Kraisid Tontisirin, Director of the Food and Nutrition Division of the FAO, Rome, declared the workshop open. In his opening address, he emphasized that assessing food and nutrition situations is a very important step leading to strategic policy formulation. He called on all nations to continue to allocate sufficient resources and personnel for such purposes. Traditionally, food-consumption data are used to determine nutrient adequacy. In addition to this, food-consumption data have wider uses for nutrition purposes, including studies of the relationship between diet and chronic diseases. In recent years, such data have become recognized as vital for determining exposure to contaminants (microbiological, chemical), to food additives, and even to excessively high levels of nutrients. For this reason, Dr. Tontisirin felt that collaboration among various professionals (nutritionists, food safety experts, agriculturists, etc.) is crucial to obtain food-consumption data that will meet the needs for the above-mentioned purposes. This is particularly important for developing countries because of the limited resources available. He urged nutritionists to play a greater role in exposure assessment. He called for greater collaboration among developing countries in their attempt to provide more data for the development of global standards, e.g., for the Codex Alimentarius. Dr. Tontisirin commended the various agencies involved in the timely organization of this workshop, which is an important step in promoting future collaborative ventures to add newer dimensions to food-consumption surveys and to strengthen and refine methodologies.

Mrs. Yeong Boon Yee, Executive Director of ILSI SEAsia, welcomed the participants to the workshop. She first gave a brief outline of the organization, objectives, and main activities of ILSI. She emphasized that ILSI SEAsia is involved in several food-consumption surveys in the region, particularly among children. In recent years, the organization has also supported work on food composition in the region. She went on to highlight the series of workshops on food-consumption methodologies that have been organized in Southeast Asia in recent years. She pointed out that in order to ensure effective discussions about meeting the objectives of the workshop, the organizers invited the participation of nutritionists as well as of experts in food safety and agriculture.

Dr. Songsak Srianujata, Director of the Institute of Nutrition, Mahidol University (INMU), cohost of the workshop, also welcomed the participants to the meeting and to Thailand. He highlighted the wider use of food-consumption data in recent years, beyond nutritional assessment. He gave the example of the use of such data in risk assessment. He called for greater collaborative efforts among developing countries in the region in order to collect more and better food-consumption data.

* Tee ES. Report of the workshop on harmonization of methods for National Nutrition Surveys and dietary studies in Southeast Asia, 28–29 September 2000, Kuala Lumpur. Unpublished report of the Division of Human Nutrition, Institute for Medical Research, Kuala Lumpur; 4 pp.

** Tee ES. Report of workshop on dietary survey of methodologies in Asia, 3 October 2000, Beijing, China. Unpublished report of the Division of Human Nutrition, Institute for Medical Research, Kuala Lumpur, 5 pp.

Summaries of keynote presentations

The first keynote lecture, entitled "Methodologic considerations in descriptive food-consumption surveys in developing countries," was presented by **Dr. Gail Harrison** [2], School of Public Health, University of California, Los Angeles, California, USA. In her introduction, she mentioned the diverse uses of food-consumption data for monitoring trends in dietary patterns, developing of food-based dietary guidelines and educational tools, investigating nutrition-disease relationships, and estimating exposure to contaminants. She discussed the pros and cons of stand-alone surveys versus integrating food consumption with other types of data into common surveys. She also discussed issues related to sampling and sample size considerations, as well as seasonal variations.

The paper gave a great deal of attention to issues related to the development of survey protocols and instruments. This includes detailed discussions of the use of appropriate methods for collecting food-consumption data and the choice of the individual or the household as the sampling unit. Community acceptance and culture-specific issues were also discussed. Dr. Harrison highlighted several culture-specific measurement challenges (e.g., shared dishes, sequential eating, nonstandard serving and eating tools, intake of items added at the table, and eating outside the home).

With regard to the problem of reporting bias, Dr. Harrison emphasized that this is central to the interpretation of data from food-consumption surveys and has been very little explored in the context of developing-country environments. Cross-country and cross-region comparability are increasingly important issues, for which standardized tools are required, e.g., standardized or harmonized protocols, manuals, software, survey tools (recipes, etc.), analytical methods, and food-composition databases. She felt that there are two major types of analytical tool required: adequate, harmonized, updated, and well-documented food-composition databases; and flexible, affordable software to provide the interface among foods, ingredients, and nutrients and other components. She further outlined several desirable key features of a good food-composition database and an ideal front-end software.

Dr. Jean Pennington of the Division of Nutrition Research Coordination, National Institutes of Health, Bethesda, Maryland, USA, delivered a presentation entitled "General approaches to estimation of dietary exposure to contaminants" [3]. She outlined the preliminary steps to be taken: gathering the necessary expertise, clarifying the intent and purpose of the work, selecting the exposure model, gathering available pertinent information, and determining additional needs and resources. Expertise is generally needed in chemistry, agriculture, toxicology, statistics, nutritional epidemiology, and computer software development. Two basic types of data are required: the kinds of food containing the contaminants and the levels of the contaminants; and how much of these foods are consumed and by whom. The main questions that might be asked in exposure assessment are: What are the daily exposures of contaminants for people in a defined geographic region? How do the exposures compare with the acceptable or tolerable standards of intake? She emphasized that it is important to understand the unique features of each contaminant, including the chemistry, distribution, and pattern of flow through the food and water supply; the effects of agricultural, environmental, and processing variables on its levels in finished food; and its physiology (bioavailability, absorption, and body storage).

Dr. Pennington outlined five models for estimating exposure: the core food model, the directed core food model, the large database model, the raw agricultural commodity (RAC) model, and the duplicate diet model. The types of data or information to gather would include analytical data on contaminants in commodities, foods, and food products; government regulations on pesticide use and standards of intake for contaminants and residues; and food-consumption data for the population. Exposure to contaminants is expressed as the weight of substance ingested per person per day, or per kilogram of body weight per day. Biochemical measurements of contaminants or their metabolites from national health surveys may serve as a means of validating dietary exposure assessments, or they may be built in as part of the dietary exposure model. Dr. Pennington felt that progress might be more substantial if various organizations within a country or region joined together to share resources and information in exposure assessment.

Summaries of country reports

The two keynote lectures were followed by six brief reports by country representatives on experiences in conducting national food-consumption and nutrition surveys in developing countries.

Dr. Corazon Barba of the Food and Nutrition Research Institute of the Philippines spoke on "Periodic National Nutrition Surveys in the Philippines." The general objective of the surveys is to reassess the food situation and the nutritional status of the population of the Philippines approximately every five years for the appropriate formulation and modification of food and nutrition policies and intervention programs, as well as related development programs. The specific objectives include providing comprehensive data on per capita food consumption and nutrient intake and on adequacy at the national and subnational levels. Another important specific objective is to analyze trends in food consumption and other key nutrition variables in relation to the socioeconomic situation.

The first National Nutrition Survey was conducted in 1978 and the second in 1982, followed by the third in 1987 and the fourth in 1993. Dr. Barba described the sampling design and coverage of each of the surveys. For the first three surveys, a three-stage stratified sampling was used, whereas for the fourth survey, a two-stage stratified procedure was employed. At the household level, the food-consumption methodologies included food records and recalls and food inventories. At the individual level, the method used was food recall. She outlined the flow of activities in food-consumption surveys. The results obtained included mean one-day food consumption according to food group and subgroup, mean one-day per capita nutrient intake and percent adequacy, the list of food items most commonly consumed, food and nutrient intakes by selected socioeconomic parameters, percent contribution of macronutrients to energy intake, and one-day dietary patterns and food wastage.

Dr. Barba summarized the uses of food-consumption data in the Philippines, which are important in relation to the food-fortification efforts of the food industry and serve as a basis for the formulation of Recommended Dietary Allowances and Nutritional Guidelines for Filipinos as well as for nutrition advocacy. The data were also used for evaluation of the adequacy of menus of the different regions and provinces, for agricultural planning at all levels, and for formulating the Philippines Plan of Action for Nutrition. She also highlighted some areas where food-consumption data are underutilized, e.g., in the study of diet-disease relationships, monitoring of dietary patterns and lifestyle changes, and agricultural planning. She pointed out other potential uses of the data, e.g., in the assessment of food safety and pesticide exposure, and in identifying opportunities to improve the nutritional quality of products and the economic potential of food enterprises.

Dr. Juan Rivera of the National Institute of Public Health, Mexico, shared with the participants experiences gained in the Mexican National Nutrition Survey (MNNS) of 1999, which included collection of food consumption data. The survey was representative at the national level, covering both urban and rural areas and four geographic regions. The sample included 21,000 households. The groups that were studied at the individual level were children under 12 years of age and women 12 to 49 years of age. The variables studied in the whole sample were socioeconomic, demographic, and health information, anthropometry, and infant feeding. Blood and urine specimens were collected from a subsample, and physical activity patterns (among women) and dietary intake (in 4,200 households) were studied. The dietary assessment included a 24-hour recall for all groups and a food-frequency questionnaire for women.

Dr. Rivera discussed the main uses of the 1999 MNNS. These included estimating the adequacy of energy and nutrient intakes; assessing trends in dietary intake that can pose health risks; estimating the bioavailability of iron, zinc, and other minerals; identifying departure from food-based dietary guidelines; assessing the contribution of centrally processed food to the diet; and identifying candidate foods for national fortification programs. He emphasized that there is a need to share experiences from different applications of national dietary surveys in developing countries. For each national dietary survey application, there are particular methodologic as well as analytical challenges that have important practical implications for data collection and analysis.

Dr. Nabuo Yoshiike of the National Institute of Health and Nutrition, Japan, presented the "Annual Nutrition Survey in Japan." He described the historical background of the Japanese surveys. The first National Nutrition Survey was carried out in the Tokyo metropolitan area in 1945, following the end of World War II. On the basis of the Nutrition Improvement Law (1952), the survey is carried out to monitor health conditions and dietary intakes in order to guide nutrition policymaking. Under the new law (Health Promotion Law, 2003), a more comprehensive National Health and Nutrition Survey will be initiated, which will include, in addition to nutrition, cardiovascular and metabolic disease risk factors.

A total of 15,000 subjects from 5,000 households in 300 randomly selected districts were surveyed in the 1999–2001 National Nutrition Survey. Data were collected by physical examination of individual subjects (anthropometry, blood pressure, blood tests, and physical activity measured by a pedometer) and by interviews on the use of medication, smoking, alcohol consumption, and exercise habits. A dietary survey was also conducted by the use of a one-day household and individual weighed record and a questionnaire on meals eaten during the survey day (meals cooked in the family, meals taken outside, and meals skipped). An additional questionnaire on diet and lifestyle was also adminstered.

Dr. Yoshiike highlighted several problems encountered when conducting the surveys. These included the lack of a database for ready-to-eat meals, problems in converting portion sizes to weights of foods, and the lack of a database for cooking factors. He outlined the sophisticated data management and analysis system used. At the local level (client software), automated coding of dietary data is performed, as well as calculation of nutrient intake, and data are transferred by the Internet. Data analysis, tabulation, and management are handled at the central level (server software). Dr. Yoshiike outlined various uses of the dietary data. These include analyses of exposure to chemical contaminants, and establishment and evaluation of new health-promotion activities (HEALTH JAPAN 21), for the next review of the Dietary Reference Intakes (DRIs).

Dr. Vongsvat Kosulwat of the Institute of Nutrition, Mahidol University, Thailand, explained that National Nutrition Surveys have been conducted in Thailand since 1962. These surveys had an initial focus on malnutrition among high-risk groups such as children under five years of age and pregnant and lactating women. Food-consumption data, collected as part of these surveys, have traditionally been obtained for the purpose of describing patterns of food consumption and adequacy of nutrient intakes. Such data may not be in an appropriate form for assessing exposure to contaminants, additives, and food chemicals, as well as for describing food-consumption patterns in relation to the risk of chronic diseases. The challenge is to optimize the large-scale food-consumption surveys in order to address all three aspects. Nutritionists are unfamiliar with risk-assessment concepts and procedures, whereas food safety experts do not realize the technical difficulty of collecting and analyzing dietary-intake data.

Dr. Kosulwat shared with the workshop participants the preparations her project team is making for the upcoming national food-consumption survey. During the planning phase, four major tasks were identified: selection of methodology to assess food intake and improvement of the available dietary assessment methods, selection of a food classification system and review of the existing food-composition database, improving the software and statistical aspects of food-intake assessment, and establishing the logistics of the food-consumption survey.

A report on the "National Household Nutrition Survey of Vietnam" was presented by **Dr. Nguyen Cong Khan** of the National Nutrition Institute, Vietnam. The general objective of the survey was to evaluate the current food consumption of households in the different ecological regions of the country in the year 2000. The data will be used for nutrition policy planning in Vietnam. Sampling of households for the survey was undertaken by dividing the country into 8 geographic regions and sampling 30 communes from each region. From each of the 240 communes, 32 households were randomly sampled, giving a total of 7,680 households. For the study of household dietary intake, two main approaches were used: the 24-hour recall method, checked by weighing, and a study of the frequency of food consumption. Nutrient intake was calculated based on the Vietnamese food-composition table, using an in-house computer program.

Dr. Khan highlighted the main findings of the 2000 national survey. Consumption of major food items and nutrient intake were presented by rural and urban area, and by ecological region, in addition to the national average.

Comparison of the data obtained in 1985, 1987, and 2000 showed that there was no marked difference in per capita energy intake. However, the percentage of energy obtained from fats was found to have doubled (6.2% in 1985 to 12% in 2000), whereas the percentage obtained from carbohydrates decreased from 82.6% to 74.9%.

Dr. Noël Marie Zagre of the Research Institute for Health Sciences, Burkina Faso, shared with the workshop participants his experiences with "Constraints on estimating usual intakes of vitamin A in West Africa." He first summarized the vitamin A deficiency situation in the region. Vitamin A deficiency has been shown to be a public health problem in most West African countries. According to a report in 2001, as many as 80% to 85% of children from one to three years of age in Burkina Faso had low serum retinol levels, and from 1% to 6% had night-blindness. Inadequate vitamin A intake and a host of related factors are believed to be the main causes of the problem. Strategies to overcome vitamin A deficiency are mainly based on vitamin A supplementation on National Immunization Days. Fortification is also a promising strategy at the regional level.

Dr. Zagre discussed the constraints on estimating usual vitamin A intake. Some of the main errors in estimating food intake result from the consumption of street foods and eating from shared plates, which are not taken account of by dietary survey tools. Determining the vitamin A content of foods is also a major constraint, since the available food-composition tables are not adequate. A third major constraint relates to factors influencing the bioefficacy of plant carotenoids, since plant foods are important sources of vitamin A in these communities.

Dr. Zagre then presented case studies for estimating usual intakes of potential food vehicles (oil and sugar) for fortification with vitamin A, conducted in Burkina Faso, Niger, Guinea, and Mauritania. The aim was to measure intakes of oil used in sauces and intakes of sugar from a commonly prepared and sold beverage using two survey tools. In the "volume ratio" method for estimating oil intake, the total volume of sauce was first estimated by the number of ladles of water used in making the sauces. The volume of oil used for this sauce was also estimated using water in ladles. Since the weight of a ladle of oil is known, the amount of oil in a ladle of sauce may be estimated. In the "cash technique" used to estimate the amount of sugar used, the total cash collected could be remembered as well as the number of bags of beverages sold. The amount of sugar was then derived from the cost of sugar used in the beverage. The amount of sugar per bag was then computed. These survey techniques were validated against actual weighings conducted during preparation of these foods. No significant differences were observed between the results obtained by these survey tools or the weighing method. High correlation coefficients were obtained.

Workshop deliberations and recommendations

Two sessions of group discussions were held concurrently. The participants in the first group discussed "Interagency coordinated food-consumption surveys: needs, feasibility and challenges," while the second group focused on "Major issues in food-consumption survey methodologies." The participants in both groups comprised a mixture of experts in nutrition, food safety, and agriculture.

Highlights of the discussions and the main recommendations of the working groups are summarized below.

Fostering coordination among agencies in conducting coordinated food-consumption surveys

The participants emphasized the vital importance of promoting interagency coordination from the beginning and ensuring that the planning stage is well coordinated, with a goal of integration. It was felt essential that the program be coordinated by a high-level body or agency, e.g., the Prime Minister's Office or the Planning Commission. All relevant agencies and clients should be involved at the planning stage. It is important to ensure that the technical needs for the food-consumption survey are sound and feasible to all partners involved. All operational issues and the role of each agency in the collaboration should be thoroughly discussed.

The workshop participants highlighted the importance of timely reporting of food-consumption data to relevant bodies and potential users. Reports should be disseminated to agencies involved to obtain feedback for the next reporting phase. It was emphasized that food-consumption data should be presented in "different languages" in user-friendly formats to all potential users. Good-quality databases should be made widely available for secondary use for policy-making and research through a variety of means, using information technologies. It was also pointed out that technical support should be provided to all users to avoid misuse or misinterpretation of the food-consumption data.

Diet assessment: General considerations

It was emphasized that countries need to institute a mechanism to conduct regular national food-consumption surveys for nutrition and exposure assessment, e.g., at five-year intervals. The methodologies to be used in such surveys should meet the needs for both types of assessment. Due consideration should be given to proper sampling procedures to obtain representative data at the national, urban/rural, and other relevant administrative levels. Consideration should also be given to issues of timing of surveys, taking into account seasonal variations, days of the week, and holidays. The participants also recognized that when methodologies change between national surveys, it is important to conduct calibration or "bridging" surveys in order to ensure that the results of consecutive surveys are comparable. The workshop also recommended conducting studies of the physical activity patterns of communities, if possible in the National Nutrition Surveys.

Diet-assessment methodologies and tools for surveys

The workshop participants agreed that 24-hour recall (preferably repeated over more than one day) was the preferred method, because it is quick and simple and provides quantitative data on nutrient intake. Moreover, they felt that a combination of 24-hour recall and food-frequency questionnaire (FFQ) would provide additional information on usual intake and was more likely to meet the needs of both nutrition and exposure assessment. Surveys on individuals are preferred, and household surveys should only be resorted to if the individual surveys are not possible. Within a household, an attempt should be made to sample one individual per age group, based on predetermined criteria.

Consideration needs to be given to the difficulty of estimating intakes from shared dishes (communal pots). To reduce errors in such circumstances, standardized methods or approaches should be developed. Other approaches that may be used include the "proportion method" (e.g., as used in Japan), household measures, and individual or reference recipes.

It is important to understand and document differences in recipes for a similarly named dish. Other approaches that were discussed were developing reference recipes for mixed dishes, using software that allows for entry of raw or cooked foods, and using software that includes an option for modifying recipes.

Some other issues that the participants felt were important to bear in mind included the operational definition of the household, possible sensitivities to some of the questions asked in surveys, and reporting bias. The intake of dietary supplements should be assessed where relevant. It was emphasized that standardization of methodologies between fieldworkers is vital. In this context, it is important to provide training to all members of survey teams. Supervisors should conduct quality-control and spot checks and should analyze differences between fieldworkers.

Food-composition databases

Because good food-composition databases are crucial in food-consumption studies, the workshop participants stressed the need to develop, maintain, and update databases at the national and regional levels for nutrients and non-nutrients (e.g., fiber, flavonoids and other biologically active components, and antinutrients). With the increased interest in assessing exposure to contaminants, there is a need to establish databases for contaminants and food additives at the national and regional levels. The countries agreed to share available food-composition databases wherever applicable. The participants also agreed to have closer collaboration in the region in food-composition database development, especially to standardize food codes, harmonize the analytical methods used, and conduct food-analysis activities at the regional level.

Advocacy and funding

The workshop participants emphasized the need to increase the awareness of policy and decision makers of nutritional issues and their impact on the health and economy of countries. They reiterated the need to institutionalize regular national food-consumption surveys. International organizations such as FAO, the World Health Organization (WHO), and UNICEF should advocate to governments the need for regular planning, funding, and implementation of national food-consumption surveys and for developing and maintaining food-composition databases. It is important to identify partners from government, international agencies, nongovernmental organizations, the food industry. and others to participate in and jointly fund surveys. It is also vital to ensure capacity-building to enable surveys to be conducted regularly and professionally.

Regional follow-up activities

The participants unanimously recommended the organization of further technical meetings or workshops to follow up on recommended activities and enable continuing regional collaboration on food-consumption surveys. Countries were urged to continue efforts to promote coordinated food-consumption surveys to meet nutrition purposes and assessment of exposure to contaminants and chemicals. It was proposed that training or exchange programs be set up to enable professionals involved in national food-consumption surveys to visit other countries to benefit from their experience by participating in actual surveys or observing data management and analysis activities. It was recommended that a database on the status of national food-consumption studies be established to obtain information on what has been carried out, the stage of development of these activities, plans for the future, and inputs required.

The representatives from the participating countries agreed to further promote regional harmonization of methods of dietary assessment. The preparation of a regional manual on dietary assessment procedures was recommended. There should be a mechanism for regular regional exchange of food-consumption data. There was a proposal to establish and maintain a regional network on food-consumption surveys. Regular activities that could be conducted through the network include holding regular workshops on new development of methods and reporting on the progress of ongoing surveys and survey results. It was felt that regional cooperation in conducting common ethnic group surveys, especially among neighboring countries, would be beneficial. A call was made to set up regional diets for the purpose of exposure assessment by using national food-consumption surveys. There was also a suggestion that the United Nations develop a regional software for analysis of food-consumption data that could be used by various countries.

Conclusions

The two keynote lectures set the stage for the workshop sessions by providing broad overviews on a variety of methodologic issues specific to the developing countries surrounding food-consumption surveys and estimates of exposure to contaminants. The six brief country reports provided an opportunity for the participants to share experiences on conducting food-consumption surveys. The group discussions covered a wide variety of topics, and there was general agreement on a number of issues. The workshop participants emphasized the need to obtain the support of policy and decision makers to establish a mechanism for conducting regular coordinated food-consumption surveys to meet food and nutrition needs as well as for assessment of exposure to contaminants. The participants emphasized the importance of identifying partners from the government, nongovernmental organizations, and the private sector and promoting interagency coordination beginning from the planning stage. All operational issues and needs, and the role of each agency in the collaboration, should be thoroughly discussed.

A number of technical issues related to food-consumption surveys were discussed. It was agreed that due consideration should be given to proper sampling procedures and timing of surveys. The participants agreed that surveys on individuals are preferred and a combination of 24-hour recall and food-frequency questionnaire would most likely provide data that would meet the purpose of both nutrition and exposure assessment. The need was emphasized to develop, maintain, and update databases at the national and regional levels for nutrients and non-nutrients, as well as contaminants and food additives. The participants realized that it is vital to undertake capacity-building to ensure that surveys are conducted regularly and professionally. Several issues related to reports of food-consumption data were discussed, including timely reporting, effective dissemination, and appropriate usage.

Finally, various regional follow-up activities were recommended to enable continuing regional collaboration on food-consumption surveys. A recommended activity was to establish a database of the status of country national food-consumption studies. Through this workshop, an important step has been taken to reach a more coordinated approach among various agencies in the conduct of food-consumption surveys so that data collected can be used to address broader national issues (including nutrition, diet-related chronic diseases, formulation of food safety standards for trade facilitation, agricultural planning, etc.). It will be a long way to go before such mechanisms can be fully instituted in developing countries. It will require continued regional collaboration and the assistance of international agencies and foundations.

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Methodologic considerations in descriptive food-consumption surveys in developing countries

Gail G. Harrison

Abstract

This paper reviews some methodologic issues relative to food-consumption studies in developing countries, including sampling considerations; capturing temporal variation in food consumption; choice of dietary instruments and protocols; and food-composition databases and needs for adequate software interfaces. Increasingly, issues of cross-country and regional comparability in food-consumption data are now coming into the decision mix. Comparability of data across countries requires comparability of several fundamental systems. Specific countries and cultural contexts must tackle problems of how to estimate individual intakes when one-dish serving is the norm; how to keep up with rapidly changing food supplies; how to capture ingredients added at the table that may be concentrated sources of nutrients or other components of interest; and how to document out-of-home eating. Assumptions about error, bias, and intra-individual variation in food intake need to be thoroughly tested in developing-country contexts. There is an urgent need for improvement in the availability of appropriate food-composition databases and software interfaces for developing-country use.

Key words: food-consumption surveys, developing countries

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Introduction

Food-consumption surveys in developing countries, as anywhere, serve a number of different objectives and have a diverse set of users. Data on food consumption—sometimes integrated with measures of nutritional status, food security, morbidity, and health risk factors—provide the basis for monitoring trends in dietary patterns and nutritional risk for agricultural, economic, and health policy. The same data can provide the basis for the development of food-based dietary guidelines and nutrition education materials. Researchers utilize these data to investigate nutrition-disease relationships, and those charged with oversight of food safety require information on food consumption to estimate exposure to contaminants in the food supply. There is wide variation from country to country as to who is responsible for collecting food-consumption data, constructing and maintaining the supporting technical databases, making data available and accessible, and analyzing, interpreting, and reporting the information. Further, there is no consistency across countries in terms of the stability or adequacy of resources to accomplish these critical tasks. This paper will review a number of questions and issues facing investigators in developing countries whose responsibility it is to design the best possible survey systems with limited resources, and articulate the need for common systems to facilitate timely and accurate analyses of food-consumption data.

Integrated versus stand-alone surveys

Integrating food consumption with other types of data into common surveys, such as combined health, nutritional status, and food-consumption surveys or combined household expenditure and food-consumption surveys, has some advantages in terms of cost and utility. This approach allows the analyst to relate food-consumption patterns to other variables, a considerable advantage for many purposes, and has the further strength of automatically creating wider, more diverse constituencies of users of the data. The disadvantage of integrated surveys, which can be substantial, is that food consumption and nutrition must compete with other priorities in survey design. Since food intake usually contributes the single largest share of respondent burden in integrated surveys, it is highly vulnerable to abbreviation in the context of a complicated, multipurpose survey.

Sampling considerations

There are a number of issues surrounding the nature and size of the sample for food-consumption surveys, and the decisions that are made with respect to sampling are among the most important, not only in determining the cost and efficiency of the survey design, but also in setting the limits of conclusions that ultimately can be drawn from the data. For example, must the data be nationally representative or should they be representative of smaller administrative units, such as provinces? Depending on where policy decisions based on the data will be made, there may be good reasons for sampling strategies that represent the smaller units. Should the sampling frame be stratified by rural/urban or other key structural variables? Will the household or the individual be the unit of sampling? The long history of household-level food-consumption surveys in many parts of the world argues for continuity at the household level; newer interest in exploring diet-disease relationships across varying cultures and environments places emphasis on individual-level data. Linking data on individuals within households requires a more complex survey design but may be worth doing when both purposes need to be served. Are there subgroups of the population that should be oversampled? Where there are ethnic minorities or other important subpopulations that would have too few numbers in a simpler sample to allow conclusions to be drawn, oversampling of population subgroups makes sense. Similarly, where fertility rates are low, there may be too few pregnant or lactating women to allow conclusions to be drawn about their food consumption unless they are systematically oversampled. Last, who is outside the sampling frame, and how important are they? Individuals without residential addresses, members of the military, and individuals residing in any kind of institutional facility are typically outside of national sampling frames. Particularly in the case of individuals or families who cannot be identified by a residential address, there may be particular nutritional vulnerability, and there may be consideration of a supplemental survey or other mechanism for obtaining data on these groups.

The total size and geographic distribution of the sample is one of the most powerful determinants of survey cost. Thus, calculations of sample size need to be done carefully, with attention to survey objectives. Key questions include: What is the most limiting prevalence that must be estimated accurately, and for what subsets of the population? Are the central tendency and dispersion of key variables sufficient for intended uses, or is it important to estimate the extremes of the distribution (i.e., the 10th or 90th percentile of intake)?

Seasonal variation in food intake is an essential issue to consider in sampling and survey design. The first question to ask is whether seasonal variation is important in the particular local or national context. If it is important with regard to food availability and/or food-consumption patterns, then seasonality must be taken into account in survey design. There are several options. The survey can be divided into two or more discrete surveys conducted in different seasons. The survey can be spread over a calendar year in each primary sampling unit—an ideal option, but one that requires a staffing pattern that allows for long-term, lower-intensity data collection. When there is no choice but to conduct the survey within a particular season, the investigators must recognize not only the loss of data on variability that is a consequence, but also the fact that future surveys will have to be conducted in the same season if data are to be comparable.

Development of survey protocols and instruments

The choice of specific instruments and protocols depends on the survey objectives (which may include continuity and comparability with earlier data), the resources available, and specific cultural considerations. The early development of household food-consumption survey methods, led by the Food and Agriculture Organization (FAO) of the United Nations, emphasized weighed records and observations of household food supplies and the preparation and consumption of food [1, 2]. Since the advent of computers capable of handling large amounts of data in reasonable time frames, it has been possible to think about and implement surveys that include relatively large, and representative, samples with less labor-intensive data-collection methods. Current uses of food-consumption data argue heavily for including individual-level data collection, whether the individual or the household is the sampling unit. Intake records pose a heavy respondent burden and are reactive (that is, they may change the very behavior they are documenting), and they also require literacy across all segments of a population. Much more feasible are recalls (single or multiple) if whole-diet quantitative data are required, food-frequency questionnaires if more stable estimates of food-consumption patterns are desired at the individual level, or targeted recalls or food-frequency instruments if only a few foods or nutrients are of interest.

Not surprisingly, the most common protocol in use today is the quantitative 24-hour recall of food intake. In sufficiently large samples, single recalls of high quality can yield accurate estimates of mean and median intakes, or at least comparably accurate estimates for population subgroups, which can therefore be compared. There are constraints, however, on going beyond this basic objective. A distribution of single recalls of intake overestimates the variance in intake, since it will be composed of both the true between-person variation and the within-person variation that derives from the day-to-day and other time-related variability in intake for individuals [3]. The result of this overestimation of variance is to systematically overestimate the prevalences of low and high intakes when cutoffs are applied to the distribution. Further, because the magnitude of intra-individual variation in intake is nontrivial, a single recall cannot be used to represent an individual's usual intake in analyses that relate food or nutrient intake to other variables. Various statistical adjustments have been proposed and utilized to compensate for the overestimation of variance, all relying on the collection of data on multiple days for at least a subsample of individuals in the survey population [3–6]. The number of replicate days required varies with the nutrient or food component of interest, but available evidence indicates that even a single replicate (i.e., two recalls) can substantially reduce the error in estimating the prevalence of low or high intakes [3]. The assumption that intra-individual variability in food intake is lower in developing countries than in more industrialized settings because of the monotonous diets in developing countries is not supported by evidence; it remains critical to investigate and document the extent of intra-individual variability in each specific survey setting.

Various visual aids for estimating portion size can be used, including foods purchased at a local market and weighed, as well as standardized two- or three-dimensional models of various kinds. For infants and young children, specific targeted or qualitative instruments designed to capture key variables are essential.

Besides the protocol or instruments to be used, the survey design must include attention to designation of the survey respondent, selection of interviewers, selection and testing of visual aids for estimation of portion sizes, and a myriad of other details. Each of these decisions may be critical in determining the ultimate quality of the data.

Community acceptance and culture-specific issues

Issues of informed consent, feedback and benefit to communities, obtaining of government and other approvals, publicity about the survey, and information provided to households and communities are basic. Nonresponse and refusal rates may be determined in large part by how well and thoroughly attention is given to these issues, beyond the requirements of governments.

Survey protocols must be developed in and adapted to local cultural contexts, and this task can be particularly challenging where quantitative information on total dietary intake by individuals is the objective. It is often necessary to carry out small-scale validation exercises to test the efficiency of protocols developed. Examples of these issues include how to estimate individual intake from shared serving dishes; how to account for the change in composition of the food served brought about by sequential eating by different members of the family; how to estimate quantities from nonstandard eating and serving tools (including hands); how to account for the contribution to intake of items added at the table, such as condiments and sauces (which may be concentrated sources of nutrients of interest); and how to estimate food intake away from the home.

A further issue in which there is large cultural variation is the extent to which food is regarded as a private or sensitive topic [7]. In some cultural contexts, talking about one's dietary habits to a stranger is neither problematic nor threatening; in fact, food may be a welcome topic for a social exchange. In others, food may be regarded as a rather private affair within the family, and opening the domain to inspection by strangers is fraught with discomfort.

Reporting bias

Issues of reporting bias are central to the interpretation of data from food-consumption surveys, and they have been very little explored in the context of developing-country environments. Reporting bias can arise from the nonrandom characteristics of nonrespondent individuals or households; from systematic bias in reporting socially desirable or undesirable items; and from individual underreporting or overreporting of intake. Nonresponse rates need to be reported, and screening data collected on sampled but nonrespondent units (households or individuals) and compared to that of respondents. Individual reporting bias can be selective (underreports of socially undesirable items such as alcoholic beverages, overreports of socially desirable items such as meat in many contexts) or general.

The most studied individual bias is the phenomenon of underreporting of intakes in surveys, which is consistent and substantial in surveys in North America and Europe. For example, in the United States, 31% of adult respondents in the National Health and Examination Survey II (NHANES II), and 18% of men and 28% of women in the NHANES III, had "implausible intakes," i.e., less than 0.92 BMR (basal metabolic rate) as estimated from anthropometry [8, 9]. The apparent underreporting is systematically greater in obese than in nonobese respondents and may be due to a variety of causes, including deliberate fabrication, failure to remember food items or eating events, lack of knowledge about the composition of mixed dishes, inability to estimate portion size accurately, and truly low intakes due to dieting behavior. The problem of underreporting has prompted a great deal of methodologic work to improve 24-hour recall methodology, with some success [10, 11]. There have been few studies of the issue in developing countries, but the limited available evidence, from Egypt and Indonesia [12, 13], shows less apparent underreporting in developing-country settings. The implications for design of surveys are clear: it is essential to collect information on anthropometry (heights and weights) and (ideally) some estimate of physical activity level within food-consumption surveys if underreporting is to be examined and reported.

Recent work using biomarkers for energy and protein intake indicates that there is additionally individual-specific bias in reporting of food intake, which further complicates the interpretation of data [14, 15].

Cross-country and cross-region comparability

Food supplies today are increasingly global, mobile, and rapidly changing, and nutrition-related health problems are increasingly similar across populations. There is a need across the globe to be able to compare food-consumption patterns, nutrient-intake patterns, and health outcomes across populations. Such comparability requires the development of food-composition databases, analytical methods, protocols, and software that meet global needs and can be shared at relatively low cost. FAO has traditionally taken the lead in the development of food-consumption survey methodology for developing countries and through its support of INFOODS is continuing that leadership. The earliest manuals of food-consumption surveys originated from FAO [1, 2]; these were followed much later by works, useful but not widely utilized, from other investigators [16, 17]. Most of the recent effort in developing comparable systems has gone into the task of harmonizing food-composition databases and making them accessible. In the 1980s, the Collaborative Research Support Program on Nutrition and Human Function (Nutrition CRSP) resulted in comparable systems for three countries (Kenya, Mexico, and Egypt), which investigators at the University of California Berkeley then developed into a six-country database called WORLDFOODS, designed to make accessible relatively complete nutrient information on foods representative of the core food supplies in important parts of the developing world [18]. Although widely used, the WORLDFOODS system has no current technical support available, and most users take advantage of the database without the entry system, which is DOS-based, and develop their own data-entry system. More recently, the International Network of Food Data Systems (INFOODS) program has made continuing efforts to create harmonized, adequately documented, and accessible food-composition databases [19]. The European Food Consumption Survey Methods group (EFCOSUM) has done impressive recent work in developing harmonized systems for the European Union countries [20, 21]. Nevertheless, many developing countries, including some very large ones, currently rely on systems hybridized from older local data and accessible international data including commercial software not suited to population-level studies.

The ideal food-composition database for use in developing countries would have several characteristics. It would include all locally important food and beverage items; it would include complete information on nutrients and non-nutrient components of interest; it would be continuously (or at least regularly) updated; it would provide information on foods both "as consumed" and "as acquired"; it would clearly differentiate between missing values and real zeros; and it would provide documentation of the ultimate source of the information. Additionally, it would be arranged hierarchically to allow for food-based analyses; it would allow the addition of new food items and the adaptation of nutrient information for local use; and it would allow the linkage of ingredients through recipes to mixed dishes.

In addition to adequate and accessible food-composition databases, we all urgently need another tool that currently does not exist: a flexible, affordable software system to provide the interface among foods, ingredients, and nutrients or food components. Such software can be developed *de novo* or from existing systems, and this development is an urgent need. The ideal front-end software would provide for data entry in the local language; allow creating of new, locally appropriate portion-size models and terms; allow entry and open-ended querying for new or unknown foods; provide for recipe modification, including changes in fat and water retention and retention/loss factors in nutrient content with cooking; and allow analyses at the levels of nutrients and food components, food, and ingredients.

None of these improvements in the toolkit is impossible, given the work that has already taken place in INFOODS, in Europe, and in the United States, and they could vastly improve the amount, timeliness, and quality of data available to solve urgent and important problems of nutritional vulnerability, food security, and improvement of human health through understanding of diet-disease relationships in developing countries.

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General approaches to estimation of dietary exposure to contaminants

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Abstract

The initial steps in estimating dietary exposure to contaminants include gathering the necessary expertise, clarifying the intent and purpose of the work, selecting a dietary exposure model, and gathering available pertinent information. Expertise is generally needed in chemistry, agriculture, toxicology, statistics, nutritional epidemiology, and computer software development. The goal might be to determine the average exposure of a population to contaminants, to identify demographic groups within a population that are especially vulnerable to a contaminant, to evaluate the regulation of agricultural and food-manufacturing practices, or to determine compliance with standards for local and/or imported foods. Examples of dietary exposure models include the core food model, directed core food model, large database model, raw agricultural commodity (RAC) model, regional diet model, duplicate diet model, and total diet composite model. Each model has advantages and disadvantages and different costs and resource requirements. Consideration of the sources and flow of selected contaminants though the food supply may help identify the best exposure model to use. Pertinent information that may already be available includes analytical data on contaminants in foods or commodities, government regulations pertaining to the levels of contaminants in foods, food-consumption data, data on the average body weights of age-gender groups (to express exposure on a body weight basis), and biochemical measures of contaminants or their residues/metabolites. Collecting available information helps to clearly define what critical information is missing so that the planned research can be most effective. Careful documentation of decisions and assumptions allows for recalculating exposure estimates with the same model using different decisions and assumptions; documentation also allows others to understand what was done and how to use the resulting intake estimates properly. Clearly identifying the limitations of the exposure model may provide justification for additional resources to further refine and improve the model.

Key words: contaminants, core food model, dietary exposure, exposure models

Introduction

It is unlikely that resources will be sufficient to make dietary exposure estimates in an optimal or ideal manner. Therefore, it is important for developers of exposure models to be creative, resourceful, and efficient. Compromise is usually necessary, but the outcome should fulfill the original objectives. Approaches for estimating dietary exposure to contaminants have been the subject of several Food and Agriculture Organization/World Health Organization (FAO/WHO) publications [1–3]. The approaches to dietary exposure estimates discussed here utilize information on the levels of contaminants in foods and information on the consumption of foods. These approaches are not as sophisticated as those of risk assessment and risk management for foods, which serve as the basis for developing food safety standards [4].

Definition of contaminants

The group of chemical compounds that are consid-

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ered to be *food contaminants* is quite diverse. The same chemical component may at times be classified as a contaminant, a nutrient, an intentional food additive, or an unintentional food additive. Intentional food additives are deliberately added during plant or animal growth (pesticides, antibiotics) or food processing (humectants, emulsifiers) and are expected to end up in the finished food. Unintentional food additives get into foods, usually during processing, and may come from conveyer belts, contact with machinery, packaging materials, etc. For purposes of this paper, food contaminants will also be referred to as *food components* (although some may argue that the term *food component* should be reserved for those chemicals that are inherently present in foods or that are potentially beneficial to humans).

Food components that have been referred to as contaminants include pesticide residues (e.g., organohalogen or organophosphorus pesticides/metabolites), industrial chemicals (e.g., polychlorinated biphenyls, carbamates), heavy or toxic metals (arsenic, cadmium, lead, mercury), radionuclides (e.g., strontium-90, cesium-137), antibiotics, hormones, other drugs, nutrients in excess (e.g., selenium, iodine, zinc), naturally occurring toxins (e.g., mycotoxins, nitrites), filth (e.g., dirt, insect parts, rodent droppings), illegal fillers or food additives, and excessive levels of food additives. Food contaminants may be inherent in a plant or animal (i.e., obtained by the living plant or animal through food, water, feed supplements, or injection and incorporated into the plant or animal tissues) or incorporated into crops during growth (i.e., fertilizers, pesticides) or acquired during processing (e.g., food additives). Some contaminants may become incorporated into plant and animal tissues; others remain on the outside surface of the food material.

Overarching thoughts

When determining dietary intakes of contaminants, the goal is usually to provide accurate, valid, and reproducible exposure estimates. However, the reality is that there are resource constraints in terms of time, people, laboratory facilities, reagents, equipment, and money, which prevent optimal or ideal exposure estimates. Therefore, it is important for researchers to be creative, resourceful, and efficient and to make the best possible use of available resources and of previously acquired information. It is usually necessary to make compromises in the research plans, but the outcomes of the research should still meet the initial objectives.

Detective work to trace contaminants

Model development for exposure estimates requires detective work to trace and follow a given contaminant through the food system from its initial point of entry to the amount present in foods as consumed. The point of entry may be the living plant or animal, or it may be during harvest, storage, transport, or processing of the food. Model development requires knowledge about the unique chemical and physical features of the contaminant to trace its distribution and pattern of flow through food, water, and air; the effects of agricultural, environmental, and processing variables on the concentration of the contaminant in finished foods; and the physiological characteristics of the contaminant with respect to human bioavailability, absorption, and body storage. The concentration of a contaminant may increase, decrease, or remain the same through various phases of food production and processing. The unique features of a contaminant include its stability, volatility, ability to bind with other atoms or molecules, pervasiveness, and conversion to other metabolites in foods or in the body after consumption.

For example, pesticides are applied directly to crops, and the pesticides and their residues may remain on the outside of plant parts or be incorporated into plant tissues. The concentration of pesticide residues in grains, fruits, and vegetables may be reduced by rainfall or other environmental factors. Residue levels on grains are reduced by refining, i.e., removing the germ and bran, and grinding into flour. Hence, the residues on whole-grain wheat may be higher than those on white wheat flour. Residue levels may also be reduced by the rinsing, peeling, and cooking of fruits and vegetables. Thus, processed and highly processed foods may be lower in residues than the original commodity from which the foods are made.

Although pesticides are applied directly to crops, they can also leach into soil and runoff water so that crops subsequently grown on the soil (whether fed to humans or animals) may contain residues, and runoff water may bring residues to other crops, fish, land animals, and drinking water. If pesticide-treated crops are fed to animals, the residues may appear in animal tissues (meat, organs, milk, dairy products, eggs) that are consumed by humans.

Metal and mineral contaminants have different and varied routes of entry into the food supply. Lead in foods comes primarily from foods in metal containers in which the soldering process is old or incomplete. The primary source of mercury in the food supply is from fish, especially larger, older fish that have accumulated mercury from contaminated waters. High levels of iodine in foods may come from unintentional additives used in the dairy industry, such as iodine feed supplements fed to cows and iodophor cleaning solutions used in dairies. Other potential sources of iodine are iodate dough conditioners (found in breads) and the red food dye, erythrosine (found in some red-colored pastries, breakfast cereals, and candies). Excessive levels of selenium are found in isolated locations in the soil and water. Crops grown in these areas and wildlife living in these areas have been found to be excessively high in selenium.

One might map the course of the food component through the food and water supply to help plan the developmental exposure model. Because there is usually an interest in measuring trends, it is important to keep the models for contaminants as consistent as possible over time. Otherwise, changes in exposure estimates may reflect changes in the model rather than actual changes in exposure.

Preliminary steps

The following are the preliminary steps for building a dietary exposure model for contaminants:

» Gather together the pertinent expertise
» Clarify the intent and purpose of the work, i.e., determine the specific question(s) to be addressed
» Review previous models and select an appropriate one, modify an existing one, or develop a new one
» Gather available pertinent information and document sources
» Determine additional needs and resources
» Identify possible limitations of the model

Pertinent expertise

The development of a dietary exposure model requires expertise in chemistry, agriculture, toxicology, statistics, nutritional epidemiology, and computer software development. Chemists provide knowledge of the unique physical and chemical properties of contaminants, their residues, and their metabolites, as well as the methods for analyzing contaminants in foods. Agricultural experts contribute their knowledge of the use of fertilizers and pesticides (i.e., which ones are used in which crops), government regulations regarding permitted use levels, and knowledge of permissible levels of contaminants in imported foods. Toxicologists have knowledge of the toxicology of contaminants, their residues, and their metabolites; the effects of the contaminants on human health and environmental health; and the standards of acceptable intake set by government and international agencies.

Two types of statistical expertise are needed to design dietary exposure models: expertise in food sampling, and expertise in human population surveys and studies. Statistical expertise with regard to foods is essential to develop sampling designs so that the analyzed commodities or foods are representative of those available to the population. Statistical expertise is also helpful in making decisions about analyzing individual foods or food composites. Statistical expertise in human populations is needed to use data from food-consumption surveys and studies and apply weighting factors to achieve data that are representative of the population and population subgroups.

Nutritionists or nutritional epidemiologists are needed because of their knowledge of the dietary patterns of the population and population subgroups. They understand the important demographic variables that are needed to identify vulnerable subgroups with respect to contaminant intake. They have knowledge of the methods used to assess food-consumption patterns and the limitations of these methods. They are also knowledgable about the various food-consumption surveys and studies carried out by government agencies and academic institutions.

Expertise in computer software development is necessary to store and organize the data, perform calculations, merge food composition and food consumption data, and present results in various formats.

Questions to be addressed

It is important to clearly specify which contaminants are of interest and the specific goals of the dietary exposure model. Some questions may be answered by data from food analyses. Other questions require data on both food composition and food consumption (and usually the merging of these two types of data). A typical question may be "What is the daily exposure of a given contaminant for the people who live in a defined geographic region, and how does the exposure compare with the acceptable or tolerable standards of intake?" Table 1 provides examples of questions that may be answered through analysis of commodities or foods, and examples of questions that require both food-composition and food-consumption data.

Models to estimate contaminant exposure

Most of the models used to estimate exposure to contaminants require the merging of food-composition and food-consumption data. The composition data are essential because they differentiate between the foods that are sources of the contaminants and those that are not sources. In addition, the data provide information on the levels of contaminants that are present, along with ranges and variations. Data on the consumption of foods are necessary to identify the foods that are typically consumed and the quantities typically consumed (along with ranges and variation) for the population and population subgroups. It is most useful if the data from food-consumption surveys also supply detailed demographic information (age, gender, body weight, urbanization, income, education, geographic region, etc.) so that these variables may be used to more accurately identify contaminant exposure.

The five general exposure models that require merging of food-composition and food-consumption data are the core food model, the directed core food model, the large database model, the raw agriculture commodity (RAC) model, and the regional diet model. The core food model requires collection of the primary foods in the food supply and analysis of these foods for contaminants. The directed core food model requires collection and analysis of only the core foods known to contain the contaminants. The large database model includes all foods consumed by a surveyed population and estimates of the levels of contaminants in each food. The RAC model collects and analyzes RACs for contaminants and then estimates the levels that might be in the foods and food products available to consumers. The regional diet models were developed to predict dietary intakes of pesticide residues and other chemicals in RACs [5].

In addition to the above models that merge food-composition and food-consumption data, there are two models that require analysis of sample diets or diet composites. The first is the duplicate diet model, which requires the collection and analysis of daily meal composites for contaminants. The second is the total diet composite model, which is a single composite of core foods to represent the daily intake for a selected age-sex group. The daily composite is analyzed for contaminants.

TABLE 1. Examples of dietary exposure questions

Questions answered by analyses of commodities or foods
Are farmers adhering to regulations regarding use of fertilizers and pesticides?
Are contaminant levels safe and acceptable
in food commodities?
in prepared foods as consumed?
in imported foods?
Which contaminants and foods are of concern to public health?
Which foods are highest in contaminants?
What are the trends and changes over time in the levels of contaminants in foods?
Are changes in government regulations needed to make or keep the food supply safe with regard to contaminants?
Questions answered by food-composition and food-consumption data
What are the average intakes of contaminants for a population and subpopulations?
What are the distributions of intakes for a population and for subpopulations?
Which foods are major sources of contaminants?
How do exposures vary by demographic variables?
Which subgroups are most vulnerable with respect to age, gender, geographic location urbanization, ethnic group, education, and income?
Are demographic variables good predictors of intakes?
Do imported foods contribute excessively to contaminant exposure?

Core food model

Core foods are those most commonly consumed by a population, and they may be identified from the results of national or regional food-consumption surveys. The US Food and Drug Administration (FDA) uses the core food approach in its Total Diet Study [6–9]. Approximately 200 to 300 foods are selected from the approximately 8,000 foods listed in the database of national food-consumption surveys. This is done by an aggregation process in which similar foods are grouped and one item (the core food) is selected to represent each group.

Table 2 provides a simple example of a core food, cooked carrots, from one of the US national food-consumption surveys. These carrot-based foods were grouped together, and the total daily intake of each food was determined. The foods are listed here in descending order of their percent contribution to total carrot intake. Note that the total intake of raw carrots is about 36% of carrot intake, and the intake of cooked carrots is about 64% of carrot intake. In the absence of other information, *cooked carrots without added fat* was selected as the core food. The consumption of all these carrot-based foods was then assigned to *cooked carrots without added fat*. This consumption figure for cooked carrots would then be merged with composition data for contaminants in cooked carrots to estimate the exposure from this food.

Each core food takes on the consumption level for all foods within its group. The core foods in the FDA Total Diet Study are purchased four times per year using a regional sampling design. The foods are prepared for consumption and then analyzed in the laboratory for about 200 pesticide residues, radionuclides, industrial chemicals, heavy metals, and nutrient minerals [10, 11]. The food-composition data are then merged with data on food consumption, and estimates of daily intakes of the food components are made for 14 age-gender groupings.

The advantages of a core food model are that the most important foods consumed in the population can be analyzed in the laboratory on a routine basis. Thus,

TABLE 2. Core food example

Food	% of intake of carrot foods
Carrots, raw	33
Carrots, cooked without fat	30
Carrots, cooked with fat	24
Carrots, cooked, no information about fat	10
Carrot salad	3
Carrots, glazed	0.12
Carrots, creamed	0.11
Carrot salad with apples	0.01

the data are current and allow for determination of trends and changes in the contaminant levels of individual foods and the effect on trends and changes in daily intakes. The model also allows for prediction of the effects of policy changes on exposure estimates (e.g., how a change in permitted use levels of a pesticide would affect the daily intake of specific age-gender groups).

The disadvantages of the model are that it is expensive to collect, transport, prepare, and analyze the foods and that only a limited number of foods available to the population can be analyzed. Another disadvantage is that because this method focuses on average intakes, individuals in the population with unusual or atypical eating patterns will not be captured or identified. This model usually provides one average intake estimate for each age-gender group, without consideration of distributions of intakes. Many countries have Total Diet Studies that use similar or other unique approaches [12].

Directed core food model

Contaminants are usually present in certain foods or types of foods rather than in all foods. With the directed core food model, only those core foods of a population that are known to contain contaminants are collected and analyzed on a routine basis. Therefore, this model requires knowledge of which foods contain the contaminants. It might be useful to use the original core food model initially to identify which foods contain contaminants and thereafter use the directed core food model. The number of directed core foods for a population might be as few as 50 or 100, or it might be higher. The food-composition data can be merged with food-consumption data to obtain measures of exposure. This model has an advantage over the core food model in that it is more efficient, as it focuses time and resources only on the foods that contain residues.

Large database model

This model includes all the foods (e.g., 8,000–15,000 foods) consumed by the participants in a food-consumption survey. Countries with a large market in processed foods, especially canned, frozen, packaged, and restaurant mixed dish items, will probably have many more foods in their database than countries with a more traditional food supply. The task for this model is to find representative values for the levels of contaminants in all the foods in the database. Analytical data will only be available for some foods, so assumptions will have to be made for other foods. Daily intakes of the contaminants are estimated by merging the food-composition data with the food-consumption information. The disadvantage of this model is that it requires considerable estimation and imputation to fill in missing values for concentrations of contaminants in the database. The accuracy of the model depends on how carefully all the contaminant concentrations for the individual foods are selected.

RAC model

In this model, RACs are analyzed for contaminants, and this information is used to estimate the levels of contaminants that would be present in each food as consumed. This model is used for contaminants that originate in crops (e.g., pesticide residues), and it requires knowledge and estimation about what happens to contaminant levels during harvest, transport, and processing (e.g., milling, grinding, rinsing, peeling, cooking, etc.). The levels of some contaminants (e.g., pesticide residues) would be diminished by these processes. For recipe foods (e.g., bread, crackers, pasta with sauce, fruit salad, mixed vegetables), estimates need to be made of the amount of contaminant from each RAC in each food (e.g., the amount of wheat and other grains in a mixed-grain bread). If a crop is consumed by animals, the contaminant may be present in animal tissue (meat, organs, eggs, milk), and it will be necessary to include these animal products in the database. A database is developed that lists all the foods and the estimated levels of each contaminant. The database is then merged with information on food consumption to provide estimates of contaminant intake. The disadvantage of this method is that mistakes might occur in the mathematical estimations and assumptions. Some of the estimated contaminant levels should be confirmed by laboratory analysis of the finished foods.

Regional diet model

The WHO Global Environment Monitoring System/ Food Contamination Monitoring and Assessment Programme has developed regional diets for five regions of the world: Middle East, Far East, Africa, Latin America, and Europe [5]. These diets were derived from FAO food-balance sheets and other expert knowledge. Daily intakes are provided for whole RACs in the groupings of cereals, roots and tubers, pulses, sugars and honey, nuts and oilseeds, vegetable oils and fats, stimulants, spices, vegetables, fish and seafood, eggs, fruits, milk and milk products, meat and offal, and animal oils and fats. These consumption data may be merged with data on the contaminant composition of these food commodities to get a rough estimate of daily exposure. The advantage of this model is the availability of the food-balance sheet data from FAO; the main disadvantage is that the data represent food disappearance rather than true consumption.

Duplicate diet model

This model requires that researchers go into homes and collect foods as prepared for consumption. The homemaker is asked to prepare an extra amount of food (the amount that would be consumed by an adult in one day), and that food is taken in a container as an analytical sample and later analyzed in the laboratory for the contaminants. The method can be highly accurate for the households included in the study. It is necessary to obtain a sufficient number of duplicate diets from households and to select the households so that they are representative of the community, region, or nation that they represent. The method is expensive and time consuming for the researchers; it is also burdensome for the participants to purchase and prepare extra food. Because the collected foods are analyzed as a one-day diet, this method will not identify the specific food sources of the contaminants when they are detected. There is also the problem of the dilution effect, where a contaminant could be detected if an individual food were analyzed, but it remains undetected in a diet composite because the amount of the contaminated food in the diet composite is too small. This method could be useful for small populations or population subgroups where a problem with a contaminant is suspected.

Total diet composite model

This model requires information on the amount of each food in the average diet of a selected age-gender group for a population. The consumption data for core foods may be used for this purpose. Each food is purchased, and the specified amount of each food is put together into a single composite that is analyzed for contaminants. The model has the same disadvantages as the duplicate diet methods regarding the inability to determine the source of any contaminants found and the dilution effects that prevent detection of some contaminants.

Averages versus distributions

Those who design dietary exposure models should consider whether they need average exposures or distributions of exposures. To estimate the average daily exposure to a contaminant, one sums the individual exposures for each food. This is achieved by multiplying the average concentration of the residue in each food by the average daily consumption of each food by the surveyed population. This could be repeated for subpopulations identified by demographic variables (age, gender, etc.).

To estimate the distributions of exposure to a contaminant for a population, one needs to calculate the exposure for each person in the survey separately. This allows one to look at distributions among the demographic groups and the whole population. For each person, one sums the average concentration of the residue in each food by the average daily intake of the food consumed by each person. Then the distributions by demographic variables are evaluated, and the mean exposures may be calculated.

Although averages are useful for monitoring purposes, they do not provide accurate exposure estimates for population extremes or vulnerable population groups. The levels of contaminants in foods do not usually follow a normal (Gaussian) distribution, and they may be highly variable. If outlying values are included in the calculation of a mean value, the mean value for the pesticide may be skewed. If high concentrations of a contaminant in a food skew the average value, this could lead to overestimates of exposure.

Likewise, the distribution of food intakes for a population is not usually normal, and again, the inclusion of outlying values may result in skewed mean values. For example, if only part of a population (a certain geographic area or certain age group) is exposed to a food with a high contaminant concentration, then the average exposure will be underestimated for the population group at risk and overestimated for the population group not exposed.

If the average values for both food-composition and food-consumption data are accompanied by standard deviations, ranges, and distributions, then the information is more useful for making decisions for exposure models. It is important to look at distributions for both food-composition data and food-consumption data, so that the information used in exposure estimates is not artificially skewed. Evaluation of distributions will help make decisions about including outlying values (high or low) and about using mean values, median values, or modes in exposure calculations.

For some contaminants, the food-composition data may show many zeros and a few positive values. Averaging such results may result in zero average values. In these cases, researchers may want to calculate a worst-case scenario, i.e., take the highest level of a contaminant in a food and estimate its consumption. If the consumption of the contaminant is below acceptable standards, there will be no concern.

Collecting available, pertinent information

To be efficient and timely and make the best use of available resources, it is best to check for available information, such as the following:

- Analytical data for contaminants in commodities, foods, and food products
- Government regulations regarding fertilizer, pesticide, and food additive use levels and standards of intake for contaminants and residues
- Food-consumption data for the population
- Body weights by age and gender
- Biochemical measures of contaminants or their metabolites

This information may provide answers or estimates to some questions regarding contaminant exposure. The information may also provide justification for resources to do additional work. Gathering available information helps to clearly define what critical information is missing, so that the planned research can be most effective.

Food-composition information

Previous laboratory data on contaminants in commodities and foods may be available from the following sources:

- Government agencies involved with foods, agriculture, and pesticides
- Universities with graduate research on foods, agriculture, and pesticides
- Companies that manufacture or distribute pesticide residues
- Private laboratories that analyze RACs and foods for clients
- Published data (culled through computer searches), such as the scientific literature, previously compiled databases, and academic theses
- Food companies, agricultural organizations, and food trade associations
- Data or databases developed in other countries that have similar food supplies, agricultural and manufacturing practices, and food patterns

For imported crops, foods, or food products, data may be available from the country of origin, such as its government agencies, the import companies, or the food companies.

It is important to document the sources of food-composition data for each contaminant level in each food so that they can be traced (especially if they are later shown to be questionable) or replaced by newer or more appropriate data as they become available. It is best to have data on individual foods, but data on food composites, meals, and daily diets may also be useful in developing dietary exposure models.

Information on government regulations

This includes information on government regulations regarding the use of fertilizers and pesticides on food crops and standards for tolerable levels on individual crops; pesticide residues and other contaminants in imported foods; levels of antibiotics, hormones, and nutrient supplements in animal feed; and tolerable levels for individual intake (expressed as weight of contaminant per person per day or weight of contaminant per kilogram of body weight per day).

Food-consumption information

Information on the food-consumption patterns for the geographic area of concern may be available from national or regional government dietary assessment surveys, research or academic dietary assessment surveys, and sales or marketing data from food companies. Other sources of information about food consumption include national food-production data along with government import and export data for RACs, foods, and food products. Another source could be information from nearby countries that have similar food systems and food-consumption patterns. In general, food-intake information from household food-consumption surveys and from food purchase and production reports will be higher than food intakes from 24-hour dietary recalls and diet records. This is because the former methods may not consider food waste or food loss during preparation and cooking. Therefore, household food-consumption data and food-purchase and -production data should be used with caution in dietary exposure models, as they will tend to overestimate exposures. Likewise, data from 24-hour dietary recalls and diet records have been shown to underestimate total food intake and total energy intake, and this should be taken into consideration.

Demographic variables

Although exposure estimates for pesticide residues are usually stratified by age and gender, they may also be stratified by other demographic variables such as geographic region, education, income level, ethnic group, urbanization, or other variables that are believed to affect food-consumption patterns or exposure estimates for the population.

Body weights

Exposure to contaminants may be expressed as the total weight of contaminant ingested on a daily basis or the weight of contaminant ingested per kilogram of body weight per day. Expressing exposures per kilogram of body weight may help to identify vulnerable populations such as infants, children, and the elderly. To express exposures per kilogram of body weight, it is necessary to obtain information on body weights by age and gender of the individuals participating in the dietary surveys or to otherwise obtain national or regional data on the average body weights of the population according to age, gender, or other demographic variables.

Biochemical measurements

Biochemical measurements of contaminants or their metabolites from national health surveys may serve as a means of validating dietary exposure assessments, or they might be built in as part of the dietary exposure model. Biochemical measurements may also be the impetus for initiating a dietary assessment and monitoring program. If the contaminant results in a metabolite that is measurable in the blood or urine, then it would be possible through a series of human dietary studies to determine what level of dietary intake produces a given level of the metabolite in the blood or urine. Generally, biochemical measures of a food component give a better indication of dietary exposure than dietary assessments alone. In the United States, the National Health and Nutrition Examination Survey (NHANES) conducted by the Centers for Disease Control and Prevention includes serum analysis for persistent organochlorines and urine analysis for nonpersistent pesticide residues from chlorpyrifos, 2,4-D, diazinon, permethrin, ortho-phenyl phenol, methyl parathion, and organophosphate pesticides.

Value of collecting and maintaining data in a database

Collecting and maintaining the above types of information in a database may provide direct answers or estimates for some questions that arise. Such a database helps to clearly define what critical information is missing so that the planned research can be most effective. Thus, the database may provide justification for resources to do additional work. In developing a dietary exposure model, one can begin with the available information and then determine the additional information that is needed and the process and resources required to obtain it. The next step is to determine how the available resources can be used to provide the information that is needed, but not available. If resources are not sufficient to obtain the information needed for the exposure model, the options are to modify the model to meet the resources, use another model, modify the question(s) to be answered, or put the work on hold until the resources are obtained.

Documentation

Careful documentation is important to make it possible to retrace decisions and assumptions. It might be possible to recalculate exposure estimates with the same model using different decisions and assumptions. Careful documentation provided with the reported exposure estimates allows others to understand what was done and to use the estimates properly. Clear identification of the limitations of the model and the effects of the limitations on estimates of exposure is also important. Such information may also provide justification for the use of additional resources to further refine the model.

Organizations working together

Progress may be more substantial if various organizations within a country or region join together to share resources and information. For example, in the United States the missions and responsibilities of various government agencies are rather clearly defined; however, resources are shared and agencies provide financial support to help each other. The FDA, which is responsible for the Total Diet Study, uses national food-consumption survey data from the NHANES, which is conducted by the Centers for Disease Control. The NHANES relies on the food-consumption methodology developed by the Agriculture Research Service of the US Department of Agriculture. The Agriculture Research Service conducts and supports analysis of food for nutrients and other food components and maintains the food-composition database used by NHANES for its food-consumption surveys. The National Institutes of Health (NIH), which needs food-consumption survey data and food-composition data to design human research studies, provides some financial support for both the NHANES and the Agriculture Research Service food-composition database. The sharing of resources and information is essential to conduct government studies and surveys, and it helps to promote knowledge that leads to improved public health.

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Book reviews

Handbook of food-drug interactions. Edited by Beverly J. McCabe, Eric H. Frankel, and Jonathan J. Wolfe. CRC Press, Boca Raton, Fla., USA, 2003. (ISBN 0-8493-1531-X) 584 pages, hardcover. US$99.95.

This handbook is written by an interdisciplinary group of contributors representing the fields of nutrition, pharmacy, dietetics, medicine, and food technology. The first six chapters give basic concepts from pharmacy and nutrition, and the next six present drug interactions in specific disorders. The final five chapters discuss guidance in planning and implementing counseling programs, meeting accreditation requirements, and the application of technology. Nearly one-third of the book is devoted to 41 appendices that contain as much useful information as the chapters themselves. Although the book will be of limited interest to most medical and nonmedical public health nutritionists, it could be very helpful to clinicians and food industry professionals confronted with food-drug interaction issues.

Handbook of obesity: Etiology and pathophysiology. 2nd edition. Edited by George Bray and Claude Bouchard. Marcel Dekker, New York, 2004. (ISBN 0-8247-0969-1) 1,046 pages, hardcover. US$165.00.

This oversize volume, which weighs almost 3 kg, with 43 chapters and 1,046 pages, is certainly the most complete and up-to-date treatise on obesity available. It covers the history, definitions, prevalence, etiology, and pathophysiology of a disease that now characterizes nearly one-third of all Americans and similar numbers in some European countries, and is increasing throughout the developing world, particularly in countries in transition. This is the second edition of a book first published in 1998. The 12 new chapters include the fetal origins of obesity and the impact that the intrauterine environs have on the future risk of developing obesity—the "Barker hypothesis."

Other chapters in the first section provide a historical framework and analyze ethnic and global influences, the global epidemic of obesity, and obesity in children and the elderly. A final updated chapter in this section on the prevalence and cost of obesity to individual countries is useful program advocacy. In the second section, genetic and molecular biological knowledge of obesity and promising new therapeutic approaches are well covered, as are the effects of obesity on morbidity from other diseases and on mortality. Recognition of the endocrine role of fat cells is new in this edition. The roles of the endocrine and autonomic nervous systems; the way fat cells function as a storage, thermogenic, or secretory organ; and the relationship of energy expenditure to the development of obesity are some of the topics included in the second section.

The third section is devoted to the pathophysiology of obesity, with chapters on mortality, the "metabolic syndrome," the cardiovascular system, lipoprotein metabolism, blood pressure regulation, diabetes, gallbladder disease, pulmonary function, arthritis and gout, pregnancy and infertility, physical activity, and quality of life. Nearly 90 authorities have contributed to this book, which will be invaluable to the professional concerned with any aspect of the major global social, economic, and health problem of obesity.

Social epidemiology. Edited by Lisa F. Berkman and Ichiro Kawachi. Oxford University Press, New York, 2000. (ISBN 0-19-508331-8) 391 pages, hardcover. US$65.00.

Nutrition is not mentioned in the index of this book, and none of its 16 individually authored chapters discuss nutrition. Nevertheless, the issues dealt with have important applications to nutrition policies and population-based programs. Some of the chapters will help program-oriented nutrition professionals understand the social considerations involved in the implementation of community- and population-based nutrition interventions. Chapter 12 on "Psychosocial intervention" will be of particular interest to nutritionists.

A strength of the volume is a recurring discussion of possible mechanisms that can explain the connections between social and health behaviors and disease. It discusses the applications of social epidemiology research and the design of effective public health policies and interventions. Public health nutrition workers can gain valuable information from this volume, which will facilitate their collaboration with anthropologists, sociologists, and economists.

Testing of genetically modified organisms in food. Edited by Farid E. Ahmed. Food Products Press/ Haworth Press, Binghamton, N.Y., USA, 2004. (ISBN 1-56022-274-3) 324 pages, softcover. US$49.95

Because nutrition policy makers are inevitably drawn into the controversy over the safety of genetically modified organisms (GMOs) in food, it is essential for them to understand how GMOs in food can be tested. This book takes advantage of the technical expertise and experience of internationally recognized experts in the field of GMO testing. It is written primarily for regulators and laboratory personnel concerned with GMOs and food industry personnel responsible for the testing of their products.

The molecular and immunological methods are described in detail, and their scope and applications are examined. Chapters cover reference materials and sampling issues. The complexity and detail of the sampling and testing required to comply with regulations are impressive. This book well describes the multifaceted testing industry that has developed since transgenic organisms have been approved for food use. The 10 chapters are authoritatively written by experts, with a focus on testing, which they cover well. However, for the applications of GMOs to food policy and food production, the reader is referred to the 2001 IFPRI publication, *The Politics of Precaution: Genetically Modified Crops in Developing Countries,* by Robert L. Paarlberg, reviewed in the June 2002 issue of the *Bulletin* (Vol. 23, No. 2, p. 234).

— *Nevin S. Scrimshaw*

News and notes

New from FAO

Community-based food and nutrition programs: What makes them successful. A review and analysis of experience

The Food and Agriculture Organization (FAO) started a process aimed at developing a methodology to allow countries to carry out in-depth assessments of their community-based food and nutrition programs. There are now a number of successful programs, and a close examination and analysis of these can help us to understand the process of achieving success. Much can be learned from the experience accumulated with community-based nutrition programs in developing countries. The purpose is to understand what works, what does not work and why, and how such programs can be expanded, strengthened, and redesigned, if necessary. Understanding these relationships requires new approaches and new ways of thinking about familiar issues.

It is these issues that this case study report considers. It is based on an in-depth assessment and analysis of three program cases per region (Africa, Asia, and Latin America) and three desk reviews. The objectives of the report are to summarize the main features and findings of the case studies; to highlight, analyze, and discuss the main lessons learned from the case studies and desk reviews; and to provide the theoretical and practical background for the preparation of a methodological guide titled *Improving Nutrition Programmes: An Assessment Tool for Action.*

The report is divided into five sections (A-E), plus annexes.

Section A provides the background and rationale for FAO's decision to undertake this exercise and describes the steps followed.

Section B presents criteria for selecting countries and three programs per region for in-depth case studies. Summaries of desk reviews and full case studies are provided in Annexes 1 to 4.

Section C analyzes the main findings of the in-depth case studies and desk reviews by drawing out the main lessons learned from the experiences of the programs, under four headings: macrocontextual factors, community-level factors, program design features, and sustainability.

It then proceeds to the results of the SWOC/T analyses (Strengths, Weaknesses, Opportunities, and Constraints or Threats) performed on the programs. Features common to all or many of the programs are presented, and some interesting findings of individual programs are highlighted.

Section D uses the findings of sections B and C to suggest ways in which community-based nutrition programs can be improved so as to become more sustainable and have a greater positive impact on nutritional status and on food and nutrition security. Based on the findings of the case studies and their practical implications, this section discusses how success is to be achieved.

Section E concludes the report by advising the reader that many of the conclusions are inevitably based on judgment and assessment. The future of nutrition programming holds its own challenges, some of which are briefly highlighted: the nutrition transition, the needs of older people, and the complexities of massive urbanization and the decentralization processes.

Nutrition planners are advised that the challenge for them is to take from this report what is appropriate in their country context and to use it to improve their existing programs or to design better programs. To help in this process, FAO has produced the companion volume *Improving Nutrition Programmes: An Assessment Tool for Action.*

We are also pleased to announce that an Assessment Tool (AT) Users Training Manual has been developed by the University of the Western Cape School of Public Health, South Africa, in close collaboration with the Food and Nutrition Division of FAO, with support from the FAO-Netherlands Partnership Programme.

The Report is available in English and Spanish. The AT Users Training Manual is available in English. Printed versions of both publications are available upon request. They can also be downloaded from the FAO website, www.fao.org

For further information contact: guy.nantel@fao.org or irela.mazar@fao.org

Organization guidelines from FAO

Incorporating nutrition considerations into agricultural research plans and programs. Resources for advancing nutritional well-being

This paper presents a series of guidelines meant to encourage and assist Member Nations of the United Nations Food and Agriculture Organization (FAO) in addressing and including nutrition and health issues in their agricultural research planning and programs. The paper explains why any nation seeking economic and social development should recognize that improving the nutrition of its population means a healthier workforce, which is a vital component of any economic development plan.

The main focus of these guidelines is resource-poor farmers and low-income rural families who derive their livelihoods from agriculture, yet are often food insecure. Rural people often lack the authority and confidence to coerce the research system to address their needs.

These guidelines have been developed in consultation with the stakeholders themselves. They take into account agronomic factors as well as gender-related issues, holistic approaches to their application, policy-level support, and institutional linkages.

The paper also offers practical suggestions for implementation of these guidelines, which are designed specifically for four different disciplines of the agriculture sector: policy makers, research planners and managers, agricultural research workers, and extension services.

Policy Brief from FAO

Incorporating nutrition considerations into development policies and programs. Brief for policymakers and program planners in developing countries

Development aims to provide people with the means and the social and economic environment necessary to lead active, healthy, and productive lives. To achieve this objective, developmental policies and programs need to be directed toward improving the human development potential, including improvement of nutritional well-being. Nutrition-focused interventions are required primarily to reach and benefit vulnerable individuals. Factors that influence nutritional status, however, fall under the responsibilities of many sectors. All these factors need to be addressed to achieve good nutrition and health status. Furthermore, it is crucial that policy makers and planners in all development sectors recognize and understand the socioeconomic background and preferences of target groups. Hence, the principle of coordinated, holistic approaches in policy formulation and program design is key to successful and sustainable development.

It is important that the integral role of nutrition in development be taken into account during policy formulation, program planning, and implementation. Most importantly, the synergistic effect of sector programs (and hence policies) needs to be well understood. This will assist in discouraging unnecessary competition for political support and funding. Instead, it will promote collaboration among different sectors and disciplines, and will contribute to the elaboration of a development agenda that is sustainable and beneficial to the target groups.

The overall objective of this Policy Brief is to create awareness and understanding of the advantages of good nutritional status for the development process, so that nutrition considerations can be incorporated into development policies to facilitate sustainable development.

The guidelines are available in English, Spanish, and French. The Policy Brief is available in English. Printed versions of both publications can be requested from FAO. The guidelines can also be downloaded from the FAO website: www.fao.org.

For further information, contact: guy.nantel@fao.org or juliet.aphane@fao.org.

Call for information from former UNU Fellows

The United Nations University (UNU) is updating its information on former UNU Fellows. If you are a former UNU Fellow, we urgently request you to forward your current postal and e-mail addresses, a description of your current responsibilities, and any other relevant information, including publications, honors, and awards, to UNUfellows@inffoundation.org. Also indicate whether you are currently receiving the *Food and Nutrition Bulletin*. The resulting database will serve as a resource for Fellows to reestablish contact with former colleagues, for the UNU and training institutions to compile information on the long-term outcomes of their training efforts, and for both the UNU and the International Nutrition Foundation (INF) to obtain additional support for fellowships. Please also ask any other UNU Fellows whom you know to send their information to the above address. This information will be placed on the INF website as it becomes available, and the *Bulletin* will publish periodic reports based on it. A similar INF database and website will be maintained for Fellows in the current Ellison Medical Foundation–International Nutrition Foundation Fellowships in Nutrition and Infection.

Former UNU Fellows and Trained Leaders from Latin American countries are invited to visit http://latinut.net for professional information and to facilitate regional contact. This website is in Spanish and offers professional profiles and e-mail addresses of former Latin American Fellows. The website is still a work in progress, so if you are a former UNU Fellow and have not yet been contacted, or if you have any questions or comments, please contact María-Teresa Oyarzun at: mtoyarzun@inta.cl.

UNU former Fellows meeting

Dr. Héctor Araya, a former UNU Fellow trained at the Institute of Nutrition of Central America and Panama (INCAP), Guatemala, from 1977 to 1978, organized, with the collaboration of the United Nations University Food and Nutrition Programme (UNU-FNP) Regional Office at the Institute of Nutrition and Food Technology (INTA), a meeting of former UNU Fellows from Latin America at the XIII Congress of the Latin American Nutrition Society, November 12, 2003, in Acapulco, Mexico. The attendees included Latin American Food and Nutrition Programme Fellows from the 1970s and 1980s and the young professionals who participated in the three Leadership Training Workshops (Antigua, Guatemala, 1997; Buenos Aires, Argentina, 2000; and Cuernavaca, Mexico, 2003).

The meeting, coordinated by Ricardo Uauy (UNU Regional Coordinator for the Food and Nutrition Program) and chaired by Dr. Araya, included Dr. Nevin Scrimshaw (former UNU Food and Nutrition Program Director and currently Adviser to the UNU Food and Nutrition Program for Human and Social Development), Helio Vannucchi (2003 elected President of the Latin American Nutrition Society [SLAN]), and Juan Rivera (Director of the Nutrition and Health Research Center of the National Institute of Public Health in Mexico) at the podium.

Dr. Araya, Dr. Uauy, and Dr. Scrimshaw addressed the group about the past and present Food and Nutrition Programme. All highlighted the importance of increasing UNU activities in the Latin American region. As part of that effort, three leadership workshops have taken place in the last decade, together with other applied research and training activities to strengthen local and regional capacity linked to joint Ellison Foundation International Nutrition Foundation/ United Nations University/International Union of Nutritional Sciences (INF/UNU/IUNS) programs at the regional level. The objective of the meeting was to facilitate the interaction among former UNU Fellows and Trained Leaders in order to promote their involvement and support of Food and Nutrition Programme regional activities.

In memoriam

Clive E. West, 1939–2004
John Thornton Dunn, 1933–2004

Clive E. West, 1939–2004

Clive Eric West, PhD, DSc, FRACI, was born on July 27, 1939, in Griffith, Australia, near Sydney. He died on August 27, 2004, at the age of 65, of cancer. Four months earlier, Dr.West had been honored with the prestigious Kellogg Prize in International Nutrition by the Society for International Nutrition Research at the Experimental Biology 2004 meeting in Washington, D.C. His inexhaustible curiosity to discover and interpret, broad expertise in nutritional sciences, unqualified commitment to educate, and dedication to improving health in malnourished societies both inspired and guided all with whom he came in contact.

Dr. West received degrees from the University of Sydney and University of New England in Armidale, Australia. His early work was conducted in his native country on livestock nutrition, with his first Index Medicus citation in 1964, for an article addressing palmitate metabolism in sheep. Other early animal studies involved intermediary metabolism in domestic fowl, sows, goats, rabbits, and guinea pigs.

After working at the University of New England, the Unilever Research Laboratory, Colworth House, in Bedford, UK, the John Curtin School of Medical Research, Australian National University in Canberra, and the Ahmadu Bello University in Zaria, Nigeria, in 1979 he received an appointment to the Division of Human Nutrition of Wageningen (Agricultural) University, a position he retained until the time of his death. In 1992, he became Visiting Professor of International Nutrition at the Division of International Health at the Rollins School of Public Health, Emory University, Atlanta, Ga., USA, to participate in the Program Against Micronutrient Malnutrition. Since 2000, Dr. West has also been Professor of Nutrition in Health and Disease, Department of Gastroenterology, University Medical Centre, Nijmegen, the Netherlands.

Dr. West's research transition from experimental animals to human lipid metabolism began in 1979 with the first of his many papers published in the Lancet, "Is serum total cholesterol outmoded?" a challenging and controversial title. Long before the "early origins of adult disease hypothesis" of David Barker et al., Dr. West and colleagues at Wageningen had been focusing on the potential consequences of serum lipid concentrations in infancy and childhood on health in later life.

Dr. West also emphasized the need to improve dietary assessment methods, including the food composition database on which dietary assessment is based. His organization of "EUROFOODS" to improve and harmonize food composition data in the European community led him to become an early and lifelong supporter of the United Nations University's "International Food Data Systems" project (INFOODS), begun in 1983. This global program, now a joint FAO/WHO program based in Rome, is still dependent on the Wageningen International Food Composition Data Base course. This course, developed jointly with David Southgate and Joanne Holden, has now been held 6 times in Wageningen and Dr. West has guided satellite courses in a number of other regions. The course in Pretoria, organized by Hetti Schönfeldt, will be held in February 2005 for the fourth time. Promoting these courses was one of his major initiatives at the time of his death and the international community is much indebted for these efforts.

The early eighties saw Dr. West's career take clear aim at a better understanding of the role of diet-disease interactions as determinants of micronutrient deficiencies and health consequences. Logically, he focused on the tragic effects of low intake and deficiency of lipid-soluble vitamin A, initiated by a paper in 1983 on post-measles corneal ulceration in children in Northern Nigeria. This publication, and others that followed in the eighties brought Dr. West (and, to the good fortune of all, his graduate students!) into the scientific world of vitamin A, inaugurated by his 1st IVACG meeting in Nairobi in 1981 and culminating in membership on the IVACG Steering Committee in 1999.

Over the next two decades, by dint of his ingenuity, dedication to science and evidence-based advocacy —and by the hard work of many capable doctoral candidates—Dr. West created a legacy of scientific contributions that has permanently advanced our science and will inform vitamin A deficiency prevention strategies for years to come. His areas of contribution are too numerous to mention here, but to illustrate the breadth of his scientific command, Dr. West authoritatively published in areas of vitamin A and immune regulation, measles, tuberculosis; vitamin A and growth, hematological status and other forms of morbidity; vitamin A in breast milk; vitamin A-micronutrient interactions, especially zinc and iron; carotenoids, folates and antioxidant activities of vegetables. And, of course, factors that affect bioavailability of provitamin A-rich vegetables and fruits, especially focusing on the ubiquitous (and still nutritious, even after Dr. West was done with it!) dark green leaf. Many factors determine bioavailability. Searching for the right mnemonic, Dr. West decided on "SLAMENGHI", standing for: chemical Species; Linkages; Amount; Matrix; Effectors; Nutritional status; Genetic factors; Host factors; and Interaction terms. Few who heard Dr. West talk about these influences will forget their significance even though they are unlikely to remember the word he invented.

It was in this effort to come to grips with carotenoid bioavailability issues that led Dr. West and several of his doctoral students, notably Saskia de Pee, to obtain exquisite data sufficiently strong and consistent to contradict the nutrition establishment view of the efficiency with which beta-carotene, and all other provitamin A carotenoids in vegetables, fruits, and tubers, are absorbed and converted to vitamin A. The dogma, supported by meager data obtained—under what are now considered suboptimal conditions in the previous four decades, was that 6 μg of beta-carotene in a mixed diet converts to 1 μg of retinol equivalency in the body. For all other provitamin A dietary carotenoids, the value was considered half as efficient (12:1). These ratios were etched into our minds by lectures, textbooks, reports of expert groups and food composition tables around the world. However, Oomen had already expressed his concerns at a conference in June 1958: "I myself can cite several examples from Celebes as well as from Central Java, that children apparently consume a fair quantity of carotene and still present xerophthalmia.... That carotene does not produce the theoretical equivalent of vitamin A under many circumstances … is of serious consequence."

The data from Dr. West and his coworkers showed clearly that vegetables, and especially dark green leaves, were nowhere near that efficient in releasing beta-carotene for vitamin A use. The controversy was played out over a decade, in original publications and reviews, in feisty scientific meetings and academic discussions, and in an informal debate arranged by Noel Solomons at the 16th International Congress of Nutrition in Montreal and testimony before the Panel on Micronutrients of the Institute of Medicine in the USA. The data became stronger and Dr. West defended his position vigorously, often noting with characteristic humor and confidence that he was not arrogant, just right!

Finally, in 2001, the National Academy of Sciences in Washington, D.C., published new bioconversion ratios for dietary beta-carotene and other active carotenoids to vitamin A. Their creation of the "retinol activity equivalent" expression, to replace the 34-year-old "retinol equivalent" is a testimony to the vision and persistence of Dr. West to "get his message across". Indeed, the evidence from the studies in the Netherlands, Indonesia, and Vietnam was instrumental in the upward re-valuation of bioefficacy for carotenes in oil to be bioconverted into the active vitamin, and the devaluation for this bioefficacy for carotenes in plant matrices. The Institute of Medicine established conversion factors of 12:1 and 24:1, for beta-carotene and other provitamin A carotenoids, respectively. This allowed us to begin to understand how xerophthalmia could co-exist amid such abundance of provitamin A-rich dark green leaves! However, based on the work in Indonesia and Vietnam, Dr. West and his colleagues insisted that the true bioefficacy of beta-carotene in a mixed diet (ratio of vegetables to fruits of 4:1) is 21:1 (and 42:1 for other provitamin A carotenoids). Time and continued rigorous research will tell us if they were right.

Dr. West was a unique and inspired investigator, one who truly made the whole world his geographical base and made a difference across his path. He navigated the tempestuous waters of a series of thorny public health problems afflicting humanity and left both understanding and programmatic solutions in his wake. He had a knack for open and honest collaboration with colleagues of various nationalities. He was a tireless traveler, and one never knew when and where one would meet him.

For the nutrition students at Wageningen University, Dr. West was an inspiration. He opened his arms, projects, and laboratories to foreign nationals for dissertation research. Dr. West expected his PhD fellows (almost 40) to work hard, trusted them to do a good job, and motivated and inspired them. His way of mentoring was inspiring, challenging, and sympathetic. Almost always the student was the first author of scientific publications that resulted from work supervised by Dr. West. Many of his students have gone on to important careers in international nutrition and in turn they are striving to transmit Dr. West's heritage to their own protégées.

Dr. West continued to plan, work and stimulate, others until the week of his death. He clearly had the will and drive to devote many more years to reaching outward and forward, and to continue the momentum of nutrition discovery. His life and productivity were cut tragically short.

—Adapted with additions by Nevin S. Scrimshaw, from the obituary by Noel W. Solomons, Saskia de Pee, and Keith P. West, Jr, published in the 3/2004 issue of Sight and Life.

John Thornton Dunn, 1933–2004

John T. Dunn, a native of Washington, DC, professor of medicine at the University of Virginia School of Medicine, died suddenly and unexpectedly at his home on April 11, 2004, of a myocardial infarction. He had a long and distinguished career in research, patient care, and international health.

A graduate of Princeton University, he attended the Duke University School of Medicine. During the summer after his third year at Duke, he began research as an exchange student at the Thyroid Unit of the Massachusetts General Hospital in Boston. There he measured the disposal rate of reverse triiodothyronine and found that the rate was remarkably rapid. After completing his medical degree at Duke and an internship, he returned to the thyroid unit at the MGH for two years, spent a year in clinical research with Dr. Sidney Werner at the Presbyterian Hospital in New York, and then returned to the MGH for two additional years. During these times and in addition to clinical responsibilities, he worked on the difficult problem of the fine structure of thyroglobulin, with the end in view that genetically linked structural errors in this protein might be responsible for certain thyroid diseases. He also observed for the first time that the thyroid gland is destroyed at a constant rate long after treatment for thyrotoxicosis with radioactive iodine.

While in the thyroid unit at MGH, he developed an interest in the worldwide problem of iodine deficiency, a long-term research program of the unit. This became a dominant theme during his 36-year research career on the faculty of the University of Virginia School of Medicine. He became a professor emeritus of the university in 2003.

Because iodine deficiency is a worldwide health problem, especially in the developing countries, this interest required extensive studies and travel in many countries around the world, such as India, China, and countries of Africa and South America. In addition, Dr. Dunn also developed methods for the measurement of iodine that are widely used in the field for ascertaining the presence and severity of iodine deficiency, and for controlling the iodine content of salt at production sites where salt is fortified with iodine in control programs for prevention of iodine deficiency. He was a member of the American Thyroid Association, which awarded him the Van Meter prize in 1968 for excellence in basic thyroid research and the Paul Starr award in 1997 for his contributions to fighting iodine deficiency and its accompanying disorders worldwide.

Dr. Dunn was a participant in the inauguration of the International Council for the Control of Iodine Deficiency Disorders in Delhi and Kathmandu in 1984 and 1985. ICCIDD has become the premier organization in the world devoted to correction of a nutritional disorder. Initially he was the secretary of that organization, guided its evolution, and became its executive director in 2001. He developed a newsletter that began as a two-page reminder and over 20 years evolved into a quarterly publication in which country profiles and descriptions of country and regional preventive programs are reported. Publications in that journal are now frequently quoted in the medical and epidemiological literature.

He was a quiet, low-key, but highly effective scientist. He was a problem solver and a resolver of conflicts. He had an insightful and balanced approach to medical research. He was also a superb musician on the organ, harpsichord, and piano. He had a huge knowledge of the musical literature, but favored Bach, Mozart, Buxtehude, and Handel. John was a devotee of the outdoors and an annual summer hiker with his wife in remote parts of Alaska. He has left a huge number of friends and admirers both in the United States and around the world.

A number of family members, colleagues, and friends were present at a service of remembrance at the University of Virginia chapel on Saturday, April 17, 2004. John is survived by his wife, Ann; three children, Robert Dunn of New York, Peggy Dunn of Austin, Texas, and Cathy Dunn Shiffman of Philadelphia; and two grandsons, Nick and Sam. In his honor the annual John T. Dunn Lectureship in Endocrinology and International Health will be established at the University of Virginia in recognition of his accomplishments in endocrinology and world health. Donations may be made to the Rector and Visitors of the University of Virginia, FBO John T. Dunn Lectureship, Attn. Jeffrey L. Moster, P.O. Box 800773, Charlottesville, VA 22908-0773, USA.

—John Stanbury

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Note for contributors to the *Food and Nutrition Bulletin*

The editors of the *Food and Nutrition Bulletin* welcome contributions of relevance to its concerns (see the statement of editorial policy). Submission of an article does not guarantee publication; acceptance depends on the judgment 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.

Language. Contributions should be submitted in English.

Format. Manuscripts should be prepared on a computer, double-spaced, and with ample margins. **Authors are encouraged to submit manuscripts electronically.**

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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.

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5. Medioni J, Boesinger E, eds. Mécanismes éthologiques de l'évolution. Paris: Masson, 1977.

—*chapter in book:*

6. Barnett HG. Compatibility and compartmentalization in cultural change. In: Desai AR, ed. Essays on modernization of underdeveloped societies. Bombay: Thacker, 1971: 20–35.

World Wide Web reference

7. WHO HIV infections page. WHO web site. Available at: http://www.who.int/topics/hiv_infections/en/. Accessed 12 October 2004.
8. Nielsen J, Palle V-B, Martins C, Cabral F, Aaby P. Malnourished children and supplementary feeding during the war emergency in Guinea-Bissau in 1998–1999. [serial online]. Am J Clin Nutr; 2004; 80:1036-42. Available at: http://www.ajcn.org/cgi/content/full/80/4/1036. Accessed 12 October 2004.

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