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Malnutrition and dietary protein: Evidence from China and from international comparisons

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Abstract

Malnutrition, as measured by anthropometric status, is a powerful risk factor for illness and elevated death rates throughout life. Understanding the relative importance of disease, dietary quantity, and dietary quality in causing malnutrition is therefore of major importance in the design of public policy. This paper contributes to the understanding of the relative importance of quantity and quality of diet by utilizing aggregate data to complement previously reported individual-level studies. Three compilations of anthropometric data—one involving subjects from 13 provinces in China, another involving subjects from 64 counties in China, and a third involving 41 populations in 40 countries—are used to examine the relative importance for human growth of inadequacies of dietary energy and protein. The analysis involves regressing average adult heights and weights against estimates of average energy and protein availability (by province, county, or country) and per capita incomes. We use protein availability in part as a marker for overall quality of the diet, while recognizing that protein is far from perfectly correlated with dietary fat or micronutrient availability. The paper discusses issues of both data quality and statistical methodology, and points to relevant resulting caveats to our conclusions. Subject to these limitations, all three analyses suggest that, at the levels of dietary intake in these populations, lower protein intake is related to growth failure whereas lower levels of energy availability are not. The protein effect appears stronger for males than for females.

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Key words: China, dietary protein, growth, malnutrition

Introduction

The mean heights and weights of individuals of a given age and sex vary substantially across countries; it is common to find the difference in means between two national populations to be several times the standard deviation of the distribution within a reference population [1]. In high-income populations, the parent–child correlation in height is high, and it is well established that genetic differences between individuals account for most of the individual variation in anthropometric status in such populations [2]. That said, available evidence suggests that differences across ethnic groups in the distribution of genetic potential account for a relatively small part of the observed differences among populations in anthropometric indicators. The more important share of variation across populations results from differences in the proportion of individuals in each population who fail to reach their genetic potential and in the magnitude of that growth failure [1-3]. Factors influencing the magnitude of growth failure within a population include dietary adequacy, disease patterns, and variations in nutrient requirements induced, for example, by variation in required activity levels or ambient temperatures.[1]

Understanding the determinants of malnutrition—and how they vary from one environment to another—is of central importance to health policy: in a recent quantitative assessment, fully 50% of the total number of deaths in children under five years of age were associated with malnutrition [4]. Better understanding of the magnitude and nature of dietary and other risk factors for malnutrition would provide a valuable avenue for improving disease-prevention strategies relevant to the needs of the poor. Recent research points to a substantial contribution of disease to malnutrition [5]. Easterlin presents historical evidence suggesting that reduction in disease accounted for the rapid rise in the rate of increase in male stature that occurred in Europe from around 1800 to around 1900 [6] (from an average 1.1 cm per century increase to an average 7.7 cm per century increase). While acknowledging the importance of infectious diseases, this paper focuses on the role of diet as a determinant of malnutrition, and in particular, it utilizes several aggregate-level data sets to assess the quantitative significance of dietary quality, particularly the protein content of the diet, as a risk factor for malnutrition.

Although dietary protein can be utilized by the body for energy, with 1 g of protein providing 4 kcal of energy [7], high-protein foods tend to be several times more expensive per kilocalorie of energy provided than foods that are low in protein or relatively inadequate in one or more essential amino acids.[2] It is generally accepted that when diets are low in energy, available protein will in fact be used for energy, although the empirical evidence for this seems to be strongest for severe reductions in energy intake. The important empirical question is how variation around current levels of energy and protein availability influences levels of malnutrition. Just as diets that are low in cost per kilocalorie of energy are low in protein, diets that are low in cost per gram of protein are relatively low in energy. This tradeoff underscores the reason for quantifying the relative importance of increasing the energy content of diets versus improving their quality in reducing malnutrition.

Nutrient intake and growth: data and methods

We specified a simple function relating an anthropometric indicator to a number of potentially determining variables. Multivariate regression is then used to estimate the parameters of this function. The first data set contains information on average adult heights and weights (both male and female), income, and energy and protein availability from urban areas of 13 provinces of China. The second set also comes from China and refers to 64 largely rural counties. Nutrient availability (energy, protein, lipids, and fiber) is measured from a population sample of actual dietary composition and intake at the county level, rather than from aggregate food balances. Estimates of income were also available. The third data set contains information on national averages from 41 populations in 40 countries of adult male height (but not weight) and from 33 populations in 32 countries of adult female height, energy and protein availability (from aggregate balances), per capita gross national product (GNP), and predominant ethnic group. The sources, methods of analysis, and main results for each data set are first discussed. The final section compares the three sets of results and draws some conclusions concerning the relative importance of energy and protein as determinants of achieved growth. The contribution of this paper lies in the inclusion of dietary energy and protein levels among the determining variables. A previous study also utilized a regression approach to assessing determinants of adult height and included a broader range of variables in its analysis [8].

A number of caveats accompany our analyses. First, available data do not include a number of variables that are potentially important determinants of growth, and the variables they do include are averages rather than individual values.[3] The data also refer to one moment in time rather than to the interval over which people grow, resulting in their final adult height (and, with much more variation, their adult weight). In all three data sets, the estimates of nutrient availability refer to the approximate time when adult heights and weights were measured; we assume that these contemporary measures provide indicators of relative availabilities during the preceding two or three decades. This assumption is most defensible for the second analysis, because "dietary patterns in these rural areas of China, being simple in food variety, have probably remained simple and similar for many years, since foods consumed in each area are produced locally under reasonably stable local crop conditions" [9]. We also assume that few people in the sample populations have migrated to or from the province, county, or country in which they grew up, so that the nutrient availability in the place where they lived when surveyed is probably similar to the nutrient availability when they were growing up.

Growth failure and health

Our principal dependent variable, stature, is increasingly used in many fields as an indicator of general well-being [8]. Evidence from a wide range of studies suggests that malnutrition impairs mental development, in the most severe cases by a direct effect on brain cells and in more moderate cases by lowering the child's motivation and energy level and thereby reducing the amount of effective learning time [10, 11]. There is also evidence that malnutrition reduces the activity levels of poor children in developing countries [12], and that malnourished children are less likely to attend school and less likely to succeed if they do attend [13, 14].

The mortality consequences of malnutrition are probably mediated through a cyclic interaction among dietary inadequacy, malnutrition, immune status, and infectious diseases. Malnourished children are more susceptible to disease, and they are more likely to die if infected. Children who are ill eat less and are less able to absorb what they do manage to eat [15–20] at a time when their nutrient requirements are actually increased.

Quantitative estimates have been developed of the extent to which infection accounts for observed levels of malnutrition in a broad range of environments [5], and such estimates vary greatly (10% to 80%) across environments, suggesting that the entry points for intervention to break the adverse cycle will also vary.

Data set 1. Height and weight of young urban adults in 13 Chinese provinces

A concern with the identification and development of sports talent among the youth of China gave rise to a detailed study in 1979 of 183,414 school-age children and young adults from 13 provinces and the three provincial-level metropolitan areas of Beijing, Shanghai, and Tianjin [21]. This study reported heights and weights of urban males and females in the age range 18 to 25 years in each province. The variables used to explain these anthropometric data came from several other sources. An early World Bank policy paper on the health sector in China used the 1979 data, data from other published sources, and data collected specifically for the report to document levels and trends in nutritional status [22, 23]. These reports describe an environment of rapidly improving nutritional status, particularly in urban areas, and of possibly worrisome inequality in the distribution of protein consumption.

We used the official Chinese estimate of total industrial and agricultural output per capita in 1981 [24] to measure provincial income. Provincial-level data on energy and protein production were obtained from another World Bank study of trends in food and nutrient availability in China [25]. These data on income and on nutrient availability cover another 13 provinces besides those for which anthropometric indicators are available. All data were for the year 1979, except the total value of industrial and agricultural output, which was for the year 1981. Table 1 gives the definitions, means, and standard deviations of all the variables, over all provinces for which they were available.

Although there were 16 observed locations for adult heights and weights (including the metropolitan areas), the relations between energy and protein, and between height and weight, are based on only 13 observations. The figures for the urban areas of Beijing, Shanghai, and Tianjin could not be included, since the data on nutrient availability excluded all interprovincial and international trade in food crops and hence resulted in gross underestimates of nutrient availability. For the 26 nonmetropolitan provinces, exclusion of trade in grain probably leads to only small errors in estimates of provincial nutrient availability [25]. All analyses are based on multiple linear regressions using height or weight as the dependent variable.

To provide context, relations between income and nutrient availability (for total energy and for energy from protein) were calculated from the logarithms of the provincial averages. Although the demand for and supply of nutrients cannot be distinguished in these data, we assumed that demand determines availability and interpreted the coefficients as demand elasticities. Not surprisingly, the income elasticity of demand for protein (0.68) was much greater than that for energy (0.40), but both were substantial and statistically significant, suggesting that the poor derive a smaller percentage of their total dietary energy from protein sources.

Results

A previous analysis used univariate regressions to relate each of these variables separately to male and female heights and weights for both urban and rural areas of each province [25]. It found that male anthropometric status was systematically more closely related to all the explanatory variables than was female status, and that urban heights and weights were better explained than those in rural areas—much better, when energy and protein availability were used as explanatory variables.

Univariate regressions say nothing about whether protein availability affects adult height or weight, given

TABLE 1. Variables for urban China in 1979

Variable	No. of observations (provinces)	Mean	SD
Male height, age 18–25 yr (cm)	16	170.3	1.43
Female height, age 18–25 yr (cm)	16	159.0	1.22
Male weight, age 18–25 yr (kg)	16	58.9	2.70
Female weight, age 18–25 yr (kg)	16	51.5	1.24
Income: industrial and agricultural output per capita (1981) (yuan)[a]	26	646	264
Energy: net dietary energy available from provincial production (kcal/capita/day)	26	2,300	386
Protein share: fraction of available dietary energy from protein (%)	26	10.7	2.1

Sources: heights and weights from Keusch [18]; income from Jamison et al. [23]; energy and protein share from State Statistical Bureau [24].
a. 1.7045 yuan = US$1 (1981).

a particular level of energy availability, nor do they distinguish the nutrient effects from those of income and other variables. Table 2 therefore shows multiple regression relations between height and weight and all the hypothesized determining variables. Because rural anthropometric status appears much harder to explain with these variables, our analysis is limited to urban areas. By itself, higher income was found to affect male height positively and significantly and to have a positive but not statistically significant effect on female height (these simple regressions are not reported in table 2). When available energy and the proportion of energy from protein were entered together with income, protein, but not energy, was found to have a positive and highly significant effect on height for both sexes.

The effects on weight were, not surprisingly, quite similar to the effects on height. The effect of income on weight was less strong than its effect on height, whereas the effect of protein on weight was almost as strong as its effect on height. In contrast to the effect on height, total energy availability was also found to have a marginally significant positive effect on the weight of males but not of females.[4]

Data set 2. Adult height and weight in 64 rural Chinese counties

In 1976 a major study was conducted of the causes of death in China, covering some 20 million deaths during the period 1973 to 1975. Primarily in order to relate cause-specific mortality, and particularly mortality from several different cancers, to a variety of lifestyle factors, including diet, a supplementary survey was undertaken in 1983 in 65 mostly rural counties. Attained height and weight for both male and female adults were also measured. Some 1,950 families participated, and three-day dietary intake measurements were made for 13,000 individuals [9].

As in the provincial-level study, the estimate of income refers to the total value of industrial and agricultural output per capita in 1982 at the county level. Average food intake in these data refer to average consumption in the specific communities studied. Relations were again estimated between the anthropometric variables and income, total dietary energy, and the share of energy obtained from protein.

Table 3 shows the means and standard deviations

TABLE 2. Determinants of the height and weight of young adults (age 18–25 years) in urban China in 1979

	Height[a]		Weight[a]	
Independent variable	Male	Female	Male	Female
Income (1981)	0.0025 (2.88)**	0.0005 (0.39)	0.0009 (0.19)	0.0004 (0.33)
Energy	0.0006 (0.93)	0.0008 (0.87)	0.0021 (1.74)*	0.00096 (1.00)
Protein share	0.46 (4.50)**	0.44 (3.00)**	0.618 (3.25)**	0.470 (3.08)**
Constant	162.0	151.8	46.13	43.80
R^2 adjusted[b]	0.78	0.43	0.53	0.44
No. of observations	13	13	13	13

a. The *t*-statistics are given in parentheses after the coefficients.
b. R^2 is the (adjusted) percentage of variance accounted for.
* $p < .10$, ** $p < .05$.

TABLE 3. Variables for rural Chinese counties in 1983

	Males		Females	
Variable	Mean	SD	Mean	SD
Male height (cm)	163.4	2.64	—	—
Female height (cm)	—	—	153.3	2.40
Male weight (kg)	54.16	2.97	—	—
Female weight (kg)	—	—	48.13	3.06
Income: industrial and agricultural output per capita (1982) (yuan)[a]	646	671	642	666
Energy: net dietary energy available from provincial production (kcal/capita/day)	2,624	392	2,461	411
Protein share: fraction of available dietary energy from protein (%)	9.88	1.27	10.02	1.66
No. of observations (counties)	63	—	64	—

Source: ref. 20.
a. 1.7045 yuan = US$1 (1981).

of the variables analyzed. These differ slightly between men and women—apart from the sex-specific differences in height and weight—because we used data for 64 counties for females and only 63 counties for males. Both men and women are shorter and weigh less in rural than in urban areas. Rural energy intakes appear to be very slightly higher and rural protein intakes somewhat smaller, but the comparison is complicated by the difference in the way intakes were estimated—by province-level availability (table 1) and by direct household-level observation (table 3).

Results

Table 4 shows the regression results for male and female heights and weights. For both sexes and for both anthropometric measures, total dietary energy is never significant, whereas the share obtained from protein is always highly significant. Income is not significant in any of the regressions.

The only notable difference between the results for men and those for women is that the coefficient on the share of protein in total energy is only about 60 percent as large for female height as for male height and about two-thirds as large for female weight as for male weight. In the provincial-level urban analysis, these coefficients do not differ between the sexes for height, but the female coefficient is appreciably smaller for weight. Male-female differences in predictors of attained weight may result from differences in the typical percentage of body mass in fat.

Data set 3. Intercountry differences in adult height

The source for adult anthropometric data in the third analysis was Eveleth and Tanner [1]. The authors of this compendium draw on an enormous range of scientific studies, some based on national samples but most based on regional samples or samples drawn from particular ethnic groups; they describe the variation in growth, adult size, and body proportions found across countries and between different genetically similar groups. The four main groups into which samples were divided were Indo-Mediterranean, European, African, and Asian. Among adults, the European and African populations were the tallest: Indo-Mediterraneans were on average shorter than Europeans by approximately 5 cm, and Asians were shorter by approximately 7 cm.

Data

For adult males, data on average heights from 41 populations were used as the dependent variable. (These correspond to 40 countries, since Surinamese of African and Asian origin were treated as separate populations.) Data on female heights were available for 33 populations (32 countries). There was considerable variation among the years in which the data were obtained, but the majority of the studies were from the 1960s (with a few from the late 1950s and a few from the early 1970s). Also included was an indicator of major ethnic group—taking a value of 1 for either Indo-Mediterranean or Asian, the two shorter populations—in order to control at least partly for possible genetic variation in potential height across countries. Since the data include only four European countries and none from North America or northern Europe, this variable serves mostly to distinguish these two groups from African populations. The other hypothesized determining variables—per capita GNP and energy and protein availability per capita—were obtained from two World Bank documents: the World Development Report 1979 [26] and the Social Indicators Data Sheet [27].

Table 5 shows the means and standard deviations of the variables in the regressions seeking determinants of cross-country variation in average height of adult males. A comparison of the values in table 5 with

TABLE 4. Determinants of adult height and weight in rural Chinese counties in 1983

	Height[a]		Weight[a]	
Independent variable	Male	Female	Male	Female
Income (1982)	–9.82(–4) (0.21)	6.78(–5) (0.16)	–1.50(–4) (0.27)	8.36(–5) (0.15)
Energy	0.001 (1.62)	8.45(–4) (1.24)	0.001 (1.29)	0.001 (1.45)
Protein share	1.013 (3.75)**	0.595 (3.51)**	0.968 (3.07)**	0.665 (3.02)**
Constant	149.8	145.1	41.3	38.0
R^2 adjusted[b]	0.16	0.15	0.10	0.11
No. of observations	63	64	63	64

a. Coefficients < 0.001 are shown in scientific notation, with the exponent (power of 10) in parentheses after the coefficient. The *t*-statistics are given in parentheses after the coefficients.
b. R^2 is the (adjusted) percentage of variance accounted for.
* $p < .10$., **$p < .05$.

TABLE 5. International comparisons

Variable	Males		Females	
	Mean	SD	Mean	SD
Male height (cm)	166.9	5.00	—	—
Female height (cm)	—	—	154.5	4.45
1960 income: GNP/capita (1977 US$)	507	468	510	431
Energy: net dietary energy available (kcal/capita/day)	2,207	349	2,207	364
Protein share: fraction of available dietary energy from protein (%)	10.61	1.67	10.64	1.71
Ethnic group: Asian or Indo-Mediterranean = 1; European or African = 0	0.54	0.50	0.48	0.51
No. of observations (populations)	41	—	33	—

Sources: height, weight, and ethnic group from Eveleth and Tanner [1]; income and energy from Piazza [25]; protein share calculated from energy and World Bank [26].

those in tables 1 and 3 shows that the average height of males in the 41 populations (166.9 cm) falls between the values for urban (170.3 cm) and rural (163.4 cm) males in China. The average per capita availability of energy was slightly lower (2,207 kcal) than in the Chinese samples (2,300 kcal in urban areas and more than 2,500 in rural areas); the average percentage of energy available from protein was nearly identical in the 40 countries (10.6%) to that in urban China (10.7%).

Results

Table 6 shows the results of regressions of the average height of adults in the 41 (or, for women, 33) populations on two different combinations of explanatory variables, using the same formulations for nutrient availability as in the analysis of the Chinese data. For males, the total available energy is not a significant determinant of height, but the percentage of energy available from protein is highly significant; this result is the same whether or not the (significant) ethnic distinction is included. For female heights, the coefficient on the share of energy from protein is only about 60 percent as large as that for male heights, while the standard error of the estimate is unchanged, so the variable is not significant. (The ratio of the coefficients for men and women is about the same as for the analysis of rural Chinese heights: protein seems systematically to make less difference in female height, except in purely urban populations.) Total energy intake continues to be nonsignificant, and ethnicity highly significant, for women.

We also tried a specification different from that used for China, which included per capita GNP, energy available from protein sources in the diet, and energy available from nonprotein sources. Energy available from protein sources was a significant predictor of adult height of males, whereas energy available from nonprotein sources was unrelated to height. These results are not reported here. Adding a control variable for ethnic group indicates that belonging to the Indo-Mediterranean or Asian group has a significantly negative effect on height (about 4 cm) relative to that of Africans or Europeans, but controlling for this component of variation in height does not reduce the significance of energy available from protein (nor does it alter the nonsignificance of per capita GNP). When dietary composition is controlled, the estimated differ-

TABLE 6. Determinants of adult male height (41 populations in 40 countries) and adult female height (33 populations in 32 countries), ca. 1960

Independent variable	Urban		Rural	
	Males	Females	Males	Females
1960 income	–0.001 (0.82)	–0.002 (1.08)	–0.001 (0.66)	–0.002 (0.86)
Energy	0.001 (0.41)	0.004 (1.35)	0.001 (0.06)	0.002 (0.84)
Protein share	1.155 (2.37)**	0.619 (1.27)	1.073 (2.39)**	0.654 (1.50)
Ethnic group: Asian or Indo-Mediterranean			–3.858 (2.80)**	–3.941 (2.92)**
Constant	153.0	141.1	157.8	145.8
R^2 adjusted	0.12	0.09	0.25	0.28
No. of observations (populations)	41	33	41	33

a. The *t*-statistics are given in parentheses after the coefficients.
b. R^2 is the (adjusted) percentage of variance accounted for.
* $p<.10$, **$p<.05$.

ences between ethnic groups in adult height are much reduced, to slightly less than 4 cm for both males and females.

Conclusions

Substantial differences exist across population groups in the average values of adult malnutrition as measured by anthropometric status. Only a small part of this can be accounted for by genetic differences among populations. It is well established that disease accounts for varying (but often large) proportions of malnutrition in different environments. The analyses presented in the three preceding sections attempt to explain the extent to which levels of nutrient availability can further account for growth retardation. Controlling for average incomes and—when populations are ethnically different—for differences in genetic potential, the analyses address the question of the extent to which energy availability in the average diet (in kilocalories per capita per day) and protein availability (in percent of total energy from protein) are associated with differences in the anthropometric status of population groups.

Limitations of the analyses

Several caveats are important. First, the numbers of observations are small, particularly for the first (urban) analysis of China; undue importance might therefore be given to a few observations. Second, our international data were collected at different times, in different ways, and with differing sampling frames. Although these shortcomings are in principle more likely to obscure than to illuminate the relations we examine, the heterogeneity of the data is cause for concern. However, neither of these limitations matters for the analysis of rural China, for which the data are most numerous and also most uniform, and where we find the same results.

A third caveat is that individual diets—and disease patterns—determine individual growth, and our data concern only average diets and average growth. Individual, longitudinal data on nutrient intake, disease episodes, and growth allow for more definitive assessments of the relative contributions to growth failure of energy and protein deficiency in diets that are typical of those found in today's developing countries. An example of such an analysis is a longitudinal study of 123 children 2 to 19 years of age from low-income families living in Lima, Peru. It found the percentage of protein from animal sources, but not total energy intake, to be strongly associated with achieved male height and weight [28]. (Our analyses do not distinguish animal and plant sources of protein.) Another study followed 70 much younger children for over a year in Bangladesh; it concluded that dietary inadequacy accounted for perhaps 50% more of the observed retardation of weight gain in the sample than did infections, but it was unable to apportion the dietary effect among nutrients [29]. Other studies (Chernichovsky [30] and Deolalikar et al.*) have modeled individual growth trajectories for different samples of children in India, and Bhargava [31] has done the same for a sample of Filipino children, again finding that protein but not energy intake is important. These individual-level longitudinal analyses complement the much more aggregated ones we present and, reassuringly, reach broadly similar conclusions.

Synthesis of findings

Despite the aggregated and cross-sectional nature of our data, the results consistently suggest that protein rather than energy deficiency is the principal dietary cause of growth failure in the populations studied, as indicated by attained adult height and weight. These findings not only complement similar ones from the limited number of studies using data on individuals, but are consistent with the observations of economic historians that high levels of animal protein availability—and therefore probably total protein intake—may have accounted for the earlier increase in average height in the United States than in Europe [32] and that periods when protein-dense food was relatively costly may have been associated with lower attained heights [33, 34]. A recent assessment [35] concluded that the Native Americans of the Great Plains in the United States were probably the world's tallest population in the mid-19th century, with males being 1 to 2 cm taller than American soldiers of European descent. The authors attribute this in part to diets with high diversity and high animal protein content.

Increases in protein availability thus appear to be more important than increases in energy availability for ameliorating growth failure. One possible reason for this is that the distribution of energy and of protein to individuals within a population almost certainly differs substantially, with protein (especially animal protein) much more unequally distributed than energy. Thus, a larger proportion of the population is likely to be in protein deficit than in energy deficit if the average availability of the two nutrients is at the same percentage of estimated requirements. Energy requirements are expressed as average population needs, on the assumption that individuals will consume more or less than the average, depending on need. The

* Deolalikar AB, Behrman JR, Lavy V. Child growth in rural south India: economic and biological determinants. Unpublished paper, Department of Economics, University of Pennsylvania, Philadelphia, Pa, USA, 1992.

population requirements for protein are given as the average requirement plus 2 SD to cover nearly all of the population.

In contrast to Steckel [8], we found that per capita income levels were generally unassociated with anthropometric outcomes (except for male height in urban China). Our finding of low association appears after controlling for nutrient intake, and, to the extent that the effects of income are mediated through increased protein consumption (and the income elasticity of demand for dietary protein is very high), the positive results concerning income in Steckel and ours concerning protein are consistent. To the extent that protein content correlates with other potential determinants of nutritional status and growth (e.g., disease and micronutrients), this paper's conclusions on the importance of protein would need to be qualified.

Our findings suggest that an increase of one percentage point in the proportion of total energy accounted for by protein would raise adult heights by about half a centimeter in urban China, by 0.60 to 1.01 cm in rural China, and by 0.65 cm (females) to 1.16 cm (males) across a large sample of countries.[5] Except in urban China, the effect would be much larger for men than for women. For Chinese men, these increases amount to 0.32 to 0.38 SD in height, indicating that they are fairly large relative to the natural variation in the population. The increase is smaller relative to the variation across countries (0.23 SD), because in that comparison ethnic differences make the total variation much larger.

As we have stressed, there are many other possible correlates of protein availability that are potential determinants of growth. Examples of other influences include water supplies, education levels, health services, general sanitation levels, and so forth. (In a sufficiently broadly specified model, these would be endogenous.) We have partly controlled for these other potential influences by including income in our regressions; however, the possibility remains that some of the effect attributed to protein availability in our regressions is due not to protein itself but to correlates of protein availability that are less well correlated with energy availability. This might be the case particularly for micronutrient deficiencies that can cause growth failure without causing specific signs of disease [36], even when protein and energy availability are adequate. If that is the case, then dietary variety may be crucial to growth because it increases access to all essential nutrients. That said, the results from each of our three data sets suggest that energy availability is usually not the problem and that protein availability may be.[6]

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Notes

1. Several lines of evidence suggest the importance of nongenetic determinants of variation in anthropometric status. Historical records indicate dramatic increases over time in anthropometric indicators for European populations, increases that have reached a limit as adequate levels of nourishment and health have extended to virtually all members of the populations studied [3]. Alternative sets of interacting variables have been proposed to account for the observed improvements [37, 38]. Evidence is available on increased height and also better health, as a result of more and better food consumption, in Europe and the United States in the 18th and 19th centuries [39], and there are studies of individuals from one country growing up in another (e.g., Japanese in California) who showed substantial anthropometric improvements [1].
2. Proteins are composed of different combinations of 20 amino acids, of which 9 are essential for humans in the sense that they cannot be synthesized but must be ingested [40]. In order for protein to be used for growth, rather than for energy, all the essential amino acids must be present in adequate amounts. Generally speaking, foods of animal origin supply needed amino acids in approximately the required proportions, and foods of plant origin are relatively deficient in one or more essential amino acids. Therefore, the amount of available protein that can be utilized from animal sources is in the range of 80% to 90%, whereas the amount of protein that can be utilized from an individual plant source is in the range of 45% to 55%. In consequence, individuals consuming only foods of plant origin must usually consume more protein or a carefully balanced mix of foods in order to meet their protein requirements.
3. The disadvantages of utilizing data aggregates to estimate production processes that occur at an individual level (person, firm, farm, or household) are well known; see Jamison and Lau [41] for an extended discussion of the advantages and disadvantages of using aggregated data in empirical work and Stoker [42] for a discussion of empirical approaches to the aggregation problem.

King [43] presents a novel approach for utilizing aggregate data to illuminate relations at the individual level, along with computational algorithms. Because relative income elasticities indicate protein consumption to be much more unequally distributed within populations than is energy consumption, aggregate per capita availabilities of energy and protein that are equally satisfactory for an individual diet will result in a larger proportion of the population being short of protein than short of energy. Scrimshaw [44] presents evidence suggesting that utilizable protein is even more unequally distributed. Whether this means that aggregated data would result in higher or lower estimated elasticities of growth with respect to protein consumption than would be estimated from individual data depends on where the aggregate observations are concentrated along the true, individual relation, since that curve is likely to rise steeply at low levels of protein consumption but level off as protein intake becomes adequate for reaching one's genetic potential growth. Unfortunately, dietary information obtained at the individual or household level is costly and often highly unreliable, although some individual-level studies (e.g., Graham et al. [28]) allow estimation of the impact of specific nutrients on growth. Other studies [45] often are restricted to utilization of much less precise determinants, such as food-consumption frequencies, or to inferences concerning relative inadequacies of particular nutrients from body composition data [46].

4. Data have also been published on anthropometric indicators of nutritional status for children between 7 and 17 years of age from the 1979 Chinese survey. Preliminary analysis of the data for seven-year-olds found neither energy nor protein availability to be a significant determinant of nutritional status. One plausible explanation is that diarrheal disease (and other health factors) are more important as determinants of children's growth than of attained adult stature.
5. This increase is comparable to the increase in the average height of native-born white males in the United States in the two centuries following the mid-1700s, which was approximately 1.2 cm [47]. Heights increased much more rapidly in the United States than in European countries, so that by the mid-1700s, male heights in the United States already exceeded those in Europe by 2.5 to 5 cm [34].
6. A recent econometric assessment [48] found further effects, in that both energy and protein in the diet remained important for worker wages (in Brazil), even after individual height and body mass index were controlled for, but with energy important only for the very malnourished, whereas increased protein content was important for a much broader range of individuals. A recent broad overview of the relation between nutrition and poverty may be found in Svedberg [49].

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A new feature in the *Food and Nutrition Bulletin*: Commentaries

Letters to the editor commenting on an article published previously are a common feature of many nutrition journals, but this approach often results in a long interval between the original article and the response to it. The approach of calling for comments to be published concurrently with a provocative article has been limited to some journals in the social sciences.

In this issue the *Bulletin* introduces a new feature—Commentaries—that will appear whenever an article comes to a conclusion that can have an important impact on nutrition policy but is nonetheless controversial. The preceding article by Jamison et al., titled "Malnutrition and dietary protein: Evidence from China and from international comparisons," meets both criteria. Accordingly, we have asked six recognized experts to provide any comments they consider appropriate. Three are nutritionists who have written extensively on the relationships between nutrition and growth. Of the two economists, one has done nutrition field studies in India and the other takes an historical approach. The final observations come from the Division of Nutrition and Food Policy of the Food and Agriculture Organization (FAO), responsible for international recommendations for both protein and energy allowances. The authors were also given an opportunity to respond to the comments.

We hope that our readers will find this new feature, introduced by the following exchange, to be informative and stimulating. We enthusiastically welcome letters to the editor on this topic.

Nevin S. Scrimshaw

Commentaries on "Malnutrition and dietary protein: Evidence from China and from international comparisons"

Commentary 1

Thirty years ago I suggested the term "stunting" to describe short stature in children that went beyond what might be regarded as physiological or genetic [1]. Since then a good deal of attention has been given to the biology of linear growth failure in children [2, 3], while shortness in adults has been neglected. The work described by Jamison and his colleagues [4] is therefore very welcome, and it is good to see, in the third part of their study, new results being gathered from Eveleth and Tanner's monumental book after a quarter-century [5].

There is, of course, a biological reason for neglecting the adult: linear growth stops when the epiphyses fuse at the end of puberty. Therefore, the average intakes per head recorded by Jamison et al. are proxies for intakes at an earlier age, starting from birth or even earlier. A study by Satyanaryana and colleagues [6] from India is of particular interest. They showed that poor children at the age of 5 years were 15 cm shorter than their well-to-do peers; nevertheless, between 5 and 18 years they grew exactly as much as children in Berkeley, California. So the critical time is before five years of age. If the environment is improved, the growth failure can be reversed, as shown by Graham in Peru [7] and by many studies on migrant children.

The conclusion from this paper is that protein intake is a critical factor in determining stature. This fits in with the conclusions of many supplementary feeding studies in children, going back to that of Boyd Orr during World War II on the effect of extra milk on the height of schoolchildren.

A common approach nowadays, strongly supported by historical research, is to regard stunting as a marker for poverty and economic deprivation and to be less interested in the biological process that causes it. Poverty has many aspects, as the authors of this paper recognize in their final paragraph; a good example of confounding factors is found in a recent article from South Africa, which showed that the major determinant of stunting was the quality of maternal care [8]. The authors implicitly accept the importance of such factors, since protein and energy intakes and income could explain only 10% to 25% of the variance in height in their populations. Nevertheless, for those responsible for policy it is an important contribution to have shown so clearly the role of protein intake, since I believe that improvement would be feasible if a serious effort were made to focus on this aspect of the problem.

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Commentary 2

Jamison et al. [1] have used aggregate international and Chinese data to explore the relative importance of dietary energy and protein availability for predicting adult height. The data sets contained information on adult anthropometry, dietary energy and protein "availability," and estimated per capita incomes. The dietary estimates were derived from a population sample of actual dietary intake data in rural China, energy and protein production in nonmetropolitan provinces of China, and energy and protein availability per capita in the international data set. Some of the more important limitations of this interesting analysis, as pointed out by the authors, include the assumption that the current food supply is similar to that which the adults consumed during their earlier growth period; that other variables not measured may have affected growth; and that most of the individuals grew up in their current place of residence. Obviously the measures of intake, heights, and income were not collected on the same individuals. However, these limitations would be expected to weaken the relationship between current diet and size, so it is even more impressive that protein availability was a significant predictor of adult height in these analyses.

The most problematic aspect of this article is that although the authors state in the abstract, "We use protein availability in part as a marker for overall quality of the diet," in fact they imply repeatedly that it is the protein ("the protein effect") that causes the differences in growth. It has been more than 25 years since it was recognized that the "protein gap" was much smaller than formerly believed [2]. A cross-project analysis in Egypt, Kenya, and Mexico revealed an almost zero prevalence of inadequate intakes of essential amino acids or protein in children, even when energy intakes were inadequate due to famine [3]. In the longitudinal study in Guatemala by INCAP (Institute of Nutrition of Central America and Panama), there was no benefit to growth from supplementing infants and preschool children with good-quality protein compared with energy alone [4].

The current analyses use the "fraction of available dietary energy from protein," not total available protein, as the independent variable, presumably to control for the strong association between dietary energy and protein intakes. It is not possible to know from this variable whether protein intakes were adequate. From the data provided, we estimate that the average protein availability is about 59 to 61 g per capita per day across the three studies, or close to recommended levels. The actual intakes may of course have been lower than this, although the energy availability was also fairly close to requirements, suggesting that the estimated intakes of both nutrients were probably reasonable.

It is arguably more likely that the associations between dietary intake and adult height were caused by micronutrient deficiencies, which are more prevalent when diets are lower in protein. In most diets, protein intakes are highly correlated with the intakes of animal-source foods and of several other nutrients. These include vitamin A, vitamin B_2, vitamin B_{12}, available iron and zinc, calcium, phosphorus, and fat [5]. Of these, deficiencies of vitamin A, vitamin B_{12}, iron, zinc, and calcium have been reported to predict growth [6].

The international community should not conclude from this article that lack of dietary protein caused poorer growth in these populations. The independent variable was the percentage of energy available as protein, and not total protein. Importantly, because dietary protein—and especially protein (or energy or fat, for that matter) from animal-source foods—is an indicator of dietary quality, the analyses do support the findings of many investigators that dietary quality is an important predictor of growth [6–8]. It is extremely important to distinguish whether it is lack of dietary protein per se or associated poor dietary quality (possibly only micronutrient inadequacies) that predicts adult size, because this can make a tremendous difference in policy decisions. The data and analyses presented here cannot make that distinction, and this fact should have been stated more clearly.

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Commentary 3

Jamison and colleagues [1] have sought to understand the relative importance of quantity and quality of dietary availability or intake for growth failure in developing countries through analyses of three cross-sectional data sets aggregated at the province, county, and country levels. Quantity was expressed as the mean per capita energy availability and quality as the mean percentage of calories available from protein. The authors concluded that growth failure was associated with a lower percentage of protein from calories, but not with lower levels of energy availability. As noted by the authors, this may not necessarily reflect an effect of protein per se, because other indicators of quality, such as micronutrients, covary with protein.

The questions posed are important from a policy perspective, but the study suffers from significant limitations. The study used mean adult height as a measure of child growth failure in all three analyses presented and related these values to contemporaneous measures of per capita food availability and income. The assumptions, both unsubstantiated, were that mean adult height was a satisfactory proxy for preschool height, and that the relationship between adult height and per capita food availability values at the time the adults were measured reflects the relationship between childhood diet and growth. The adult height data for the country-level analyses were taken from the 1976 edition of Eveleth and Tanner [2], a compilation of data from anthropometric studies carried out since the 1950s. Only a few of the studies were national surveys, which one would prefer, and many were small, localized studies of uncertain representativeness. Adult height means were used as the dependent variables for 41 populations representing 40 countries in the case of men and for 33 populations and 32 countries in the case of women. The authors appear not to be aware of the second edition of Eveleth and Tanner [3], which included additional studies.

The measure of choice as the dependent variable for the type of questions posed by the authors is the height of preschool children. There is strong support for the notion that variation among nations in mean preschool heights is the result of environmental causes associated with poverty, such as poor diets and infection, and not genetics [4]. Whereas massive growth failure during intrauterine life and the first two years of life is a universal characteristic of poor societies, there is no evidence that growth failure is a public health concern in these societies at later ages. Thus, growth beyond the early postnatal period is determined differently, so that adult height, while certainly reflecting environmental influences on growth in early childhood, will also reflect other influences. Why not just use data on preschool growth? It is the appropriate measure and is available from many surveys and for most countries.

The Program in Nutrition of the World Health Organization (WHO) has created a huge database of nationally representative anthropometric surveys and has made these data available to the public [5]. New surveys are added as they become available. Several regional- and country-level analyses of the factors associated with child stunting [6, 7] and wasting [8] have been published using the WHO database or similar ones. Food availability and income, as well as many other variables, were included in these studies. Interestingly, per capita energy availability was the only food-related measure used; future analyses should consider incorporating indicators of dietary quality. Whereas Jamison and his colleagues did not find energy and income to be generally related to adult height, the studies focused on stunting found that these two variables were strongly and consistently related to growth failure [6, 7]. Two reasons may account for the contrasting results. One is that adult height has too much noise to be an adequate measure of child growth failure. Also, the power was better in the studies of child size. For example, Frongillo et al. [6] examined the factors associated with stunting using nationally representative data since 1980 for 70 countries representing more than 90% of the population of children under five years old from developing countries. Three years later, analyses of trends in stunting since 1980 used 241 nationally representative surveys from 106 countries [9].

There is a large literature on the risk factors of stunting based on cross-sectional or longitudinal studies of children from cities and villages of developing countries, but not all studies have included dietary assessments of individuals. Two small studies used consumption of animal-origin foods as the indicator of dietary quality and showed this to be important for child growth rates [10, 11]. Again, caution is required in interpreting possible associations with indicators of dietary quality. In a study of Mexican children, consumption of animal foods was associated with eating fewer tortillas and a more diverse diet; thus, the possible mechanisms for an effect of animal foods include increased amounts of limiting amino acids, greater micronutrient intakes, and decreased consumption of phytates and fiber [10]. The impact of dietary quality on growth rates may depend on other factors. For example, in a study of Peruvian toddlers, the intake of animal-product foods was positively related to growth in length only among those with low intakes of complementary foods. Breastfeeding frequency, on the other hand, was positively related to growth in length only among those with low intakes of animal-product foods [11]. Direct experimental evidence of the importance of dietary quality for child growth and health is strongest for zinc [12–14]. Experimental evidence for a specific protein effect remains weak, in part because providing increased protein intake by improving complementary foods also provides energy and additional nutrients. What we do know is that improving complementary feeding of children at risk for malnutrition, including both quantity and quality, and resulting in increased energy, more and better-quality protein, and increased micronutrients, has demonstrable effects on growth [15, 16].

Modeling dietary and other influences on growth offers the possibility of teasing apart possible effects and interactions of dietary quantity and quality. These analyses will not be credible if adult height is used as the measure of child growth, as done by Jamison et al. [1] The ideal would be longitudinal studies of growth during the first two years of life, with detailed infant-feeding data that permit construction of several dietary quality indicators.

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Commentary 4

The paper by Jamison et al. [1] emphasizes the significant associations between the average proportions of energy derived from protein and adult height and weight in certain Chinese and international data sets. The ratio of individuals' intakes of protein to dietary energy has received attention in the nutritional literature because of the pathological conditions marasmus and kwashiorkor [2]. Furthermore, the protein–energy ratio was found to increase with household incomes in India and is generally a good indicator of diet quality [3]. However, the Keynesian dictum in economics that "everything depends on everything else" also applies to nutrition research, i.e., interactions between nutrients in the meal critically affect their absorption. The importance of nutrient interactions was recognized in economics by Stigler [4]. With recent reductions in energy deficiencies, researchers have focused on micronutrient deficiencies, such as those of iron, where nutrient interactions effectively determine the absorbable iron [5].

The authors note numerous caveats in applying simple regression models to data that are aggregated for regions. The paper creates the impression that increasing the proportion of protein in the diet would facilitate increases in height. This may be true, in view of the fact that a diet high in protein, especially animal protein, is likely to supply larger quantities of calcium and micronutrients, which are important for growth. The increases in heights in the Netherlands, for example, were probably achieved by the elaborate school programs encouraging milk consumption by slogans such as *Melk is goed voor elk* (Milk is good for everybody). From a methodological standpoint, it is important to spell out the pathways through which nutrient intakes affect indicators such as height, weight, and morbidity, especially in developing countries [6]. Cost-effective strategies for preventing stunting, wasting, and illness are likely to be different.

In view of the aggregative level of data and the small sample sizes available to Jamison et al., it would perhaps be unrealistic to propose that the authors should have disentangled the effects of calcium and iron intakes from those of protein and energy by including all these variables in the models. Moreover, even where individual-level data are available, the use of alternative dietary assessment methods can influence the conclusions regarding the effects of nutrient intakes on health outcomes. For example, although the use of the 24-hour recall method is popular in developing countries, high internal variation in the data can complicate the modeling of the diet and health outcome relationships [7].

I would like to make two points. The first pertains to inclusion of energy intakes in models for anthropometrics. There are two strands of reasoning within the nutritional literature that need to be considered simultaneously. The Food and Agriculture Organization/United Nations University/World Health Organization (FAO/UNU/WHO) expert consultation [8] emphasized the need to take into account individuals' energy expenditures when defining energy requirements. Energy expenditures are influenced by the basal metabolic rate, which in turn depends on weight [9]. Thus, at a given point in time, energy intakes are likely to be affected by weight [10]. On the other hand, epidemiologists such as Willett [11] have argued that the total energy intake is likely to be a positive predictor of body weight.

Although both of these approaches are applicable, depending on the circumstances, there is a danger in overinterpreting the estimated coefficients of energy intakes. As reported by Bhargava and Guthrie [12] for subjects from developed countries, the coefficients of energy intakes in the model for weight were often negative. The negative coefficients do not reflect the underlying biological relationship between energy intakes and body weight. Rather, they result from the statistical properties of the model formulated. Individuals' "habitual" diets have specific percentages of energy from macronutrients such as carbohydrates, protein, and fats. Including energy intake in the model for weight can lead to statistical criteria that favor the conversion of nutrient intakes as ratios to energy intakes. From this viewpoint, the magnitudes of the coefficients of dietary energy in the aggregate relationships estimated by Jamison et al. are not of practical significance. However, inclusion of the energy variable is essential for strengthening the conclusion that energy derived from protein is a predictor of height and weight in these populations.

My second point is that some policy makers prefer the use of a single indicator of diet quality in developing countries, even though it may not be the most effective strategy. Jamison et al. have emphasized protein intake, although it is plausible that the authors might have found animal protein to be an equally or more significant predictor if the data were available. A possible way of assessing the potential importance of intakes of protein, animal protein, calcium, and micronutrients for growth may be to look at the correlations between these nutrients in a population for which the data are based on several measurements of food intakes. If, for example, the intakes of animal protein and calcium are more highly correlated than the intakes of total protein and calcium, then promoting higher consumption of animal protein would also ensure higher calcium intakes. A similar argument may not apply to iron intakes because of the difficulties in estimating absorbable iron in diets high in phytates and with protein predominantly of vegetable origin.

The nutritional surveys in Kenya [13] recorded individual food intakes for two days per month. In a previous analysis of longitudinal data separated by three-month intervals on more than 100 Kenyan schoolchildren, Bhargava [14] found that the ratio of protein to energy intake was a highly significant predictor of children's weight ($p<.001$). He also found that calcium intakes were significant predictors of height at the 10% level. Although calcium has not been reported to be a major determinant of linear growth, it could be an indicator of other essential components of the diet. Overall, these results are plausible, not least because six days of food measurements were used to approximate the children's intakes at each of the three time points. Further averaging the intakes over the three time points is likely to reduce within-subject variations in the intakes; 18 days of food intakes should give a better approximation for the "habitual" intakes. The simple correlations between the intakes of protein/energy, animal protein/energy, calcium, and iron by 124 Kenyan schoolchildren were as follows:

	Animal protein/ energy	Calcium	Iron
Protein/energy	0.378*	0.315*	0.374*
Animal protein/ energy	1.0	0.682*	–0.091

*$p<.05$.

Although these results are only suggestive, when the total energy intake was controlled for, the intake of animal protein in the diets of Kenyan schoolchildren was twice as highly correlated with the calcium intake than with the total protein intake. Moreover, although the ratio of protein to energy intake was significantly correlated with the iron intake, the ratio of animal protein to energy intake was not. The animal protein in this population was mainly derived from milk products, whereas iron was obtained primarily from cereals and thus had a low bioavailability. However, it was not feasible to calculate the absorbable iron intake, because intake data for meals were not available.

Overall, increasing the intake of animal protein is likely to lead to greater increases in calcium and micronutrient intakes; the use of animal protein is potentially a better indicator of diet quality from the standpoint of reducing stunting and possibly wasting in developing countries. Moreover, for the assessment of diet quality, researchers should look at the intakes of various nutrients depending on the policy objectives. For example, the intakes of vitamin A and some other micronutrients are important for reducing morbidity [15]. However, the correlations between the ratios of protein and animal protein intake to energy intake and the intakes of vitamins A and C were not significantly different from zero in the sample of Kenyan schoolchildren. It is evident that the design of food and nutrition policies in developing countries requires broader strategies, such as those recognizing the interdependence of specific nutritional intakes and health outcomes.

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Commentary 5

The paper by Jamison et al. [1] is riveting in its analysis and conclusions. If the results are taken at face value, they require a significant change in thinking about policy and about anthropometric history. If insufficient protein is the major factor limiting physical growth and human health, then resources should be diverted from other uses to increase its intake. Moreover, anthropometric historians who have wrestled with measuring the extensive list of ingredients in net nutritional intake should first examine the availability of protein to understand trends and differences in human stature in the past.

Any paper with significant implications invites appraisal. Should researchers accept the results at face value? Is the analysis solid and are the conclusions justified? Where do we go from here? I offer my perspective as an anthropometric historian whose earlier work on the vast catch-up growth of American slaves and the tall stature of equestrian nomads of the Great Plains points to the importance of protein in human growth [2–5]. I have also studied the relationship between height and per capita gross national product [6, 7].

A couple of years ago I read an earlier version of this research effort, and upon rereading I continue to find the results surprising and important, but unsettling. The latter is not because I think protein is unimportant for growth; my own work shows otherwise. Instead, my wariness is based on the statistical finding that protein apparently dominates growth. There is a small mountain of evidence indicating that other things also matter. Yet, in the regressions protein consumption displaces not only calories but per capita GNP and all the things that it summarizes, such as the public health environment, quality and quantity of medical care, level of education, work effort, degree of income inequality, dietary diversity and abundance, quality of housing, and so forth.

How can this be? The authors are cautious in qualifying many aspects of their analysis, particularly the limitations of using aggregate as opposed to individual or household data—or better yet, experimental evidence. My case for caution rests on the nature of their samples, while reiterating certain limitations of aggregate data.

Anyone familiar with the appendix of Eveleth and Tanner [8] or with the extensive literature in anthropometric history will know that average adult heights have varied by more than 25 cm across the globe [7]. Therefore, the first two samples (urban China and rural Chinese counties), in which the standard deviations of the means are in the range of 1.22 to 2.64 cm, represent only a modest slice of human anthropometric experience. These samples are reasonably homogeneous. The urban sample has the lowest standard deviation and the highest explained variation. Quite possibly, protein consumption could dominate within the range of circumstances depicted by these samples, but one cannot conclude that it does so across a larger and more varied landscape.

The international sample is the most diverse of the three data sets studied. Compared with those in the Chinese samples, the standard deviations of the dependent variable are larger (5.00 cm for males and 4.45 cm for females), but the adjusted R^2 is also the lowest among the three sets of regressions that have the same specification (using income, energy, and protein share as explanatory variables). Much of the weight in the second specification of table 6, where the R^2 is higher, is carried by ethnic variables that lack a clear interpretation. It is also a puzzle why protein is nonsignificant for women in the international comparisons.

Why does the protein variable perform least well in the most diverse sample? This is a challenging arena for study, with the most varied mix of heights and levels of factors that affect health outcomes. Possible explanations include misspecification (important explanatory variables are omitted or there are significant nonlinearities in the relationship), inadequate measurement of desired concepts, and inequalities in explanatory variables within countries that affect average heights. Without more information, it is difficult to evaluate these alternatives.

The paper has nudged me in the direction of believing that protein is even more important that I previously thought, but I remain skeptical that its consumption dominates trends and differences in human stature. On the other hand, doubters should accept that the authors have displayed enough evidence and analysis to justify considerably more study to understand why they obtained their results. How should the research community proceed? It is important to know whether the most favorable results (from two samples in China) are outliers. Studies of data within countries have some advantages, including a uniformity of concepts and measures that may not be found in international comparisons. Hopefully, it will be possible to find evidence similar to that used by the authors, but for states, provinces, or counties within other countries. The international comparisons they use were probably compiled from more disaggregate data within countries. Ideally, the units of study should be reasonably homogeneous within units but quite different across units in their consumption of protein. Moreover, they should be reasonably free from bias introduced by migration, whereby residents grow up in one circumstance and then move as older teenagers or adults to a unit with a substantially different environment to be observed or measured. I look forward to any such studies.

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Commentary 6

The investigation of any research question is constrained by the limitations in the data that are available. This is true whether the researcher has collected the data himself or herself or has drawn upon existing large data sets. The latter is the case with the analysis described in the article by Jamison et al. [1] The authors are very cognizant of this issue and go to considerable length to explain the caveats that must be kept in mind when reading the paper and reviewing the results.

Specifically, the reader is reminded that the available data "do not include a number of variables that are potentially important determinants of growth, and the variables they do include are averages rather than individual values. The data also refer to one moment in time rather than to the interval over which people grow, resulting in their final adult height (and, with much more variation, their adult weight)." These issues are fully and openly discussed.

The analysis revolves around height or stature. The authors are correct in noting that stature is an increasingly recognized indicator of the well-being of a society. Cross-country analyses show consistently that the average height of the adult population is positively and consistently related to the general well-being of the society—usually reflected in a composite index of wealth, environmental cleanliness, public health status, availability of health services, and assorted other factors. However, short stature should not be equated with the general term "malnutrition," and the authors do this several times in the article. In the initial discussion, the issue addressed is low heights and weights or "the failure to reach one's genetic potential" with regard to growth. In the analyses that follow, the dependent variables of choice are attained height and weight, but in fact, height is the more telling variable and weight is for the most part discarded. It should be remembered that stunting is one form or expression of malnutrition. We are in agreement that attained stature is closely related to protein intake, both quantitatively and qualitatively, along with the intakes of certain micronutrients. However, malnutrition is a dynamic phenomenon, caused by many factors over a long and complex time frame. Because of this, care must be exercised in attributing the causes for both optimal and less than optimal stature.

We also note that after an accurate and full discussion of the caveats regarding the data sets, another series of arguments is presented for dismissing or rationalizing these very same caveats. The authors have drawn upon three different data sets to conduct their analysis. Each data set is unique and dissimilar from the other two, except for the inclusion of height. In addition, the data consist of average measurements or indicator values. As the authors explain: "In all three data sets, the estimates of nutrient availability refer to the approximate time when adult heights and weights were measured; we assume that these contemporary measures provide indicators of relative availabilities during the preceding two or three decades.... We also assume that few people in the sample populations have migrated to or from the province, county, or country in which they grew up, so that the nutrient availability where they lived when surveyed is probably similar to the nutrient availability when they were growing up." These are major assumptions, and even if such assumptions are necessary in order to proceed with the analysis, the fact that they may not be correct should temper the conclusions.

In our opinion, the time sequence of comparisons is a serious limitation of the interpretation of the results of this study. Since human growth has several phases (e.g., infancy and early childhood, school age, and pubertal growth spurt), relating stature to diet from surveys conducted at one moment in time is a problem. Unless the authors can provide supportive data based on dietary intakes, consumption surveys, or even national food statistics that the nutrient intakes of these communities in 1979 (when the young adults measured were between 18 and 25 years of age) were largely identical to the intakes (individual and average) in 1969 and 1960 (or thereabouts), it is difficult to conclude that in fact protein and not energy intake is the principal determinant of growth failure in these populations. This criticism is valid for all other comparisons in this paper.

While conceding that current intakes of protein are more closely related to the stature of young adults than are energy intakes, according to the analysis carried out by Jamison et al., one has to be careful in attributing causal relationship to this finding. The current protein intakes related to better stature may be a proxy for a wide range of nutritional and non-nutritional determinants. For example, the higher protein intakes may also mean higher intakes of zinc and iron. Higher protein intakes may reflect better incomes and hence better social environments, and consequently fewer environmental insults, such as childhood infections, which may impair normal growth. However, it is also important to remember that here again the true causality may only be established with intakes of protein one to two decades earlier.

The question of relating stature to food intakes at the same time as stature is measured may indeed be a serious problem in China and thus limit the importance of these findings. Nowhere else have there been such dramatic changes in food intake, consisting of increases in the consumption of meat products, proteins, and fats, as in China over the last two to three decades. This fact cannot be neglected.

In the analysis and discussion of results, we would like to have seen attention given to those results which were not as dramatic. For example, the rural areas showed a much less dramatic relationship between protein availability and attained height than was the case in the urban areas. We would have liked some speculation as to what was responsible for this difference. Is it the source of the protein, for instance? Do urban populations receive more animal protein regularly than rural populations? The quality of the protein then becomes an important issue to look at. In addition, the same relationship was less revealing for women than for men. Again, why might this be the case?

Finally, we caution against trying to quantitatively relate a theoretical gain in height with a percentage increase in protein consumption, which was done in the penultimate paragraph of the article. We doubt that the data are sufficiently robust to allow this sort of calculation.

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Authors' response to commentaries

We are grateful to Waterlow, Allen, Martorell, Bhargava, Steckel, and Weisell et al. for their thoughtful comments on our examination of dietary influence on adult height and weight. We were careful to spell out the many limitations of our analysis, and we are pleased to see that expressly recognized by most of the discussants. This reply concentrates on just four issues: the choice of the dependent variables; the quality of the dietary data; the interpretation of our finding that protein intake appears to have more impact than energy intake, particularly on height; and the importance of these questions for research and policy.

It was not our intention to analyze stunting as such, but rather the entire distribution of adult heights; there is no separation between "stunted" and "normal" and no attempt specifically to explain the former. We used the largest available collection of data on adult heights for international comparisons, and although it is true, as Martorell says, that there has been a second edition of Eveleth and Tanner's study, it does not add any information that could have been incorporated in our analysis while maintaining comparability. We recognize that the crucial period for linear growth ends before the ages at which adult heights were measured, but we do not regard our dependent variable simply as "a measure of child growth failure" (Martorell). As Waterlow notes, "shortness in adults has been neglected," and whatever happens between the age of five and early adulthood can only introduce some noise into such relations as exist between childhood diet (and other factors) and growth. Since noise would bias our coefficients toward zero, "it is even more impressive," as Allen notes, that we find statistically significant effects.

If adult height is not perfectly correlated with height at age five, it is partly because of catch-up growth, as Waterlow notes. Such growth might "not necessarily reverse the effects of early childhood stunting on cognitive failure," but "would probably reduce obstetric risk" [1, p. 19]. Given that "difficult labor due to a small pelvis is rare in tall women, and comparatively common in short women" and that "obstructed labor and its sequelae are the most important causes of maternal death in tropical Africa" [2, p. 79], anything that affects women's adult heights has important health effects. For both sexes, greater height is associated with greater longevity and better adult health [3]. The apparent effect of protein share on height is weaker for women than for men in all our analyses, but in both of the Chinese samples it is still significant. We note that if men eat more of the available protein than women do, as is likely in many cultures, that alone might explain why we find larger effects on male than on female height and solve the "puzzle why protein is nonsignificant for women in the international comparisons" (Steckel).

Our dietary independent variables are average energy availability and the share of energy derived from protein. Energy availability never had a significant effect on height in any sample, and only once did it appear to affect weight (for young urban Chinese males). We agree that these findings "are not of practical significance" (Bhargava), but the inclusion of energy required us to specify protein intake relative to energy rather than in absolute amounts, and this treatment of the variables is essential to any conclusion about the effect of protein on heights. Just as we studied the entire distribution of adult heights and weights, we looked at the entire distribution of the dietary variables, without considering whether the average absolute protein intake was adequate or not, or whether there was any "protein gap" (Allen). In any case, we do not know who actually ate what or how much; again, that makes it the more significant that we find strong associations among averages.

As noted, we expressly assumed, in the analysis of rural China, that dietary patterns had been relatively stable since the time the subjects were children. Weisell et al. regard this assumption as "a serious problem," since "nowhere else have there been such dramatic changes in food intakes" in recent decades. But if the Chinese now eat much more meat, total protein, and fat than two or three decades ago, it is even more remarkable that adult heights are so strongly related to current protein availability. This is less surprising in the case of urban China, since the adults range in age only from 18 to 25. Their current consumption is therefore probably very similar to that in adolescence, and perhaps even to that in early childhood. The results for rural China, however, include adults of all ages, so dietary changes in recent decades have occurred well after adolescence for some subjects and might be expected to have no effect on stature.

Granted that there are surprisingly strong and consistent relations between adult heights (and weights, in

China) and the share of energy derived from protein, is the protein itself the cause, or is it only an indicator of dietary quality? Waterlow accepts the conclusion "that the protein intake is a critical factor in determining stature," which he finds consistent with other studies. Steckel similarly believes, on the basis of his own research, that protein is important, partly because of catch-up growth, although it can hardly be the only thing that matters. The other commentators variously suggest that "it is arguably more likely that the associations between dietary intake and adult height were caused by micronutrient deficiencies" (Allen), that "the current protein intakes related to better stature may be a proxy for a wide range of nutritional and non-nutritional determinants… [and] may also mean higher intakes of zinc and iron" (Weisell et al.), or that our findings "may not necessarily reflect an effect of protein per se, because other indicators of quality, such as micronutrients, covary with protein" (Martorell). Bhargava notes the potential importance of calcium and its higher correlation with animal protein, especially from milk, than with protein in general.

As some of the commentators recognize, we have expressly considered that "micronutrient deficiencies that can cause growth failure without causing specific signs of disease" may contribute to our findings. In the absence of more detailed data on dietary composition, it is impossible to be certain that all of the effect is due to protein. However, we think it is quite implausible that protein by itself accounts for little or none of the effect we see. And we note that a measure of income is included in each of our analyses, and only once—for urban male Chinese heights—does it appear to be significant. Even if income is only loosely associated with "the public health environment, quality and quantity of medical care, levels of education" and other plausible determinants (Steckel), it is striking that none of these show any effect via income. If something besides protein accounts for our results, it is probably other characteristics of the diet rather than non-nutritional factors.

We would like to make three observations in conclusion. One is that the revealed preference of human beings for more protein and more varied diets, once their energy needs are satisfied, makes excellent nutritional sense and is associated with greater stature and the health benefits that come with it. People everywhere tend to pursue better-quality diets and show appreciably higher income elasticities for protein than for calories, even if they are poor and even if they do not know what is in the food they eat. Animal protein shows an even stronger relation to income than protein from vegetable sources, and animal protein may be "a better indicator of diet quality" (Bhargava). A second observation is that the nutrition research community does not yet know enough about the influence of specific nutrients on growth. Data such as we have used here do not allow us to separate the contribution of protein from that of micronutrients or other components, such as fat and fiber. What is known about the importance of micronutrients to growth is tantalizing, but there is need for considerably more research on the actual content of diets and the contribution of different components to stature and health. Such research needs to draw on longitudinal observations of diet, as Bhargava suggests, and to take account of interactions among nutrients. As Steckel indicates, it is also important to understand why protein intake appears to have more effect when comparisons are made within relatively homogeneous populations with little variation in adult height (our two Chinese samples) than when comparisons are made between more heterogeneous populations with much more variation both in height and in its possible determinants.

Only better knowledge can support more detailed policy recommendations than the simple conclusion that protein, and whatever is associated with it but not markedly correlated with energy intake, is crucial. Finally, we observe that better understanding of what exactly accounts for increased height and weight has important implications not only for dietary advice but also for agricultural policy and for efforts to reduce or mitigate poverty. In particular, as Steckel says, "If insufficient protein is the major factor limiting physical growth and human health, then resources should be diverted from other uses to increasing its intake." If it is not the major factor, it is surely urgent to discover what factor(s) are essential.

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Food-consumption patterns in Central West Africa, 1961 to 2000, and challenges to combating malnutrition

B. G. Honfoga and G. J. M. van den Boom

Abstract

We discuss food-consumption patterns in Central West Africa from 1961 to 2000 and some implications for combating malnutrition. The availability of food in the region improved in the 1960s, declined sharply in the 1970s and the early 1980s, and has shown a modest positive trend since the mid-1980s. Notwithstanding obvious progress over the past decades and in the region as a whole, food availability today remains below the required levels for large parts of the population and appears unstable over time, particularly in the Sahelian zone. On average, diets in this zone contain fewer than 2,200 kcal, compared with almost 2,500 kcal in the coastal zone. Conversely, protein deficiency is more common in the coastal zone, where a typical diet contains only 45 g of protein, compared with 60 g in the Sahelian zone. Furthermore, consumption is showing a dietary shift toward cereals, while yield growth lags far behind population growth. The associated import dependency and pressure on land seem to gain significance regardless of the region's agro-ecological capacity to increase and to substitute cereal imports for locally produced food. Moreover, food consumption appears responsive to income changes (calorie-income elasticity ranges from 0.25 to 0.62), while, in turn, it has a significant impact on nutritional outcomes (stunting-calorie elasticity of –1.42). We conclude that combating malnutrition requires first broad-spectrum income growth, and next specific policies that promote the yield and the contribution to diets of nutritious food produced within the region.

Key words: Central West Africa, food consumption, malnutrition

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Introduction

Food security is a fundamental concept for elaborating development strategies, particularly in West Africa. It has been defined as access for all individuals at any time to sufficient nourishing food for a healthy and active life [1, 2]. Accordingly, it has several aspects, including the availability of foodstuffs, the quality of the diet, the stability of supplies over time and space, and the access to food produced at home or purchased [3]. Accessibility further includes access to price and other relevant information, such as nutritional education and culinary knowledge.

In this paper we consider various aspects of food security in five Central West African countries—Burkina Faso, Côte d'Ivoire, Ghana, Mali, and Togo—henceforth referred to as the SADAOC region. In 1992, the Fondation Sécurité Alimentaire Durable en Afrique de l'Ouest Centrale (SADAOC) implemented a research and policy dialogue program in this region aimed at improving the formulation of food-security policies by the concerned governments. The region is currently inhabited by about 60 million people, and the landscape ranges from the dry Sahelian zones beneath the Sahara desert to the coastal zones with humid rain forests, with Sudanian or Sudano-Sahelian climates in between. Food insecurity has been manifest in all its aspects and remains a large concern of the regional governments. Local food production is insufficient to cover the needs of the population, especially in the Sahelian zone. Production systems are still extensive, with output well below potential. Despite apparent progress achieved in cereal production, food availability remains dependent on a favorable climate and considerable imports of rice and wheat. The adoption of high-yielding varieties and improved technologies has been very limited, while a continual expansion of cultivated areas is risky because of infertile soils. The resulting insufficiency of domestic supplies and the problems of satisfying the demands of a growing population in a sustainable manner create the need for importation of large quantities of food, among which cereals are predominant.

In the effort to satisfy food needs, policies have focused on the availability of cereals, because cereals dominate the diet of a majority of people in the region. However, because of erratic rainfall patterns and very low use of improved technologies, production remains unstable and inadequate, which constitutes a subtle but serious threat to food security. Especially in the Sahelian zone, each year a large part of the population suffers from poverty and malnutrition.

Traditionally, two broad diets can be distinguished: cereal-based diets in the Sahelian countries of Burkina Faso and Mali, and roots-and-tuber-based diets in the coastal countries of Côte d'Ivoire, Ghana, and Togo [4]. High levels of malnutrition persist in the region, and the countries of West Africa have shown very little progress in reducing child malnutrition, as determined by stunting since 1980 [5]. Indeed, deficiencies in nutrient intake are widespread in the Sahelian countries as well as in the coastal countries. In Burkina Faso in 1990, for example, one-third of the households consumed less than 80% of the calories required for a healthy and active life. [6]

Policy makers have been concerned about the discrepancies between food availability and diets of the people in the Sahelian and coastal subzones on the one hand, and nonutilization of the agro-ecological complementary potentials of the two subregions on the other hand. Likewise, they are concerned with the possible incongruity between income growth and improvements in food consumption and nutritional status. Considering the concerns of development specialists, policy makers, and the civil society about the food situation in the SADAOC region, a systematic analysis of the various discrepancies could contribute to more focused actions to reduce food insecurity and malnutrition.

This paper addresses some of these issues, primarily by exploiting data on food-consumption patterns in the SADAOC region during the period 1961 to 2000, and by linking them to income and malnutrition data.

Methods

The analysis is made both from the quantitative viewpoint of nutrient needs and from the qualitative perspective of the most suitable diet in relation to the agro-ecological potentials in the SADAOC region. The study relies on cross-country time-series data compiled for the SADAOC food exchange information database "matrice" [7]. The matrice is based on various data sources, including the Supply Utilization Accounts for agricultural products [8], the World Development Indicators [9], the Global Database on Child Growth and Malnutrition [10], and national data sources. Analytical tools include consistent data aggregation, tabulation, trend analysis, polynomial curve fitting, and regression techniques.

The Food and Agriculture Organization (FAO) database on the Supply–Utilization Accounts of agricultural products is a major data source. It has four dimensions—regions, products, variables, and years—and covers almost every country of the world and almost every food product for which production, consumption, and trade figures are recorded for the period 1961 to 2000. Further variables include the cultivated area, the size of livestock herds, the values of imports and exports, and, finally, the equivalents in the consumption of calories, proteins, and fats. Employing the FAO database and dedicated aggregation software [11, 12], we extracted time series for 1961 to 2000 for the five countries of the SADAOC region. Additional time series for income are drawn from the World Development Indicators in order to analyze the response of food consumption to income. Finally, we employ nutritional status data from the Global Database on Child Growth and Malnutrition and mortality data to explore the impact of food consumption on malnutrition.

This study uses the data to examine food-consumption patterns in the region and relate these to income and malnutrition. In the next section, we display the time-series data from 1961 to 2000 and fit the data to regression curves that indicate dietary trends with respect to both the calorie and protein content of consumption and the contribution of cereals, roots and tubers, and other products to the diet. Particular attention is devoted to the changing role of imported cereals in the consumption pattern.

Next, we briefly explore the relation between food consumption, population, and poverty. In particular, we try to estimate income elasticities of calorie and protein consumption. We recognize the limitations of the methodologies and inaccuracies of the data, especially in the light of conceptual and data-collection issues associated with the construction of variables that reflect true food consumption and true income [13–15]. Unlike Diakosavvas [16], who considered a range of economic factors influencing cereal consumption, we concentrate on aggregate food Engel curves,* considering the entire range of foodstuffs. Because of data limitations, we do not consider specific factors, such as seasonality and consumption smoothing opportunities. Evidence suggests that survey-based poverty estimates can have a seasonality bias [17], whereas idiosyncratic income fluctuations tend to be smoothed [18, 19]. Yet, the Supply Utilization Accounts provide a rough approximation of food-consumption patterns in the SADAOC region, since they give cross-country time-series information for all food products. Such comprehensive information is difficult to gather

* An Engel curve is a graphic representation of the demand for a particular good as a function of income when all prices are held fixed. In this paper, Engel curves for energy, proteins, and food are defined in equation 2, with corresponding estimates and plots in table 4 and figure 4, respectively.

from sources such as food-expenditure and food-recall surveys. Likewise, the income variables from the World Development Indicators are the only comprehensive source of cross-country time series for per capita income.

Finally, though it is well established that the causes of malnutrition are complex, we consider the impact of food consumption on the reduction of malnutrition. Since full analysis requires more data than are available for this paper, a comprehensive analysis is not possible here. Nonetheless, we look for evidence that lack of food availability is the most important single cause of malnutrition [20]. We conclude with a discussion of the findings, suggesting the formulation of strategies and policies that would be effective for combating food insecurity and malnutrition in the population of the SADAOC region.

The figures for nutrient availability, diets, production, acreage, yields, and imports were calculated by the authors from the Supply Utilization Accounts 1961 to 2000 [8], employing dedicated software to aggregate food products [11, 12]. Income figures (expressed in dollars) and population figures are taken from the World Development Indicators on CD-ROM [9]. Time series for gross domestic product (GDP) in the Sahelian zone and for the region as a whole start in 1967 because of missing GDP data for Mali from 1961 to 1966. Time series for purchasing power parity (PPP)-adjusted (or "international dollar") income start in 1975 and derive from GDP figures after the application of purchasing power parity-adjusted exchange rates. Child malnutrition and mortality figures are from the Global Database on Child Growth and Malnutrition [10]. The malnutrition indicator, height-for-age Z score (HAZ), denotes the percentage of children younger than five years whose height is more than 2 standard deviations below the median of a reference distribution (i.e., the distribution of nutritional status among healthy North American children). Child mortality is expressed as the number of children dying before reaching the age of five (per 1,000 live births). The time series in figures 1, 2, and 3 are fitted on a fourth-order polynomial regression curve.

Food-consumption patterns from 1961 to 2000

Nutrient availability

Figure 1 shows the trends in overall food availability in the SADAOC region during the period from 1961 to 2000. The estimates of the corresponding long-term growth rate are listed in table 1. The growth rate of a variable y is estimated by the equation

$$\log (yt) = \log (y_0) + rt \qquad (1)$$

TABLE 1. Growth rate of population and food availability in the SADAOC region, 1961 to 2000

Variable	Growth rate
Population (millions)	2.84
Calories (per capita per day)	0.41
Proteins (g per capita per day)	0.35
Calories (per kilogram of food consumed)	0.28

with estimated initial value y_0 at $t = 0$ (i.e., the year 1961) and estimated growth rate r.

At rates of 0.41% and 0.35% per annum for calories and protein, respectively, the long-term average growth of food availability per capita during the period has been positive, though small. Nonetheless, this trend has led to an increased availability of calories by almost 20%, from about 1,900 kcal per capita per day in the 1960s to about 2,300 in recent years. Likewise, the availability of proteins rose by about 15%, from around 45 g per capita per day to around 50 g. This protein availability is still far below the recommended intake of 1 g per kilogram of body weight [21]. The recent figure for the average availability of calories is, however, comparable to the benchmark recommended average intake of calories under normal activity levels.* Still, large parts of the population will have actual calorie intakes below the recommended levels, since availability figures tend to overestimate intakes, whereas both the availability and the intake of calories tend to be unevenly spread.

The uneven spread is evident in fig. 1 when one considers the disparities of food availability between the coastal and Sahelian countries of the region. Whereas calorie availability is around 2,500 kcal per capita per day in the coastal zone, it is less than 2,200 in the Sahelian zone.

Similarly, at around 60 g per capita per day, proteins are more available in the Sahelian zone and reach only 45 g in the coastal zone. Changes over time are significant, reflecting the various phases of the development path of the countries in the region as well as variability of production, especially in the Sahelian zone. Table 2 gives estimates of the absolute deviations over time and space of the growth rate in food availability.**

* Recommended intake (RI) is calculated from a person's body weight (WT) and activity level (A) using the formula RI = (a + b*WT) * A, with age and sex specific constants a and b (see FAO/WHO/UNU [21]). For example, the equation reads RI = (679 + 15.3*WT) * A for males aged 18 to 30. With a body weight of 60 kg and involvement in light activities, A = 1.5 times the person's basic metabolic rate implies requirements of about 2,400 kcal. Likewise, A = 2 for more demanding work, and the person's caloric needs rise to about 3,200 kcal.

**The figures in table 2 are deviations from the respective averages in table 1. The deviations are obtained from separate estimation of the growth rate for the coastal and Sahelian countries and for the four subsequent decades.

It appears that the improvement in the availability of calories has been slower in the coastal countries, which had faster population growth. Furthermore, most of the improvement in the coastal zone was due to a shift toward food with much higher calorie content, probably because of the increased importance of imported cereal products over root crop products. Such a dietary shift is much less pronounced in the Sahelian zone,

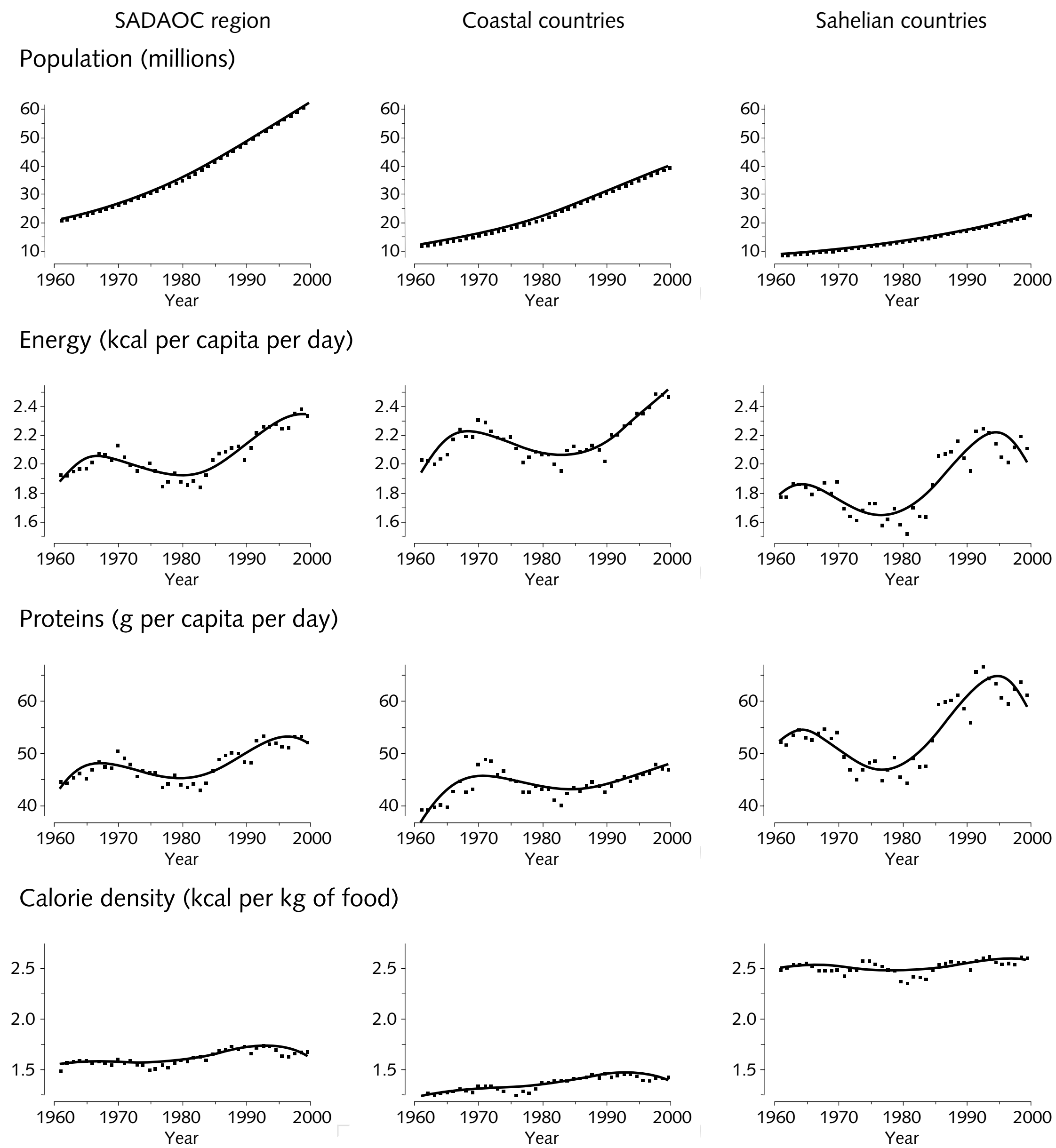

FIG. 1. Population and nutrient availability in the SADAOC Region, 1961 to 2000

TABLE 2. Variation over space and over time of growth rates[a] of population and food availability in the SADAOC region, 1961 to 2000

Variable	Coast	Sahel	1960s	1970s	1980s	1990s
Population	+0.28	–0.43	–0.22	+0.07	+0.14	–0.02
Calories per capita per day	–0.14	+0.18	+0.67	–0.98	+0.10	+0.30

a. Growth rates are expressed as deviations from the respective averages in table 1.

where locally produced cereals are already the predominant source of calories. The developments over time reflect the pattern of favorable developments in the 1960s, crises and collapses during the 1970s, and recovery since the 1980s, whereas recent figures seem to indicate slower population growth and trends in higher levels of food availability.

The first decade (the 1960s) marks the commitment, after independence, to food self-sufficiency with government support for locally grown food crops. In spite of rapid population increases, food availability improved, although it remained insufficient during the 1960s. During the second decade (the 1970s), population growth accelerated, and a general decline in the support of agriculture began to affect production and consumption capacities negatively. Droughts in the years 1975, 1977, and 1982, and an upsurge of economic mismanagement practices also played a major role in this. The per capita availability of calories fell sharply at an average rate of 0.5%. Structural adjustment policies began to take shape in the mid-1980s, when the economic recession reached its lowest ebb. Access to relatively expensive products of high nutritional value, such as animal products, dwindled during the 1980s and 1990s. Although per capita income has gradually recovered since the mid-1980s, the role of relatively nutritious products in total consumption has remained small or even diminished. For example, real prices of beef increased considerably during the years following the devaluation of the CFA (the local currency for SADAOC countries except Ghana) in 1994 [22].

Composition of the diet

Figure 2 illustrates the composition of the regional diet and its trends since the 1960s. In the SADAOC region as a whole, the broad structure of food consumption has remained fairly stable throughout the period. Staple foods contribute around 80% of dietary energy calo-

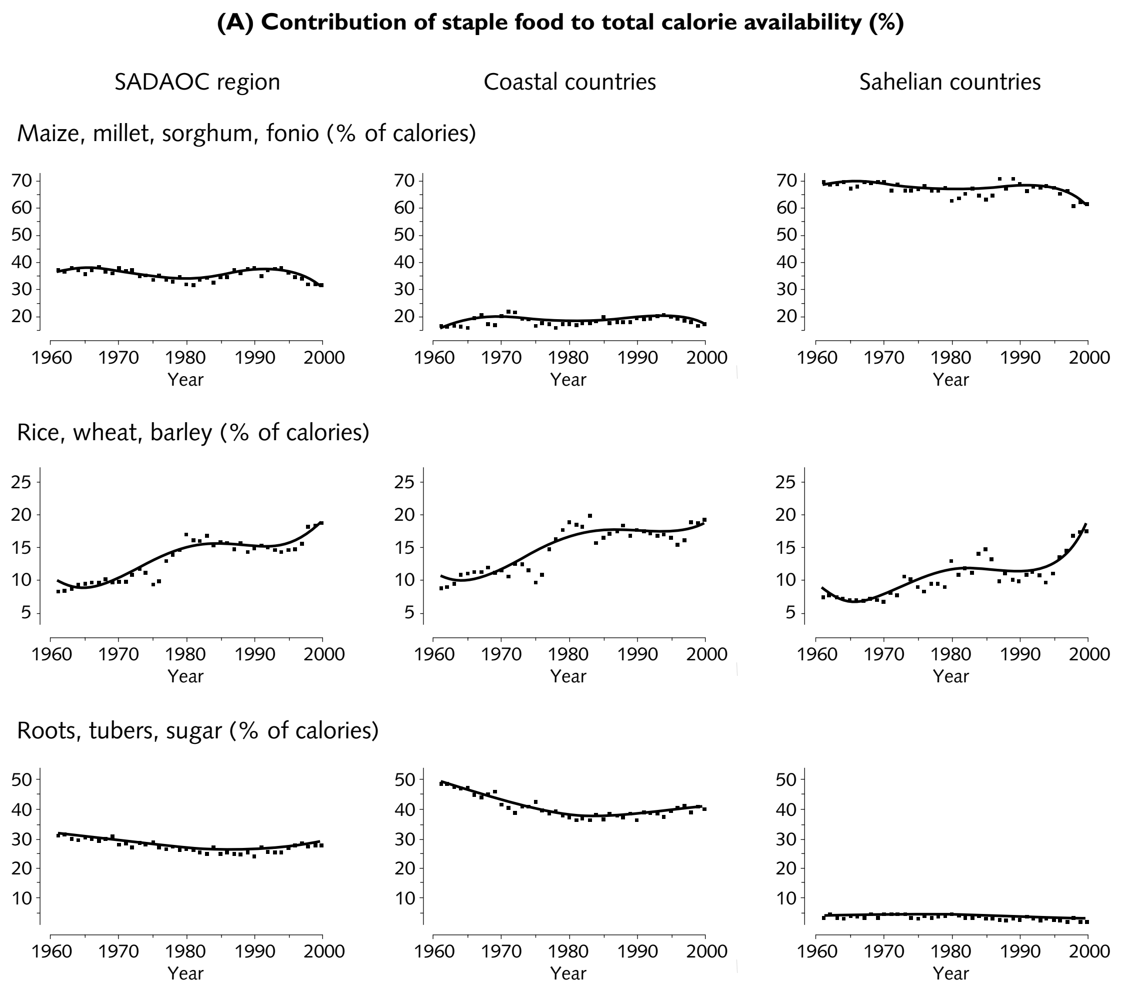

FIG. 2. Diets in the SADAOC Region, 1961 to 2000

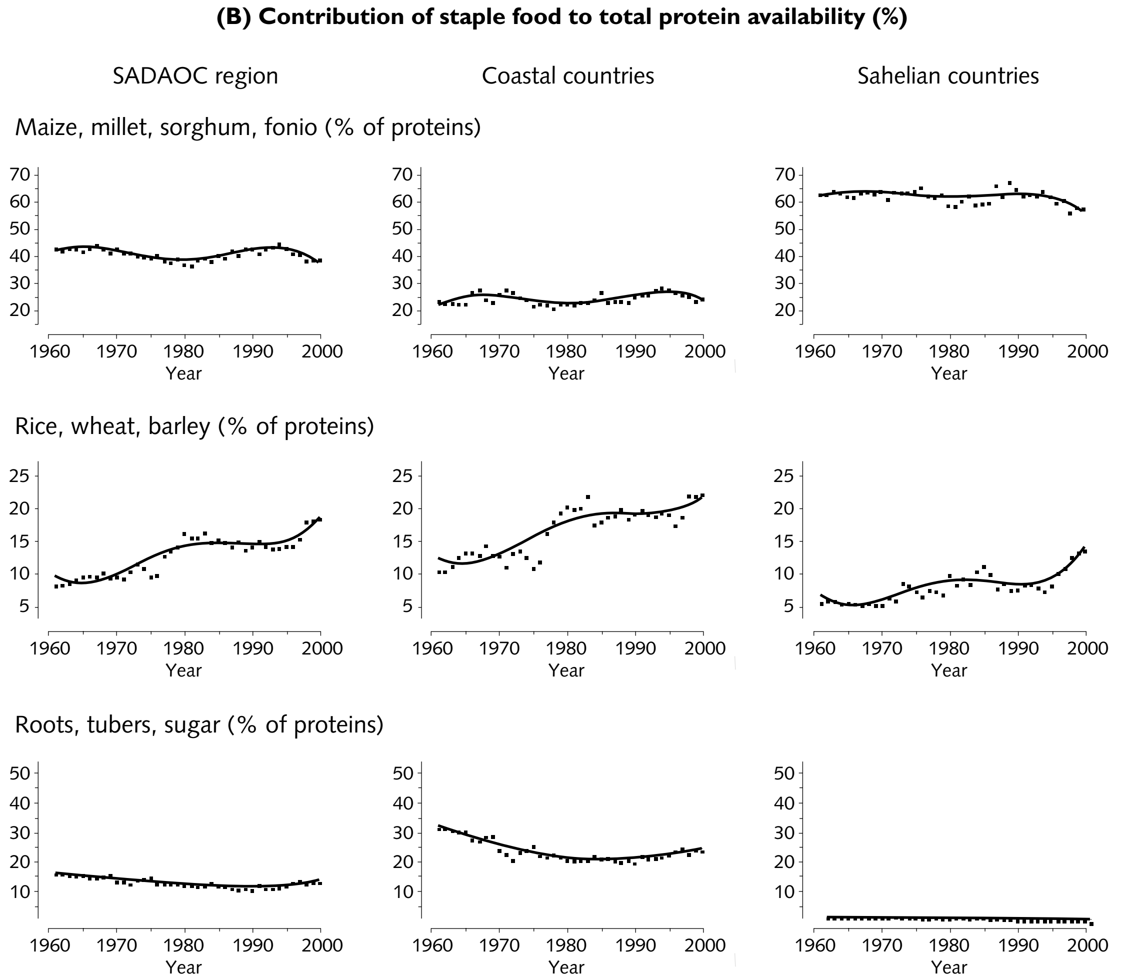

FIG. 2. Diets in the SADAOC Region, 1961 to 2000 (continued)

ries, with cereals accounting for 50% and tubers and roots for some 30% (fig. 2A). Staple foods are also the predominant providers of proteins, contributing close to 70% of total availability (fig. 2B). The position of oil crop products (10% and 6% of calories and proteins, respectively), fruits and vegetables (6% and 4%), pulses (2% and 4%), and animal products (4% and 15%) has remained relatively stable (fig. 2C and D).

Huge differences appear when the diets in the coastal countries are compared with those in the Sahelian countries. Diets in the Sahelian zone remained very much cereal-based during the period, with cereals providing about 80% of total calories and 70% of total proteins. Millet and sorghum are the predominant cereals, and the production of these two crops is close to 10 times the production of maize. Conversely, diets in the coastal zone have a mixed base of cereals and roots/tubers, each providing close to 40% of total calories, with an additional 10% and 8% deriving from oil crops and fruits, respectively. This result refutes the popular idea that diets in the coastal zone are mainly based on tubers and fruits, as would be expected considering the agro-ecological potentials. An increased and accelerated production and trade of tubers and plantains produced in forest zones and consumed in the capitals and other growing cities probably lacks adequate processing and transportation capacities in terms of both equipment and knowledge. Fruit consumption is negligible in the Sahelian zone.

A further notable feature is the diminishing role of pulses and animal products, particularly in the coastal countries, where their contribution to protein availability has declined from around 25% and more in the 1960s and 1970s to less than 20% in recent years. Since these two groups of foods are the best sources of quality protein, this dietary shift suggests that the quality of the diet has decreased somewhat.

The quality of the diet is a matter of both insufficient supplies and an uneven distribution of the different groups of food. The comparative analysis of protein consumption in the SADAOC region shows that in the coastal countries animal proteins contributed

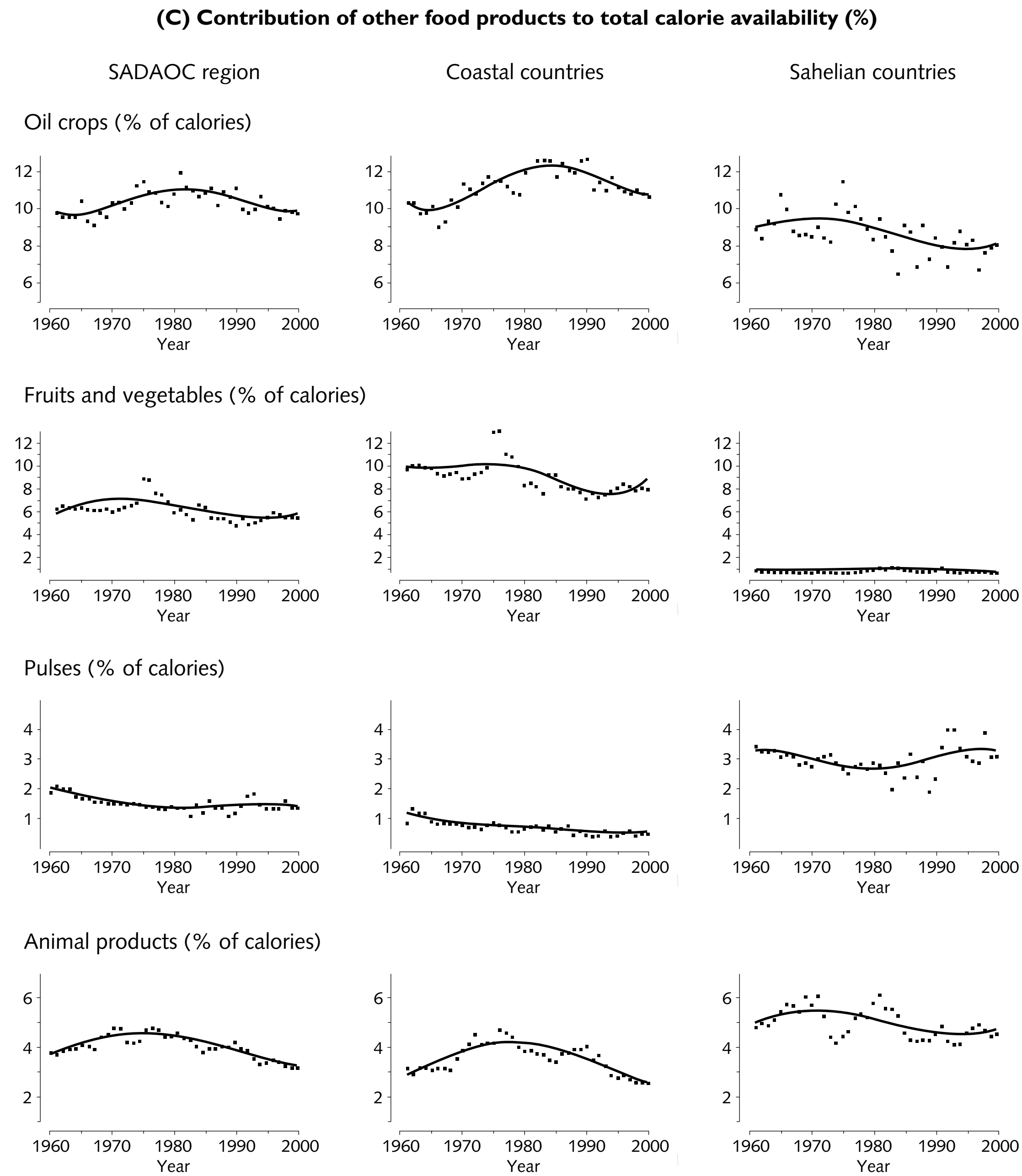

FIG. 2. Diets in the SADAOC Region, 1961 to 2000 (continued)

only some 16%, while cereals and tubers provided 45% and 25%, respectively. In the Sahelian countries, animal proteins provide about 15% of the total protein supply, whereas cereals account for some 75%. The large proportion of the protein in the diets of Sahelian people derived from cereals is striking. Indeed, despite the potential animal resources of this subregion, the low share of animal protein consumption is not greatly different from that of coastal countries. It would thus seem that the high prevalence of protein deficiency in the coastal countries must be attributed to the role of root crops in the southern diets and their relative absence in those of the north.

The most notable diet change in all of the countries of the region is the shift in recent years toward rice, wheat, and barley products. This probably reflects the taste for such cereals associated with urbanization and income growth, and we pay special attention to the consequences of this dietary shift in both the Sahelian and the coastal countries.

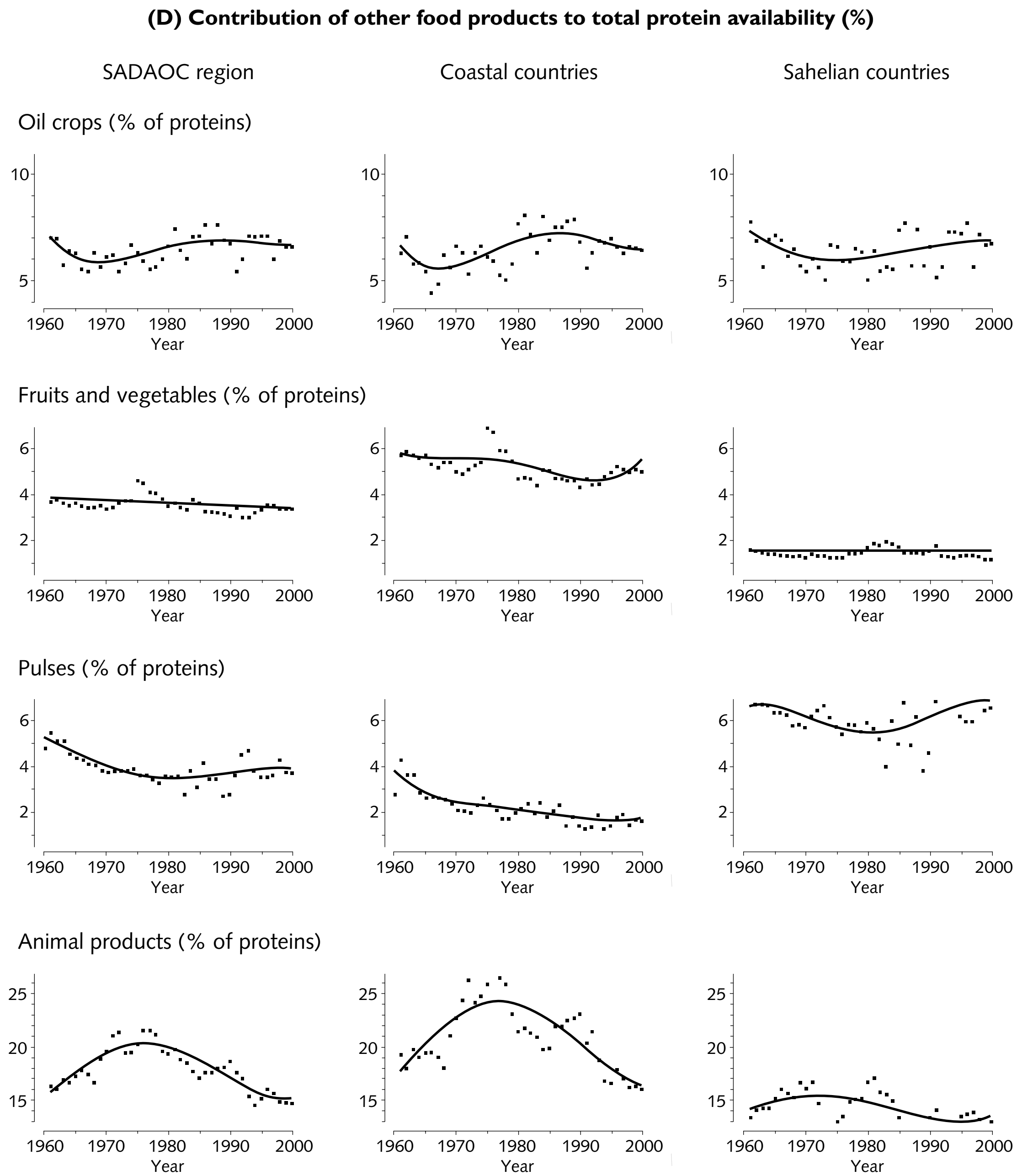

FIG. 2. Diets in the SADAOC Region, 1961 to 2000 (continued)

The role of cereals

The preceding discussion on the availability of food and the composition of the diet has revealed that the role of cereals is gaining significance for food security in the SADAOC region. The observed improvement in the quality of diets over the past decade has largely been due to greater cereal consumption. As figure 2 shows, the increase in the per capita availability of calories in the coastal zone is due to an increased consumption of rice, wheat, and barley products. In the Sahelian zone, millet and sorghum continue to be the predominant providers of both calories and proteins, but rice, wheat, and barley products are beginning to play a larger role.

Part of this increased consumption has led to increased imports of rice and wheat flour that are further encouraged by the unstable per capita levels of locally produced cereals. This pattern is shown in figure 3, and a further analysis of the figures reveals several other interesting characteristics of cereal production and import patterns during the period 1961

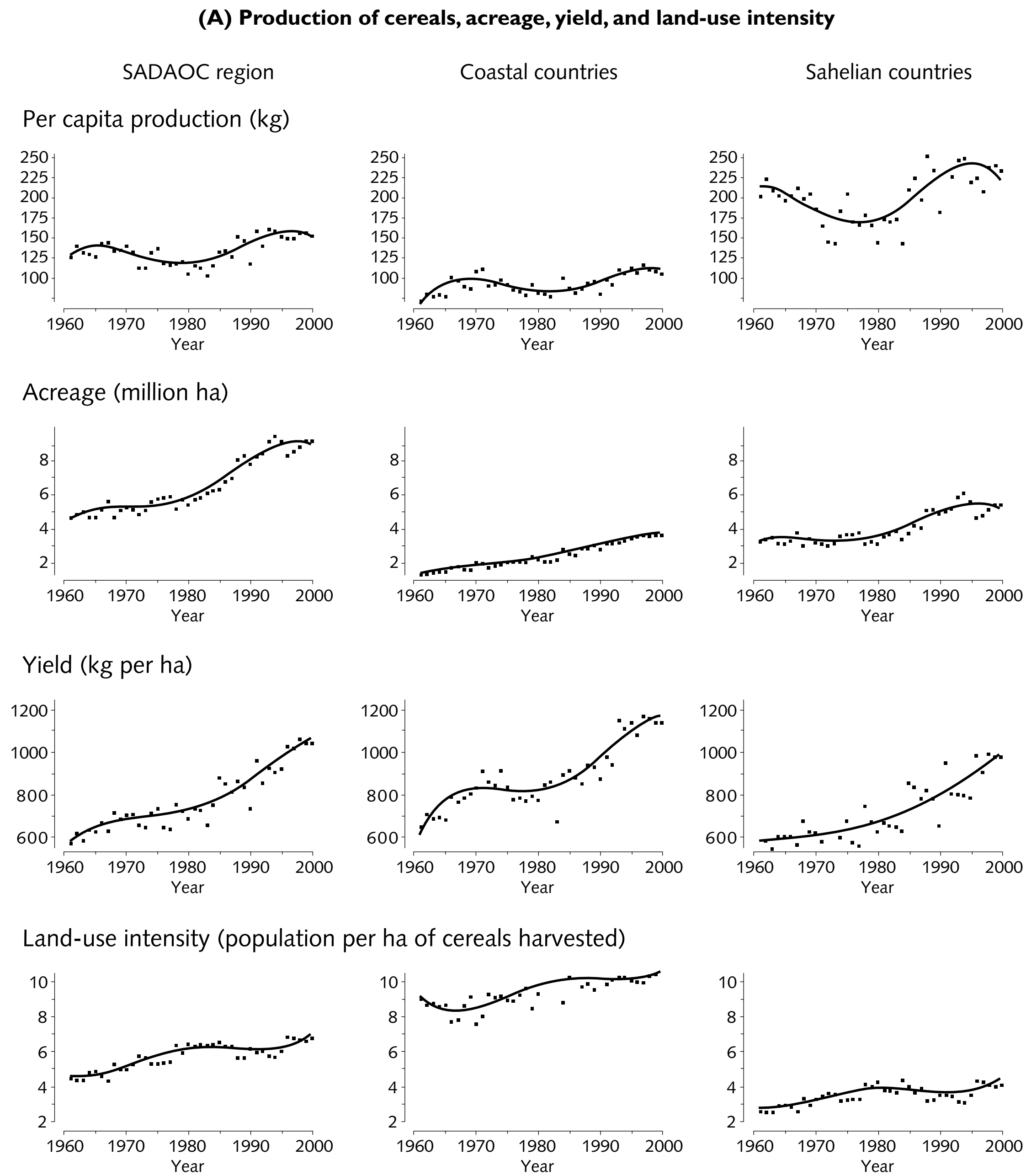

FIG. 3. Production, yields, and imports of cereals in the SADAOC Region, 1961 to 2000

to 2000. For example, equation 1 describes and table 3 illustrates the long-term growth rates of production and imports as well as those of acreage, yields, and land-use intensity.

Apparently, food-consumption patterns have been putting pressure on cereal production. The long-term production trend has exceeded population growth and led to improvements in per capita cereal production by 0.5% per annum, in both the coastal and the Sahelian zones of the region. At the same time, the growth of cereal imports has exceeded population growth by far, suggesting that food-consumption patterns led to substantial and increasing cereal imports. Moreover, the largest part of the pressure exerted on dry cereals (millet, sorghum, maize, and upland rice) is borne by the increase in cultivated areas under a relentless, extractive, low-input agriculture that remains unstable because of undependable rainfalls and a failure to improve yields. At current average yields of around 1,000 kg per hectare, long-term annual growth in production is estimated at 1.2% to 1.4%, well below that of population growth, necessitating a continual expansion

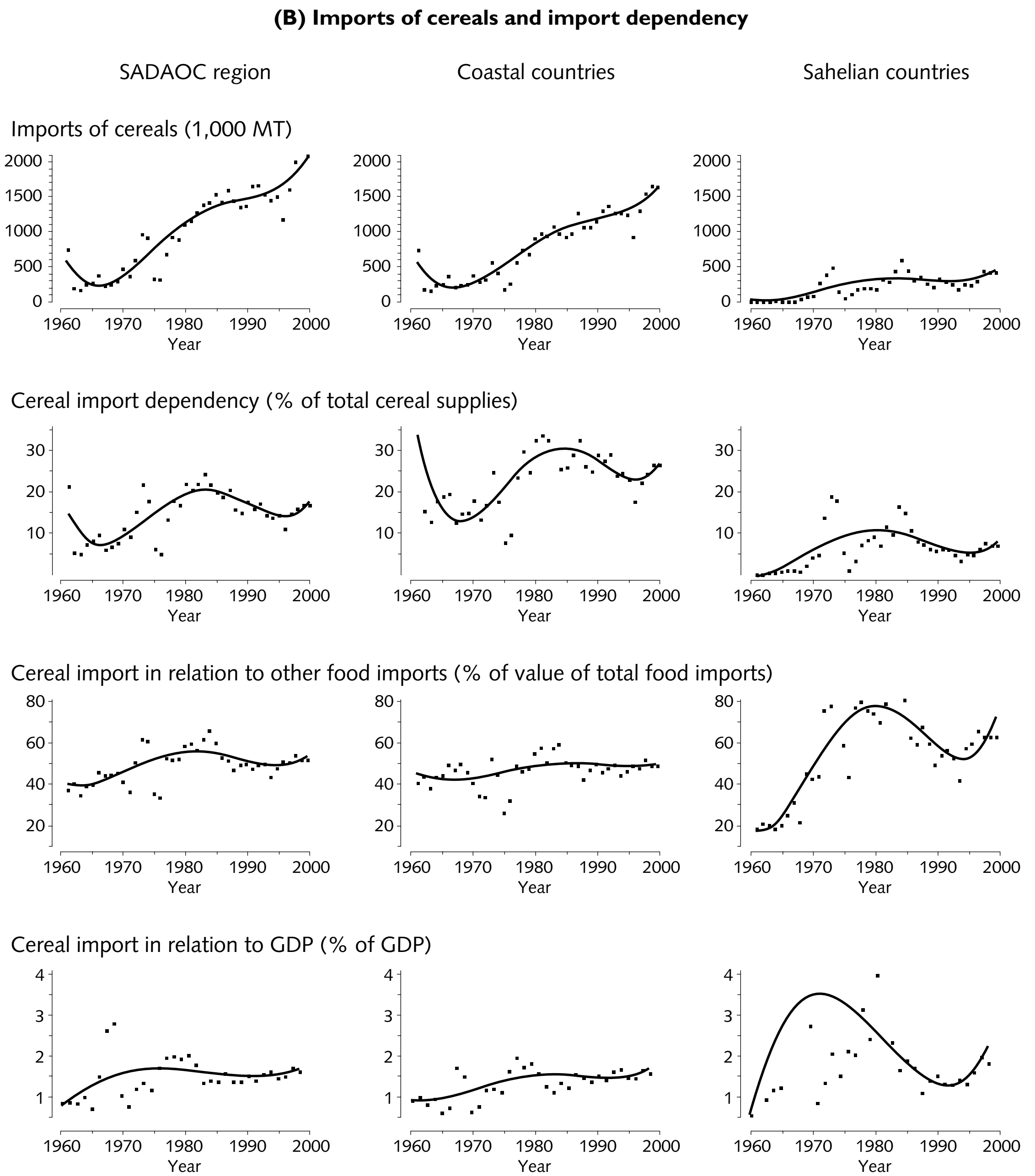

FIG. 3. Production, yields, and imports of cereals in the SADAOC Region, 1961 to 2000 (continued)

of cultivated areas.

Land is under pressure, particularly in the Sahelian zone, where already cleared lands that used to be under shifting cultivation are now undergoing constant tillage with associated soil depletion and restraints on future growth in productivity. With the use of traditional cropping techniques which, in general, do not care much about the protection of natural resources (mainly soils and vegetation), the risk of environmental degradation and productivity decrease becomes higher than ever. During the 2000–2001 crop season in Burkina Faso, for example, a low rainfall was recorded, and cereal deficits were estimated at about 440,000 metric tons, exposing more than 1 million people to hunger.*

It is noteworthy that in the coastal countries, cereal imports constitute some 25% of total cereal supplies, whereas this import dependency is only around 5%

* Kaboré I. Opening speech of the CEDA seminar on "Challenges in land tenure, food security and biological diversity," Ouagadougou, Burkina Faso, 2001.

TABLE 3. Growth rates (%) of cereal import and production in the SADAOC region, 1961 to 2000

Variable[a]	SADAOC	Coast	Sahel
Imports	5.55	5.35	8.12
Production	3.26	3.70	2.98
Yield	1.36	1.20	1.41
Acreage	1.90	2.49	1.57
Land-use intensity	0.94	0.62	0.85

a. Import and production figures are given in metric tons (MT); yield in kg/ha; acreage in hectares (ha); and land-use intensity as the ratio of cultivated land to total agricultural land available.

in the Sahelian zone (fig. 3B). Food imports consist mainly of cereals (about 50% of the total value of food imports) and include substantial amounts of food aid, especially in years with erratic rainfalls. Finally, in terms of income, cereal imports on average cost about 1.5% of gross domestic product in SADAOC countries in aggregate, a cost that is fairly stable in the coastal countries but very volatile in the Sahelian zone.

Food consumption: responsiveness to income

In the previous section we discussed food-consumption patterns in the SADAOC region through time-series curve-fitting and trend regressions and decomposition of the diet. We continue the discussion by considering the responsiveness of total food availability to income. Indeed, the insufficiency of income in poor population groups is generally seen as the single most important cause of inadequate food availability. In particular, the responsiveness of food demand to income in developing countries is generally expressed through an estimate of calorie-income elasticity, which is considered an important parameter both in the literature and in the policy arena.

Many studies have addressed the issue and estimated the effect of increases in income on the consumption of calories by the poor; see, for example, tables 5 and 8.4 in the surveys by Bouis [13] and Ray [23], respectively. The studies mostly employ data from countries in Asia or Latin America. Two exceptions are studies in Kenya [24] and Ghana [25] that reported average elasticities of 0.15 and 0.57, using, respectively, per capita income and per capita expenditure of the household as the explanatory variables.

We will now try to estimate the calorie-income relation in the SADAOC region and also consider the responsiveness of protein availability to income, although the results must be interpreted cautiously, given the inaccuracies of the data employed.*

The cross-country time-series data are displayed in figure 4, where a per capita food-consumption variable is on the y axis and the logarithm of per capita income is on the x axis. This is the common form for estimating food Engel curves, and it also shows that the corresponding food-income elasticities decrease with income.**

The following equation specifies food Engel curves, i.e., the demand for food F as a function of income Y:

$$F = a + b \log(Y) \qquad (2)$$

with per capita income Y taken from the World Development Indicators database and expressed in international dollars (time series available for 1975 to 1999) and per capita availability of calories or proteins F.

* Though the food consumption data may not be accurate, they are comprehensive. Such comprehensive information is difficult to gather from sources such as food expenditure and food recall surveys. Likewise, the World Development Indicators are the only comprehensive source of cross-country time series for per capita income in the region.

** We also included the average price of imported calories (proteins) as an additional explanatory variable. The price variable had a negative but insignificant effect on the availability of calories (proteins) and did not affect the respective income elasticity. This corroborates the finding by Skoufias [15], who concludes that the calorie-income elasticity is remarkably insensitive to price changes.

TABLE 4. Calorie-income and protein-income elasticities in the SADAOC region, 1975 to 1999[a]

Equation 2	*a*	*b*	*b/F*
F = 1000 kcal/capita			Calorie-income elasticity (at F = 3.0 to 1.5)
SADAOC region	1.196 (16.6)	0.851 (12.8)	0.28–0.57
Coast	1.221 (9.5)	0.750 (7.6)	0.25–0.50
Sahel	1.493 (22.5)	0.935 (7.7)	0.31–0.62
F = g protein/capita			Protein-income elasticity (at F = 70 to 35)
SADAOC region	30.5 (17.3)	17.2 (10.5)	0.25–0.49
Coast	32.3 (20.5)	9.3 (7.7)	0.13–0.27
Sahel	42.7 (22.8)	28.3 (8.2)	0.40–0.81

a. The t-scores of the parameter estimates a and b are given in parentheses.

Table 4 contains the estimates, their significance,* and the corresponding estimates of the income elasticities.

The estimates show that in the SADAOC region, both calorie and protein availability are highly responsive to income. The estimated calorie-income elasticities range from 0.25 for relatively high incomes in the coastal zone to 0.65 for low incomes in the Sahelian zone. Likewise, protein-income elasticities are estimated to range from 0.13 for relatively high incomes in the coastal zone to 0.81 for low incomes in the Sahelian zone. These estimates support the idea that food availability in the region is highly responsive to income, whereas protein is more responsive to income than to caloric intake.

Food consumption: impact on child malnutrition and mortality

It is commonly believed that the availability of nutritious food translates into favorable nutritional status, which in turn is an immediate indicator of food security. Indeed, studies of malnutrition seem to indicate that lack of food availability is the most important single cause of malnutrition, particularly for the case of child malnutrition in Africa [16]. Therefore, we attempt to relate food-consumption patterns to child nutritional status, although we recognize that an elaborate treatment is beyond the scope of this paper and would require a more sophisticated treatment of both data and methodological considerations.

We obtained child malnutrition and mortality figures for the period from 1970 to 1999 from the Global Database on Child Growth and Malnutrition (table 5) [10]. These figures are based on representative samples of the populations of the SADAOC region at large. The malnutrition indicator denotes the percentage of children under five years of age whose height-for-age is more than 2 standard deviations below the median of a reference distribution (i.e., the distribution of nutritional status among healthy North American children). Infant mortality is expressed as the number of children dying before reaching the age of five per 1,000 live births.

According to these figures, the prevalence of child malnutrition in the region currently ranges from 20% to 25% in the coastal countries and from 30% to 50% in the Sahelian countries. Over time, the figures indicate a significant relapse in Côte d'Ivoire and Mali, and alternating periods with gradual improvements and stagnation in Ghana and Togo, whereas there is only a single observation for Burkina Faso.

The patterns of child mortality reflect a similar geographic picture, with much higher mortality rates of more than 200 per 1,000 live births in the Sahelian zone and rates between 110 and 180 in the coastal

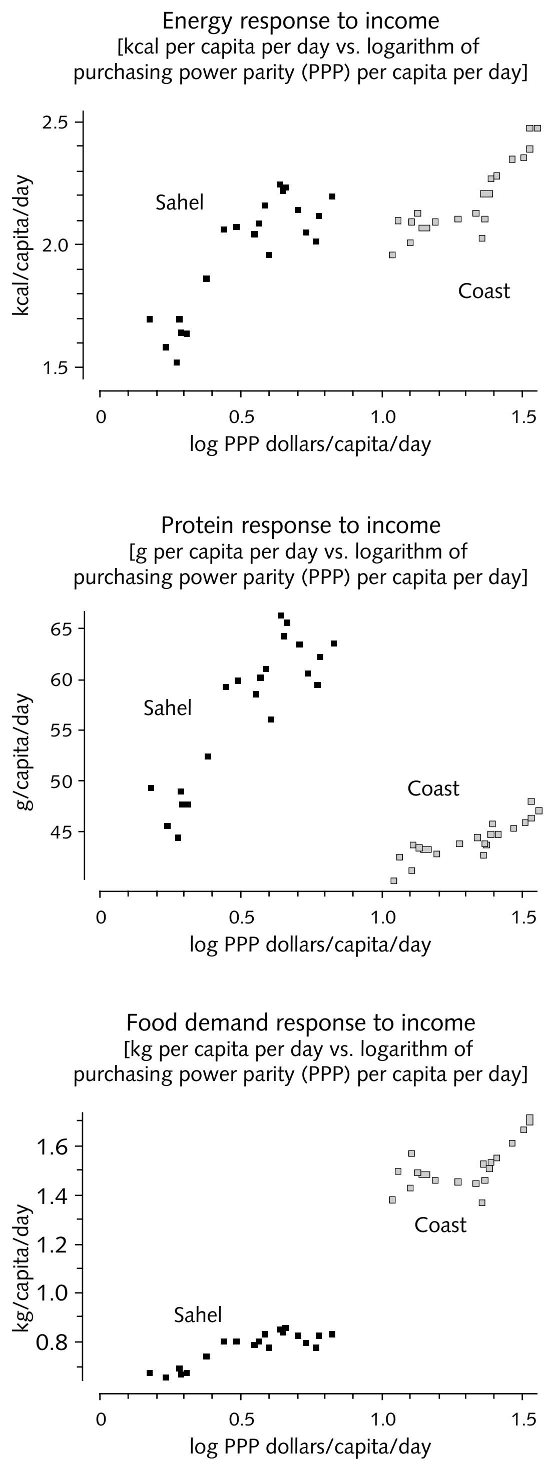

FIG. 4. Food availability in the SADAOC Region: responsiveness to income

* With 25 observations, t-scores of 2.0 and higher indicate that parameters are significantly positive at the 1% confidence level. Also, the fit is fairly high, with income explaining about 75% of the variation in both calorie and protein availability.

TABLE 5. Child malnutrition and mortality in the SADAOC region, 1970 to 1999

Year	% of children under 5 with stunted growth					No. of children per 1,000 live births not reaching age 5				
	Burkina Faso	Côte d'Ivoire	Ghana	Mali	Togo	Burkina Faso	Côte d'Ivoire	Ghana	Mali	Togo
1970	—	—	—	—	—	278	240	186	391	216
1977	—	—	—	—	33.7	—	—	—	—	—
1979	—	—	—	—	—	—	—	—	315	—
1980	—	—	—	—	—	—	170	157	—	—
1982	—	—	—	—	—	245	—	—	—	188
1984	—	—	—	—	—	—	—	—	292	—
1986	—	17.2	—	—	—	—	—	—	—	—
1987	—	—	30.5	23.8	—	217	—	—	—	158
1988	—	—	29.4	—	33.6	—	—	—	—	—
1989	—	—	—	—	—	—	—	—	268	—
1990	—	—	—	—	—	—	150	119	—	—
1992	—	—	—	—	—	229	—	—	—	142
1993	33.3	—	—	—	—	—	—	—	—	—
1994	—	24.4	25.9	—	—	—	—	—	238	—
1995	—	—	—	—	—	—	—	108	—	—
1996	—	—	—	48.6	34.0	—	—	—	—	—
1997	—	—	—	—	—	219	180	104	235	146
1998	—	—	—	—	21.7	—	—	—	—	—
1999	—	—	25.9	—	—	210	180	109	223	143

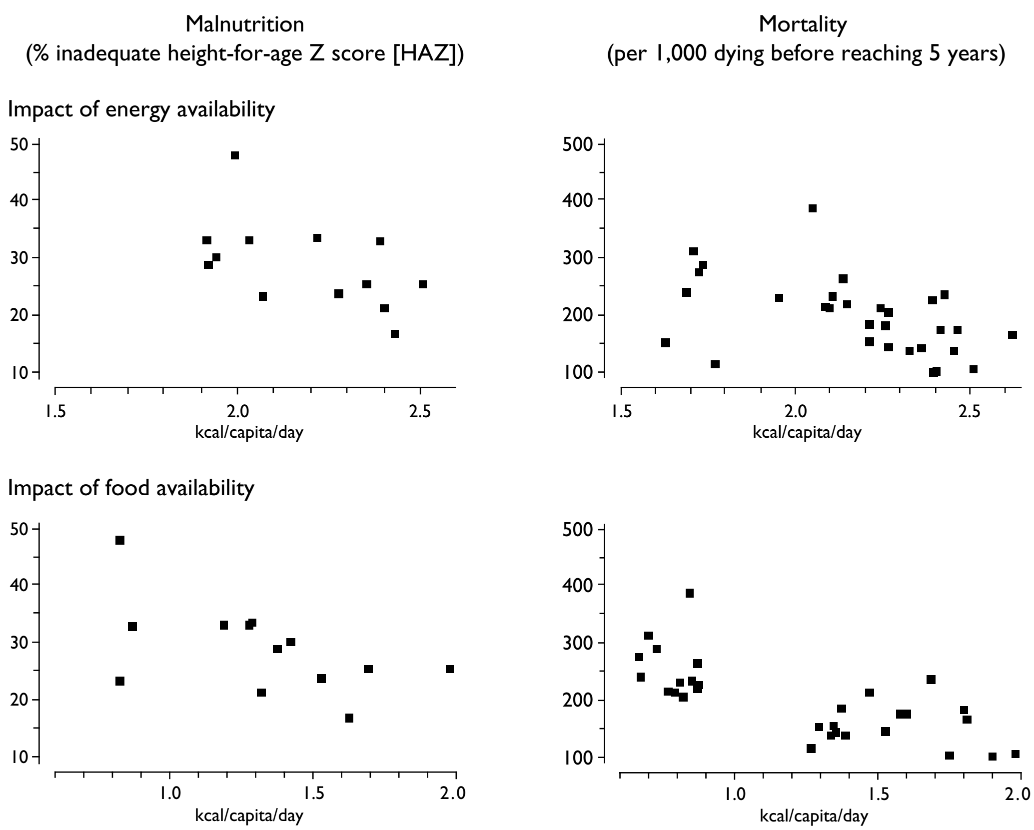

FIG. 5. Food availability in the SADAOC Region: impact on child malnutrition and mortality

TABLE 6. Stunting-calorie and mortality-calorie elasticities in the SADAOC region, 1970 to 1999[a]

Equation 3	*c*	*d*	*d* * *F/M*
M = percent stunted			Stunting-calorie elasticity (at the mean of *F* and *M*)
	71.5 (9.46)	19.2 (–2.13)	–1.42
M = per 1,000 dying before age 5			Mortality-calorie elasticity (at the mean of *F* and *M*)
	451 (5.21)	115 (–2.90)	–1.24

a. The *t*-scores of the parameter estimates *c* and *d* are given in parentheses.

zone. Developments since 1970 indicate significant improvements in all countries until 1990. During the 1990s, more gradual improvements were reported in the Sahelian zone, while child mortality seems to have leveled off in the coastal zone.

In figure 5, these figures are displayed as a function of the availability of food in the respective countries and during the respective years. Finally, we consider the relationship between food *F* and malnutrition *M* and estimate

$$M = c - dF \qquad (3)$$

with the per capita availability of calories *F* and the malnutrition or mortality rate *M*. The significance of food availability for reducing malnutrition and mortality rates is shown in table 6, which contains estimates of the parameters of equation 3 and the corresponding calorie elasticities. These elasticities equal *d* * *F/M* and are evaluated at the mean per capita calorie availability $F = 2.180$ and at the mean prevalence of stunting $M = 29.4$ and the mean mortality rate $M = 202$, respectively.

Food availability appears to have a negative and statistically significant impact on both stunting and mortality. However, given the complexity of the causes of malnutrition and the limitations of the data, it is not surprising that the regression of the stunting and mortality variables on the food-availability variable shows a low fit.* Other underlying causes of malnutrition and death, such as vitamin and micronutrient deficiency, lack of hygienic food-processing, and recurrence of infectious diseases, are equally important and frequently counteract the positive effect of improved availability of foodstuffs. This situation may be furthered by an inadequate distribution of nutritious food at the household level, to the detriment of children. These additional factors help to explain the poor nutritional status in the southern and middle belt districts of Ghana, in spite of the relative abundance of food in these areas [26].

* The *t*-scores in table 6 are lower than –2, indicating that the effect of food availability on stunting and mortality is significantly negative at the 1% confidence level. However, the fit is rather poor, with calorie availability explaining only 29% and 23% of the variation of the stunting and mortality rates, respectively.

Conclusions and policy implications

This study has described food-consumption patterns in Central West Africa during the period 1961 to 2000 and draws attention to the following:

» The positive trends in calorie and protein availability, which, however, are still below requirements and unstable;
» The extent to which cereals are in high demand because of their increasing contribution to total calorie and protein consumption, and the resulting risk of import dependency and scope for increased regional trade between the Sahelian and coastal zones;
» The responsiveness of food consumption to income;
» The positive impact of food availability on nutritional status and mortality rates in children.

These findings indicate that food insecurity and malnutrition are still persistent in the region, despite the progress made over the past two decades. They reveal that in general, food-consumption patterns have not changed much in Central West Africa since the 1960s. Calories and proteins are still mainly provided by cereals, which increasingly dominate the diet over leguminous and animal products. There has been a slow increase in per capita food availability, but protein needs remain uncovered. This situation shows regressive food-consumption patterns that are ineffective in using existing food-production potential and contribute to the current degree of malnutrition. Furthermore, the situation reflects a structural defect in food production in addition to its vulnerability to natural calamities, such as droughts or flooding. The structural limitations are also reflected in the ineffectiveness of supply systems and the inadequacy of food-consumption patterns relative to nutritional needs.

Two major factors are of particular interest.

The first is poverty, which limits the land available to families for producing sufficient quantities of food crops and restricts their ability to buy additional food, whether locally produced or imported. Indeed, the long-term economic growth in the SADAOC region is now low after relatively high growth in the 1960s, recessions in the 1970s and early 1980s, recovery from the mid-1980s to the mid-1990s, and stagnation in recent years.

The second structural factor affecting the persistence of food insecurity and malnutrition in the region is insufficient improvement in food-consumption patterns that bear the burden of low and vulnerable yields and of consumption habits dominated by cereals. The quality of the diet is deficient. For example, cereals, roots, and tubers currently provide some 80% of the calories, fruits some 5%, and oil crops some 10%, while animal products and pulses together provide 5% of the calories. This compares unfavorably to the recommended distribution of calorie sources, which is about 55% to 60% of carbohydrates from cereals, roots and tubers, and fruits; 25% of lipids from oil crops and animal products; and 15% of proteins from animal products and pulses. Over time the dietary pattern has shown a tendency to shift to imported cereals, further increasing the share of carbohydrates, while the contribution of oil crops and leguminous and animal products to the total energy input has gradually decreased.

The harsh climate in the north is certainly not favorable to the development of the drought-sensitive leguminous crops of humid zones. The latter therefore cannot provide the main sources of proteins in the Sahelian zones. But it is remarkable that despite their huge potential and high capacities in meat and dairy production, Sahelian countries still obtain most of their proteins from cereals. Cattle are a capital good, and the supply depends on herd size and price and on health risks [27]. It is popularly assumed that animal breeding belongs to wealth-keeping and risk-avoidance strategies in the Sahelian zone, limiting meat consumption to a critically low level. Pilot studies have shown that poultry farming can be intensified and is well adapted to the socioeconomic conditions of rural communities in Sahelian countries [28].

It is also noteworthy that in coastal countries, animal products (mainly fish) make only a small contribution to the protein supply, although these areas have access to the sea and a huge potential in the availability of fresh water (rivers and lagoons) and a favorable climate for fish breeding. The potential of fish production has not been exploited because of the constraints to investment in equipment and training.

The reduction of malnutrition is restricted by national policies that simply accommodate cereal-based consumption behaviors without focusing on exploiting the region's comparative advantages to provide for a more balanced diet with less dependence on cereals. Indeed, although political support is usually strong for emergency food imports during periods of drought, a lot remains to be done to improve the production of roots and tubers in coastal countries and traditional cereals in Sahelian countries. In the face of rapid population growth, and especially the increase in urban food demand, the diversification of food production in general and the intensification of cereal cultivation in particular must be undertaken. Food policy in all of these countries should seek to rationalize a transformation of the production and supply systems and, most importantly, of consumption patterns, which are major determinants of the latter.

The results of the present study indicate that per capita income is a key determinant of per capita food consumption, while, in turn, improvements in per capita food consumption are significant for combating malnutrition. Policies and strategies to combat malnutrition thus involve broad-spectrum income growth and specific actions that promote the yield and the contribution to diets of nutritious food produced within the region.

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An evaluation of the national food and nutrition policy of Bangladesh

M. A. Mannan

Editor's note

The Bulletin *would prefer articles describing the success of programs and policies. But occasionally it is useful to review why apparently good policies and careful planning are not sufficient. The reader will be impressed in the following article with the thoroughness of the process followed to develop such a policy and to identify opportunities for intervention, but will lament the fact that despite substantial progress, this promising effort did not result in as successful implementation as was intended.*

This article is a reminder of the seemingly obvious point that even the best plans and policies cannot be effective if they are not appropriately implemented. Those responsible for developing them have an obligation to put equal emphasis on the task of putting them into practice. This article uses the qualitative anthropological techniques of semistructured interviews and focus groups to determine the strengths and weaknesses of the food and nutrition policy developed by Bangladesh, and the reasons why its implementation has been unsatisfactory. This approach reveals lessons learned that may be used to improve future initiatives.

The many examples of successes that the Bulletin *has published in previous issues were achieved after dedicated individuals persistently, and ultimately effectively, promoted their projects with the governmental agencies, nongovernmental organizations, or both whose participation was essential for realization of the projects. It is to be hoped that this will ultimately be the case for the national nutrition program evaluated in this article.*

Abstract

Food and nutrition policy activities directed toward improvement of the nutritional status of the people of Bangladesh began in the 1980s. The government formulated a national food and nutrition policy and approved it in 1997. Qualitative methods, including observational techniques, in-depth interviews of the key informants, and focus group discussions, were used to collect information on the strengths, weaknesses, opportunities, and threats (SWOT) of the policy. The information obtained has been transcribed and analyzed using this model. The strengths of the policy are that it is a consensus document that emphasizes human rights, was formulated by a multisectoral approach, complements other government policies, and has broad goals and wide-ranging objectives. The weaknesses include lack of implementation, monitoring, and evaluation guidelines; lack of strong government commitment; inadequate support of policy makers; perhaps an excessively ambitious target; and ignorance of past lessons learned. The opportunities include the scope of social mobilization, the wide scope of the policy, suggested programs and measures to improve nutritional status, a congenial policy environment, and the ability to modify the scope of the policy as needed. The threats to the policy are lack of knowledge of the policy, lack of resources to implement the policy, tension between technical people and bureaucrats, vested business interests, and, possibly, discontinuity of political commitment. The key to reducing the weaknesses of the food and nutrition policy of Bangladesh and minimizing the threats to it is for the stakeholders in the policy to coordinate efforts to use the strengths and opportunities of the policy to effectively implement it.

Key words: Bangladesh, national food and nutrition policies

Introduction

The World Summit for Children in 1990 emphasized that with the right policies, appropriate institutional arrangements, and placement among political priori-

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ties, the world was in a position to feed all of its children and overcome the worst form of malnutrition [1]. In addition, leaders from 159 countries in attendance at the 1992 International Conference on Nutrition in Rome declared their determination to eliminate hunger and reduce all forms of malnutrition [2]. Both industrialized and developing countries have started to formulate and implement food and nutrition policies since the 1974 World Food Congress [3–8]. Twenty years after the Congress, not much had been done by either developing or industrialized governments toward achieving the proclaimed goals [9]. Food and nutrition policy formulation, implementation, and reformulation have been adopted by many countries to improve the nutritional status of the people. Broadly, this type of policy involves the full range of public decisions that influence individuals and institutional sectors to decide what actions should be taken to improve nutritional status, how these actions shall be implemented, and who are the target populations to benefit from these policies.

The Bangladesh Constitution states in article 18 (1) that "The State shall regard raising the level of nutrition and improvement of public health as among its primary duties" [10]. A national nutrition survey on food intake in the Bangladeshi population, which found a declining trend in nutrient intake, has been assessed [11]. The Bangladesh National Nutrition Council (BNNC) prepared the Nutrition Policy and Program for Bangladesh, which was approved by the BNNC and published in 1984 [12]. This was reviewed and modified in a workshop in June 1989.* The final recommendations were approved by the BNNC in a meeting presided over by the Prime Minister and the Cabinet in 1997 [13]. This study evaluates this national food and nutrition policy for its strengths, weaknesses, opportunities, and threats (SWOT) during its formulation and attempted implementation.

Methods

We conducted a qualitative evaluation of the national food and nutrition policy of Bangladesh, using observation, in-depth interviews with key informants, and focus group discussions. This approach was useful in collecting historical information as well as suggestions for solutions of problems that arose from the policy implementation process. This approach provided us with information that we could analyze quickly to determine our next steps [14].

Observations

The offices of the policy maker (BNNC) and other stakeholders (e.g., government ministries, institutes, and the Non-Governmental Organization Affairs Bureau) concerned with nutrition were visited and observed with the use of the checklist technique.

In-depth interviews

The qualitative approach was used to obtain information from the key informants who were able to describe, on the basis of in-depth personal knowledge, what actually occurred [14]. These informants were selected mainly from high-ranking government authorities as well as from members of autonomous, nongovernmental, and private organizations. They included the policy makers, members of the BNNC, donors and development partners, policy implementers, academics, and interested beneficiaries of the policy, such as executive committee members from food industry groups, crop and vegetable producers, and consumer advocates. The informants were classified into four broad groups: policy makers, policy implementers, academics, and beneficiaries of the policy.

A total of 40 key informants agreed to participate, 10 from each category. Appointments were made with each informant. Among the 40 informants interviewed, 14 were from different sectors of the government (including a cabinet minister); 7 were from autonomous organizations, including universities; 8 were from nongovernmental organizations; 6 were from the private sector; and 5 were from donors or development partners. Each respondent was interviewed for a period of one and one-half to three hours, for a total of more than 90 hours for all interviews.

An interview guide was used that covered general information about the importance of the policy; its strengths, weaknesses, opportunities, and threats; the suitability of its implementation; its success factors; and suggestions to fill the gaps. We then compared the information obtained from the interviews with the information and data available from focus group discussions.

All interviews were conducted by the author, who has had practical experience in qualitative research at the University of Queensland, Australia, and Khon Kein University, Thailand.

Focus group discussions

Focus group discussions are extremely useful for collecting certain types of information. In some cultures, it is safer for individuals to speak truthfully as members of a group than on their own [15].

Six focus group discussions (four discussion sessions with 7 people in each group and two discussion

* Rubbi SF, Faruque AJMO, Mannan MA. National food and nutrition policy (draft). Presented in the workshop for finalization of the national food and nutrition policy, organized by Bangladesh National Nutrition Council, Dhaka, June 21, 1989.

sessions with 8 people in each group) were conducted separately with a total of 44 participants.

Each session contained participants from each of the four categories: policy makers, policy implementers, academics, and interested beneficiaries of the policy. We also included in each session at least one participant who was known to be contentious and not sympathetic to the process. The inclusion of this type of participant was intended to stimulate additional comments and insights. We did not include any authority figures in the groups, since their presence could prevent some from speaking freely.

Among the focus group participants, 17 were from different sectors of the government, 8 were from autonomous organizations, 9 were from nongovernmental organizations, 7 were from the private sector, and 3 were from donors. A total of more than 100 person-hours (each discussion lasted from two to three hours) was required to obtain information from focus group discussions.

The researcher, along with an experienced social anthropologist, collected the information and data using a semistructured interview guide and a micro-cassette tape recorder. However, there was flexibility in data collection, since such flexibility in qualitative research provides the best opportunity to obtain in-depth explanations and clarifications of the opinions of the respondents. The tape recordings of the interviews of the key informants and focus group discussions were transcribed and analyzed.

Analysis of the information

The information gathered from the interviews and focus group discussions was examined by the SWOT analysis [16]. Strengths and weaknesses are related to factors of the internal environment [17], such as policy process, leadership, authority, complementarity, and goals and objectives, that influence the effectiveness of the policy. Opportunities and threats are related to the external environment [17] and constitute prevailing conditions that influence the development and implementation of the policy, including awareness of the stakeholders, the policy environment, resources, trained personnel, tension between implementing factions, and, importantly, the level of political commitment.

Results and discussion

Regarding the importance of the policy, the key informants and focus group discussants stated that "The policy is a guideline to improve the nutritional status of the whole population," "It is instrumental to guide the nation and to give future direction," and "It is essential to mitigate the nutritional problems."

Strengths in the implementation of the policy

The strengths of the national food and nutrition policy were important indicators of its successful implementation. The following five major strengths in the implementation of the policy were identified.

A consensus document

The greatest strength of the food and nutrition policy was that the government recognized nutrition as a human right and that the Government approved the policy. The policy formulators and academics as key informants claimed that "Both public and private sectors provided support during the policy formulation process, which might be the strength of the policy." This was also stated by participants in the focus group discussions, who said that "The policy strengths depended on integration of all efforts, particularly public and private sectors' efforts." Some of the government-sector respondents emphasized that "The government considered nutritional improvement not only as a developmental issue but also as a human right." They also said that "Nutrition is the constitutional right of the people and the Cabinet members are mentioning it in different forums." One of the focus group participants raised a doubt about consensus, since the Ministry of Labour and Manpower was not invited to participate in drafting the policy. However, overall the policy was considered a consensus document that was prepared with the collaboration of different sectors, public and private, and that considered nutrition as a human right.

Formulated by multisectoral approach

The majority of the policy makers and academicians and some of the implementers (during in-depth and focus group discussions) said that "The policy is a comprehensive and well-thought-out document, formulated by a good process, involving the experts of the country." They also stated that "All concerned sectors (agriculture, fisheries and livestock, food, health and family welfare, women and children's affairs, rural development and cooperatives, social welfare, education, and information) cooperated in its formulation and their concurrence was obtained through confidence and sharing of commitments." A few donor respondents said that "The policy document has good strength as all the concerned nutrition sector's guidelines are brought under four major sectors: food, agriculture, fisheries, livestock, and forestry; health, family welfare, and environment; nutrition education and communication; and community development and social welfare. The academics noted that the guidelines of these four major sectors have been elaborated into the 10 themes of the National Plan of Action for Nutrition (NPAN). If these themes are implemented successfully, the objectives of the policy will be achieved.

They added that the strengths of the policy lie in the thorough preparation and its approval in the multisectoral NPAN, and its incorporation in the National Nutrition Project. A few policy makers observed that the technical controversies were compromised through discussions and negotiations. Others suggested that the approval of food and nutrition policy by the cabinet with multisectoral support was the strength of the policy.

Complements other government policies

Most of the key informants stated that "These policy guidelines are complementary to other policies of the Government." Two agricultural-sector respondents said that they "envisaged the need to intensify the process of crop diversification, an important component of the agricultural policy." Similarly, the health-sector participants in the focus group discussions and in-depth interviews stated that "The policy guideline considered the prevention and treatment of nutrition-related noncommunicable diseases an important component of health policy." The key informants and focus group discussion participants stated that "This policy has the advantage that the individual sectoral policy makers were involved in its formulation and thus have ownership and responsibility to implement it through their sectoral policies, plans, and programs." The focus group discussants stated that "It is a unique policy document and is complementary to the existing government policies in food, agriculture, fisheries, livestock, forestry, primary health care, environment, education, information, industries, commerce, and other development areas." They added that "It will not conflict with other existing policies and will in fact assist them." Many of the guidelines have already been implemented in the agriculture sector; for example, in food production, where vegetable and fruit production, and rice production in particular, have increased. National nutrition weeks have also been established to create awareness about nutrition.

Broad goals and objectives with wider coverage

The respondents stated that the goals and objectives of the policy were stated broadly, as were its four major strategies. One participant from the donor category said that "This policy is not limiting the formulation of any specific plans and programs for nutritional development. Food security, health, and caring practices have been well taken care of in the policy." Education is also considered as a behavioral issue, and family members may be educated through the mass media. Home gardening is a social movement, and the Ministry of Agriculture is promoting home gardening seriously. Income generation and community participation are now incorporated in government policies and in the food and nutrition policy. The respondent from the planning sector said that "For the rural poor, home gardening would be excellent for income generation and the availability of micronutrients at the household level." One academic raised the question of the bioavailability of micronutrients, stating that "The per capita oil consumption is so low (8 g per day) that one cannot obtain enough vitamin A absorption from garden products." He pointed out that because iron is so poorly absorbed, anemia is highly prevalent, even among people who consume more than the requirement of iron.

The strengths of the policy are the consideration of the elderly as nutritionally vulnerable, development of food-preservation and food-distribution technologies as a policy objective, giving importance to the family unit, advocating intercropping, and public education through the mass media. Many respondents said that "The policy document should provide a broad guiding framework, with the details of specific activities to be developed by each sector within the broad framework; the policy is excellent in this regard." They stated that this policy was not creating any obstacles to the preparation of specific nutrition plans and programs for national development.

An enabling document

Few informants recognized the national food and nutrition policy as an enabling document. One respondent from the donor category said, "It will help us to guide and will give us the future direction rather than give us future solutions, which will come from specific sectors and specific programs…. This is a live document—each sector will use it and modify it according to necessity. There is enough flexibility, and the document itself includes options for its modification, which is also a strength." Many points identified as strengths for implementing the policy by the participants of the focus group discussions agreed with those emerging from the individual interviews. Both groups believed that the policy guidelines had strengths for implementation.

Weaknesses in the implementation of the policy

The key informants and the focus group participants said that there were no major weaknesses in the policy. However, both the in-depth interviews and the focus group discussions identified five weaknesses that need to be minimized for effective implementation of the policy.

Lack of guidelines for implementation, monitoring, and evaluation

A few key informants from the implementers group stated that "There is no mention of effective and specific policy implementation, monitoring, and evaluation strategy in the document, which might be a weakness." The focus group discussion respondents stated that "The implementation strategies or follow-up provisions of the policy by different sectors, agencies, and organizations are not discussed, except as they relate to the Ministry of Health and Family Welfare and the Ministry of Agriculture." The Ministry of Health has developed a long-term vision for the next 20 years, but although the Ministry of Agriculture has production as their major target, they have no vision for consumption. The Ministry of Fisheries and Livestock is not included.

Some of the respondents suggested that a more comprehensive dialogue was needed to craft a comprehensive nutrition program. One focus group discussion participant from the food sector said that "The food production, distribution, and marketing systems have not been elaborated in the policy." However, participants from the BNNC stated that "Every sector should prepare their own implementing strategies according to the policy guidelines, ensuring coordination of the implementing guidelines or strategies at some level, maybe at BNNC, as it is the apex body headed by the Prime Minister." The informants and focus group discussion respondents all emphasized the necessity of guidelines for implementation, monitoring, and evaluation at different levels.

Lack of strong commitment and earmarking of funds

Strong commitment of the government and political leaders, as well as donors, professionals, and even beneficiaries, is essential for implementation of any policy. Food and nutrition policy is not obligatory for the government, as demonstrated by the lack of commitment during policy formulation. Allocation of funds for implementation, coordination, and monitoring of the policy is still lacking. The informants from the implementers' group said that "Allocation of funds from different sources (government and donors; central and local) should have been more specifically mentioned in the policy; it is now written in the policy only that different concerned sectors will allocate funds." A few key informants said that the policy did not earmark allocation of funds even for central activities. One informant from the donor community asked, "We are saying that we are all committed, but is it true?" In Bangladesh only 0.03% of the gross national product (GNP) is used for nutrition, far below the global target of at least 0.5% for developing countries. India spends 0.3% of its GNP for nutrition, and even Sri Lanka spends 1.0 % of its GNP for nutrition. The commitment of the government should be reflected by allocating a budget for nutrition and giving the policy coordinator (BNNC) full authority to implement, monitor, and evaluate the policy. Lack of strong commitment and allocation of resources (financial and human) for implementing the policy was identified as a weakness of the document by the majority of the informants and focus group participants.

Policy keepers' inadequate leadership, authority, and support

The key informants stated that "The role of BNNC is not appropriately mentioned in the policy. The Council's role should be more specific; it should have adequate leadership with more authority to exert power to implement the policy through NPAN and nutrition programs.... The implementation of the policy depends on the strong performance of the policy implementing body." The focus group discussion participants added that social mobilization of the policy to create awareness among the population is lacking. It is necessary to establish a nutrition information and documentation center at BNNC.

One academic stated that "The BNNC should have appropriate status, enough authority and resources to implement the activities called for by the nutrition policy and plan." One of the focus group discussion participants said that "Multisectoral policy is being formulated well as a document by some enthusiastic or interested groups, but its implementation faces a lot of problems. There is no group to take responsibility to resolve these problems." Many of them said that a policy that exists only as a paper document remains useless if it is not implemented or monitored. The policy maker's leadership and authority are essential for the successful implementation of the policy.

Too ambitious a target

The focus group discussion participants from the implementer category stated that the document was really a very comprehensive one, but that there was no direction on how to transform it into programs and activities. "The vision is very high, broad, and long, with an ambitious target that cannot be achieved," they said. But the representative from the Consumers Association disagreed and said, "An ambitious target is necessary for actions to be taken to reach the targets." A few key informants stated that everything could not be specified in such a small document. The policy maker group said that "The national nutrition goals should not be time-bound, but should have a longer vision. The targets and achievements should be reviewed periodically and the targets recast." Some of the key informants stated that targets should be fixed in such a way that they are achievable.

The lessons learned were ignored

Some key informants stated that "The policy should be considered as a document in development, because promotion of breastfeeding, elimination of micronutrient malnutrition, monitoring and evaluation strategy, and lifestyle and food-safety issues are only weakly elaborated." An agricultural scientist as key informant said, "The policy does not mention the relationship between the ecological zones and food availability, and the need for nutritional mapping and specific guidelines in it, which are weaknesses." The academics said that “Research on nutrition, particularly on the biological availability of nutrients in local diets, could improve the policy.”

One respondent from the university proposed that surveys on nutrition be done at regular intervals and the findings disseminated to different sectors to help them address the problems. Another respondent from the implementation group said, “Successes and failures of nutrition actions should be disseminated to influence future actions.” A few key informants suggested that the excessive use of fertilizers, insecticides, and pesticides for growing food crops, especially rice, had diminished the production of fish in the country. One development partner stated that a lot of activities on nutrition were going on in the country and in the region, and that the lessons learned should be included in the policy. The 1985 nutrition sector review by the World Bank could be mentioned in the policy.

Much of the information collected from the focus group discussions on the weaknesses of policy implementation was similar to that obtained from the interviews of key informants. Both agreed that there were more strengths than weaknesses in the policy and that the identified weaknesses of the policy could be overcome by taking appropriate measures. The academics could play an important role in moving the policy in the right direction by suggesting appropriate measures to overcome the weaknesses.

Opportunities to implement the policy

Opportunities to implement the policy refer to the external environment of the policy. The key informants and the focus group discussion participants stated confidently that the policy had a wide scope and opportunity. They identified the following five opportunities that needed to be addressed for effective implementation of the policy.

Social mobilization of the policy

Most of the key informants in the implementer and academic categories emphasized that “An effort should be made to publicize the policy, targeting all groups of people, starting with parliamentarians, political leaders, bureaucrats, and professionals and extending to all beneficiaries. Popularization of the policy is the first step. Anything wrong and unnecessary found in the policy may then be discarded.” Some of the respondents said that “Nothing will happen in the field of nutrition if community participation is ignored—social mobilization is necessary.” Creation of awareness of the components of the policy among policy makers, community leaders, officials of governmental and nongovernmental organizations, and professionals will create more opportunity. One respondent from the private sector said, “We have gone a long way but much more needs to be done.” Many of the focus group discussion participants also stressed the importance of the involvement of every sector in regular dialogue and decision-making on nutrition issues at various levels.

Wide scope of the policy

The majority of the key informants stated that the policy had a wide scope and should be implemented. They saw no reason for failing to implement any of the sectoral nutrition activities. It was felt that the Ministry of Health and Family Welfare should be the lead ministry to coordinate nutrition activities through the BNNC. One cabinet minister stated with confidence, “If we can implement the nutrition policy of the government through NPAN and subsequent nutrition programs, then malnutrition will no longer be a public health problem in the country.” The sectoral leaders also stated that “The policy presents the opportunity of formulating NPAN and sectoral programs and projects on nutrition. The NPAN has also mentioned the sectoral projects that need to be implemented, with strategies of implementation.” Some of the focus group discussion participants who were involved in the policy-formulation process stated that only the implementable guidelines were considered and that nonimplementable guidelines were discarded in the policy creation. They felt that the practicality of the proposed policies was considered initially and that this increased the opportunities for their implementation.

Problems and measures suggested

The key informants stated that the policy identified the problems of malnutrition in each sector and suggested remedial measures. Many of the informants described the policy document as providing broad guidelines for nutritional improvements that give any nutrition sector flexibility to take the lead in addressing nutrition problems in its sector. One of the key informants from the research sector stated that special attention should be given to nutritional improvements for targeted beneficiaries, such as older people and other vulnerable groups, and also to the control of infectious diseases. A few focus group discussion participants urged translation of the policy into Bengali for wide dissemination.

Congenial policy environment

The majority of key informants said that there was a high level of opportunity for the policy if steps were taken to motivate the donors, government officials, political leaders, and nongovernmental organizations to provide the necessary resources. It would also be important to strengthen the BNNC. Some informants stated that there were many opportunities to make the implementation of the policy more feasible. The focus group discussion participants from the academic and implementer groups said that “It requires the integration of government and nutrition professionals' commitment and the recognition of successful implementers." It was also stated in the focus group discussions that "The national food and nutrition policy could be implemented successfully if the political commitment continues. However, this must result in the increased allocation of funds for nutrition and improvement of the environment among the government, development partners, and nongovernmental organizations for nutritional improvement to be sustained." Two-thirds of the key informants stated that "BNNC should have enough authority and additional funds to take the policy keeping and supervisory role in the country."

Modification of the scope of the policy

The policy should be updated, incorporating the government's commitment, including financial allocations, and considering the existing situation, including changes in the field of nutrition. The respondents, especially critics of the policy, suggested that the identified gaps in the policy should be minimized. Some of the focus group discussion participants from the research community stated that "The policy guidelines should be viewed as a living document and should not be specific or fixed, but modified according to need." Informants from the Planning Commission and policy makers sector said that "The policy can be updated, synchronizing the plan timetable and considering the progress and achievements at macro and micro levels." Details on how the community will be involved in the process of implementing the policy are missing.

The implementers suggested that for successful implementation the food and nutrition policy needs to be modified by incorporating strategies for implementation, financial commitment, and wider participation in crafting the policy. One of the policy makers warned that "Policy modification is not easy, since it requires approval of the Cabinet." The participants also mentioned that monitoring the policy from the grassroots level and regular dissemination of reports to the public are necessary. They believed that experiences from the Bangladesh Integrated Nutrition Project (BINP) and the National Nutrition Program (NNP) should be used to help identify the opportunities in policy implementation, but that this will take time.

Threats to implementation of the policy

Threats refer to the external environment of the policy. During in-depth interviews and focus group discussions, the following six possible threats to successful implementation of the policy were identified.

Lack of knowledge

Most of the key informants identified the number one threat as ignorance of the contents of the policy among, for example, physicians and other people in the community. Lack of knowledge of the policy guidelines on the part of the development partners, policy makers, bureaucrats, governmental and nongovernmental organization officials, program managers, community leaders, and even farmers will hinder its implementation. One of the participants said, "Understanding the contents of the policy and taking actions accordingly is the right of the people." They also felt that ignorance of the policy among many nutritionists, the donor community, managers of nutrition projects, decision makers, and policy makers was an important barrier to implementation. One focus group discussion respondent stated that "The ignorance of the stakeholders about the contents of the policy can be a threat during implementation, as their concepts may not be in line with the policy." One of the respondents recalled that even though the existing law did not permit the importation of noniodized salt, the Ministry of Commerce once imported noniodized salt to the country because of ignorance of the law and of the importance of iodine. For successful implementation of the nutrition policy document, it needs to be widely publicized.

Lack of resources for BNNC

Lack of sufficient funds for implementation of the policy has created serious problems. One key informant from the health sector said, "Many plans have been suggested in the NPAN, but because of the lack of resources (both financial and technical), projects cannot be implemented." One member of BNNC said, "Different sectors are proposing the BNNC for technical and financial support of their sectoral nutrition projects, but the BNNC does not have the resources to support their proposals. Lack of timely fund flow from the government and donors is a limitation." Some of the focus group discussion participants said that the present lack of status and authority of the BNNC may the reason for the failure to get sufficient funds from donors. The focus group discussion participants added that lack of a nutrition information and documentation center within the BNNC is a barrier to proper monitoring and implementation of the policy. Participants from the donor community identified weak and poor support from government officials and lack of strong coordination as other threats to policy implementation.

Lack of trained personnel and management capacity

Several informants from program management said that "The country has very few trained personnel and limited expertise in nutrition, and this is a threat to policy implementation." In the focus group discussions, one respondent said, "Excessive diversity of donors' support is also a barrier, particularly for multisectoral nutrition policies; it would be best for aid to be channeled through a single agency." Compounding the lack of trained nutritionists is the poor coordination and supervision of other necessary fieldworkers (health assistants, family welfare visitors, family welfare assistants, and block supervisors). One senior administrator said, “The scarcity of suitable and efficient managers and frequent transfer of good managers from one sector to another is a threat to policy implementation.”

These statements were confirmed during focus group discussion meetings. It was emphasized that all these barriers could be removed easily if we really mean business and take responsibility.

Tension among technical people and bureaucrats

Many key informants from different sectors of the government and from nongovernmental organizations stated that a threat exists in the conflicts and competition among health professionals, agriculturists, and even laboratory scientists. They emphasized the need for the participation of all professionals whose work relates in some way to nutrition. One nutrition specialist said, “The funding agencies and donor communities often have their own preconceived ideas about how to reach their nutrition targets that they discuss with the policy makers but that ignore the local nutrition.” The result is often conflict between the professionals and the policy makers in the bureaucracy. These conflicts can be reduced by frequent discussions among these groups.

Vested interests

No policy can satisfy all constituents. Many of the respondents said that “We have to see whether it is beneficial to the majority of the population or target group.” The academics said that “Enforcement of laws for breastmilk substitutes and edible salt iodization will go against the interests of some business groups, who oppose them. However, this is a global problem and not unique to Bangladesh.” Two key informants added another example: “Tobacco is a cash crop and public health policy discourages its production, but the tobacco companies are so powerful globally that they can block policies that go against them.” Focus group discussion participants questioned the impact of tobacco on foreign income and employment. The technical experts replied that “The land used for tobacco cultivation could be better used for the production of pulses and oilseed, to counter their decreasing production and consumption in the country.”

The nutritionists and implementers in focus group discussions said that “Introduction of every new policy faces challenges and has proponents and opponents, beneficiaries and victims, and also vested interest groups for and against. Whenever an act, ordinance, or regulation is formulated for the benefit of the majority of the people and the country, some industries, companies, or farms try to actively promote their vested interest and became a threat to its implementation.” Two discussants stated that laws may not be sufficiently effective for implementation of policy decisions. One informant suggested that “Some practitioners biased toward curative medicine may believe that preventive measures take resources better used for medical treatment.” However, the focus group discussion participants agreed that threats to policy implementation should be removed by appropriate motivation, advocacy, dialogue, and public education.

Discontinuity of political commitment

Most of the key informants and focus group discussion participants said that “Continuity of political will and commitment to policy formulation, implementation, and improvement is essential. If it is lacking at any stage, this is a major threat.” One respondent from a nongovernmental organization said, “If political commitments are available and the policy is part of a political agenda, implementation becomes feasible.” One focus group discussion respondent, an implementer in the government sector, said, “Lack of firm and continued commitment of policy makers and different sectors is the major barrier to implementation of the nutrition policy.” Some respondents stated that changes in the government and movement of influential and motivated officials in nutrition often caused discontinuity of political commitment and posed a threat to policy implementation.

Analysis of the policy development and implementation

Based on the foregoing, a SWOT (strengths, weaknesses, opportunities, and threats) analysis on the effectiveness and suitability of implementation of the policy was performed. In the SWOT model, the strengths and weakness refer to factors of the internal environment, and opportunities and threats refer to factors external to the implementation of the policy.

The most transparent strengths of the policy implementation lie in the facts that it is a consensus document emphasizing human rights; it was formulated by a multisectoral approach involving all concerned sectoral leaders and stakeholders in nutrition; it will complement other policies of the government with ownership of a broad spectrum of constituents; it has achievable broad goals and objectives with wide coverage; and it is also an enabling document. The major weaknesses include lack of guidelines for implementation, monitoring, and evaluation; lack of strong commitment and earmarking of funds; inadequate leadership of the policy coordinator’s authority and support; an overly ambitious target; and lack of attention to the lessons learned.

The major opportunities for policy implementation include social mobilization to make the public aware of its contents; the wide scope of the policy; the congenial policy environment; and modification of the scope. The threats to policy implementation include lack of knowledge about it; lack of resources for the BNNC; lack of trained personnel and management capacity to implement the plans and programs; tensions among technical people and bureaucrats; vested interests of business; and discontinuity of political will and commitment due to changes of political parties in the government.

It was concluded that there are more strengths than weaknesses and more opportunities than threats. Moreover, the policy has had its successes. Examples include the preparation and approval of a multisectoral national plan of action for nutrition, the formulation and implementation of the BINP in 60 upazillas (subdistricts), and the subsequent preparation of the NNP with multisectoral participation in the country. The president of the World Bank visited the BINP project and was impressed by the community participation in the efforts to improve nutrition, and confirmed the Bank's interest in financing such a nutrition project covering the whole country. The government's commitment to the implementation of the food and nutrition policy was instrumental in obtaining World Bank support. The plan calls for the NNP to be implemented initially in 139 upazillas of the country and gradually expanded. The nutrition sector review of the World Bank in December 1999 stated that a first draft of strategic goals has been achieved in Bangladesh, mainly since the last sector review in 1985–86. These include the generation of high-level support, the development of an effective programmatic approach (BINP), the evolution of nutrition-promoting structures in the health and food policy arenas, and the development of policies that have generated some improvement in nutritional status among young children (by roughly 0.5 percentage points a year).

Food production has significantly increased to meet the requirement of the growing population. The agricultural policy for crop diversification, as well as increased production of nutritionally rich foods, vegetables, and fruits, has substantially met the requirements of the people. Government food policy has been turned into food-security policy. Dietary guidelines have been approved nationally for implementation by the BNNC. The budgetary allocation for nutrition has been significantly increased for the health, nutrition, and population sectors to nearly 7% of the total annual budget, a 67% increase in the government contribution.

There has been a 20% reduction in the proportion of underweight children and a 25% reduction in stunting among 0- to 5-year-old children since 1985–86, as well as a relatively dramatic decrease in infant mortality from 94 to 66 deaths per 1,000 live births (the rate in 1974 was 140 per 1,000). Child immunization coverage has increased from 10% to more than 70% over the last two decades. Distribution of vitamin A capsules to children along with homestead garden expansion has reduced vitamin A deficiency among preschool children to one-sixth of the levels of 1985–86, and salt iodization is now universal in the country. With a prevalence of approximately 0.6%, vitamin A deficiency among children is not a public health problem at present.

In spite of these impressive achievements, the translation of policy into social reality through planned actions in different sectors is inadequate. The policy should be shared with the implementers and the beneficiaries at all levels for better implementation. All sectoral programs should be developed and implemented through allocation of sectoral funds. Local resources should be accumulated and used for the improvement of nutritional status of the local people with plans and programs developed by the local people according to their local needs. The policy keepers' authority, financial support, and leadership should be strengthened, providing government and stakeholder support. As in the case of the success of immunization coverage in the country, involvement of the stakeholders, professionals, development partners, and community in regular dialogue and dissemination of policy activities is necessary. Regular monitoring of the policy activities of the stakeholders should also be carried out. The ongoing sectoral nutrition plans and programs that are being implemented by the stakeholders still require adequate financial and technical resources, management experts, and nutritionists. Another important issue is continuous dialogue or at least regular communication of nutrition information at all government levels in order to have continuity of political support. With positive and appropriate utilization of opportunities for the implementation of the national food and nutrition policy, the weaknesses in its implementation can be eliminated or converted into strengths, and as a consequence, the influence of threats can be minimized.

Conclusions

The opportunity exists for the efficient and appropriate implementation of the national food and nutrition policy. The weaknesses in the implementation of this policy should be corrected by taking the steps identified above. It will require strong efforts among the stakeholders, professionals, development partners, and community to promote the strengths and opportunities of the policy and reduce the threats to it. Although the threats are not as strong as the opportunities, they cannot be ignored. The internal and external environments for policy implementation are dynamic. The environment for each of the components (strengths, weaknesses, opportunities, and threats) may be changed by strong advocacy. Policy makers and strategists need to prepare SWOT matrices for different points in time to assess the continued effectiveness of implementation. There can be no complaisance until malnutrition is drastically reduced by the effective implementation of the policy guidelines.

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Timed activity studies for assessing the energy expenditure of women from an urban slum in South India

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Abstract

*Time-disposition studies are necessary for computing energy requirements of populations. This study captures the rich information on the timed activity pattern of adult women from poor households engaged in home-based work. We studied 34 women beedimakers (cigarette makers), 21 tailors, and 34 homemakers. Data were collected by direct observation of the women's activities on a typical day. Time spent on related activities was pooled and classified as sleep, household work, child care, occupational work, and residual work. These were further categorized on the basis of our published work on the energy cost of women's activities and the World Health Organization (WHO) classification of occupational activities as sedentary, moderate, and heavy. Most of the household activities could be classified as moderate to heavy (> 2.2 times basal metabolic rate [BMR]). Child-care activities were distributed on a scale from sedentary to heavy, whereas occupational activities, such as beedimaking and tailoring, were sedentary (< 2.2 BMR). Homemakers spent significantly more time on moderate to heavy work (*p < .05 *) than beedimakers and tailors. Women working for income spent only four to six hours on occupational work, which was possible because they reduced the time spent on heavy work (i.e., housework), and reduced the time on personal care. Still, more than 80% of women could not put in eight hours of paid work. Thus, women in the home-based sector constantly negotiate among time spent on heavy household work, child care, and occupational work in order to continue in the labor market.*

Key words: Time-disposition studies, women's work, energy requirement, time spent on housework, time spent on occupational work, time spent on child care, India

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Introduction

Time-disposition studies are useful for mapping the physical activity patterns of populations. Information thus generated may also be used for computing energy expenditures of women and their energy requirements, planning public services, such as crèches and child-care centers, and even health care in the rural areas. Social scientists, policy makers, and economists utilize this information for understanding the labor markets, planning developmental programs in rural areas, and designing relevant policies [1].

International Labor Organization teams from Asian, African, and Latin American countries have highlighted the effect of deforestation on the work patterns of women [1]. Using time-disposition studies, Berio [2] was able to demonstrate the triple burden of rural women involving household maintenance, family agricultural tasks for income generation, and child care. There are some previous studies on the patterns of use of time by women from India. Information generated thus far highlights the double work burden of women [3–8], quantifying the time spent on food production and household work. These studies do not extrapolate this information to energy requirements of poor women, although Durnin et al. [9] have documented the seasonal influence on physical activity patterns of rural agricultural women for purposes of energy expenditure.

Studies from the National Institute of Nutrition (NIN) [10] on women from the low socioeconomic group based on 24-hour recall of women's activities showed that time spent on housework accounted for most of their waking hours. Poor women were able to work for income only when they were free from stresses such as ill health, pregnancy, or other crises that placed demands on their time. It was obvious that women constantly negotiated their time and energy expenditure among tasks. However, there have been no systematic studies on the pattern of use of time by women of the low socioeconomic group working in different occupations in relation to energy expenditure and requirements.

Therefore, this study was designed to collect the activity profiles of women from the low socioeconomic group working in different occupations by actual observations of a typical day. The investigators also assessed the time spent on each task in relation to the total time in a day. Attempts were made to quantify women's participation in activities of different intensities for the purpose of assessing energy requirements.

Materials and methods

The study was carried out in a large urban slum with a population of more than 25,000, located in the heart of Secunderabad, a city in south India. The slum is located on a sprawling hilly area with huts perched precariously on the slopes. The houses have mud walls and asbestos roofs, and most families live in one-room tenements. The women had a bare minimum of water supply, drainage, roads, and sanitation. People living on the hilltops depend on water tankers from the Municipal Corporation of Hyderabad for their daily water supply. Because there is no underground drainage system, the waste water from the houses is released into the open, so that women must spend a considerable amount of time clearing it.

Women living in this area work throughout the day as homemakers, beedimakers, tailors, small-shop vendors, and wage workers, such as maids or sweepers in hospitals or in the Municipal Corporation of Hyderabad. Men are employed generally as rickshaw pullers, electricians, construction workers, carpenters, or auto drivers.

Eighty-nine apparently healthy women aged between 18 and 40 years were selected by a stratified random process in a census of all households according to the occupational groups of women in this age group. This was followed by an enumeration of all the women in the three occupational groups, with 34 being selected randomly from each occupational group. (Because there were only 21 tailors, all were included in the sample.) Informed consent was obtained from the women before the initiation of the study.

The activity profiles of the selected women were collected by the activity diary method. This involved the recording of duration and postures of the activities on a typical day by direct observation by a team of trained investigators. On the basis of the information generated from an earlier study [11], a typical day was defined as one on which there were no visitors, festivals, weddings, or other celebrations in the family. Days when a child, another family member, or the woman herself was ill were also avoided.

The investigators informed each subject the day before she was to be observed. On the day of observation, the investigator had to reach the subject's home early in the morning to record the activities without interfering with her usual daily chores. The time spent on each of the activities was carefully noted with a digital watch, with three investigators dividing the observation time of each subject. The period of observation lasted from the time of awakening to the time the subject retired for the night. The investigators accompanied the women during all her chores, such as fetching water or marketing, and the distance traveled and the duration of the time spent on each were noted.

After completion of the day's activity dairy, the durations of various activities were pooled. For example, all the time spent walking during the day was consolidated and classified under walking time. The time spent on cooking at various times during the day was likewise consolidated to give the total time spent cooking in a day. The durations of each activity were grouped into sleep, household work, child care, occupational needs, personal needs, and residual activities. Household activities included cooking, serving, sweeping, swabbing, cleaning vessels, washing clothes, fetching water, arranging things, folding beds, and cutting vegetables while sitting. Child-care activities included bathing and dressing the child, standing or walking while holding the child, breastfeeding, and the like.

Occupational activities, such as making beedis (a type of Indian cigarette), involve a set of complex tasks. The beedimaker sits on the floor with the powdered tobacco, leaves, and thread arranged on a tray. To make a beedi, a woman picks up a pinch of tobacco, places it on the leaf, and then rolls the leaf into a 30- to 40-mm-long conical-shaped beedi. The narrow end is tied with a piece of thread to prevent the tobacco from slipping out, and the other end is tucked in with the tip of the finger. Normally a woman can make four or five beedis per minute. A woman sews while sitting on a small stool (about 1 meter in height) in front of her sewing machine. She works with her feet on a pedal, controlling the speed of the machine with physical force applied to the pedal. The tasks included in personal needs are brushing the teeth, bathing, going out for defecation, dressing, drinking tea, and eating. Residual activities include sitting (watching television or chatting) and standing without any substantial activity. Personal needs and residual activity also include social and recreational activities, such as attending meetings, watching television, and so forth. Anthropometric measurements, including height and weight, were carried out by standard methods [12] on the day following the observations. Hemoglobin was estimated from a fingerprick blood sample by the cyanmethemoglobin method.

The predominant activities were identified from the activity diaries of the women. These diaries were detailed records of daily activities based on actual observation of a typical day and simultaneous recording by the observers. This method is commonly used to compute the energy requirements of populations. Two teams of trained investigators recorded the various activities of the selected women by observing them during waking hours on a typical day. Table 2 shows the predominant activities identified from the pooled records of the day. The energy cost of the identified activities was measured by standard procedures [13].

With the use of the WHO/FAO/UNU classification of occupational activities [14] and the results of the actual energy cost, each of the activities were classified into sedentary (< 2.2 times the basal metabolic rate [BMR]), moderate (2.2 to 2.8 BMR), and heavy (> 2.8 BMR).

The data were analyzed with the SPSS package, with mean, SD, and SE calculated for each variable. Analysis of variance (ANOVA) was used to test the significance of the differences between the values for women of different occupations. The data are represented as means ± SE. Duncan's multiple range test was used to examine pairwise differences.

Results

The mean age of the subjects was 29.0 ± 0.59 years and their mean family size was 5.1 ± 0.11. These values were comparable in the three occupational groups. Table 1 presents anthropometric measurements of the study group. Their mean height was 150.4 ± 0.62 cm, and their mean weight was 43.6 ± 0.83 kg. There were no differences in height among the three occupational groups. However, the tailors had a greater body weight (47.0 ± 1.62 kg) than the beedimakers and homemakers (42.7 ± 1.33 kg and 42.0 ± 1.28 kg, respectively) ($p < .05$). The mean hemoglobin value of the women was normal (12.4 g/dl), and the values did not differ among the three groups.

Table 2 lists the activities performed on a typical day and their durations for each of the occupational groups. Although a total of 21 activities were recorded, all the women did not participate in all the activities; for example, out of 89 women, only 69 fetched water and only 19 swabbed their huts. Among the household activities, homemakers spent significantly ($p < .05$) more time than beedimakers and tailors on cooking (124 vs. 84 and 96 minutes, respectively), scouring vessels (41 vs. 35 and 30 minutes, respectively), and arranging household things and folding beds (44 vs. 29 and 38 minutes, respectively. Homemakers also spent significantly more time on child-care activities than members of the other two groups. The tailors spent more time breastfeeding than the other groups, but the number of women in the study who breastfed was too small to show a statistically significant difference.

Beedimakers and tailors spent 372 and 277 minutes, respectively, on their occupational work. Homemakers spent significantly more time sitting without activity than beedimakers and tailors (159 vs. 59 and 95 minutes, respectively; $p < .05$), but the times spent on standing without activity were not different among the three groups. There were no differences among the three groups in the time spent on sleep (522 minutes) and personal care (85 minutes).

Table 3 shows the mean time spent on different categories of activities according to occupation. Homemakers spent more than eight hours (491 minutes) on household work, as compared with 367 minutes for beedimakers and 398 minutes for tailors ($p < .05$). An overall average of 79 minutes was spent on child care. Homemakers spent 131 minutes on child care, which was significantly greater than the amount of time spent on child care by beedimakers (38 minutes) and tailors (51 minutes)($p < .05$).

Women who worked for pay spent a mean of 335 minutes on their occupation, but beedimakers were able to work for 372 minutes and tailors for only 277 minutes. The time spent on personal needs and residual activities was 156 minutes and 206 minutes for beedimakers and tailors, respectively, which was significantly lower than the time spent by homemakers (285 minutes; $p < .05$).

Based on the WHO classification of occupational activities [14] and the results of actual measurements of energy costs of 17 activities from this laboratory [13], women's activities were classified as very light, light, moderate, or heavy (table 4). Sitting and standing (standard activities) were classified as sedentary, since they required less than 2.2 times the BMR, but walking was classified as moderate. It was significant

TABLE 1. Anthropometric measurements of women according to occupation (means ± SE)

Measurement	Homemakers ($n = 34$)	Beedimakers ($n = 34$)	Tailors ($n = 21$)	Total ($n = 89$)
Height (cm)	149.0 ± 0.90	150.0 ± 1.11	152.0 ± 1.19	150.4 ± 0.62
Weight (kg)	42.0 ± 1.28^{a}	42.7 ± 1.33^{a}	47.0 ± 1.62^{b}	43.6 ± 0.83
Hemoglobin (g/dl)	11.9 ± 0.33	12.7 ± 0.29	12.4 ± 0.43	12.4 ± 0.20
BMI^{c}	18.9	18.9	20.3	19.2

a,b. Values in the same row with different superscripts are significantly different from each other (p<.05).
c. The body mass index (BMI) is the weight in kilograms divided by the square of the height in meters.

TABLE 2. Mean ± SE number of minutes spent on activities according to occupation (number of women in parentheses)

Activity	Homemakers	Beedimakers	Tailors	Total
Sleep	538 ± 11.58 (34)	513 ± 8.89 (34)	510 ± 13.13 (21)	522 ± 6.45 (89)
Household activities				
Cooking	124.3 ± 7.82[a] (34)	84.0 ± 6.14[b] (34)	95.9 ± 9.39[b] (21)	102.2 ± 4.75 (89)
Sitting with activity	58.2 ± 9.85 (29)	36.7 ± 6.65 (27)	53.1 ± 15.59 (14)	48.9 ± 5.77 (70)
Walking	55.7 ± 4.33 (34)	57.3 ± 4.33 (34)	58.4 ± 9.48 (21)	56.9 ± 5.22 (89)
Fetching water	46.1 ± 5.16 (28)	37.7 ± 5.38 (24)	47.0 ± 9.35 (17)	43.4 ± 3.60 (69)
Washing clothes	44.9 ± 5.05 (32)	36.2 ± 4.58 (28)	36.2 ± 5.42 (16)	39.9 ± 2.95 (76)
Arranging vessels and folding beds	43.7 ± 4.49[a] (34)	29.4 ± 3.14[b] (34)	37.7 ± 4.15[ab] (21)	36.8 ± 2.38 (89)
Scouring vessels	41.2 ± 3.26[a] (34)	34.7 ± 2.80[ab] (33)	29.5 ± 3.33[b] (21)	35.9 ± 1.87 (88)
Pounding	34.5 ± 11.07 (4)	18.5 ± 10.50 (2)	—	29.2 ± 8.23 (6)
Standing with activity	33.1 ± 4.59 (29)	26.6 ± 3.53 (30)	41.3 ± 11.42 (16)	32.3 ± 3.33 (75)
Sweeping	26.5 ± 2.25 (33)	20.8 ± 1.62 (34)	21.3 ± 2.26 (21)	23.1 ± 1.20 (88)
Serving	26.3 ± 1.99 (32)	29.2 ± 3.02 (34)	24.8 ± 2.65 (21)	26.9 ± 1.49 (87)
Swabbing	24.9 ± 5.38 (9)	17.5 ± 5.38 (8)	11.0 ± 6.00 (2)	20.3 ± 3.50 (19)
Child care				
Breastfeeding	74.1 ± 9.27[a] (21)	28.7 ± 6.89[b] (6)	111.7 ± 58.95[a] (3)	68.8 ± 9.23 (30)
Other child-care activities	62.6 ± 8.49[a] (32)	29.1 ± 3.68[b] (28)	32.9 ± 8.27[b] (18)	44.1 ± 4.58 (78)
Standing holding the child	29.6 ± 5.42 (18)	11.8 ± 5.11 (6)	22.7 ± 6.55 (4)	24.8 ± 3.94 (28)
Walking holding the child	21.1 ± 5.13 (14)	13.0 ± 8.00 (3)	22.5 ± 16.50 (2)	19.9 ± 4.15 (19)
Occupational				
Paid work	—	372.1 ± 24.30 (34)	276.8 ± 25.00 (21)	335.7 ± 19.53 (55)
Personal care and residual				
Personal needs	88.7 ± 3.78 (34)	80.3 ± 3.69 (34)	87.4 ± 4.58 (21)	85.2 ± 2.30 (89)
Sitting without activity	159.5 ± 17.5[a] (34)	59.4 ± 9.63[b] (34)	95.2 ± 9.58[b] (21)	108.3 ± 9.58 (89)
Standing without activity	36.8 ± 5.27 (34)	27.4 ± 4.55 (29)	32.7 ± 8.71 (21)	32.5 ± 3.41 (84)

a,b. Values in the same row with different superscripts are significantly different from each other ($p < .05$).

TABLE 3. Mean ± SE number of minutes spent on different categories of activities according to occupation (number of women in parentheses)

Occupation	Household work	Child care time	Paid work	Personal care and residual	Sleep
Homemaker	491.0 ± 20.89[a] (34)	131.0 ± 16.93[a] (34)	-	285.0 ± 20.76[a] (34)	538.0 ± 11.58 (34)
Beedimaker	367.0 ± 19.88[b] (34)	38.0 ± 6.18[b] (28)	372.0 ± 24.33 (34)	156.0 ± 12.11[b] (34)	513.0 ± 8.89 (34)
Tailor	398.0 ± 27.60[b] (21)	51.0 ± 23.72[b] (17)	277.0 ± 25.03 (21)	206.0 ± 12.99[b] (21)	510.0 ± 13.13 (21)
All occupations	420.0 ± 14.00 (89)	79.0 ± 10.19 (79)	335.0 ± 19.53 (55)	216.0 ± 11.29 (89)	522.0 ± 6.45 (89)

a,b. Values in the same column with different superscripts are significantly different from each other ($p<.05$).

TABLE 4. Energy cost of activities according to WHO classification [14] (multiples of basal metabolic rate [BMR] in parentheses)

Very light (< 1.7 BMR)	Light (1.7–2.2 BMR)	Moderate (2.2–2.8 BMR)	Heavy (> 2.8 BMR)
Sitting (1.07) Standing (1.14) Breastfeeding (1.46) Beedimaking (1.50) Standing holding the child (1.63)	Cooking (1.98) Tailoring (2.07)	Scouring vessels (2.53) Bathing the child (2.67) Walking (2.78)	Arranging things and folding beds (3.07) Walking holding the child (3.18) Sweeping (3.2) Washing clothes (3.5) Fetching water (4.1) Swabbing (4.25)

that most of the household activities were classified as moderate to heavy, requiring energy expenditures of more than 2.2 times the BMR. Child-care activities ranged from sedentary to heavy, whereas occupational activities such as beedimaking and tailoring were classified as sedentary.

Table 5 shows the mean total durations of sedentary, moderate, and heavy activities performed daily by women from the three occupational groups. Overall, the women spent 1,035 minutes (72% of their time) on sedentary activities, 267 minutes (19%) on moderate activities, and 138 minutes (9%) on heavy activities. Beedimakers and tailors spent more time on sedentary work (1,081 and 1,063 minutes, respectively) than homemakers (968 minutes), whereas homemakers spent significantly more time on moderate to heavy activities (470 minutes) than beedimakers and tailors (377 and 358 minutes, respectively; $p < .05$)

Table 6 shows the amount of time spent on occupational activities by the two groups of working women. Three-fourths of the women spent less than eight hours on paid work, and one-third of these spent less than four hours. Surprisingly, only 18% worked for more than eight hours. Ninety-five percent of the tailors spent less than eight hours on paid work, and 52% of these spent less than four hours. Only 5% worked for more than eight hours, whereas 27% of beedimakers worked for more than eight hours and 18% worked less than four hours.

Table 7 shows the amount of time spent on different categories of activity by the three groups of women. As the time spent on housework and child care decreased, the time spent on occupational work increased. An increase in the time spent on occupational work was also accompanied by a decrease in the time spent on personal care. Women spending more than eight hours on occupational work spent significantly less time on household work than women who were able to do less than four hours of paid work (223 vs. 442 minutes; $p < .05$).

Discussion

Only those women who spent a minimal amount of time on child care (23 minutes) and who were able to reduce their time spent on housework and personal care were able to spend more than eight hours on their occupations. Women from the low socioeconomic group engaged in productive work with no household or state support have to constantly negotiate between housework, child care, and paid work. Their poor nutritional status is reflected in their low body weight and height, which are not different from the values reported for urban Indian women of the low socioeconomic group [15].

Homemakers spent more than eight hours on household tasks, whereas beedimakers and tailors were able to participate in the labor force by decreasing the time spent on housework and child care. Homemakers spent 124 minutes on cooking, whereas beedimakers and tailors spent 40 and 30 minutes less time on cooking, respectively. Similarly, homemakers spent 62 minutes on child care, whereas beedimakers and tailors spent only half as much time on child care other than breastfeeding or standing or walking while holding a child (29 and 32 minutes, respectively). Such a reduction of the time spent on household and child-care activities

TABLE 5. Mean duration (minutes) of sedentary, moderate, and heavy activities performed by women of different occupations

Occupation	*N*	Sedentary	%	Moderate	%	Heavy	%
Homemaker	34	968^a	67	302^a	21	170^a	12
Tailor	21	$1,063^b$	74	249^b	17	128^b	9
Beedimakers	34	$1,081^b$	75	245^b	17	113^b	8
All occupations	89	1,035	72	267	19	138	9

a,b. Values in the same column with different superscripts are significantly different from each other ($p < .05$).

TABLE 6. Distribution of working women according to occupation and time spent in performing paid work: number (percent) of women

Time spent in paid work (h)	Occupation		
	Beedimaking	Tailoring	Total
< 4	6 (18)	11 (52)	17 (31)
4–8	19 (56)	9 (43)	28 (51)
> 8	9 (27)	1 (5)	10 (18)

TABLE 7. Mean ± SE number of minutes spent on different categories of activities according to time spent in performing paid work (number of women in parentheses)

Time spent in paid work (h)	Household work	Child care	Personal care and residual
< 4	442^a (17)	79 (14)	210^a (17)
4–8	393^a (28)	35 (24)	169^b (28)
> 8	223^b (10)	23 (8)	137^b (10)

a,b. Values in the same column with different superscripts are significantly different from each other $p < .05$)

by women working for pay has been reported earlier [10]; however, those studies were based on a 24-hour recall of how the time was spent.

Homemakers spent significantly more time than the other two groups on activities classified by WHO [14] as moderate and heavy (table 5). These were largely household activities, such as swabbing, fetching water, washing clothes, and walking (table 4). If housework and child care are recognized as work in addition to occupational work, women in this group work for about 12 hours a day. Homemakers spent about 622 minutes (43% of the day) on work, whereas beedimakers and tailors spent 777 minutes (54%) and 726 minutes (50%), respectively, on work. Although homemakers spent less total time on work than beedimakers and tailors (622 minutes vs. 726 and 777 minutes, respectively), they spent more time on household work that was classified as heavy (tables 4 and 5). Beedimakers and tailors reduced the time spent on heavy housework, child care, and personal care compared with time spent by homemakers (156 and 206 minutes, respectively, vs. 285 minutes for homemakers). Varghese et al. [16] reported that middle-class women who did not work for pay also spent long hours on housework and child care. However, housework done with the help of mechanical appliances or household support in middle-class homes would not be classified as moderate work.

There was an inverse relationship between the amount of time the women spent on paid work and the amount of time they spent on housework and child care (table 7). The homemakers used all their available time and energy on housework and child care, whereas women doing paid work cut down on housework and child care and staggered their energy expenditure to do paid work. However, any increase in housework would result in decreased time spent on paid work or the need to opt out of paid work, as reported in our earlier studies [10].

For the purposes of calculating energy expenditure, a reference woman is defined as one who is between 20 and 39 years of age, is healthy, and weighs 50 kg. She may be engaged in eight hours of general household work, in light industry or in any other moderately active work. She spends eight hours in bed, four to six hours sitting or moving around in light activity, and two hours walking or engaged in active recreation or household chores [17].

In contrast, the homemakers in this study weighed an average of 42.0 kg and were engaged in largely heavy housework for more than eight hours, with an additional two hours spent on moderate to heavy child care. The reference woman spends some time on personal care and rest, but because of heavy housework and child care she is unable to participate in either social or recreational activities or to spend time for her physical well-being.

Women who worked for pay were underweight and conserved energy by cutting down on heavy household work. They cut down on rest and reduced their time for social and recreational activities and other activities for their physical well-being. But even with these adjustments, they were able to spend only four to six hours on paid work. Sleeping time was not different among the three groups despite long hours of work and energy balance at low body weights. This illustrates the physiological double burden of women from poor households.

Thus, the undernourished women are constantly negotiating the time spent on household work, child care, and occupational work in order to continue to be in the labor market. If they do not cut down on their long hours of heavy housework to do paid work, they may further lose weight, resulting in chronic energy deficiency. Their paid work is usually home-based production, which is sedentary work. To put in more hours of paid work or to do heavy labor without slipping into a negative energy balance, they would have to either eat more or decrease their time spent on housework.

Conclusions

This study highlights the fact that women from the low socioeconomic group of India work long hours doing housework, child care, and paid work. Homemakers spend significantly more time than women of the other two occupational groups on housework and child care, both of which are moderate to heavy work. Because of the unavoidable heavy household work, women beedimakers and tailors are able to do only four hours of paid work and must give up social and recreational activities.

In addition, undernutrition compels them to juggle their time and energy to stay in the labor force while taking care of the household tasks. Similar studies need to be carried out on Indian women with other occupations in the low socioeconomic group as well as in the middle and high socioeconomic groups in order to understand their patterns of time use and energy requirements.

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Combating iodine and iron deficiencies through the double fortification of fish sauce, mixed fish sauce, and salt brine

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Abstract

Two iodine and seven iron compounds were tested for use in the fortification of pure fish sauce, mixed fish sauce, and salt brine for cooking as a means to combat iodine and iron deficiencies. Ferrous sulfate, sodium iron ethylenediaminetetraacetic acid, ferric ammonium citrate, and ferrous lactate were combined with potassium iodide with no effect on sensory quality. Product shelf-life testing revealed that no iron or iodine losses occurred during a three-month storage period. Although the color of most products darkened, the color was not significantly different from that of nonfortified products after two to three months. Sensory home-use tests revealed that the fortified products were acceptable to highly acceptable, with only 1.2% to 8.2% of the dishes cooked using the fortified products being reported as discolored. The cost of fortification was minimal, at 0.13 to 2.73 baht per bottle (750 ml)(42 baht = US$1). Consequently, these products show a potential for inclusion in national programs for the prevention of micronutrient deficiencies in Asian countries where fish sauce and its products are routinely consumed.

Introduction

Micronutrient deficiency is a public health problem in most developing countries [1, 2]. In Thailand, iron-deficiency anemia affects such vulnerable groups as pregnant women and children, with prevalences as high as 70% in some rural areas [3]. Moreover, although the overall prevalence of iodine-deficiency disorders is low in Thailand (2.1%), food-based strategies are needed to maintain this level, as well as to reduce the prevalence of iodine-deficiency disorders in areas where it remains high [4].

Fish sauce and related products are potential vehicles for micronutrient fortification in Thailand and other countries such as Cambodia, Indonesia, Laos, Myanmar, and Vietnam, where such products are a traditional part of the cuisine. In Thailand especially, they are widely accessible to and used by people of all socioeconomic classes and in all parts of the country because of their availability, acceptability, and affordability [5]. In many parts of the country, fish sauce and related products are used instead of iodized salt for seasoning.

Thailand's Food and Drug Administration (FDA) classifies fish sauce-related products as those that are produced to lower the cost compared with pure fish sauce. Such products include mixed fish sauce (fish sauce mixed with other ingredients) and salt brine for cooking (salt brine and colorant mixed with liquid, which is a by-product of monosodium glutamate production). Technically, fish sauce products are in liquid form and can be homogeneously mixed with a suitable fortificant [6]. It is estimated that Thai people consume 15 ml of fish sauce products per meal [7].

Since 1998, fish sauce and soy sauce have been fortified with iron in Vietnam and China using sodium iron ethylenediaminetetraacetic acid (NaFeEDTA) [8, 9]. In Thailand, fortifying fish sauce with iron and the double fortification of fish sauce with iron and iodine were successfully achieved by using NaFeEDTA and potassium iodate as iron and iodine sources, respectively [5, 10]. However, NaFeEDTA is one of the most expensive iron fortificants. For a low-profit-margin product such as fish sauce, the cost of NaFeEDTA is not acceptable to Thai producers, thus hindering the nationwide fortification program. To determine the most economical and practical fortification method or methods, the present study on the technical feasibility of fortifying fish sauce and related products with iron and iodine with lower-cost fortificants was undertaken.

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Materials and methods

Food and nutrient samples

Fish sauce, mixed fish sauce, and salt brine for cooking were obtained from the Rayong Fish Sauce Industry Co., Rayong, Thailand. Iodine sources, including potassium iodide and potassium iodate, were obtained from Ajax (Auburn, Australia). Seven iron fortificants were used, including ferrous sulfate from Ajax, NaFeEDTA from Akza Nobel (Singapore), ferrous lactate from Purac (Gorinchern, Netherlands), ferrous fumarate from Siam Union (Budenheim, Germany), ferrous bisglycinate from Albion (Utah, USA), ferric ammonium citrate from Merck (Frankfurt, Germany), and ferrous gluconate from Merck.

Effect of individual and combined nutrients on product sensory appearance

Fish sauce, mixed fish sauce, and salt brine for cooking were fortified with individual and combined fortificants (for iodine and iron), packed in capped glass bottles, and incubated at room temperature for three months along with unfortified products as controls. The fortification dosage was 5 mg for iron and 50 µg for iodine per 15 ml of fish sauce product (one-third the Thai Recommended Dietary Intakes [RDI] per serving). Changes in the products' sensory appearance (color and precipitate) were observed during incubation.

Modification of the production method

Citric acid was used in the modification process, since fish sauce producers use it as an acidulant and it is an efficient, economical chelating agent. To evaluate acceptable levels of acid, citric acid was added to the fish sauce products at concentrations of 0.1%, 0.3%, 0.5%, and 0.7%. The detectable acid level was determined using the sensory difference from controls to compare acidified with nonacidified samples [11, 12]. A boiled, 1-cm cube of chicken breast was used as the sample carrier. Thirty staff and students from Mahidol University performed the tests under daylight fluorescent light in individual testing booths at the Sensory Science Laboratory, Institute of Nutrition, Mahidol University.

Selection of fortificants used in double fortification

The acidified double-fortified fish sauce and salt brine for cooking with different forms of iron and iodine fortificants were observed for changes in general sensory appearance compared with unfortified products during the storage period under accelerated test conditions (40°C, two weeks). Another selection criterion was fortified iodine stability. If the combination did not cause any loss in iodine, potassium iodide would be the first priority, because of its lower cost and greater stability.

Shelf-life study

A shelf-life study was performed on the double-fortified products, which were acidified at different citric acid concentrations (0.1% to 0.3%). The products were packed in glass bottles and stored under severe (daytime, 34° to 36°C; nighttime, 32°C) and normal (daytime, 25° to 30°C; nighttime, 25°C) conditions for three months. The products were sampled on a monthly basis to determine residual fortified nutrients and sensory qualities. Differences from control and hedonic scales were used for the sensory analysis of changes in color during storage and acceptability of the products, respectively. Fifty nursing students from the Royal Thai Naval Nursing College in Bangkok performed the sensory analysis in individual testing booths under a daylight fluorescent lamp. Data from sensory analyses were assessed for significant differences ($p = .05$) by analysis of variance (ANOVA) and the Scheffé method.

Chemical analysis

Iodine content was determined by the spectrophotometric method at 410 nm absorbency as noted by Moxon and Dixon [13] and Sandell and Kolthoff [14]. Iron content was determined after wet digestion by a flame atomic absorption spectrophotometer (model Spectr AA-20, Varian Associates, Australia) [15].

Production trial at industrial level

The production trial was performed at the Rayong Fish Sauce Industry Co. by double-fortifying 100 L of fish sauce and mixed fish sauce with each kind of iron fortificant. The fortified product was then sensory tested, and comments were made by factory experts before it was filtered and bottled in 750-ml glass bottles and capped.

Home-use test

Staff and students of the Institute of Nutrition, Mahidol University, performed the home-use test [11]. These panelists were divided into two groups of about 60 each, consisting of fish sauce users (higher-cost product) and mixed fish sauce users (lower-cost product). Every week each panelist was randomly given a bottle of a fortified fish sauce product for use in his or her normal cooking and asked to complete a questionnaire about its use. The panelists returned completed questionnaires after at least 10 dishes had been cooked, giving overall product acceptability ratings according to a hedonic scale. If 25% of the questionnaires reported dishes to be different from normal, those dishes were cooked in the laboratory with that fortified product in order to confirm the findings and observe the abnormal sensory characteristics.

Results and discussion

Effect of individual and combined nutrients on product sensory appearance

The effects of fortified nutrients on sensory characteristics were found to be the same in all fish sauce products. Table 1 shows that neither potassium iodide nor potassium iodate affected the sensory appearance. The effects resulted solely from iron fortificants, which also affected the products in the case of combined nutrients. Food producers are greatly concerned with any changes in the sensory appearance of fortified food products. Most iron fortificants catalyzed an oxidation reaction and caused precipitate and color changes in all products. NaFeEDTA affected color only slightly, but the fortified products precipitated after 1.5 months. The shelf life of most unfortified fish sauce products is about three months.

Modification of production method

Acetic and citric acids are commonly used in the acidification process to improve taste and prevent the formation of precipitate and crystals in fish sauce products. In other food industries, citric acid is also used as a metal chelator. In a preliminary study, only citric acid prevented the formation of precipitate, which was caused by the reaction of the iron fortificant and protein in fish sauce and its related products. In this study, the maximum level of citric acid that could be added without significantly affecting sensory quality was 0.7%. Citric acid was therefore the best choice for acidification because of its wide use and low cost.

Fortificants used in double fortification

The results from the acceleration test indicated that four iron fortificants—ferrous sulfate, NaFeEDTA, ferric ammonium citrate, and ferrous lactate—could be used in all fish sauce products that had been acidified with citric acid (table 2). The other three kinds of iron fortificant caused precipitate and color changes that could not be prevented. However, different concentrations of citric acid were required for different iron fortificants. For example, only 0.1% citric acid was needed for NaFeEDTA, while 0.3% was needed for the other three kinds of iron fortificant. In some acidified products, the sources of iodine in combination with iron sources could also affect sensory appearance (darker color and precipitate) and cause losses of the fortified nutrients.

Acidified fish sauces fortified with ferric ammonium citrate and potassium iodate precipitated even when 0.3% citric acid was used. The same was found with ferrous lactate and potassium iodide. Only potassium iodate could be used for double fortification with ferrous sulfate in salt brine for cooking. When both forms

TABLE 1. Sensory appearance of fish sauce, mixed fish sauce, and salt brine for cooking fortified with different kinds of fortificants during different storage periods[a]

		Iron fortificant							
Month	Iodine fortificant	None	Ferrous sulfate	NaFeEDTA	Ferric ammonium citrate	Ferrous lactate	Ferrous gluconate	Ferrous fumarate	Ferrous bisglycinate
0	None	—	X	—	X	X	X	X	X
	KI	—	X	—	X	X	X	X	X
	KIO_3	—	X	—	X	X	X	X	X
1	None	—	X	—	X	X	X	X	X
	KI	—	X	—	X	X	X	X	X
	KIO_3	—	X	—	X	X	X	X	X
2	None	—	X	X	X	X	X	X	X
	KI	—	X	X	X	X	X	X	X
	KIO_3	—	X	X	X	X	X	X	X
3	None	—	X	X	X	X	X	X	X
	KI	—	X	X	X	X	X	X	X
	KIO_3	—	X	X	X	X	X	X	X

a. X, Precipitate and color change; —, no precipitate and no or slight change in color.

of iodine could be used without affecting the sensory characteristics, potassium iodide was preferred because of its lower cost. Table 3 shows the same result when the double-fortified products were packed in commercial packages and stored at normal and severe room temperatures. However, severe room temperature caused a higher amount of precipitate in some fortificants.

Shelf-life study

Table 4 shows the amounts of iodine and iron in the fortified products. The nonfortified products or controls contained very small amounts of both nutrients. The amounts of the fortified nutrients did not change significantly during the three-month storage. The fish sauce fortified with ferrous sulfate lost more iodine than the others; however, the residual iodine after three months was still more than 80% of the expected dosage (333 µg/100 ml), which was still an acceptable amount. Ferrous sulfate and certain amino acids in the fish sauce would probably interact and have an oxidation effect on the fortified potassium iodide. The iron contents of the products fortified with NaFeEDTA, ferric ammonium citrate, and ferrous lactate were found to be only 80% to 90% of the expected values (33 mg/100 ml), which might have been related to the degree of purity and hygroscopicity of those fortificants. Even though the products were not stored in a 100% light-protected condition, the amounts of fortified nutrients did not change for at least three months.

The sensory scores for the double-fortified fish sauce were not significantly different, except for the lower acceptability of the NaFeEDTA-fortified product (table 5). The color of the fortified mixed fish sauce was also a problem, since the acceptability scores for those fortified with ferrous sulfate and ferrous lactate were significantly lower than the controls after three months. However, the scores for overall acceptability were not significantly different from those of the controls in both cases. There was a significant difference in the scores of certain characteristics of salt brine for cooking during storage periods, which showed that the sensory quality of the fortified products was different from that of the controls during the first one to two months. After the products had been stored for three months, the sensory characteristics of the unfortified products were not very different from those of the fortified ones.

TABLE 2. Sources of iron and iodine and concentration of citric acid used to prevent change in sensory appearance of the double-fortified products during the acceleration test (40°C for 2 weeks)

Product	Iron source	Iodine source	% Citric acid
Fish sauce	Ferrous sulfate	KI	0.3
	NaFeEDTA	KI	0.1
	Ferric ammonium citrate	KI	0.3
	Ferrous lactate	KIO_3	0.3
Mixed fish sauce	Ferrous sulfate	KI	0.3
	NaFeEDTA	KI	0.1
	Ferric ammonium citrate	KI	0.3
	Ferrous lactate	KI	0.3
Salt brine for cooking	Ferrous sulfate	KIO_3	0.3
	NaFeEDTA	KI	0.1
	Ferric ammonium citrate	KI	0.3
	Ferrous lactate	KI	0.3

TABLE 3. Effect of storage conditions on stability of the double-fortified products during three months of storage[a]

% Citric acid	Time (mo)	Ferrous sulfate						NaFeEDTA						Ferric ammonium citrate						Ferrous lactate					
		Fs (KI)		MFs (KI)		Sbc (KIO_3)		Fs (KI)		MFs (KI)		Sbc (KI)		Fs (KI)		MFs (KI)		Sbc (KI)		Fs (KIO_3)		MFs (KI)		Sbc (KI)	
		M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S
0.1	1	+1	+2	+1	+2	+1	+2	0	0	0	0	0	0	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1
	2	+2	+3	+2	+3	+2	+3	0	0	0	0	0	0	+1	+2	+1	+2	+1	+2	+1	+2	+1	+2	+1	+2
	3	+2	+4	+2	+4	+2	+4	0	0	0	0	0	0	+2	+4	+2	+4	+2	+4	+2	+4	+2	+4	+2	+4
0.2	1	+1	+2	+1	+2	+1	+2	0	0	0	0	0	0	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1
	2	+2	+3	+2	+3	+2	+3	0	0	0	0	0	0	+1	+2	+1	+2	+1	+2	+1	+2	+1	+2	+1	+2
	3	+2	+4	+2	+4	+2	+4	0	0	0	0	0	0	+2	+3	+2	+3	+2	+3	+2	+3	+2	+3	+2	+3
0.3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

a. Fs, Fish sauce; MFs, mixed fish sauce; Sbc, salt brine for cooking; M, mild storage conditions (daytime 25° to 30°C, nighttime 25°C); S, severe conditions (daytime 34° to 36°C, nighttime 32°C); amount of precipitate is scored from 0 (no precipitate) to +1 (small amount) to +4 (large amount).

Table 6 shows that the subjects found a significant difference in color ($p < .05$) in the double-fortified products packed in glass bottles after the fortificants had been added. The rating showed that the colors of the fortified products were darker; however, in the case of fish sauce, the color of the nonfortified product darkened to the same degree or even more in comparison with the product fortified with NaFeEDTA after

TABLE 4. Amounts of fortificants (per 100 ml) in the double-fortified fish sauce products during three months of storage[a]

Product	Month	1		2		3		4	
		I (μg)	Fe (mg)	I (μg)	Fe (mg)	I (μg)	Fe (mg)	I (μg)	Fe (mg)
Fs	0	270.12	34.20	347.60	27.48	332.27	30.58	340.64	27.00
	1	270.82	33.00	335.91	27.34	336.10	31.23	333.30	26.77
	2	272.32	32.62	352.91	27.50	320.30	29.86	335.26	26.99
	3	268.65	33.56	343.20	28.00	330.50	30.00	331.70	27.22
MFs	0	306.51	33.08	362.27	27.76	367.55	31.12	323.42	27.52
	1	305.60	33.10	336.65	29.10	341.44	31.10	310.01	28.10
	2	300.43	33.46	337.60	28.57	331.80	31.19	335.08	29.33
	3	304.24	33.20	338.06	28.02	321.02	31.50	338.82	29.54
Sbc	0	330.06	34.04	384.54	30.07	347.10	31.24	345.70	28.19
	1	340.89	34.04	364.55	30.35	310.30	31.80	326.17	28.40
	2	339.30	34.33	369.33	30.24	305.35	31.12	328.63	28.14
	3	329.36	33.95	362.85	30.43	313.00	31.34	321.97	28.18

a. Fs, Fish sauce; MFs, mixed fish sauce; Sbc, salt brine for cooking; 1, ferrous sulfate + KI for fish sauce and mixed fish sauce, and ferrous sulfate + KIO_3 for salt brine for cooking; 2, NaFeEDTA + KI; 3, ferric ammonium citrate + KI; 4, ferrous lactate + KIO_3 for fish sauce, and ferrous lactate + KI for mixed fish sauce and salt brine for cooking; nonfortified fish sauce, mixed fish sauce, and salt brine for cooking contained 0.90, 0.50, and 0.11 mg of iron, and 30.87, 19.59, and 16.04 μg of iodine per 100 g, respectively.

TABLE 5. Changes in sensory acceptability of the double-fortified fish sauce products as compared with the nonfortified products during three months of storage[a]

Sensory quality	Month	Degree of significant difference of sensory acceptability score ($p = .05$)											
		Fs				MFs				Sbc			
		1	2	3	4	1	2	3	4	1	2	3	4
Overall	0	N	N	N	N	N	N	N	N	N	N	N	N
	1	N	N	N	N	N	N	N	N	N	N	N	N
	2	N	N	N	N	N	N	N	N	*	*	*	*
	3	N	N	N	N	N	N	N	N	N	N	N	N
Color	0	N	N	N	N	N	N	N	N	N	N	N	N
	1	N	N	N	N	N	N	N	N	*	*	*	*
	2	N	N	N	N	N	N	N	N	*	*	N	*
	3	N	*	N	N	*	*	N	*	N	N	N	N
Odor	0	N	N	N	N	N	N	N	N	N	N	N	N
	1	N	N	N	N	N	N	N	N	N	N	N	N
	2	N	N	N	N	N	N	N	N	*	*	*	*
	3	N	N	N	N	N	N	N	N	N	N	N	N
Saltiness	0	N	N	N	N	N	N	N	N	N	N	N	N
	1	N	N	N	N	N	N	N	N	N	N	N	N
	2	N	N	N	N	N	N	N	N	*	*	N	*
	3	N	N	N	N	N	N	N	N	N	N	N	N

a. Fs, Fish sauce; MFs, mixed fish sauce; Sbc, salt brine for cooking; 1, ferrous sulfate + KI for fish sauce and mixed fish sauce, and ferrous sulfate + KIO_3 for salt brine for cooking; 2, NaFeEDTA + KI; 3, ferric ammonium citrate + KI; 4, ferrous lactate + KIO_3 for fish sauce, and ferrous lactate + KI for mixed fish sauce and salt brine for cooking.

* Significant difference from the internal control sample ($p < .05$); N, no significant difference from the internal control sample.

being stored for two to three months. The color of the fortified products tended to be darker because of the catalytic effect of iron and certain compounds formed by iron itself and sulfur-containing amino acid in the products [16].

Production trial at industrial level

The sensory evaluation and the preparation process affect whether the fortification program and its products would be accepted by the industry. To investigate these factors, a fish sauce expert, familiar with his own product, was asked to review and comment on the quality of the fortified products (table 7). In his assessment, the quality of the products and the preparation process differed according to the type and solubility of the iron fortificant. His final comment was that general consumers would probably not detect such differences in sensory characteristics; however, industrial producers would prefer the type of iron fortificant that was easily soluble.

Cost estimation

Cost was calculated from the prices of both fortificants and citric acid (table 8). The cost of the raw materials used for fortification with ferric ammonium citrate plus potassium iodide was highest in both products, whereas the ones with ferrous sulfate plus potassium iodide were the lowest. Ferrous sulfate was the best choice for an iron fortificant to be used in a national fortification program.

Home-use test

Table 9 shows the number of dishes that were cooked by the subjects at home. The subjects cooked approximately 300 to 400 recipes a total of 1,700 to 2,400 times.

TABLE 6. Results (mean ± SD) of the difference from control test for color of double-fortified fish sauce products compared with the nonfortified products (packed in the 750-ml glass bottle used for commercial distribution)

		Test score				
	Month	Control	Ferrous sulfate + KI/ KIO_3	NaFeEDTA + KI	Ferric ammonium citrate + KI	Ferrous lactate + KI/KIO_3
Fish sauce	0	4.97 ± 0.93^{d}	7.43 ± 1.01^{ab}	7.87 ± 0.94^{a}	6.70 ± 1.15^{bc}	5.97 ± 1.07^{c}
	1	5.47 ± 1.25^{c}	7.57 ± 1.30^{a}	6.33 ± 0.99^{bc}	7.10 ± 1.09^{ab}	6.20 ± 1.00^{bc}
	2	5.63 ± 1.07^{c}	6.80 ± 1.16^{b}	5.23 ± 1.19^{c}	7.40 ± 1.28^{ab}	8.07 ± 0.98^{a}
	3	5.80 ± 1.35^{b}	6.67 ± 1.21^{b}	4.80 ± 0.96^{c}	7.83 ± 1.09^{a}	6.10 ± 1.18^{b}
Mixed fish sauce	0	4.43 ± 0.63^{c}	7.57 ± 1.00^{a}	5.47 ± 0.97^{b}	5.60 ± 0.81^{b}	7.53 ± 1.11^{a}
	1	4.73 ± 0.58^{c}	7.97 ± 1.22^{a}	6.97 ± 1.07^{b}	6.53 ± 1.04^{b}	6.93 ± 1.11^{b}
	2	4.87 ± 0.57^{d}	7.90 ± 0.96^{a}	7.00 ± 1.11^{b}	6.17 ± 0.91^{c}	7.27 ± 0.69^{ab}
	3	4.30 ± 0.84^{c}	7.90 ± 0.84^{a}	7.27 ± 1.01^{ab}	6.73 ± 0.94^{b}	7.73 ± 1.17^{a}
Salt brine for cooking	0	4.67 ± 0.61^{c}	6.97 ± 1.75^{a}	5.17 ± 0.95^{bc}	7.73 ± 1.48^{a}	5.80 ± 1.42^{b}
	1	4.90 ± 0.55^{c}	7.97 ± 1.03^{a}	6.17 ± 0.65^{b}	5.93 ± 0.83^{b}	8.00 ± 0.87^{a}
	2	4.97 ± 0.18^{d}	8.23 ± 0.73^{a}	6.10 ± 1.09^{c}	6.00 ± 0.87^{c}	7.57 ± 0.94^{b}
	3	4.87 ± 0.51^{e}	8.00 ± 0.59^{b}	6.03 ± 0.72^{d}	8.77 ± 0.43^{a}	6.77 ± 0.57^{c}

The score of difference from control ranged from 1 (very much milder color) to 5 (no difference from control) to 9 (very much darker color). KIO_3 instead of KI was used with ferrous lactate and ferrous sulfate in fish sauce and salt brine for cooking, respectively. Means within the same row with different superscripts are significantly different from each other ($p < .05$).

TABLE 7. Comments made by a fish sauce expert on the sensory quality of the double-fortified fish sauce and mixed fish sauce produced at the industrial level

Product	Fe+I	Preparation	Comment on sensory quality
Fish sauce	Ferrous sulfate + KI	Easy	Sour, cockroach excreta aroma
	NaFeEDTA + KI	Difficult	Not sour, banana leaf aroma
	Ferric ammonium citrate + KI	Medium	Not sour, no off-aroma
	Ferrous lactate + KIO_3	Difficult	Not sour, chemical tincture aroma
Mixed fish sauce	Ferrous sulfate + KI	Easy	Not sour, fishy aroma after swollen
	NaFeEDTA + KI	Difficult	Sour, no off-aroma
	Ferric ammonium citrate + KI	Medium	Sour, slightly off-aroma
	Ferrous lactate + KI	Difficult	Strong sour, metallic aroma

Fewer than 10% of the dishes that were cooked with fortified fish sauce products differed from normal in their sensory characteristics. The difference was greatest in the products with ferrous sulfate as the iron fortificant, whereas the product with ferric ammonium citrate showed the least difference. Since ferrous sulfate had the highest potential for national implementation (table 8), the dishes cooked with products fortified with ferrous sulfate (and which the subjects had identified as different from normal by more than 25%) were cooked again in the laboratory. Twenty-four dishes needed to be cooked with fish sauce fortified with ferrous sulfate plus potassium iodide, and only 10 were found to be different (mainly by having a darker color). Only 15 dishes needed to be cooked with mixed fish sauce fortified with ferrous sulfate plus potassium iodide, and only two of these were found to be different from normal. Table 10 reports the results from the home-use test questionnaire that indicated the comments on the sensory acceptability of fish sauce and mixed fish sauce fortified with the nutrients studied. Most of the double-fortified products were rated as acceptable to highly acceptable.

TABLE 8. Cost of fortificants and processing aid used in the preparation of double-fortified fish sauce products

Fortificants	Cost of fortificant[a]
Ferrous sulfate + KI or KIO_3	0.13
NaFeEDTA + KI	0.62
Ferric ammonium citrate + KI	2.73
Ferrous lactate + KIO_3 or KI	0.83

a. Cost in baht per bottle (750 ml); 42 baht = US$1. Cost includes iron and iodine fortificants and citric acid.

Conclusions

Double fortification at one-third of the Thai RDI per serving (15 ml) of fish sauce, mixed fish sauce, and salt brine for cooking was feasible with the use of ferrous sulfate, NaFeEDTA, ferric ammonium citrate, or ferrous lactate as the iron fortificant and with potassium iodide or iodate as the iodine source. However, the most promising for national implementation were the double-fortified products with ferrous sulfate as the iron fortificant, because they were lowest in cost. This study has identified these products as the most beneficial and cost-effective and thus as having the potential for incorporation into a national micronutrient prevention program in Thailand, as well as other countries in the south and east Asian region that are affected by iodine-deficiency disorders and iron-deficiency anemia, and in which fish sauce and its products are routinely consumed.

TABLE 9. Number (%) of dishes that had different sensory characteristic mentioned by the subjects who used double–fortified fish sauce and mixed fish sauce for cooking during the home-use test[a]

Product	Total no. of recipes	Total no. of dishes	Fortificants							
			1		2		3		4	
			N	D	N	D	N	D	N	D
Fish sauce	433	2,355	493 (91.8)	44 (8.2)	526 (94.1)	33 (5.9)	587 (94.7)	33 (5.3)	598 (93.6)	41 (6.4)
Mixed fish sauce	344	1,676	422 (92.7)	33 (7.3)	390 (93.3)	28 (6.7)	400 (98.8)	5 (1.2)	376 (94.5)	22 (5.5)

a. 1, Ferrous sulfate + KI; 2, NaFeEDTA + KI; 3, ferric ammonium citrate + KI; 4, ferrous lactate + KIO_3 for fish sauce, and ferrous lactate + KI for mixed fish sauce; N, normal characteristic; D, different characteristic from normal.

TABLE 10. Results of home-use sensory acceptability test of fish sauce and mixed fish sauce double-fortified with different sources of iron and iodine[a]

Comment	Frequency							
	1		2		3		4	
	Fs	MFs	Fs	MFs	Fs	MFs	Fs	MFs
Excellent (similar to normal fish sauce)	16	8	14	11	16	10	14	15
Acceptable	42	36	42	33	37	31	40	26
No comment	1	0	4	1	3	2	2	2
Needs more improvement	3	4	4	0	2	2	3	1
Absolutely unacceptable	1	0	0	0	0	0	0	0
Total	63	48	64	45	58	45	59	45

a. Fs, Fish sauce; MFs, mixed fish sauce; 1, ferrous sulfate + KI; 2, NaFeEDTA + KI; 3, ferric ammonium citrate + KI; 4, ferrous lactate + KIO_3 for fish sauce, and ferrous lactate + KI for mixed fish sauce.

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Red palm oil supplementation: A feasible diet-based approach to improve the vitamin A status of pregnant women and their infants

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Abstract

This double-blinded, randomized, controlled study was designed to study the effect of dietary supplementation with red palm oil during pregnancy on maternal and neonatal vitamin A status. A total of 170 women were recruited at 16 to 24 weeks of gestation and randomly assigned to an experimental group that received red palm oil to supply approximately one recommended dietary amount (RDA) (2,400 µg) of β-carotene or to a control group that received an equivalent volume of groundnut oil. The women received the oils for a period of 8 weeks, starting at 26 to 28 weeks of gestation and extending to 34 to 36 weeks of gestation. The mean postintervention (34 to 36 weeks) levels of serum retinol were 1.20 ± 0.22 (SD) µmol/L (95% CI, 1.15–1.25) in women receiving red palm oil and 0.73 ± 0.15 µmol/L (95% CI, 0.69–0.77) in their infants; these levels were significantly higher than those in women receiving groundnut oil (1.07 ± 0.26 µmol/L; 95% CI, 1.01–1.13; $p < .01$*) and their infants (0.62 ± 0.17 µmol/L; 95% CI, 0.57–0.67;* $p < .001$*). A significantly lower proportion of women in the red palm oil group than in the control group had vitamin A deficiency (serum retinol levels < 0.7 µmol/L) after intervention (1.5% vs. 9.7%). The proportion of women having anemia was significantly lower (*$p < .01$*) in the red palm oil-supplemented group (80.6%) than in the control group (96.7%). The mean birthweight and gestational age of the infants did not differ significantly between the two groups. An increased risk of low birthweight (*$p = .003$*) and preterm delivery (*$p = .000$*) was observed with decreasing serum retinol levels in the third trimester of pregnancy. These results show that red palm oil supplementation significantly improved maternal and neonatal vitamin A status and reduced the prevalence of maternal anemia. Maternal vitamin A status in the later part of pregnancy is significantly associated with fetal growth and maturation. Hence red palm oil, a rich source of bioavailable vitamin A, could be used as a diet-based approach for improving vitamin A status in pregnancy.*

Key words: India, red palm oil, serum retinol, anemia, pregnant women, infant, birthweight, gestational age

Introduction

Vitamin A deficiency, defined as serum retinol < 0.7 µmol/L, has been recognized for more than two decades as a major public health problem among preschool children in the developing world [1]. However, it is only in recent years that attention has been drawn to the extent and functional significance of vitamin A deficiency during pregnancy. In Southeast Asian countries, where childhood vitamin A deficiency is a significant problem, night-blindness has also been observed in 10% to 20% of women during pregnancy [2]. Studies from India also report a prevalence of night-blindness during pregnancy ranging from 3% to 39% in different parts of the country [3–5]. We have recently reported subclinical vitamin A deficiency in 27% of pregnant women attending prenatal clinics during the later part of pregnancy, which was associated with maternal anemia and preterm delivery [5]. It has also been observed that nearly 80% of newborns have serum retinol < 0.7 µmol/L, and 30% of these breastfed infants continue to have low retinol levels throughout infancy, even after maternal supplementation with vitamin A (a single dose of 200,000 IU within 48 hours after delivery) in the postpartum period [6].

These studies suggest the need for improving the vitamin A status of women during pregnancy as well as that of newborns. Food-based approaches offer feasible, sustainable, and cost-effective strategies that are required to improve the vitamin A content of the routine diets of the population, particularly providing a safe intake of vitamin A during pregnancy. Crude

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palm oil is the richest known source of carotenoids, and refined red palm oil has 17,500 mg of β-carotene per 100 g, and 28,000 mg of α-carotene per 100 g for a total of 6,140 retinol equivalents per 100 g. [7] Thus it has the potential for enriching routine diets with carotenoids. The safety, acceptability, and efficacy of red palm oil as a human food have been evaluated in supplementary feeding trials among children and lactating women [8–13]. The present study was conducted with the major objective of investigating the effect of red palm oil supplementation during pregnancy on maternal and neonatal vitamin A status. The effects of supplementation on maternal anemia, birthweight, and gestational age of newborns were also studied.

Methods

Study population and selection of sample

A randomized clinical trial of red palm oil supplementation was conducted in pregnant women attending the outpatient department of Niloufer Hospital, Hyderabad, India, between January 2001 and March 2002. A sample size of 43 in each group was required to detect a difference of 0.17 µmol/L (5 µg/dl) in serum retinol of the infants at birth between the control and experimental groups, with a significance level of $p < .05$, and a power of 80% using a mean of 0.63 ± 0.28 (SD) µmol/L in the cord blood, as reported in our earlier study [5]. In this study, more women than required (a total of 170) were recruited to account for an assumed dropout rate of 35% to 40%. Only women who were willing to have a follow-up every two weeks and who resided in the city area were chosen for the study. Women with recurrent pregnancy loss or earlier preterm delivery and those with diabetes, hypertension, or any other metabolic disorder were excluded. All the women were recruited between 16 and 24 weeks of gestation as confirmed by ultrasound examination. Each woman was given a serial identification number at recruitment. The women received a detailed explanation of the study, and written informed consent was obtained. Ethical approval for the study was obtained from the institutional ethical committee, the scientific advisory committee, and the Indian Council of Medical Research.

Experimental design

The women were randomly allocated to experimental and control groups. The supplements (CAROTINO molecular-distilled red palm oil provided by Global Palm Products, Malaysia, and groundnut oil obtained from the local market in Hyderabad) were coded as A and B. The serial identification number given at recruitment was used for random allocation of the women to one of the two supplementation groups.

The women in the experimental group received red palm oil providing 2,173 to 2,307 µg of β-carotene per day with a dosage schedule of one sachet per day (8 ml), which provided 91% to 96% of the daily requirement of vitamin A in pregnancy, i.e., 2400 µg of β-carotene)[14]. The women in the control group received one sachet of groundnut oil (8 ml). Both the red palm oil and the groundnut oil were packed and supplied in identical-appearing sachets and placed in identical-appearing boxes. A person not involved in the study did the coding, and the boxes were labeled with one of the two letter codes and handed over to the investigators. A set of 15 sachets from each box was further packed in larger polyethylene bags. A field assistant using the list of assigned random numbers and codes labeled each polyethylene bag used for dispensing the supplements with the identification number of the woman and the supplement code. Supplementation was given for a period of 8 weeks starting from 26 to 28 weeks of gestation up to 34 to 36 weeks of gestation. Enough supplements for two weeks were dispensed by the field investigator once every 15 days to the women. The women were instructed to consume the contents of one sachet with food in one sitting each day.

A detailed clinical anthropometric and obstetric examination was conducted in all the women at baseline and every 2 weeks up to 36 weeks and thereafter every week until delivery. All the women received iron-folate tablets (60 mg of iron and 500 µg of folic acid) for 100 days and routine prenatal care. The gestational age of the infant was calculated from the date of the last menstrual period and confirmed by developmental criteria at birth [15]. Infants born before 37 weeks of gestation as a result of spontaneous onset of labor were considered preterm.

Anthropometric studies

The mother's height and changes in her weight were measured up to delivery. The mother's weight was measured within 48 hours after delivery, and her body mass index (the weight in kilograms divided by the square of the height in meters) was calculated. The infant's weight was measured to an accuracy of 10 g with a Seca lever-activated weighing balance within one hour after birth. Birthweights under 2,500 g were considered low birthweights.

Dietary survey

Dietary surveys by the oral questionnaire method (24-hour dietary recall) were conducted on every second woman at recruitment, using the standardized cups developed by the National Institute of Nutrition, Hyderabad [16]. The dietary intakes obtained from the standardized cups were converted into quantities of raw food ingredients, and the vitamin A content was computed from food-composition tables [17].

Biochemical analysis

Hemoglobin and serum retinol were measured in the maternal blood at baseline (2 ml of venous blood), at 26 to 28 weeks, at 34 to 36 weeks, and in the cord blood after delivery. Serum retinol was determined by reverse-phase high-performance liquid chromatography (HPLC) following the method of Bieri et al. [18], and the hemoglobin concentration was determined by the cyanmethemoglobin method of Dacie and Lewis [19]. A hemoglobin level under 110 g/L was considered to indicate anemia, according to the World Health Organization (WHO) criteria [20], and a serum retinol level under 0.7 μmol/L was considered to indicate vitamin A deficiency, according to the cutoff for pregnant women defined by the authors in an earlier study [5].

Surveillance

A trained field investigator visited each of the recruited women at home every week. If the woman was not available, an attempt at a second visit, and, if required, a third visit was made within the next two days. If the attempts at visitation failed, the reason for the nonavailability of the woman was recorded. The field investigator conducted surprise checks to ensure compliance with the supplement intake. Side effects, such as nausea and vomiting, were recorded. Women who failed to come for follow-up on their own were brought to the hospital from their homes by the field investigator.

Data management

The maternal data of each woman at recruitment, 26 to 28 weeks of gestation, and 34 to 36 weeks of gestation and the data for both the mother and her infant at delivery were entered by the tabulator using the FoxPro database, version 2.5, on a personal computer. The printout was manually checked, and entry errors were corrected.

Statistical analysis

Descriptive statistics, which included geometric means, prevalence rates, and 95% confidence intervals in the two groups, were computed, and the differences were tested by Student's *t*-test and the normal curve proportion test (Z test) using the SPSS/PC statistical package (version 10.0). The paired *t*-test was used to calculate the net increase in serum retinol and hemoglobin concentrations from preintervention (26 to 28 weeks) to postintervention (34 to 36 weeks) within the same group. Analysis of covariance (ANCOVA) was used to adjust the mean values of dependent variables. Stepwise logistic regression analysis was performed to test the association of various independent maternal factors with the dependent variables birthweight (values of 1 for birthweight < 2,500 g and 0 for birthweight ≥ 2,500 g were assigned in the regression model) and gestational age of the infant (values of 1 for gestational age < 37 weeks and 0 for gestational age ≥ 37 weeks were assigned). The independent variables included in the model were age, maternal education, family income, family size, parity, postintervention serum retinol and hemoglobin values, individual weight gain from 26 to 28 weeks until delivery, and experimental group (values of 1 for the control and 0 for the red palm oil group were assigned). Values are expressed as means ± SD with 95% confidence intervals (CI) or percentages.

The flow of participants through each stage of the randomized trial is described in the flow chart (fig. 1).

Results

Baseline characteristics of the women at recruitment and at 16 to 24 weeks of gestation

The socioeconomic status, mean age (years), parity, mean height (centimeters), and mean weight were comparable between the two groups. The mean dietary intakes of vitamin A were 352.0 ± 414.6 μg/day (95% CI, 214.6–489.3 μg/day) in the red palm oil group and 289.2 ± 255.5 μg/day (95% CI, 208.0–370.5 μg/day) in the control group; the difference between the groups was not statistically significant. The mean serum retinol was comparable in the two groups, whereas the mean hemoglobin concentration was significantly higher in the red palm oil group (98.0 ± 13.2 g/L; 95% CI, 94.5–101.5 g/L) than in the control group (89.2 ± 11.7 g/L; 95% CI, 84.9–93.5 g/L; $p < .01$) (table 1).

Compliance

Of the 170 women enrolled in the study, 23 were not available for supplementation, while 18 dropped out after initiating supplementation. Of the 18 women who did not complete full supplementation, 5 in the red palm oil and 7 in the control group emigrated, and 2 in the red palm oil and 4 in the control group withdrew consent to continue the supplement because of either vomiting or nausea. Sixty-four women in the red palm oil group and 58 in the control group delivered in the hospital where the neonatal measurements could be recorded. All of the characteristics of the women who dropped out, including age, parity, height, body weight, hemoglobin, and serum retinol, were comparable to those of the compliant cohort within their respective groups during the preintervention period at 26 to 28

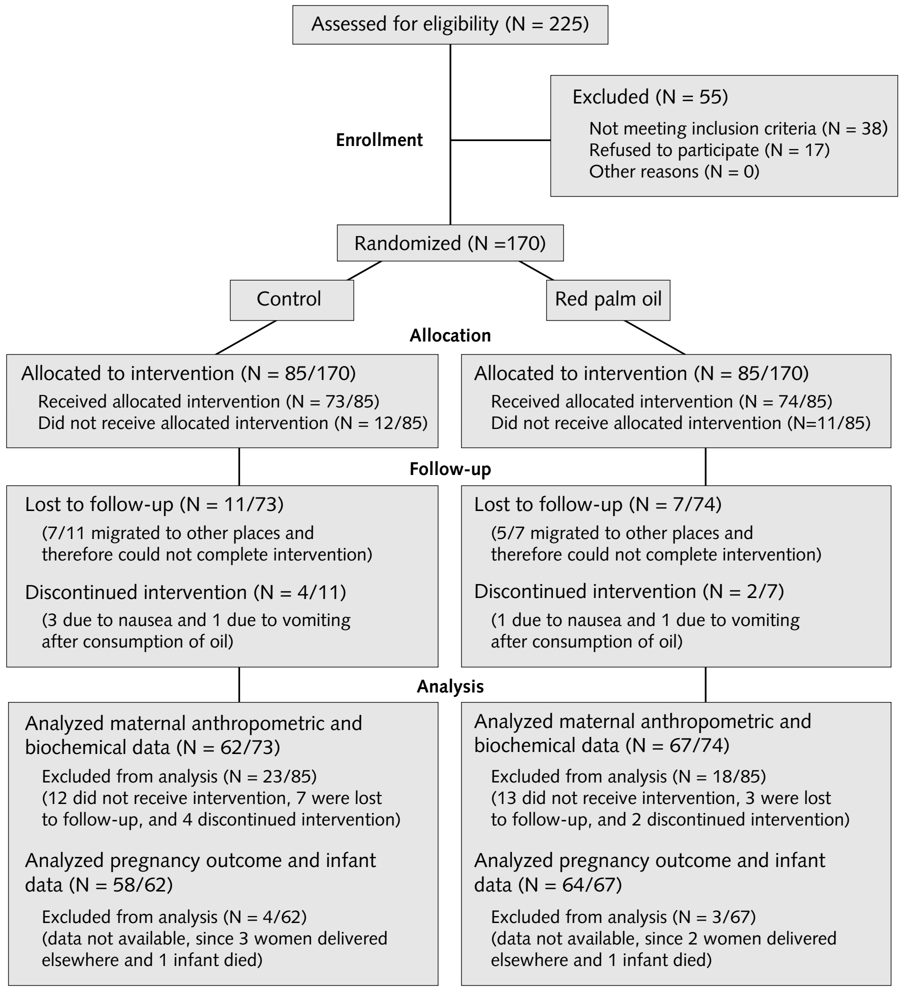

FIG. 1. Flow of participants through each stage of the randomized trial

TABLE 1. Baseline characteristics of the women at 16 to 24 weeks of gestation[a]

Variable	Red palm oil (n = 67)		Control (n = 62)	
Maternal education (yr)	5.3 ± 4.60	(4.2–6.5)	5.1 ± 4.45	(4.0–6.2)
Family income (Rs)[b]	3,062.7 ± 1,957.41	(2,585.2–3,540.1)	2,724.2 ± 1,856.11	(2,252.8–3,195.6)
Family size (no.)	4.4 ± 2.86	(3.7–5.1)	4.1 ± 1.76	(3.6–4.5)
Age (yr)	21.5 ± 2.74	(20.9–22.2)	21.6 ± 2.78	(20.9–22.3)
Parity	0.57 ± 0.72	(0.4–0.7)	0.66 ± 0.68	(0.5–0.8)
Height (cm)	152.3 ± 6.70	(150.6–153.9)	151.3 ± 6.25	(149.7–152.9)
Weight (kg)	46.5 ± 6.81	(44.5–48.5)	44.5 ± 5.31	(42.8–46.1)
Systolic blood pressure (mm Hg)	100.4 ± 4.69	(99.0–101.8)	100.0 ± 3.16	(99.0–101.0)
Diastolic blood pressure (mm Hg)	69.6 ± 4.19	(68.3–70.8)	69.0 ± 3.00	(68.1–70.0)
Hemoglobin (g/L)	98.0 ± 13.2	(94.5–101.5)	89.2 ± 11.7**	(84.9–93.5)
Serum retinol (μmol/L)	1.24 ± 0.24	(1.17–1.31)	1.20 ± 0.31	(1.10–1.30)

a. Values are means ± SD (95% CI).
b. Rs. 50 = US$1.
** $p < .01$ for the difference between the two groups.

weeks of gestation, suggesting that the results from the compliant group were unbiased. Maternal anthropometric and biochemical data from only those women who completed the full eight weeks of supplementation (67 women receiving red palm oil and 62 in the control group) and pregnancy outcome data from 64 and 58 members of the red palm oil and the control groups, respectively, were included in the final analysis. Because one maternal blood sample from the red palm oil group and three from the control group were clotted, hemoglobin could be analyzed in only 66 pairs from the red palm oil group and 59 pairs from the control group. Cord blood could be collected from 57 members of the red palm oil group and 50 members of the control group.

The acceptability of red palm oil by the pregnant women was above 90%. Reports of minor side effects, such as nausea and vomiting, were comparable in the red palm oil (6%) and control (8.9%) groups.

Serum retinol and hemoglobin profile during pregnancy and in the newborn

There was a significant decline in the mean values of serum retinol and hemoglobin at 26 to 28 weeks from the respective values at recruitment, whereas there was a subsequent significant rise by 34 to 36 weeks in both groups (figs. 2 and 3). The mean cord blood retinol level was 0.73 ± 0.15 μmol/L (95% CI, 0.69–0.77 μmol/L) in the red palm oil group and 0.62 ± 0.17 μmol/L (95% CI, 0.57-0.67 μmol/L) in the control group, which was about 50% of the respective maternal third trimester value in each of the groups. The mean hemoglobin values were higher than the respective maternal third trimester values: 123.4 ± 18.96 g/L (95% CI, 119.0–129.0 g/L) and 124.4 ± 16.69 g/L (95% CI, 119.6–129.1 g/L) in the red palm oil and control groups, respectively.

Impact of intervention in the mother

Serum retinol

The mean postintervention serum retinol was significantly higher in the red palm oil group (1.20 ± 0.22 μmol/L; 95% CI, 1.15–1.25 μmol/L) than the control group (1.07 ± 0.26 μmol/L; 95% CI, 1.01–1.13 μmol/L). The mean individual increase from preintervention to postintervention was significantly higher in the red palm oil group (0.30 ± 0.16 μmol/L; 95% CI, 0.23–0.34 μmol/L) than in the control group (0.14 ± 0.14 μmol/L; 95% CI, 0.11–0.18 μmol/L; $p < .01$) (table 2).

The pre- and postintervention proportions of women having serum retinol levels below 0.7 μmol/L were compared in the two groups (fig. 4). Since the proportion of women with vitamin A deficiency was similar in the two groups at the preintervention time point, the data were pooled and compared with the postintervention proportions of each of the two groups. There was a reduction of 15.6% in the prevalence of vitamin A deficiency among women with red palm oil supplementation. In the control group, there was a nonsignificant drop of 7.9% in the prevalence of vitamin A deficiency. At the end of the intervention, the red palm oil group had a significant reduction in the prevalence of vitamin A deficiency as compared with the control group.

Hemoglobin

The mean hemoglobin level was comparable in the two groups of women in both the preintervention (26 to 28 weeks of gestation) and the postintervention (34 to 36 weeks of gestation) periods after adjustment for the initial differences at baseline. The mean individual rise in the hemoglobin level from the preintervention to the postintervention period was also comparable in the two groups (table 2). The proportion of women with anemia was significantly lower in the red palm oil group than in the control group after intervention (80.6% vs. 96.7%; $p < .01$)(fig. 4).

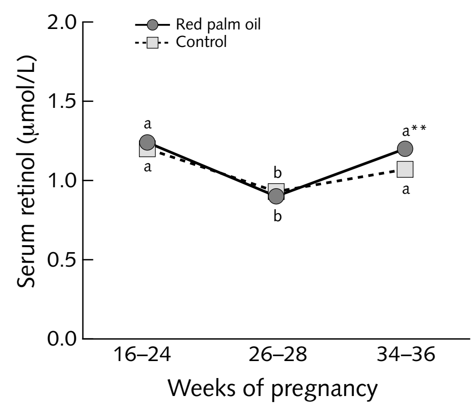

FIG. 2. Mean serum retinol status of mothers during pregnancy. A difference in superscripts indicates a significant difference between different weeks of pregnancy within the same group. ** $p < .01$ indicates a significant difference between the red palm oil and the control groups

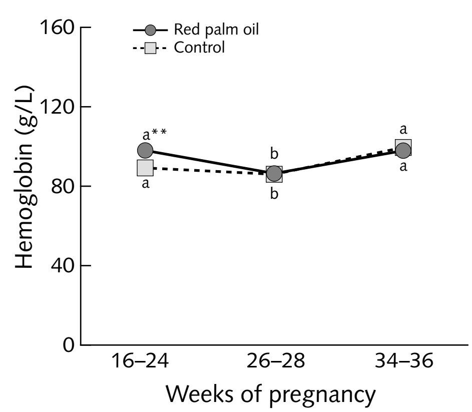

FIG. 3. Mean hemoglobin status of mothers during pregnancy. A difference in superscripts indicates a significant difference between different weeks of pregnancy within the same group. ** $p < .01$ indicates a significant difference between the red palm oil and the control groups

Maternal weight

The mean gain in maternal body weight from the presupplementation period (26 to 28 weeks of gestation) until delivery was comparable in the red palm oil group (4.05 ± 2.58 kg; 95% CI, 3.42–4.69 kg) and the control group (3.83 ± 2.24 kg; 95% CI, 3.26–4.41 kg) (table 2).

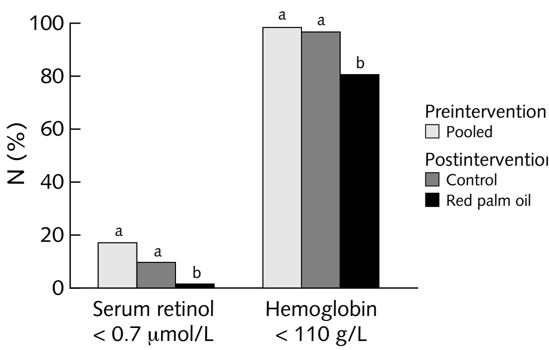

FIG. 4. Prevalence of maternal anemia and vitamin A deficiency in pregnant women before and after intervention

Impact of intervention in the newborn

Serum retinol

The mean cord blood retinol level was higher in the red palm oil group (0.73 ± 0.15 µmol/L; 95% CI, 0.69–0.77 µmol/L) than in the control group (0.62 ± 0.17 µmol/L; 95% CI, 0.57–0.67 µmol/L; $p<.001$) (table 3).

Hemoglobin

The mean cord blood hemoglobin was comparable in the two groups: 123.4 ± 18.96 g/L (95% CI, 119.0–129.0 g/L) in the red palm oil group and 124.4 ± 16.69 g/L (95% CI, 119.6–129.1 g/L) in the control group (table 3).

Birthweight and gestational age

The mean birthweight and gestational age of the infants were similar in the two groups: 2,747 ± 505.20 g (95% CI, 2,621–2,873 g) and 39.2 ± 2.22 weeks (95% CI, 38.6–39.7), respectively, in the red palm oil group and 2,666 ± 493.14 g (95% CI, 2,537–2,796 g) and 38.7 ± 2.57 weeks (95% CI, 38.1–39.4 weeks) in the control group. The mean birthweights were similar in the two groups even after adjustment for gestational age of the infant at birth. The proportions of low birthweight and preterm infants were also similar in the two groups (table 3).

TABLE 2. Impact of red palm oil intervention on the mother[a]

Variable	Group	Before intervention (26–28 wk)	After intervention (34–36 wk)	Mean increase
Hemoglobin (g/L)	RPO (n = 66)	86.0 ± 14.09 (82.7–89.4)	99.5 ± 14.44*** (95.9–103.0)	12.8 ± 11.96^{a} (9.9–15.8)
	Control (n = 59)	86.4 ± 12.15 (83.3–89.5)	97.9 ± 10.30*** (95.3–100.6)	12.0 ± 11.07^{a} (9.2–14.9)
Retinol (µmol/L)	RPO (n = 67)	0.90 ± 0.19 (0.85–0.95)	1.20 ± 0.22*** (1.15–1.25)	0.30 ± 0.16^{a} (0.23–0.34)
	Control (n = 62)	0.93 ± 0.23 (0.87–0.99)	1.07 ± 0.26* (1.01–1.13)	0.14 ± 0.14^{b} (0.11–0.18)
Body weight (kg)	RPO (n = 67)	49.2 ± 7.24 (47.5–51.0)	53.2 ± 8.75 (51.2–55.3)	4.05 ± 2.58^{a} (3.42–4.69)
	Control (n = 62)	48.0 ± 5.70 (46.5–49.4)	51.8 ± 6.85 (50.1–53.5)	3.83 ± 2.24^{a} (3.26–4.41)

a. Values are means ± SD (95% CI). RPO, Red palm oil. A difference in superscripts indicates a significant difference (p <.01) between the two groups.
* p <.05, *** p <.01 indicate a significant difference within the same group from the preintervention to the postintervention period.

TABLE 3. Impact of red palm oil intervention on the newborn[a]

Variable	Red palm oil			Control		
Cord retinol (µmol/L)	0.73 ± 0.15***	(0.69–0.77)	(n = 57)	0.62 ± 0.17	(0.57–0.67)	(n = 50)
Cord hemoglobin (g/L)	123.4 ± 18.96	(119.0–129.0)	(n = 57)	124.4 ± 16.69	(119.6–129.1)	(n = 50)
Mean birthweight (g)	2747 ± 505.20	(2,621–2,873)	(n = 64)	2666 ± 493.14	(2,537–2,796)	(n = 58)
% low-birthweight infants (< 2.5 kg)	15.6	(8.7–26.4)	(n = 64)	20.7	(12.2–32.8)	(n = 58)
Mean gestational age (wk)	39.2 ± 2.22	(38.6–39.7)	(n = 64)	38.7 ± 2.57	(38.1–39.4)	(n = 58)
% preterm infants (< 37 wk)	13.6	(7.4–24.0)	(n = 64)	18.6	(10.8–30.4)	(n = 58)
Mean birthweight (g) (after adjustment for gestation)	2720 ± 384.0	(2,625–2,815)	(n = 64)	2696 ± 381.0	(2,597–2,796)	(n = 58)

a. Values are means ± SD (95% CI).
***p < .001

When the data were analyzed by stepwise logistic regression to study the association between the dependent variables, birthweight and gestational age of the infant, separately and the independent variables (age, maternal education, family income, family size, parity, individual weight gain from 26 to 28 weeks of gestation until delivery, postintervention serum retinol and hemoglobin values, and experimental group), the risk of low birthweight (odds ratio [OR], 0.857; 95% CI, 0.77–0.95; p = .003) and preterm delivery (OR, 0.818; 95% CI, 0.74–0.91; p = .000) decreased significantly with increasing serum retinol levels during the third trimester of pregnancy. The risk of low birthweight also decreased significantly with increasing maternal weight gain (OR, 0.687; 95% CI, 0.51– 0.93; p = .014) and parity (OR, 0.321; 95% CI, 0.12–0.87; p = .025 (table 4).

Discussion

We observed in this study that giving pregnant women red palm oil as a supplement providing approximately one RDA of β-carotene significantly improved maternal and neonatal vitamin A status. The safety of red palm oil consumption was established by toxicological and nutritional evaluation of the oil by Manorama et al. in the early 1990s [8, 9]. Since then, evidence has been provided for the health benefits of red palm oil, including supporting cardiovascular health in both experimental animals and humans [21, 22], offering antioxidant potential against certain types of cancers in experimental animals [23, 24], and preventing nutritional deficiencies, most promisingly vitamin A deficiency in children [10–12]. However, there are very few studies documenting the efficacy of maternal vitamin A supplementation in pregnancy.

There are conflicting reports on the changes in serum retinol levels at different periods of gestation. Some authors have observed a progressive decline [25–27], whereas others have observed a rise in serum retinol values with advancing gestation [28, 29]. In the present study, we observed a significant decrease in serum retinol near mid-gestation (26 to 28 weeks) compared with the earlier period of pregnancy, which again increased significantly at 34 to 36 weeks in both groups of women. These changes could be attributed to the normal plasma serum retinol volume changes in pregnancy, which reach peak expansion by 24 to 26 weeks. This expansion causes hemodilution, after which there is minimal or no further significant expansion of plasma volume until term, as demonstrated by Lund and Donovan [30].

Supplementary feeding trials in preschool children have shown that daily supplementation with red palm oil in a diet providing 2,400 μg of β-carotene for one month significantly improved serum retinol status [10]. Sivan et al. [12] reported a reduction in the prevalence of Bitot's spots of 50% and significant improvement in β-carotene levels in preschool children when red palm oil providing 415 μg of β-carotene was administered daily for 10 months. There are several reports indicating beneficial effects of vitamin A supplementation during pregnancy on maternal and neonatal vitamin A status [25, 31, 32]. However, this is not universally accepted, even though daily supplements of up to 10,000 IU per day have been found to have no adverse effects and are recommended by WHO [33].

Food-based approaches to vitamin A supplementation are safe and natural and could be sustainable compared with synthetic vitamin A supplementation, especially during pregnancy. In rural Tanzanian women, maternal supplementation with 1,100 μg of β-carotene from red palm oil daily from the third trimester of pregnancy to the third month postpartum significantly improved maternal plasma and breastmilk β-carotene levels [34]. We demonstrated in this study that dietary supplementation with red palm oil providing 2,173 to 2,307 μg of β-carotene per day for a period of two months significantly improved the vitamin A status of the mother during pregnancy and of the infant at birth. This confirms the bioavailability and efficacy of β-carotene from red palm oil in pregnant women.

We also observed a significantly lower prevalence of maternal anemia at 34 to 36 weeks of gestation in the women receiving red palm oil. It has been consistently shown in both experimental animals and humans that vitamin A is essential for iron mobilization in hemat-

TABLE 4. Association of maternal factors with birthweight and gestational age of the infant (logistic regression model)[a]

Dependent variable	Constant	Independent variable	Regression coefficient (β)	Odds ratio	95% CI	p
Birthweight (g)	5.001	Serum retinol	–0.155	0.857	0.77–0.95	.003
		Weight gain	–0.376	0.687	0.51–0.93	.014
		Parity	–1.138	0.321	0.12–0.87	.025
Gestational age (wk)	4.361	Serum retinol	–0.201	0.818	0.74–0.91	.000

a. The independent variables included in the model were age, maternal education, income, family size, parity, weight gain from 26–28 weeks until delivery, postintervention serum retinol, postintervention hemoglobin, and experimental group. Codes of 1 for birthweight < 2,500 g and 0 for birthweight > 2,500 g, and 1 for gestational age < 37 weeks and 0 for gestational age > 37 weeks, were assigned in the regression model.

opoiesis [35], and the beneficial effects of supplementation of vitamin A along with iron and folic acid on hemoglobin levels in individuals with anemia have been well established [36, 37]. Suharno et al. reported that administration of 8,000 IU of vitamin A along with 60 mg of iron during pregnancy was more effective in eliminating anemia than administration of iron alone [38]. Similar results were obtained by Muslimatun et al. [39] when vitamin A was administered at weekly doses of 20,000 IU with 120 mg of iron and 500 μg of folic acid. However, Semba et al. [40] failed to demonstrate any improvement in hemoglobin when only 30 mg of iron and 400 μg of folic acid were administered with 10,000 IU of vitamin A to a group of pregnant women with a high prevalence of anemia. In the present study, the prevalence of anemia was reduced by consumption of enough red palm oil to provide 2,173 to 2,307 μg of β-carotene per day (the RDA of β-carotene for pregnant Indian women is 2,400 μg), together with 60 mg of elemental iron and 500 μg of folic acid. This result suggests that adequate intake of both vitamin A and iron-folate is required to have a beneficial effect in anemic populations. Maternal weight gain during pregnancy was not influenced by red palm oil supplementation.

Reviews by Kramer [41] and Rush [42] indicate that a few intervention trials using dietary supplements resulted in modest increases in maternal weight gain, whereas some others did not have an impact. There is limited evidence from controlled studies of the effects of supplementation with synthetic vitamin A during gestation on pregnancy outcome [27, 31]. In these studies, supplementation significantly improved maternal and neonatal vitamin A status but had no effect on birthweight. Studies from Nepal found a 40% reduction in maternal morbidity in addition to a reduction in the prevalence of maternal vitamin A deficiency (serum retinol < 0.7 μmol/L), but no effect on birthweight [43, 44]. In the present study, because the sample size is adequate to show a difference of 250 g in birthweight (at $p < .05$ and 80% power), an attempt was made to examine the effect of supplementation with red palm oil as a source of bioavailable vitamin A on the birthweight and gestational age of the infants.

Stepwise logistic regression analysis showed that the risk of low birthweight and preterm delivery significantly decreased with increasing serum retinol levels during the third trimester of pregnancy, irrespective of the group to which the woman was assigned. These results support our earlier observations on the association between low serum retinol levels (< 0.7 μmol/L) during the third trimester of pregnancy and preterm delivery [6]. More research is required to explore the mechanism of the association.

The results obtained in this study show that supplementation with red palm oil as a source of bioavailable vitamin A significantly improves maternal and neonatal vitamin A status, as well as reducing the prevalence of maternal anemia. Hence, red palm oil can be used as a dietary approach to improving the vitamin A status of pregnant women and their infants.

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A multinutrient package of iron, vitamin A, and iodine improved the productivity and earnings of women tea pickers in South India

Tara Gopaldas and Sunder Gujral

Abstract

Tea-picking is a highly skilled activity that is usually performed by women. This study, conducted on the Balanoor Plantations, India, from 1996 to 1998, was successful in empowering 339 women pickers and their families to take iron (60 mg of elemental iron two times a week) and vitamin A (1,600 IU) once a week, and to purchase subsidized iodized salt (30 ppm) from the plantation ration shop. The average hemoglobin level of the pickers rose significantly ($p < .001$) from 11.0 g/dl at baseline to 11.9 g/dl at the end of the nine months of intervention. The average amount of tea per picker increased significantly ($p < .001$) from 22.9 to 25.6 kg. There was a significant decrease in the number of "moderate pickers," who picked between 14 and 25 kg per day, and a significant increase in the number of "good pickers," who picked more than 25 kg per day, and the earnings of the majority of the pickers increased. The management of the estate where the intervention occurred benefited from a decrease in the number of pickers needed during the supplement period from 2,857 to 2,763, with no significant change in the yield per hectare in the two years. The yield per hectare on the control estate was not significantly different from that on the intervention estate, and the average amount of tea picked per worker was the same for the two periods (20.8 and 20.7 kg).

Key words: Enhanced earnings, enhanced productivity, India nutrition, micronutrient supplementation, tea pickers

Introduction

We have reported previously [1] on the significant reduction in the hidden hunger for iron, iodine, and vitamin A among the entire workforce of 617 persons and their families (a total of approximately 2,500 persons) on a tea estate in Chikmagalur District of Karnataka in South India after supplementation with iron, vitamin A, and iodine. The plantation employees were responsible for administering iron and vitamin A tablets to themselves and their families and for purchasing iodized salt from the plantation ration shop. This paper describes the improved productivity and earnings of the women tea pickers.

There have been many demonstrations over the last three decades of the relationship between iron-deficiency anemia and the capacity for physical work [2–7]. Basta et al. [2] observed an increase in the earnings of male rubber tappers in Indonesia of nearly 20% when they were given an iron supplement. The cost of the iron supplement at the time was 50 US cents (US$0.50) per person per year. We attempted to go beyond this by giving a multinutrient supplement of iron, iodine, and vitamin A. In 1997 the cost to the plantation management was only Rs. 12/– (US$1 = Rs. 30) per individual per year. If both cost effectiveness and easy procurement of the multinutrient supplements are taken into account, it is more likely that such projects will be scaled up to state and national levels. A central purpose of the research project from 1996 to 1998 was to persuade and empower the management and the workers themselves to continue with the intervention after our study had been phased out.

The study and control estates had excellent computerized data on crop yield, rainfall, the average amount of tea picked per worker per day, attendance, and so forth to complement our research data. Surprisingly, the tea pickers were not poor. Practically all of the women earned about Rs. 3,000 per month. The majority did not have young children and were between 30 and 50 years of age. Moreover, under the Comprehensive Labor Welfare Schemes (CLAWS) proposed by the United Planters of Southern India (UPASI), the study and control estates provide all their employees with free medical treatment, free crèche facilities, sickness ben-

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efits, free housing, paid leave, maternity benefits, family planning incentive, a reading room with newspapers, a canteen, and recreation expenses. The management of the tea plantations has a permanent workforce as well as temporary workers whom they call as needed. The temporary workers are also trained pickers and receive the same wages as the permanent workforce, but they do not get free accommodation, water, and electricity. The majority of the permanent workforce, but not the temporary workers, receive free housing (three rooms and a toilet), electricity, and piped drinking water. The management also provides its employees with a 10-bed hospital with a fully qualified doctor, head nurse, pharmacist, and head ward boy; two crèches with trained ayahs (caregivers) where the mothers can leave their children under 3 years of age and come to breastfeed their infants during two breaks; an anganwadi (preschool) for children from 3 to 6 years old, with a trained staff to look after the children; a primary school for children from 6 to 12 years old, with trained teachers; and a ration shop where rice is sold at a subsidized rate every week.

During the nine-month intervention, the management provided iodized salt at a subsidized rate. Almost all the pickers had a primary or secondary level of school education. Nevertheless, the previous study [1] found that a large proportion of them were deficient in iron, iodine, and vitamin A and had intestinal helminth infections. The overall objective of the study was to determine whether the productivity of the workers on an Indian tea estate could be improved by providing a simple, cost-effective, and sustainable micronutrient package of iron plus vitamin A and iodized salt to all the workers and their families over a nine-month intervention period.

Methods

Study design

The entire study estate workforce of 617 (pickers and nonpickers) and their families (approximately 2,500 persons) participated in the nine-month micronutrient intervention from August 1996 to April 1997. The internal control for the study was a preintervention period from August 1995 to April 1996. In addition a control estate was included for comparison. Table 1 shows the similarity of the two estates.

Micronutrient intervention

The supplement consisted of 240 mg of ferrous sulfate delivering 60 mg of elemental iron twice a week, 1,600 IU of vitamin A once a week, and heavily subsidized iodized salt (30 ppm of iodine) to be used for daily cooking for the whole family. The workers were given 250 tablets of iron and 125 capsules of vitamins A + D in screw-top plastic containers, which was enough to last a family of five persons for five months. The containers were given to the workers during the baseline survey in August 1996 and refilled in December 1996 to last another five months. The cost of the micronutrients was Rs. 61.50 per family per year or Rs. 12 per individual per year.

Information-education-communication sheet

A simple information-education-communication (IEC) sheet was developed for the dosing regimen and its potential benefits in Kannada (the major local language) and distributed to the workforce and supervisors at frequent intervals throughout the intervention period. The supervisors were responsible for transmitting this to their workers.

TABLE 1. Comparison of study and control estates

Feature	Study estate	Control estate
Salaries paid to workers per labor laws in force	Yes	Yes
Implementation of the Comprehensive Labour and Welfare Scheme (CLAWS)	Yes	Yes
10-bed hospital with resident doctor and staff	Yes	Yes
No. of women tea pickers	350	390
No. of male workers	267	150
Acres planted with tea	552	406
Acres planted with coffee	210	309
Elevation above sea level (ft)	1,200	1,200
Tea factory	Yes	Yes
Crop yield in April-March 1995–96 (kg/hectare/yr)	2,378	2,278
Crop yield in April-March 1996–97 (kg/hectare/yr)	2,356	2,328
Average amount of tea picked August-April 1995–96 (kg/worker/day)	22.9	20.8
Average amount of tea picked August-April 1996–97 (kg/worker/day)	25.6	20.8
Annual rainfall (inches)		
1995–96	99	211
1996–97	98	244
No. of rainy days		
1995–96	126	121
1996–97	125	107

Data processing and analysis

Data entry and validation

The data were entered by using Foxbase and data files were created. The data were checked and validated for internal consistency. Separate files were created for attendance and pluckability data.

Tabulation and statistical analysis

SPSS was used for tabulation and statistical analysis. SPSS commands were written to describe all variables and specify missing values. SPSS commands to produce tables were written and tested. SPSS commands were written to apply statistical tests (*t*-test, chi-square test, Pearson correlation, and analysis of variance). When the complete data set was ready, tables were constructed and statistical analysis was carried out. Differences with $p < .05$ were considered significant. Bar and line charts were generated by using Harvard Graphics.

Results

In the study estate, the average weight of tea leaves picked increased to 25.6 kg during the nine-month intervention period from 22.9 kg during the same nine-month period in the previous year, with essentially no change in the composition of the work force or in the total productivity per hectare (table 2). The average gain of 2.70 kg was highly significant ($p < .001$). The average weight of tea picked in the control estate did not increase.

The average crop yield in the comparable periods before and during the study were 1,668 and 1,607 kg/hectare, respectively. This is extremely important to the interpretation of the data, since the amount of tea a worker can pick depends on the yield of the bushes, as well as her picking ability. Since the yields were almost identical in the two periods, it was appropriate to compare the amount picked per worker in each period. This amount increased significantly in the study estate from 22.9 kg in the preintervention period to 25.6 kg in the intervention period, while it remained stagnant at 20.80 kg (preintervention) and 20.69 kg (postintervention) in the control estate (fig. 1).

The Labour Law requires that a worker pick a minimum of 14 kg of tea leaves per day to be paid the minimum of Rs. 43/– per day. The management would rather pay a "good picker" (one who picks more than 25 kg per day) Rs. 8/– in addition to Rs. 43/– than employ a borderline picker at Rs. 43/–. During the preintervention period, there were 113 good pickers, who picked an average of 28.1 kg per day. Their average hemoglobin level was 11.1 g/dl. During the intervention period, the number of good pickers rose to 166, the mean amount they picked per day increased to 29.3 kg, and their mean hemoglobin level increased to 11.9 g/dl. In contrast, there were 224 "moderate pickers" (who

TABLE 2. Effect of the micronutrient package (iron, vitamin A, and iodine) on hemoglobin levels and amount of tea picked over nine months of intervention

Received package during intervention (%)	Used package during intervention (%)[a]	Hemoglobin (g/dl)		Amount of tea picked (kg/picker/day)[b]				
					Preintervention		Intervention	
		Preintervention	Intervention	Month	*N*	Mean	*N*	Mean
Aug '96–Dec '96 (4½ mo) 99 (*N* = 334)	Regular 54 (*N* = 180)	Regular 11.1 (*N* = 180)	Regular 12.0 * (*N* = 180)	Aug	327	25.7	315	27.4***
				Sep	313	24.8	322	33.6***
				Oct	326	29.2	315	27.6**
Dec '96–Apr '97 (4½ mo) 99 (*N* = 334)	Irregular 44 (*N* = 147)	Irregular 10.9 (*N* = 147)	Irregular 11.8* (*N* = 147)	Nov	324	27.7	321	34.4***
				Dec	326	22.4	315	25.9***
				Jan	313	17.3	268	16.3*
	Stopped 2 (*N* = 7)	Stopped 11.0 (*N* = 7)	Stopped 11.3 (*N* = 7)	Feb	311	17.6	317	20.5***
				Mar	305	16.1	288	18.6***
				Apr	322	24.8	302	24.2
Overall 99 (*N* = 334)	Overall about half were regular users	Overall 11.0	Overall 11.9***	Overall	2,857	22.9	2,763	25.6***

a. Regular: took iron supplement twice a week, took vitamin A once a week, and used iodized salt daily in cooking. Irregular: took iron and vitamin A once a week. Stopped: stopped taking iron and vitamin A within the first week but continued to use salt in daily cooking.

b. About 95% of the sample was available both before and during intervention for calculation of the amount of tea picked. Note the variation over nine months in the number of pickers and the average amount picked.

***$p < .001$, **$p < .01$, *$p < .05$.

picked between 14 and 25 kg per day) and 3 "poor pickers" (who picked less than 14 kg per day) in the preintervention period. Their average picking rate was 19.9 kg, and their mean hemoglobin level was 11.0 g/dl. At resurvey, there were 173 moderate pickers, with a mean picking rate of 21 kg. Thus, the micronutrient intervention was successful not only in improving the mean hemoglobin levels, but also in reducing the number of moderate pickers and increasing the number of good pickers.

In the study plantation, more tea was picked by fewer workers and profitability improved. The number of pickers employed decreased substantially from January to April in the nine-month intervention period. In all, 94 fewer pickers were employed during the intervention period (2,763) than during the preintervention period (2,857). The cost of labor saved was Rs. 1,11,800 in the intervention period.

In the intervention period, 166 good pickers earned about Rs. 245/– per month (25 days) as an incentive over and above the mandatory wage of Rs. 1,075/– per month (fig. 1). The 173 moderate workers would have earned an average of Rs. 135/– as an incentive over and above their mandatory wage. Management paid approximately Rs. 80,000/– more as an incentive wage in the intervention period than in the preintervention period. Hence, a very large number of the women (339) picked more tea and earned more money.

Management paid Rs. 43,000/– for the micronutrient supplements, but they benefited from the better health of their workforce and the higher rate of picking per worker. Hence, what management saved by employing fewer pickers, Rs. 12/– (approximately 40 US cents in 1997), more than compensated for the cost of the micronutrients for this intervention (Rs. 43,050). In other words, management more than recovered the money and time spent in implementing and managing this intervention.

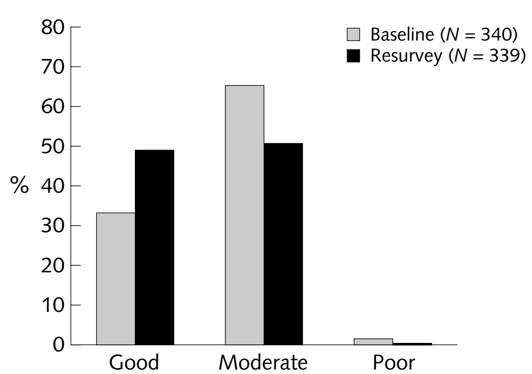

FIG. 1. Shift in the proportions of good (> 25kg/day), moderate (14–25 kg/day), and poor (< 14 kg/day) pickers from baseline to resurvey in the study estate. The shift is significant at $p < .001$

Discussion

Potential confounders

Rainfall and season are important determinants of the average amount of tea picked per worker per day. In this study, the correlation coefficient (0.81) between crop yield and average tea leaves picked (kg/worker/day) was highly significant at the .01 level. The best crop-yield months in the nine months of both the preliminary and the intervention periods were August, September, October, and November; the moderately good crop months were December and April; and the sparse months were January and February. Therefore, comparisons between the average picked per worker over nine months in different years are not valid unless the yields are the same in the two periods. Because this was the case for the two years of this study, the comparisons between the preintervention and the intervention periods can appropriately be made.

We also have monthly data for the crop yield per hectare and the average amount of tea picked per worker. Both measurements show marked monthly variations, but for most months the latter measurement is higher during the intervention year. Comparisons of groups of pickers on the same plantations can also be confounded by differences in the yield of different sectors, so it was important to include all areas and pickers in the data.

Unlike the studies cited below, in which iron supplementation improved work performance, ours was not a double-blind study, and the workers receiving the supplement knew that improved health and performance were expected. This knowledge alone could have accounted for an initial improvement by the "Hawthorne effect" (an increase in productivity by study subjects in response to the increased attention and the subtle pressure of being observed during an experimental study). However, there is no precedent for such a response to be sustained for many months unless there is also a biological basis. The improved hemoglobin values offer a biological explanation.

Significance of correcting deficiencies of iron, iodine, and vitamin A

There is proof from tea plantation–based studies in India [3], Indonesia [2, 7], Sri Lanka [6, 8], and China [9] of increased productivity of anemic workers given iron and a lack of similar evidence that giving iodine or vitamin A has a similar effect. In Indonesia the iron supplementation was continued by the plantation after completion of the study and spread to other plantations [2].

As reported above, the intervention increased labor productivity in this study, as measured by increases in the average amount of tea picked. This was associated with a significant increase in the mean hemoglobin levels of the women pickers. Pickers with hemoglobin levels of more than 12 g/dl had better monthly attendance (more than 21 days) and picked more than those whose hemoglobin levels were between 10 and 11 g/dl at resurvey [1]. We recognize that with the administration of four micronutrients, the present study cannot distinguish which are responsible for the positive results reported. However, there is extensive evidence from double-blind single-nutrient supplementation with iron alone to attribute these improvements to the iron and not the vitamin A or iodine.

A 1983 study in Kerala, South India [3], showed that iron supplementation for 100 days increased the mean hemoglobin level of anemic women tea pickers from 6.2 to 8.5 g/dl, the mean picking rate from 17 to 22 kg per worker per day, and the mean monthly attendance from 19 to 22 days. A 1990 investigation in Bombay of the effect of daily ferrous fumarate on the iron status and work capacity of women concluded that even middle-class Maharashtrian women suffering from mild to moderate iron-deficiency anemia showed significant benefits in increased work capacity and hemoglobin levels [9].

Edgerton et al. [5, 6] in a Sri Lankan study on iron-deficiency anemia and its effect on worker productivity and activity patterns among female tea pickers also established the significant relationship between iron supplementation and work capacity. The impact evaluation was done after two months (the entire duration of the study). The investigators reported that work productivity had improved in subjects even with moderate iron deficiency (hemoglobin levels of 11 g/dl). Subjects with lower hemoglobin concentrations initially experienced the greatest increase in productivity. Hussaini and co-workers [7] compared the effect of the use of iron-fortified salt (1.5 mg of iron per gram of salt) and supplementation with 60 mg of elemental iron per worker per day for four months on the productivity of anemic female tea pickers on a plantation in Indonesia. Iron supplementation with either form of iron enhanced hemoglobin status and increased the average amount of tea picked. A direct relationship between hemoglobin concentration and physical work capacity has also been established for agricultural labor in Guatemala [10], Africa [11], and Indonesia [2, 7]. A 1994 study in China found that iron supplementation enabled iron-deficient female cotton mill workers to do the same work at a lower energy cost [12].

Our study was longer than the above studies and was designed to be a demonstration that would lead to sustainable action. We attempted to empower a tea plantation's management and workers to implement and manage their own micronutrient program. Sustainability was helped by the fact that all family members received the nutrient supplements and the effects on their health were evaluated. Most of the women tea pickers were responsible about dosing themselves and their families. Moreover, the plantation has continued to give the iron supplements, iodized salt, and vitamin A. On our advice, they also added deworming tablets (400 mg of albendazole) twice a year.

Increase in plantation profitability

Another important objective of our study was to improve the earnings of the women tea pickers and the profitability of the plantation. The cost of the triple supplementation was very cheap, at Rs. 61.50/– (about US$1.23 in 2002) per family per annum, or Rs. 12/– (25 US cents) per individual (assuming that there were five individuals per family). Basta et al. [2] quoted a figure of 50 US cents for supplementation with 100 mg of elemental iron per day for 60 days/man/year in the 1970s.

We do not know the basis for management decisions, but our data show that during the intervention period 94 fewer pickers were employed to pick more tea leaves per person than in the previous year, even though the crop yield per hectare was essentially the same in the two years. This translates to a saving in wages of a little more than Rs.1,11,800.

Concluding comments

Usually, multinutrient interventions are as easy to implement as single interventions and are more cost effective [13]. Moreover, vitamin A contributes to the effectiveness of iron supplementation [14–15]. Where these micronutrient deficiencies are common, we believe that it is good sense to deliver at least iron, iodine, and vitamin A concurrently. This study has shown that twice-weekly iron supplementation worked well. There is extensive evidence from other studies that weekly iron supplementation is as effective as daily supplementation [16–19]. We chose twice weekly to help ensure that the families took the iron at least once a week. The fact that the Goddess Lakshmi (Friday) and the God Hanuman (Tuesday) are venerated in Karnataka also helped the subjects to remember to take their tablets. However, a strategy that advocates either biweekly or weekly iron supplementation, particularly in institutions such as schools or colleges or even in sectors such as industry or agriculture, is likely to be more acceptable, cheaper, and more sustainable than daily supplementation.

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A method of preserving and testing the acceptability of gac fruit oil, a good source of β-carotene and essential fatty acids

L. T. Vuong and J. C. King

Abstract

*Gac fruit (*Momordica cochinchinensis *Spreng) is indigenous to Vietnam and other countries in Southeast Asia. Its seed pulp contains high concentrations of carotenoids, especially the provitamin A, β-carotene. In northern Vietnam, gac fruits are seasonal and are mainly used in making a rice dish called xoi gac. The purpose of this study was to develop a method to collect and preserve gac fruit oil, to evaluate the nutritional composition of the oil, and to assess the acceptability of the gac oil by typical Vietnamese homemakers. One hundred women participated in training to learn how to prepare the fruits and operate the oil press. The women also participated in a survey of gac fruit use and their habitual use of animal fat and vegetable oil. Among all the participants in the training and surveys, 35 women actually produced oil from gac fruits grown in the village, using manual oil presses and locally available materials. The total carotene concentration in gac fruit oil was 5,700 μg/ml. The concentration of β-carotene was 2,710 μg/ml. Sixty-nine percent of total fat was unsaturated, and 35% of that was polyunsaturated. The average daily consumption of gac fruit oil was estimated at 2 ml per person. The daily β-carotene intake (from gac fruit oil) averaged approximately 5 mg per person. It was found that gac oil can be produced locally by village women using manual presses and locally available materials. The oil is a rich source of β-carotene, vitamin E, and essential fatty acids. Although the β-carotene concentration declines with time without a preservative or proper storage, it was still high after three months. The oil was readily accepted by the women and their children, and consumption of the oil increased the intake of β-carotene and reduced the intake of lard.*

Key words: β-Carotene, essential fatty acids, gac fruit, oil production, Vietnam

Introduction

In rural Vietnam, where animal foods are not economically available, adequate intake of food rich in β-carotene might alleviate vitamin A deficiency. Among all the fruits and vegetables available in Vietnam, ripe gac fruit pulp contains the highest β-carotene concentration (17,000-35,000 μg/100 g of edible portion) [1, 2]. In addition to β-carotene, gac fruit pulp contains a significant amount of oil, 69% of which is unsaturated fatty acids [3]. Descriptions of gac fruit (*Momordica cochinchinensis* Spreng), its traditional use in Vietnam, and the bioavailability and efficacy of xoi gac (a rice preparation with gac fruit pulp) in improving plasma retinol and β-carotene levels have been published elsewhere [3–5]. Gac fruit, a rich source of β-carotene, is indigenous to Vietnam and easy to cultivate. Growing the gac vine does not require significant land or cash investment. In most communes in northern Vietnam, 30% to 35% of households grow the gac vine.*

Despite its nutritional value, the fruit has been underutilized because of seasonality and lack of postharvest processing. Ripe gac fruits are available for only about three months each year. Gac fruit oil is available all year, although the fruit itself is available only from October to February. During the months gac fruit is available, the local people make xoi gac, a rice dish reddened by the juice of gac pulp. This rice dish is commonly eaten for breakfast and is traditionally served on special occasions such as weddings or New Year celebrations. Because β-carotene is best preserved and delivered into the body in oil, a process to extract oil from the gac pulp was devised and carried out on

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* Personal communication, Mr. Bach Trung Hung, Vietnam Agricultural Science Institute (VASI), Hanoi, September 1999.

a small scale in Vietnam in 1999. Based on the success of that pilot production, a community workshop to produce gac pulp oil was conducted in December 2000. The main objective of the project was to assess the feasibility of producing gac oil using only a hand-operated oil press and locally available materials. A secondary objective was to evaluate the acceptability of the oil to typical Vietnamese homemakers. Gac fruit oil should not be used in frying, because high temperatures quickly destroy β-carotene. The viscosity of the oil makes it more appropriate to be mixed in with cooked rice or added directly to soup or vegetable dishes

Materials and methods

Location

The production was carried out at the health post of Tan-Minh village of Soc-Son District, a group of seven villages with approximately 2,200 households each, about 35 km from Hanoi City. Two villages, Tan-Minh and Bac-Son, were selected as the study sites. The two villages were not adjacent to each other but were comparable in terms of demography, geography, and socioeconomic status (table 1). The Soc-Son District was selected because it is a poor district with a high percentage of undernourished children and low-income households; the majority of the households had no income-generating activities other than rice farming. In the past five years, there has been no nutrition intervention project in the two villages. Because workers at the health post in the villages follow the directive of the district health center, it was essential to have the full cooperation of administrators and health officials at the district level. Selection of the two communes (Tan-Minh and Bac-Son) was approved by local administrators at the district and commune levels.

Selection of participants

Health workers at each commune assisted in identifying households growing the gac vine and having at least one child under five years of age at home. Women of those households were invited to learn about gac fruit oil production and participate in the study. The selection criteria were willingness to participate in the production of gac oil and the gac oil consumption survey, the presence of at least one child of preschool age in the household, ability to provide at least 100 kg of gac (80 to 90 fruits) from a household garden, and the presence of one adult in the household willing and capable of operating the oil press. Since women in these villages have the main responsibility for cooking and food selection in the households, all of the participants were women. Husbands were encouraged to participate in the production of the oil.

TABLE 1. Demographic data of Tan-Minh and Bac-Son communes

Feature	Tan-Minh	Bac-Son
Population	11,836	12,000
Area (km^2)	33	34
No. of households	2,416	2,400
No. of women 15-49 yr old	3,084	3,038
No. of children < 5 yr old	1,150	1,161
% of children < 5 yr old who were malnourished	36.5	37.01

Fifty-two women from Tan-Minh and 48 women from Bac-Son who met the selection criteria participated in the introductory training meeting on producing gac oil and participated in the survey of gac fruit and oil use. Thirty-five women from Tan-Minh were randomly selected to participate in the oil production. Thus, all 100 participants received instructions on how to produce gac fruit oil, from preparing the fruit to operating the oil press. However, only 35 women actually produced the oil from fruit gathered in their gardens. All women participating in the oil production signed an agreement form after the details of the study were explained. Each produced approximately 1 L of oil.

Nutritional analysis

Sample collections

Over three days, a 50-ml sample was taken from each day's yield of gac oil. The samples were packed in 10-ml vials and sent to the University of California, Davis, California, USA for analysis. A second set of 10-ml samples was collected and stored at the houses of participants under the same conditions as other cooking oils for three months. The purpose of collecting the second set was to determine the stability of carotenoids and other nutrients in the oil after three months under the storage conditions typically used in households.

Acceptability survey

Gac production and use survey

Before production, a survey of gac fruit planting and use of gac fruits, fat, and oils was conducted among all participants, including those not involved in the oil production.

Gac fruit oil use and acceptability survey

One hundred women from Tan-Minh and Bac-Son villages participated in personal interviews by the primary investigator and two local research assistants. Survey forms, in Vietnamese, contained mostly open-ended questions about the use of gac fruits, oil, and lard. Each participant who received 1 L of gac fruit oil for home use was instructed to record in detail the amount and the way the oil was used each time on a preprinted form. The form was collected at a follow-up interview three months later. During the interview, the participants were asked whether they liked gac fruit oil, about the ways the oil was used, and any changes in the amount of oil and lard used during the study period. To quantify the amount of gac oil used, the remaining oil in each bottle was weighed.

Results

Oil preservation

Gac oil production

Production was carried out in early December when gac fruits were in season. Rice harvesting had been completed, and there was no other economic activity during this time in these villages; hence the production of gac oil did not interfere with the regular income-generating activities of the local women. The total amount of time needed for oil production was two days for each group of 10 women. It takes approximately 100 kg of whole fresh gac fruits (approximately 80 to 90 fruits) to produce 1 liter of gac oil. Thirty-five women were selected from Tan-Minh village to produce the oil. Two oil presses were shared among the participants. The gac fruits used to produce the oil were purchased from the participants. The purchase price was agreed between the project and a farmers' cooperative that represented the growers in the community. About 36 L of gac oil were produced. Of this, 600 ml was set aside for chemical analysis, and the rest was divided among the participants.

The processing method for gac oil, which included seeding, drying, pressing, separation of water, and packaging, was devised and tested by the primary investigator prior to oil production. The technique was designed to retain the maximum amount of β-carotene with a minimum amount of water activity and a low rancidity value in the oil.

The cost of production, including fixed costs (oil press, dryer, filter, facility, and storage) and variable costs (fruit, labor, containers, coal, electricity, and water) was between US$20 and $30 per liter.

Seeding and drying

Although gac seeds also contain oil, for this project only gac pulp oil was extracted. The 35 participants were divided into three groups, and preparation of the fruit for oil production was scheduled for three consecutive days. All fruits were weighed, washed, and split in half. All seed pulp (covering seeds) was then removed and dried. The pulp dried quickly (one hour at 60°C) in a drying oven until the surface was no longer sticky. After the pulp was dried, seeds were removed from the pulp. The pulp can also be covered by clean cloth and sun-dried for four to five hours, or in a pan over low flame for about one hour. However, those techniques are expected to incur higher losses of light- and heat-sensitive carotenoids. Drying seed pulp before seeding has been proved to speed up the seeding process and reduce water, which is necessary for oil production. After it was seeded, the pulp was dried again in a drying oven at 60°C until the volume of water was reduced to about 12% to 15%.

Pressing and oil separation

Just before pressing, the gac pulp was smashed and heated slightly by hot steam for five minutes, since heating increases the yield of the seed oils [6]. The pulp was pressed by a manual single press, powered by a four-ton hydraulic jack (Bottle Jack, Napa Lifting Equipment, made in China for Bakkamp). The press prototype was provided by the Pilot Plant of the Department of Food Science and Technology at the University of California Davis and brought to Hanoi. Using the prototype as an example, a second press was constructed locally in Vietnam. Each press weighed about 35 kg and could process 1 kg of gac pulp per batch. The pressing time, including loading and cleaning, was 10 to 20 minutes per batch. The oil produced was allowed to settle in a large container and filtered through a cloth into individual 1-L amber Boston round bottles. At the end of production, each participant received a labeled bottle of oil, along with an oil-use record form.

Workshop

Detailed written instructions of the production process in Vietnamese were developed and distributed to all participants in a workshop before production started. The workshop allowed participants to review the procedure, ask questions, and provide feedback prior to the start of production. During the workshop, use of the oil presses and basic food hygiene were demonstrated to all participants. Although 95% of the villagers could read and write, the procedure of oil production was also explained to all participants orally by field workers.

Nutritional composition of the oil and stability of the nutrients

Chemical analysis of gac fruit oil was performed at the laboratory of the Department of Nutrition, University of California Davis, and by Analytical Services VFHA (Vitamins and Fine Chemicals Division) of Hoffman-La Roche. Identification and quantification of carotenoids and vitamin E in gac fruit oil were performed by reversed-phase high performance liquid chromatography (RP-HPLC) using published methods [7,8]. The results listed in table 2 are the means of triplicate assays. β-Carotene and lycopene are the major carotenoids in gac fruit oil.

Gac fruit oil distributed to participants of the study was kept in sealed amber bottles at room temperature, which in the study area during the season was between 25° and 27°C. Since the oil did not contain preservatives or antioxidants, and refrigeration is not available in rural areas, loss of β-carotene by oxidation was the major concern. A sample was collected after three months in clear 10-ml scintillation vials and sent to the University of California at Davis and Hoffman-La Roche in Basel, Switzerland, for analysis. The oil samples were kept at 0°C until analyzed by RP-HPLC. There was a 47% reduction of β-carotene in the oil compared with the first analysis. The concentration of β-carotene in this sample was 1,622 parts per million (ppm). There was no deterioration of vitamin E in the oil after six months.

Results of surveys of acceptability by the women and use of gac fruits and gac oil

Acceptability

Ninety-four percent of all participants in the gac fruit oil survey used gac fruit oil daily. The reasons given for using it included the following: it was convenient to use in making xoi gac or in rice (100%); it was flavorful (82%); it was healthful (47%); it was good for the skin (29%); children preferred rice mixed with gac fruit oil (24%); and it was cheaper than lard (17%). Some respondents liked to mix gac fruit oil with other food because of the color (12%).

Use of gac fruits

Less than 50% of the total number of gac fruits harvested was consumed. The rest was given away, sold, or, in few cases, used as pig feed. Growers with large yields (100 kg or more) sold the fruits at local markets or to vendors who supplied gac fruits to markets in Hanoi. Only 10% of the growers could quantify the income received from selling gac fruits. Some answered that the amount was too insignificant to remember. All respondents used gac pulp in preparing xoi gac. In addition to making xoi gac, 25% of respondents cooked gac seed kernels with eggs for children, 21% mixed gac pulp with other vegetables in stir-fried dishes, and one respondent used the mesocarp (peel) of the fruit as a vegetable. Few women (5%) preserved gac pulp with sugar or alcohol, and 4% of them fed raw gac pulp to their children. None of the respondents had previously heard of gac fruit oil (table 3).

All respondents stated that gac fruit was healthful; 35% stated that gac fruit was good for the eyes, and some believed that gac seed kernel contained vitamin A. Many respondents (18%) thought that gac fruit was good for the blood, perhaps because of the red color of the pulp. Some women said that gac pulp added color to skin (4%). Some respondents also believed that gac fruits could be used to relieve headache (2%), lower blood pressure (1%), treat diarrhea in children (4%), and relieve dizziness (2%). Eight percent of the respondents thought that gac fruit maintained a healthy body, and one said that eating xoi gac made her feel good.

Use of gac fruit oil

Table 4 contains information from the follow-up interviews of the 35 participants who produced the oil. The survey was conducted three months after the oil production. The interviews were performed by the primary investigator and field assistants at the Tan-Minh health post. At this time, the amount of leftover oil in the bottles distributed to the participants was recorded. Samples of the oil were also collected to determine the loss of β-carotene and other nutrients after three months of storage under typical local conditions.

All of the 35 participants said they used gac fruit

TABLE 2. β-Carotene, lycopene, and α-tocopherol concentrations (μg/ml) in gac fruit oil

Carotenoid	1st analysis (March 2001)	2nd analysis (June 2001)
Total carotenoids	5,770	3,190
β-Carotene and isomers	2,710	1,622
Lycopene	3,020	1,186
α-Tocopherol	334	380

TABLE 3. Uses of gac fruits in food by growers and participants in the study

Use of fruit	% (n = 100)
Making xoi gac	100
Pulp cooked with other vegetables	21
Pulp preserved in alcohol or sugar	5
Mesocarp stir-fried with other vegetables	1
Pulp eaten raw	4
Seed kernels stir-fried with egg	25

TABLE 4. Uses of gac fruit oil by participants in oil production

Use of oil	% (n = 35)
Making xoi gac	100
Mixed with a vegetable dish	100
Mixed with cooked rice	100
Mixed with soup	100
Vitamin supplement for children	12
On skin	40

oil daily. Most of these respondents perceived that gac fruit oil had benefits for the health of their children. All mothers gave gac fruit oil to their children every day with rice and other dishes, and 12% also gave it directly to their children as a supplement. After the study, 82% of the women requested assistance in planting techniques and materials in order to produce more gac fruits. Sixty-five percent wanted to produce gac fruit oil for home use, and 18% wanted to make gac fruit oil to sell for extra income. Fifty-three percent of the participants wanted to have a larger-scale production of the oil so that everyone in the community could have gac fruit oil. Six percent complained that the production was time-consuming and the press was too hard to operate.

Impact of gac oil use on diet quality

Daily β-carotene consumption

Although gac fruit oil was a new food to the participants, it was well accepted because it was convenient to use, had the familiar gac flavor, and was perceived to have heath benefits. According to data from the gac oil use form and the amount left over in the bottles after three months, a household of five people consumed an average of 840 ml of gac oil over three months. The daily consumption per person was estimated as 1.9 ml, which would provide about 5 mg of β-carotene daily.

Daily lard and oil use

In these villages, peanut oil was the only type of vegetable oil available. Fifty-six percent of all respondents did not use oil at all, and 90% stated that they used oil only for deep frying. On the average, oil consumption per household of five people was one half-liter per month. All respondents preferred pork fat to vegetable oil. The reasons given were its taste, convenience, availability, and cost. In these villages, lard is sold in the market in the form of raw fat, which is cut into small pieces and fried. Both the liquid and the fried fat are used. The liquid fat (lard) is used in the same way as vegetable oil: drizzled directly onto rice when other oils are not available. Fried pork fat may be eaten with rice instead of meat or mixed with vegetables. Pork fat is meat to poor families. Thirty-five percent of the women said that they did not use vegetable oil because their children ate more rice with fried pork fat. Most respondents (67%) believed that lard was more healthful than vegetable oil.

Discussion

This study demonstrated that it is feasible to preserve gac oil for year-round use. The preservation process is low in cost and can be performed with the use of local resources.

Drying box

It was critical to dry the pulp before pressing to remove water, which reduces the oil's shelf-life. The drying box used in this study is simple to construct and very cost effective. The temperature is controlled by attaching a thermometer inside the oven wall and adjusting the heat by removing or adding more coal to the burners periodically. This kind of drying box can also be used on a large scale and is more effective and cost efficient than electrically powered heating chambers.

Oil press

The oil press was a modified hand-operated screw-press. The power for the pressing was provided by a removable 4-ton hydraulic jack. The press can easily be disassembled, making it convenient to transport and store, while the steel frame provides sufficient weight and stability for the pressing. This manual press can be used in small household production. However, for a larger-scale application, or at a community level, a small, electrically powered, continuous oil expeller is recommended. The oil yield from the manual press is about 50% of that from a mechanical press, but the latter requires more time for loading the press with fruit and for cleaning between batches.

Local acceptability

Gac oil has a very mild nutty taste, comparable to that of sesame or peanut oil. The oil has a viscosity similar to that of red palm oil and an intense red color. The field setting and budget limitations did not allow a complete sensory evaluation; however, personal in-depth interviews in combination with investigators' observations revealed a high degree of acceptability among the participants as well as the fieldworkers.

The uses of gac oil were expanded beyond the traditional uses of gac fruit. Gac fruits have been used mainly to make xoi gac for special occasions, such as weddings or Tet. With the availability of gac oil, the participants used it daily in cooked rice and mixed with stir-fried vegetables, meat dishes, tomato-based dishes, or soup. Some participants (12%) gave gac oil to their children every day as a vitamin supplement.

Nutritional quality of gac fruit oil

The total carotenoid concentration of gac fruit oil is 5,770 ppm, consisting mainly of two carotenes, β-carotene and lycopene. The concentration of the most efficient provitamin A carotene, trans-β-carotene, is more than five times that in red palm oil [9]. There is a quantifiable amount of α-carotene in gac oil and a small amount of canthaxanthine. The distribution of carotenes in gac oil is closer to that in tomatoes. The concentration of vitamin E, expressed as the concentration of α-tocopherol, is 330 ppm. As a natural antioxidant, vitamin E helps protect gac oil from oxidation. The percentage of loss of β-carotene after three months without a preservative or proper storage was 47%. However, gac fruit oil kept at room temperature for three months still provided 1,622 ppm of β-carotene and 330 ppm of α-tocopherol.

The concentration of saturated fatty acids in gac fruit oil is lower than that in animal fats and coconut oil, and the concentration of polyunsaturated fatty acids is higher (table 5). Because saturated fatty acids are associated with an increased risk of cardiovascular disease [10] and polyunsaturated fatty acids may be protective for normal development [11,12], gac fruit oil may have a health advantage over coconut oil and fat of animal origin.

Impact of gac fruit oil on the health of children

Eighty-eight percent of the participants reported that they had reduced the amount of animal fats and vegetable oils they used and replaced them by gac fruit oil. Vegetable oil consumption was reduced in 29% of the households. Replacement of pork fat with gac fruit oil increased the intake of β-carotene and essential fatty acids and lowered the intake of saturated fatty acids. Studies of children and adolescents in developed countries and countries in transition show a correlation between high intakes of foods rich in saturated fatty acids and cholesterol with an increasing prevalence of obesity, cardiovascular disease, and other degenerative diseases [13,14]. Although the problems of obesity and cardiovascular disease are not prevalent in the population studied here, reduction in the daily intake of animal fat will probably have a positive long-term effect on health.

Conclusions

This study shows that gac fruit oil can be produced at the household or community level with the use of a hand press and locally available materials. The oil has a high concentration of β-carotene and is well accepted by local people in their daily diet and in cooking. The production of gac fruit oil increased the intake of β-carotene and extended the use of gac fruits beyond the season when gac fruits are available. In addition to provitamin A carotenoids, gac fruit oil provided essential fatty acids that are important for proper growth and development in children. Household consumption of animal fat was lower when gac fruit oil was available. Future work is needed to achieve the commercial production of gac oil as a food source for Southeast Asia.

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TABLE 5. Nutritional quality of gac fruit oil and of other fat and oil sources (per 100 g of edible portion) [a]

Oil	Carotene (μg)	Vitamin E (mg)	Vitamin A[b] (μg RE)	Saturated fat (g)	MUFA (g)	PUFA (g)	Cholesterol (mg)	Energy (kcal)	Phytosterol
Coconut	—	0.280	0	87	6	2	0	862	86
Corn	—	21.1	0	13	25	62	0	884	968
Gac[c]	577	33	40	31	45	24	0	n/a	n/a
Lard	—	0.12	—	41	47	12	12	902	0
Olive	1	12.4	0.1	14	77	9	0	884	221
Peanut	—	12.9	—	18	49	33	0	884	207
Red palm[d]	50	21.7	8	48	37	10	0	n/a	n/a
Soy bean	0.168	11.2	—	15	24	61	0	884	250

RE, Retinol equivalents; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

a. USDA Nutrient Database for Standard Reference, Release 13, November 1999, USDA, Nutrient Data Laboratory, Agricultural Research Service.

b. Based on a conversion ratio of 6 to 1 for β-carotene to retinol.

c. Data from this paper.

d. From Nagendran et al. [9].

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Is dietary diversity an indicator of food security or dietary quality? A review of measurement issues and research needs

Marie T. Ruel

Key words: Child growth, dietary diversity, dietary quality, child nutritional status, food security, nutrient adequacy, validation studies

Although dietary diversity is universally recognized as a key component of healthy diets, there is a lack of consensus on how to measure and operationalize it. This literature review focuses on issues of dietary diversity in developing countries, but it also draws upon experience from developed countries. The study considers the following questions:

» How is dietary diversity conceptualized, operationalized, and measured, and how does it relate operationally to dietary quality?
» Is there an association between dietary diversity and nutrient adequacy in developing countries? Between dietary diversity and child growth?
» What is the relationship between household-level dietary diversity and socioeconomic factors and food security?
» What key measurement issues need to be addressed to better operationalize and understand dietary diversity?

How is dietary diversity conceptualized, operationalized, and measured?

Dietary diversity is usually measured using a simple count of foods or food groups over a given reference period. Our overview, however, revealed that studies in developed and developing countries have used a variety of food and food-group classification systems, different numbers of foods and food groups, and varying reference period lengths (ranging from 1 to 15 days). Research should be conducted to validate and compare indicators based on different methodological approaches. It would also be useful to continue to explore whether indicators based on food groups (a simpler approach) perform as well as those based on single foods in predicting outcomes of interest.

Is dietary diversity related to nutrient adequacy and child growth?

Our review of developing-country studies confirms the positive associations found in developed countries between dietary diversity and nutrient adequacy (i.e., diets that meet requirements of energy and all essential nutrients). Additional validation studies with existing data sets should be carried out to confirm these findings in a variety of contexts and population groups, and to compare diversity indicators constructed using different approaches.

Dietary diversity has also been consistently associated with better child growth in a number of studies in developing countries. The magnitude of association is large, including in the few studies that have controlled for socioeconomic (SES) factors. More rigorous control of SES factors will be necessary in future research, however, to disentangle the mechanisms that underlie these associations. More specifically, research should apply suitable analytical methods that will allow determining whether the association between dietary diversity and child growth is independent from socioeconomic factors.

Is there a relationship between household-level dietary diversity and socioeconomic factors and food security?

Recent evidence from a 10-country analysis shows a strong association between household-level dietary diversity and per capita consumption and energy availability. This suggests that dietary diversity could be a useful indicator of food security (defined as energy availability). The study has important programmatic implications, because diversity is much easier and

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cheaper to use than traditional food-security measures, which usually involve collecting complex quantitative information. Future research should test the association between household dietary diversity and food security defined in terms of dietary quality—i.e., using adequacy of multiple nutrients as opposed to energy only, as in traditional food-security measures.

What measurement issues need to be addressed?

A number of measurement issues still need to be addressed to better understand dietary diversity. These include the selection of foods and food groupings, the consideration of portion size and frequency of intake, and the selection of scoring systems, cutoff points, and reference periods that will ensure the validity and reliability of the diversity indicators for the specific purposes for which they are used.

Conclusion and discussion

Dietary diversity is clearly a promising measurement tool, but additional research is needed to validate and test alternative indicators for different purposes. First, research is needed to continue to develop valid and reliable indicators of dietary diversity that accurately predict individual nutrient adequacy in a variety of population groups and settings. Second, the potential of household-level dietary diversity indicators to accurately reflect household food security and overall socioeconomic status needs to be confirmed. Specific indicators will need to be developed for each of these purposes, but in both cases it will be necessary to address the various measurement issues identified in this review. Finally, rigorous analytical approaches should be employed to disentangle the complex relationships between dietary diversity, household socioeconomic factors, and child growth. It is particularly important for future programming efforts to understand whether dietary diversity has an effect on child growth, independent of socioeconomic factors. This will help program managers and policy makers understand what levels of reductions in childhood malnutrition they can achieve from poverty alleviation and dietary diversification interventions, and whether they can expect a synergistic effect if they combine the two approaches.

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Letter to the Editor

Response to the FNB Supplement on the Positive Deviance Approach to Improve Health Outcomes

6 January 2003

Dear Sir,

The *Food and Nutrition Bulletin* is to be congratulated on the recent Supplement on the Positive Deviance Approach to Improve Health Outcomes. It brings encouragement to those who are working in a field where disappointments tend to outweigh achievements.

It was fascinating to learn that Joe Wray's challenging 1972 article "Can we learn from successful mothers?" failed to elicit any response, although a few years later it led to efforts to identify PD (positive deviant) families. [1]

By the early 1970s in our Nutrition Research Program at the American University of Beirut in Lebanon, our field unit, led by Dr. Abdullah Kanawati, had developed a Somatic Index (SI), consisting of two bony and two soft-tissue measurements, for studying in a series of papers we called "Failure to thrive in Lebanon" [2–5]. The same protocol was applied simultaneously to three very different deprived areas: a village in the south, an urban slum in Beirut, and a Palestinian refugee camp in the suburbs. We collected many data of a socioeconomic nature relating to children aged two years and under. When the top quintile for SI scores was compared with the bottom, it became very clear that physical growth correlated closely with quality of life, especially as it related to the mother.

Our plans to implement measures along the lines of the PD approach among these communities in Lebanon were overwhelmed in 1975 when civil war broke out. As Robert Burns, the Scottish "immortal bard," said, "The best-laid schemes o' mice and men gang aft a-gley," but it is good to hear when they do triumph over the vicissitudes of life.

Donald S. McLaren
Consultant
Sight and Life
Basel, Switzerland

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Books received

Botanical medicines: The desk reference for major herbal supplements. Second edition. Kenneth Jones and Kerry Hughes. Haworth Press, New York, 2002 (ISBN 0-7890-1266-9) 1138 pages, paperback. List price: US$169.95.

This is a large volume with chapters summarizing and analyzing information on 34 well-known botanical medicines. Each chapter provides available information on history and traditional uses, chemistry, therapeutic applications, preclinical and clinical studies, dosage, safety profile, and extensive references. As might be expected, evidence of efficacy is highly variable. Of particular interest to nutritionists in this large and comprehensive volume are the botanicals that stimulate lactation and the risks that some of them pose for pregnancy.

Exercise and immune function. Edited by Laurie Hoffman-Goetz. CRC Press, Boca Raton, Fla., USA, 1996 (ISBN 0-8493-8190-8) 266 pages, hardcover. List price: US$159.95.

In recent years, a growing number of research papers have explored the effect of exercise on various types of immunity. This volume critically reviews the evidence for exercise-induced change in 13 chapters written by 23 experts in the field. The preface points out that "the two opening chapters consider the hormonal consequences of exercise and stress, and how neuroendocrine factors influence the immune system." The next two chapters focus on cytokine and acute-phase response during exercise. Cytokines will probably prove to be key players in the exercise–immune response link involved in local regulation of immune responses and providing coordinated information to the brain about systemic immunological changes occurring with exercise. Current reviews on the specific immunological responses to acute exercise, training, and overtraining are included in Chapters 3 through 7. Chapters 8 through 11 deal specifically with the health immunological implications of exercise-induced changes in immune function for infectious disease, autoimmunity, colon cancer, and aging. The final two chapters address contemporary behavior concerns of addictions and the effects of dieting in the context of exercise-associated change in immunity.

Strong evidence is provided that some forms of exercise can have long-lasting consequences for immune regulation. However, the state of current knowledge does not yet provide clear guidelines for individual and population-based health promotion. This book will be useful to anyone interested in the knowledge currently available on this potentially important topic and establishes the need for further research relating to it.

Functions of vitamins beyond recommended dietary allowances. Edited by Paul Walter, Dietrich Horning, and Ulrich Moser. Karger, Basel, Switzerland, 2001 (ISBN 3-8055-7073-2) 214 pages, hardcover. List price: US$198.25.

Even the most recently revised Recommended Dietary Allowances (RDAs) are still based essentially on the prevention of deficiencies. However, more and more scientific evidence is accumulating that several nutrients have additional functions at somewhat higher levels, and that in addition there are many other phytochemicals in food that may play a role in the enhancement of immunity and the prevention of some cancers and heart disease. After reviewing the current dietary reference intakes and recommendations, this book examines the evidence for vitamin functions beyond RDAs.

Chapters discuss the use of folic acid to prevent neural tube defects, reduce elevated homocysteine, and decrease the risk of coronary heart disease. Vitamins A, B_6, C, D, and E are reviewed for their role in promoting optimum protective host immune responses. A separate chapter deals with vitamin E and the immune response in the aged and argues for supplementation with higher than recommended levels of these vitamins for ideal immune function under all conditions. The same conclusion is reached for vitamin K and optimal hemostasis and for some vitamins and the regulation of gene expression.

There is certainly a need for a critical review on this subject, and there is considerable evidence that many vitamins have functions that are not optimally met by RDAs based on current criteria. However, committees developing the most recent US Food and Nutrition Board recommendations did review the evidence for additional functions of vitamins and concluded that there was not sufficient quantitative evidence to use these new functions in setting the new recommendations for the micronutrients [1].

This volume fails to present conclusive evidence on most of the topics discussed, but it does serve to stimulate more research and continuing discussion. However, it does not have the comprehensiveness and objectivity expected in a volume focused on such a specific topic.

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1. IOM/FNB (Institute of Medicine/Food and Nutrition Board). Dietary reference intakes for vitamin C, vitamin E , selenium and carotenoids. Washington, DC: National Academy Press, 2000.

Gender, physical activity and aging. Edited by Roy Shephard. CRC Press, Boca Raton, Fla., USA, 2001 (ISBN 0-8493-1027-X) 304 pages, hardcover. List price: US$84.95.

The single most important finding of research on aging in recent decades is the extent to which the aging process is not just a genetically programmed deterioration, as originally described, but is highly dependent on sociocultural factors. Diet and physical and mental activity are important determinants of the aging process. The excellent research of the Tufts University USDA Human Nutrition Research Center on Aging has shown that strength training at any age can improve mobility and decrease dependence, especially in women [1]. This small volume enlists 16 authors over 12 chapters to examine critically the respective contributions of genetics, environmental influences, and sociocultural influences to observed gender differences in human performance at various ages as well as differences among societies.

Critical evaluation of the extent and causation of gender differences has particular practical importance when issues of physical activity and health in aging are considered. A large proportion of those reaching advanced ages are women, and it is frail elderly women who find difficulty with the activities of daily living. There is increasing evidence that for both men and women a more physically active lifestyle can greatly improve motor and mental functioning, particularly at older ages. The evidence suggests that the greater prevalence of disability among elderly women is mainly a consequence of traditional behaviors and social disadvantage as compared with men.

A final chapter considers the implication for health policy of the increasing numbers and proportions of the elderly in most countries today and their increasing cost to society. It suggests that the costs can be alleviated by encouraging acceptance of the active lifestyle seen in individuals who age most successfully. This book will be of interest to the growing number of researchers and public health workers who are interested in the health problems of the elderly and the impact on them of interactions of aging and physical activity. It will be valuable collateral reading for advanced nutrition students.

Reference

1. Nelson, M. Strong women stay young, revised edition. Bantam Books, New York, 2000.

Growth, physical activity and motor development in prepubertal children. Toivo Jürimäe and Jaak Jürimäe. CRC Press, Boca Raton, Fla., USA, 2001 (ISBN 0-8493-0530-6) 188 pages, hardcover. List price: US$109.95.

There are many good studies and several classic books on somatic child growth. This small book, written by two experts in sports medicine at the University of Tartu, Estonia, adds an emphasis on motor abilities and skills of prepubertal children for whom no universally accepted tests are available. It also provides data on the growth and motor development of children in the countries of the former Soviet Union and eastern Europe that were not previously accessible. The book analyzes the effects of climate, traditions, types of sports, and sports facilities on patterns of physical activity, motor abilities, and motor skills.

Less physical activity and dietary excess are the major causes of the epidemic of childhood obesity and early diabetes that is sweeping not only most industrialized countries but also the more affluent populations in developing countries. This book reinforces the conclusions of a number of national health agencies that children must be taught early the skills, knowledge, attitudes, and behaviors that lead to regular participation in physical activity. It is important to improve elementary motor skills, such as running and walking, and the more difficult skills of individual and organized sports. At a time when changes in lifestyle are reducing the activity of prepubertal children, financial constraints are leading many school systems to eliminate physical education and reduce organized sports. This book provides information to resist this unfortunate trend.

Keep fit for life: Meeting the nutritional needs of older persons. World Health Organization, Geneva, 2002 (ISBN 92-4-156210-2) 127 pages, paperback. List price: US$27.00.

This approach to healthy aging is based on an expert consultation organized by WHO in collaboration with the Tufts University USDA Human Nutrition Research Center on Aging. After discussion of the epidemiological and social aspects of aging and health and function changes with aging, it describes assessment of the nutritional status of older people and provides detailed nutrient-by-nutrient guidelines for a healthy diet.

As would be expected from a meeting held at the Tufts Center, it has a strong section dealing with the impact of physical activity and stresses strength training as well as aerobic exercise. It concludes that no group can benefit more from regular exercise than older people. Exercise is important for the treatment of many chronic and typically age-associated diseases, including insulin-dependent diabetes mellitus, hypertension, heart disease, and osteoporosis, as well as for preventing and even reversing sarcopenia, increasing bone density, and improving muscle strength.

This volume is also useful for the internationally endorsed quantitative recommendations for the intake of individual nutrients as well as for its practical qualitative food-based guidelines in an Annex. More than previously it stresses that food components other than specific nutrients may have important antiinflammatory, antimicrobial, antioxidant, antimutagenic, and other biological effects capable of lowering the risk of major health problems, such as heart disease and cancer. This leads to a recommendation that the diets of the elderly should be not only rich in variety and nutrient-dense, but also dense in phytochemicals. Tables provide the information to implement these suggestions.

The consultation concluded that the five main ways to compress morbidity as nearly as possible to the end of life are to consume nutrient and phytochemical-dense foods; maintain physical activity throughout life; have access to relevant, efficient, and caring health services; avoid substance abuse; and, as important as any of the above, maintain social networks and social activity levels with advancing age. The useful "Heidelberg guidelines for promoting physical activity among older persons" are given in an Appendix. This small and inexpensive publication provides the most essential information for achieving healthy aging.

Nutrition in the prevention and treatment of disease. Edited by Ann M. Coulston, Cheryl L. Rock, and Elaine R. Monsen. Academic Press, San Diego, Calif., USA, 2001 (ISBN 0-12-193155-2) 801 pages, hardcover. List price: US$99.95.

As knowledge of nutrition has grown in complexity, textbooks must cover more and more topics and use multiple authors to do so. This book has 48 chapters with an epilogue and 85 authors to provide a comprehensive update of current knowledge in clinical nutrition. It succeeds in providing the basic knowledge required for the management of nutrition-related clinical problems, including nutrition interventions with patients; the genetics of obesity and cancer risk; major inborn errors of metabolism; dietary supplements; parenteral and enteral nutrition; three chapters on obesity; four chapters each on diet and cardiovascular disease, diabetes, and gastrointestinal diseases; and five chapters on obesity. Other chapters cover nutrition and breast cancer, colon cancer, prostate cancer, and lung cancer and the general nutritional management of patients with cancer. The other major diseases covered are renal disease, Parkinson's and Alzheimer's diseases, osteopororosis, eating disorders, food allergies, cystic fibrosis, osteomalacia, and immunodeficiency syndromes.

The final chapter discusses nutritional guidelines to maintain health. However, no single-volume textbook can now cover the entire field of nutrition. What this textbook does not cover is an indication of how far the knowledge of nutrition has developed. It does not attempt to include the nutritional diseases and problems of developing-country, refugee, and other underprivileged populations. It is not a text on nutritional biochemistry, nutritional epidemiology, public health nutrition, nutrition policy and planning, or nutrition interventions. Yet it meets an important need, and can be recommended for the way in which it deals with the major nutritional problems of industrialized countries and the more affluent populations of developing countries.

Editorial comment

Several of the books reviewed above approach aging and chronic disease from different perspectives, but they all demonstrate a clear consensus on the importance of a varied diet that will provide phytochemicals as well as essential nutrients, physical activity that includes both aerobic exercise and strength training, and maintenance of a healthy lifestyle that includes social interactions and mental stimuli.

News and notes

Information on Vitamin A Deficiency and Its Prevention

A very good and free source of information on vitamin A deficiency, its occurrence, and progress in prevention is the quarterly *Sight and Life* newsletter, incorporating the former *Xerophthalmia Club Bulletin* published by the Sight and Life Task Force. Contact the Task Force at:

Sight and Life
Grenzacherstrasse 124
PO Box 2116
CH-4002 Basel, Switzerland
Phone: ++41-61-688 74 94
Fax: ++41-61-688 19 10
E-mail: sight.life@roche.com
Web address: http://www.sightandlife.org

The issue for the last quarter of 2002 has an excellent digest of recent literature by Donald McLaren, a report on the diverse carotenoid sources in Brazil, a report on fortification of vegetable oil and cassava with vitamins, and reports from Afghanistan, Bolivia, Ghana, Haiti, India, Mali, Morocco, Nepal, and Nigeria.

Health and Nutrition of Schoolchildren

A new initiative from the International Union of Nutritional Sciences (IUNS) was launched recently in the form of a new task force on “Health and nutrition of schoolchildren.” This initiative comes as a follow-up to the recent International Council for Science (ICSU) General Assembly meeting in Rio de Janeiro, where there was a major concentration on capacity building in developing countries. The focus was on upscaling the educational systems in developing countries, with special concentration on strengthening language and science teaching in primary schools. Not much was mentioned about the importance of good health and nutrition for these schoolchildren. Both Dr. Mark Wahlqvist, president of the IUNS, and Dr. Osman Galal, secretary general, were present and participated in the discussions, and they concluded that a task force in the IUNS structure should be established to address and highlight the issue of health and nutrition among schoolchildren.

Many developing countries have signed on to the United Nations declaration of the goal of achieving basic education for all by the year 2015. Together with international organizations, they are making massive efforts to upscale access to and improve the quality of basic educational systems. These efforts raise urgent questions regarding the impact of deficits in the health and nutritional status of the school-aged population and the effect of these deficits on cognitive functions and learning. These constrain the success of the efforts in development and poverty alleviation through education. One legacy of the Child Survival revolution of the 1980s and 1990s is that large cohorts of now school-aged children survived the hazards of infancy and early childhood with some degree of chronic malnutrition and other health deficits. In spite of a growing body of knowledge of the health status of this age group, clear articulation of the issues is largely absent from the education policy agenda.

The nutritional and health status of schoolchildren in the world is seldom articulated in planning for the current goal of Education for All, except for attention to HIV/AIDS prevention through schools, which is a recognized agenda (UNESCO 2001). There is a substantial body of literature attesting to the causative links between health deficits, particularly malnutrition, and school performance, but this focus is largely missing from the Education for All debate. The disjoint may be attributable to the fact that health and nutrition is perceived as a health-sector concern rather than as being integral to the education sector. Besides demonstrating the linkage between the nutrition and health of schoolchildren and their learning performance and scholastic achievements, the task force will seek to argue for consideration of the nutrition and health of children in planning and implementing Education for All in developing countries. The goals of the new IUNS task force on “Health and nutrition of schoolchildren" are to review the magnitude of efforts being instituted to improve the health and nutrition situation of students in developing countries, and particularly to review available data on the nutrition and health status of these students; and to project the impact that these deficits will have on the success of investments in education unless improvement in nutritional and health status occur at the same time. The expected completion of this exploratory review by the new IUNS task force will allow international organizations, scientific associations, and governments to increase awareness of the problem, formulate hypotheses about its relative importance, devise methods for involving teachers in the betterment of the health of students, and integrate their strategies with other variables (such as attitudes towards family structures and the role of women) that affect the nutrition and health of children.

International commitment to improving educational access in developing countries is not lacking. UNESCO and many nongovernmental development agencies are actively engaged in practice towards this end. Governmental commitment is also evident from the significant percentage of national public expenditure allocated to the education sector, even in countries with observable declining economic performance. The new IUNS task force will draw attention to the reality that universal access without specific attention to nutrition and related health considerations will not necessarily result in improved human welfare. IUNS also recognizes the impact of the HIV/AIDS pandemic on the education sector from loss of teachers and dropout of schoolchildren to take care of siblings at home. The task force will acknowledge and act upon the demonstrated negative impact of malnutrition (which affects a far larger proportion of children) on educational outcomes. The work of the task force is intended to bring to the fore concern for the intervening effects of malnutrition on the educational outcome measures for the developing countries, where nutritional inadequacy prevails, even as we begin to witness overnutrition in some pockets of these regions.

The IUNS Council invites all interested parties to communicate with the secretary general with the objective of creating an international network that will address this issue. The charges of the Task Force are on the IUNS web site http://www.iuns.org.

In other activities, the 5th International Conference on Dietary Assessment Methods was held recently (26–29 January 2003) in Chiang Rai, Thailand, hosted by the Institute of Nutrition of Mahidol University. Almost 400 attendees spent three days in multiple sessions devoted to dietary assessment research. Prior to the conference (24–25 January) a workshop on Food Consumption Surveys in Developing Countries was sponsored by FAO, Mahidol University, and ILSI/Southeast Asia; the IUNS secretary-general attended as an observer. The 6th International Conference on Dietary Assessment Methods is scheduled for 26–29 April 2006 in Copenhagen, Denmark.

Osman Galal
Secretary General
International Union of Nutritional Sciences (IUNS)

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Corrections to Vol. 24, No. 1

Update on technical issues concerning complementary feeding of young children in developing countries and implications for intervention programs. Kathryn G. Dewey and Kenneth Brown (pp. 5–28)

On page 6, all references to FAO should read FAO/WHO/UNU (Food and Agriculture Organization, World Health Organization, United Nations University).

In tables 1 and 2, page 7, the reference number at the end of the table titles should be 5.

In table 9, page 13, units for Vitamin B_{12} should be micrograms per day (μg/day).

Promotion and advocacy for improved complementary feeding: Can we apply the lessons learned from breastfeeding? Ellen G. Piwoz, Sandra L. Huffman, and Victoria J. Quinn (pp. 29–44)

In table 1, page 32, left-hand column, reference number for IMCI should be 47.

In reference 47, the relevant website is http://www.who.int/child-adolescent-health

Macrolevel approaches to improve the availability of complementary foods. Chessa K. Lutter (pp. 83–103)

Please see revised tables 1 (page 88) and 2 (page 90) on the following pages. Corrected values are shown in **bold**.

The title of Table 3, page 92, should read: Estimated nutrient needs from complementary foods by average breastmilk intake[a]

Page 95, the final sentence in the last full paragraph, bottom right column, should read, "On the basis of dietary intakes from complementary foods in Latin America, a level of fortification of 250 μg RE per 100 g of daily ration would meet 80% of the vitamin A needs of nonbreastfed children and all the needs of breastfed children, and it would not exceed the upper limit set by the United States for intake by breastfed children consuming the recommended daily ration [38].

Pages 102–103, the year of publication in references 4, 34–39, and 41 should be 2003.

TABLE 1. Summary of the nutritional characteristics of fortified complementary foods and cost of foods used in Latin America per 100 g of dry product[a]

	Ecuador (US$0.14)	Peru (US$0.21)	Mexico (US$0.18)	Guatemala	USAID/WFP		Colombia (US$0.07)		
Energy and nutrients	Mi Papilla	Alli Alimentu	Nutrisano	Inca-parina[b]	Wheat-soy blend[c]	Corn-soy blend[c]	Bienesta-rina	Colombia-rina	Solidarina
Energy (kcal)	423	444	440	375	355	376	319	383	340
Protein (g)	16.0	14.4	13.3	21.3	21.5	17.2	26.0	21.7	23.0
Fat (g)	10.0	14.8	—	5.3	5.9	6.9	**1.4**	1.3	2.0
Vitamins									
Vitamin A (μg RE)	**127**	720	921	1,351	698	784	601	1,502	520
Biotin (μg)	—	—	—	—	—	—	—	—	—
Folic Acid (μg)	**50**	30.0	**115**	—	**275**	**300**	—	—	170
Niacin (mg)	**5.4**	5.0	—	13.6	8.2	6.2	9.7	13.3	**6.6**
Panthothenic acid (mg)	—	—	—	—	**3.7**	**3.4**	—	—	—
Riboflavin (mg)	**0.48**	0.5	1.8	1.0	0.5	0.5	0.5	1.1	**0.5**
Thiamine (vitamin B_1) (mg)	**0.42**	0.5	—	1.7	0.5	0.5	2.0	1.8	**0.4**
Vitamin B_6 (mg)	**0.6**	0.6	—	—	0.5	0.5	—	—	—
Vitamin B_{12} (μg)	**0.7**	0.5	**1.6**	—	**1.0**	**1.0**	—	—	**1.7**
Vitamin C (mg)	**24**	50	92	—	40	40	27	—	29
Vitamin D (μg)	—	—	—	—	198	198	—	—	0.4
Vitamin E (mg)	**3.6**	—	13.8	—	8.7	8.7	2.1	1.8	0.4
Vitamin K (μg)	—	—	—	—	—	—	—	—	—
Minerals									
Calcium (mg)	**240**	200	—	305	842	831	512	500	568
Chloride (mg)	—	—	—	—	—	—	—	—	—
Copper (mg)	—	—	—	—	—	—	**1.1**	—	—
Fluoride (mg)	—	—	—	—	—	—	—	—	—
Iodine (μg)	—	70	—	—	56	57	—	—	—
Iron (mg)	**10**	10.0	23.0	11.2	17.9	17.5	14.1	14.2	10.0
Magnesium (mg)	**48**	50	—	**—**	227	174	**140**	—	—
Manganese (mg)	—	—	—	—	—	—	—	—	—
Phosphorus (mg)	**240**	200	—	**65**	294	206	766	275	440
Potassium (mg)	—	—	—	—	—	—	—	—	—
Selenium (μg)	—	—	—	—	—	—	—	—	—
Sodium (mg)	—	—	—	—	—	—	—	—	—
Zinc (mg)	**10**	10.0	23.0	—	5.5	5.0	**1.8**	8.3	6.0

a. A dash indicates that the product was not fortified with the nutrient. However, the nutrient may be present if it occurs naturally in the macro ingredients. Costs include those of production and distribution to the community, though not to the beneficiary.
b. Assumes two servings per day at 18.75 g per serving.
c. Amount of nutrient in the product occurring both in the macro ingredients and through fortification.

TABLE 2. Summary of nutritional requirements, ration sizes, and nutritional characteristics per ration size of fortified complementary foods in Latin America[a]

	Dietary reference values [3][b]		Ecuador	Peru	Mexico	Guatemala	USAID/WFP		Colombia		
Energy and nutrients	6–11 mo	12–24 mo	Mi Papilla	Alli Alimentu	Nutrisano	Incaparina[b]	Wheat-soy blend[c]	Corn-soy blend[c]	Bienestarina	Colombia-rina	Solidarina
Ration size	—	—	65	90	44	37.5–56.25	47	47	30	NA	40
Energy (kcal)[d]	750 (255)	894 (548)	275	400	194	140–210	167	177	96	—	136
Protein (g)	9.4	10.9	16	**13.0**	**5.8**	**8.0–12.0**	**10.0**	17.2	**7.8**	—	**9.2**
Fat (g)	—	—	6.5	**12.0**	NA	2.0–3.0	2.8	3.2	0.4	—	0.8
Vitamins											
Vitamin A (µg RE)	350	400	**83**	**628**	**400**	810–1,215	328	369	**180**	—	**208**
Biotin (µg)	—	—	—	—	—	—	—	—	—	—	—
Folic Acid (µg)	32	50	**32.5**	**27**	**50.0**	—	**129**	**141**	—	—	**68**
Niacin (mg)	5	8	**3.5**	**4.5**	—	**5.1–7.65**	**3.9**	**2.9**	**2.9**	—	—
Panthothenic acid (mg)	—	—	—	—	—	—	**1.7**	**1.6**	—	—	—
Riboflavin (mg)	0.4	0.6	**0.31**	**0.45**	**0.8**	**0.38–0.56**	**0.24**	**0.24**	**0.24**	—	**2.6**
Thiamine (vitamin B_1) (mg)	0.3	0.5	**0.3**	**0.45**	—	**0.64–0.96**	**0.24**	**0.24**	**0.6**	—	**0.2**
Vitamin B_6 (mg)	0.4	0.7	**0.4**	**0.54**	—	—	**0.24**	**0.24**	—	—	
Vitamin B_{12} (µg)	0.4	0.5	**0.46**	**0.45**	**0.7**	—	**0.47**	**0.47**	—	—	**0.9**
Vitamin C (mg)	25	30	**16**	**45**	**40**	—	**19**	**19**	**8.1**	—	**11.6**
Vitamin D (µg)	7	7	—	—	—	—	**93**	**93**	—	—	**0.2**
Vitamin E (mg)	—	—	**2.3**	—	**6.0**	—	**4.1**	**4.1**	**0.6**	—	**0.2**
Vitamin K (µg)	—	—	—	—	—	—	—	—	—	—	—
Minerals	—	—	—	—	—	—	—	—	—	—	—
Calcium (mg)	525	350	156	**180**	—	**114–172**	**396**	**391**	**154**	—	**227**
Chloride (mg)	500	800	—	—	—	—	—	—	—	—	—
Copper (mg)	0.3	0.4	—	—	—	—	—	—	**0.3**	—	—
Fluoride (mg)	—	—	—	—	—	—	—	—	—	—	—
Iodine (µg)	60	70	—	63	—	—	**26**	**27**	—	—	—
Iron (mg)—bioavailability											
Low	21	12									
Medium	11	6	**6.5**	**9.0**	**10.0**	**4.2–6.3**	**8.4**	**8.4**	**4.2**	—	**0.4**
High	7	4									
Magnesium (mg)	80	85	**31**	**45**	—	—	**107**	**82**	—	—	—
Manganese (mg)	—	—	—	—	—	—	—	—	—	—	—
Phosphorus (mg)	400	270	**156**	**180**	—	**24–37**	**138**	**97**	**230**	—	**176**
Potassium (mg)	700	800	—	—	—	—	—	—	—	—	
Selenium (µg)	10	15	—	—	—	—	—	—	—	—	
Sodium (mg)	350	500	—	—	—	—	—	—	—	—	
Zinc (mg)	5.0 (UK) 2.8 (WHO)	6.5 (UK) 2.8 (WHO)	**6.5**	**9.0**	**10.0**	—	**2.6**	**2.6**	**0.5**	—	**2.4**

a. A dash indicates that the product was not fortified with the nutrient. However, the nutrient may be present if it occurs naturally in the product.
b. Unless otherwise noted, Dietary Reference Values are from the United Kingdom (Department of Health 1991).
c. Amount of nutrient in the product occurring both in the macro ingredients and through fortification.
d. Based on a longitudinal study of healthy US children [22]. The first figure is the total daily energy requirement. The figure in parentheses is the estimated amount of energy required from complementary foods, assuming average breastmilk intake.

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1. Alvarez MI, Mikasic D, Ottenberger A, Salazar ME. Caracteristicas de familias urbanas con lactante desnutrido: un análisis critico. Arch Latinoam Nutr 1979;29:220–30.

—*corporate author:*

2. Committee on Enzymes of the Scandinavian Society for Clinical Chemistry and Clinical Physiology. Recommended method for the determination of gammaglutamyltransferase in blood. Scand J Clin Lab Invest 1976;36:119–25.

Book or other monograph reference

—*personal author(s):*

3. Brozek J. Malnutrition and human behavior: experimental, clinical and community studies. New York: Van Nostrand Reinhold, 1985.

—*corporate author:*

4. American Medical Association, Department of Drugs. AMA drug evaluations, 3rd ed. Littleton, Mass, USA: Publishing Sciences Group, 1977.

—*editor, compiler, chairman as author:*

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.

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