Processed Complementary Food Does Not Improve Growth or Hemoglobin Status of Rural Tanzanian Infants from 6–12 Months of Age in Kilosa District, Tanzania[1]

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ABSTRACT A double-blind, randomized, placebo-controlled trial was conducted from March 2001 to March 2002 involving 309 infants who received either a processed complementary food (CF) or an unprocessed placebo from 6 to 12 mo of age. The groups were comparable in baseline characteristics. The study took place in Kilosa district, Tanzania. The processed CF contained germinated, autoclaved, and dried finger millet (65.2%), kidney beans (19.1%), roasted-peanuts (8%), and mango purée (7.7%). The same blend, but not processed, served as the placebo. Processing increased iron solubility and energy density without affecting viscosity. Mean length for age, weight for age, hemoglobin, and zinc protoporphyrin at 6 and 12 mo did not differ between the 2 groups. The results show that the processed food did not differ from the unprocessed placebo in improving growth, hemoglobin, and iron status of infants when given under the study conditions. The control group consumed equal amounts of macronutrients, and the higher energy density in this study did not seem to have any benefits. In our study, there was a very intensive follow-up; at every encounter with mothers, giving the required amounts and adding extra lipids was strongly reinforced. Under those conditions, a well-balanced complementary food with additional lipids can meet the energy needs of young children. The reduction in phytates by 34% and improvement in iron solubility to 19% due to processing might not have been enough to compensate for the rather low iron content of the complementary food. J. Nutr. 134: 1084–1090, 2004.

KEY WORDS: • *complementary feeding* • *iron deficiency* • *anemia*

Growth and the chance of survival at birth are determined to a large extent by the intrauterine period (1). Exclusive breast-feeding for the first 4–6 mo protects the infant from nutritional deficiencies and decreases the stress of infection. Young infants are most vulnerable at the time complementary foods are introduced. Traditional complementary foods are often bulky, have a low energy density and contain insufficient amounts of micronutrients, in particular iron and zinc (2,3). Complementary foods are largely cereal based and contain considerable amounts of phytate, which negatively affects micronutrient bioavailability, thereby inducing deficiencies in minerals. They are also not without risk of contamination (4). Low infant feeding frequency further contributes to the undernutrition of children. Surveys carried out in Tanzania (5) indeed showed that most children are fed only 2 or 3 times a day.

Iron deficiency anemia is an important nutritional problem in Tanzania. It is estimated that 45% of the children < 5 y old are suffering from nutritional anemia (6). It is more prevalent in infants and pregnant women and is usually the result of low bioavailability of dietary iron (7). Although the effects of iron deficiency anemia are reversible, including impaired intellectual development, this will rarely be the case under the local suboptimal conditions. Thus, despite the fact that the diagnosis of anemia is fairly simple and treatment is inexpensive, the prevalence of anemia remains high (8).

The most frequently used strategies to correct iron deficiency are food fortification and/or iron supplementation (9). Local staples have been fortified with ferrous sulfate (10), zinc sulfate (11), vitamin A, and vitamin C (12–14). The effectiveness of large-scale fortification programs, however, is reduced due to factors such as cost, constant availability, timely distribution of fortificants, and compliance with the prescribed fortificant (15). Similar experiences were observed in many places with iron supplementation (16).

The above-mentioned limitations of fortification and supplementation underline the importance of preventing growth faltering and micronutrient deficiencies, such as iron deficiency anemia through a food-based approach (7,17). Food modification approaches that employ natural processes such as

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germination to combat micronutrient deficiencies and improve the growth of infants deserve more attention because they are likely to be more sustainable in the long run (4).

Based on the knowledge of the traditional complementary foods (CFs)[3] in Tanzania collected by the authors earlier, a processed CF prepared from locally produced crops was formulated. The present study aimed to compare the growth and iron status of Tanzanian infants, from 6 to 11 mo, provided processed and unprocessed (placebo) CF. The main hypothesis was that a processed CF with higher energy density and lower concentration in phytates and tannins would improve growth of infants and decrease iron deficiency.

MATERIALS AND METHODS

The study was conducted from March 2001 to March 2002 in Kilosa District in the Morogoro region, Tanzania. Morogoro is located ~300 km west of Dar-es-Salaam. Kilosa is a district with a population of ~350,000 inhabitants. Kilosa was chosen for this study because it is among the districts in the Morogoro region that have a high prevalence of iron deficiency anemia (18).

Design of the study. The study was set up as a double-blind, randomized, controlled trial in which the main investigator and the mothers had no knowledge of the type of food given to the infants (**Fig. 1**). Processed complementary food constituted the intervention group and the unprocessed food served as the control. Infants were continuously enrolled when they reached the age of 6 mo and assigned to the respective groups on the basis of their previously determined allocation. For this, all parents with infants < 6 mo old were contacted and invited to participate in the study. Parents of 364 infants agreed to participate and were randomly assigned to treatment or control. We expected a number of dropouts in the period between randomization and actual enrolment; therefore, we increased the number recruited to be sure to reach the minimal required number of infants for the study. Allocation to the treatment or control group was determined using a bloc randomization technique. The main investigator was informed of group assignments at the end of the data collection. The 2 types of CF were distributed until the infants reached the age of 12 mo. Mothers were free to give their infants any other food of their choice in addition to the CF provided during the study. Measurements were taken twice, at the age of 6 and 12 mo, with a malaria blood smear at 9 mo. Verbal consent was sought from mothers for their infants to participate in the trial. The ethics committee of the Tanzania Food and Nutrition Centre and University of Gent reviewed the protocol and gave approval for the trial.

The sample size for the trial was computed to detect a hemoglobin (Hb) difference of 8 g/L (equivalent to 0.5 SD) between the 2 groups with a significance level of 0.5% and power of 95%. A pilot study conducted in the area before the trial revealed that the Hb concentration in infants between 4 and 12 mo old was 84.0 ± 17.0 g/L. The calculated minimum sample size for the experimental and placebo groups was 117 infants.

The processed CF consisted of 65.2% finger millet, 19.1% kidney beans, 8% peanuts, and 7.7% mango purée. Finger millet and kidney beans were washed and soaked in preboiled water for 2 and 7 h, respectively, and germinated for 48 h at 30°C. Later the lot was autoclaved and then solar dried for ~6 h. Peanuts were roasted in an oven at 150°C for 20 min. Mangoes were washed, peeled, sliced, and the purée extracted. Later the purée was dried in a solar drier for 12 h. The ingredients were mixed and milled to make a flour. The unprocessed CF was a blend of finger millet, kidney beans, peanuts and dried mango purée, mixed in the same proportion as the processed CF, and then milled to make a flour. The director at the production site did the packing and labeling. Packages and labels were identical and the 2 preparations were visually indistinguishable. The label contained preparation (cooking) instructions. Before the intervention, an acceptability trial for the CF was done involving 50 mothers with their infants.

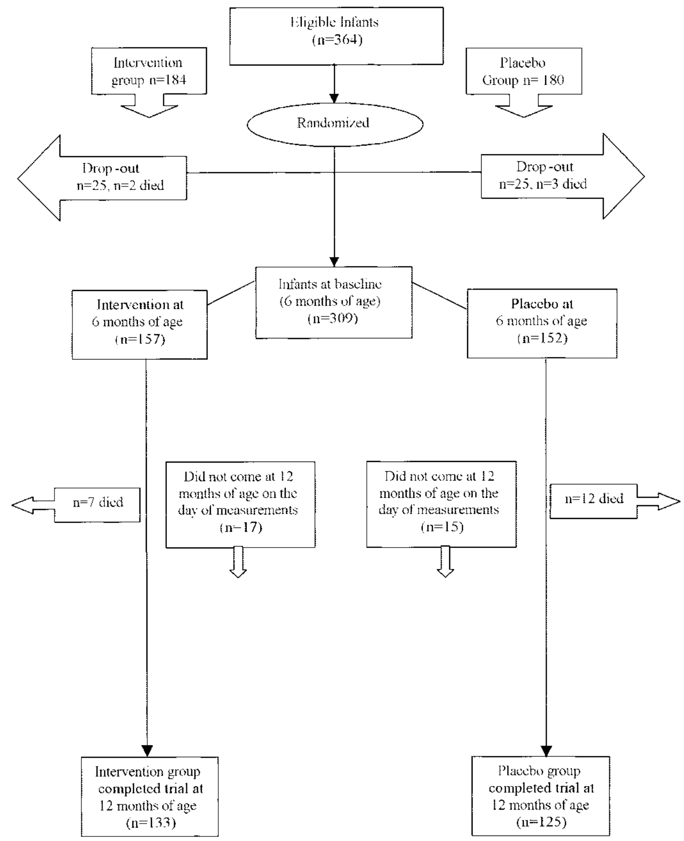

FIGURE 1 Study design. Infants (n = 309) in Tanzania received either a processed CF of an unprocessed CF (placebo) from 6–12 mo of age.

Quality control was observed from the purchase of raw materials to processing and distribution. For qualitative and quick examination for aflatoxin contamination, a UV lamp (Type B-4 W Kurtz-und langwellig) was used. At various CF production stages, samples were checked for contamination with fumonisins (RIDASCREEN FAST Fumonisin kit, Biopharm), aflatoxins (RIDASCREEN FAST Aflatoxin kit, Biopharm), and cyanides (19). Fumonisins and aflatoxin concentrations were below the recommended limits of 1 mg/kg and 2 μg/kg, respectively, and cyanides were not detected. Outgrowth of pathogens including *Bacillus cereus*, *Staphylococcus aureus* and *Clostridium perfringens* was investigated for each batch of CF according to the HACCP plan (20) and found to be <100 colony forming units/g (21).

Every 2 wk, 1 and 1.6 kg of CF were allocated for infants 6–8 mo and 9–11 mo old, respectively. On a daily basis, each child was supplied with 69 and 113 g dry matter of CF, providing 1194 and 1956 kJ/d for infants aged 6–8 and 9–11 mo, respectively (22). The detailed formulation of the CF is described in Mbithi-Mwikya et al. (23).

Mothers came to collect the food every 2 wk. The MCH nurses supervising the mothers had a list of the infants and recorded every food collection. They demonstrated to the mothers how to prepare the CF (although the packets had a self-explanatory label) and reminded them how much in local measures (tablespoons) of the CF powder to use each day. The CF for 1 d was prepared once. The nurses also advised the mothers to add 1–2 teaspoonfuls (5–10 mL) of oil to the preparation. The goal was to administer 1151 kJ/d (275 kcal/d) and 1883 kJ/d (450 kcal/d) from CF. In case of absence, the nurse made certain that a message was sent to the responsible mother to collect her consignment on the same day. Nutrition officers from the

[3] Abbreviations used: CF, complementary food; LAZ, length-for-age Z-score, WLZ, weight-for-length Z-score; Hb, hemoglobin; ZP, zinc protoporphyrin.

center followed up the mothers in their homes at least twice each week to make sure the CF was prepared correctly.

Weight and length were recorded at enrollment (age 6 mo) and at the end of the trial (age 12 mo). Recumbent lengths of the infants were measured to the nearest 0.1 cm using an infant measuring board (Perspective Enterprises). Weight of infants was measured to the nearest 100 g using a Salter scale (Model 235 6S) with a capacity of measuring up to 25 kg. The infant's birth weight was obtained from his/her clinic card. The MCH nurse is responsible for measuring the infant's weight immediately after birth.

Hb concentration was measured from a finger prick blood sample by the Hemocue B-Hemoglobin System (Hemocue AB) (24,25). Zinc protoporphyrin (ZP) was determined on a drop of blood with a portable hematofluorometer (Aviv Biomedical). The instrument was standardized using control solutions from the same company (26,27). The analyses were performed at a later date.

Blood smears, stained with Giemsa, were analyzed within 10 h for quantitative determination of malarial parasites. Malaria parasite counts were made per 200 white blood cells. Infants found infected with malaria and those who became ill at any time during the trial were treated free of charge at the respective health centers.

A 24-h dietary recall was conducted among mothers of 137 randomly selected infants aged between 6 and 11 mo; this was ~50% of the total number of infants and they were equally distributed among the 2 intervention groups. A new appointment was fixed for others who were not found at home at the time of the visit. Random numbers were used to select infants from each group. The dietary recall interviews were conducted in the home by a nutritionist accompanied by a village health worker. The mother was requested to show the type and amounts of foods the infant had actually consumed over the last 24 h. The amount of food consumed by the infant was weighed using a digital weighing scale (Tefal scales) with an accuracy of 0.5 g or measured by a measuring cylinder (Pyrex-UK) with an accuracy of 0.5 mL in the case of volumes. Spilled food was not estimated. Macro- and micronutrient contents of the foods were calculated using the FAO food composition table (28) with Excel Office 2000.

Samples of CF weighing 250 g from each production batch were analyzed for protein [Kjedahl AOAC method 920.87 (19)], fat [Weibull method (29)], and iron [atomic absorption spectrophotometry AOAC method 970.12 (19)]. The nitrogen protein conversion factor for millet was 5.83, and 5.3 for beans and peanuts. The solubility of iron was determined by the method of Svanberg and Sandberg (30) and phytate using the technique of Haugh and Lantzsch (31).

Infants were excluded from the trial if they had received blood transfusions or presented a health condition that required further treatment as assessed by a medical doctor at the time of enrollment. These excluded infants were referred to the local health facilities for appropriate treatment. All infants were examined for malaria at 6 mo of age and treated accordingly. Because all infants were breast-fed and Kilosa is a malaria endemic area, anemia was considered to be due to malaria in the standard protocols. At the end of the trial, the infants were reevaluated and treated for most likely etiology of anemia by the supervising medical doctor.

Statistical analysis. Data were entered in EPI-INFO (version 6.04d; Centers for Disease Control and Prevention, WHO, 1996), and analysis was done using the Stata 8.0 package (Stata version 8.0; STATA). Weight-for-length and length-for-age Z-scores were computed using EPINUT according to National Centre for Health Statistics Standards of 1977.

Descriptive statistics were done on each variable to identify outliers and assess the normal distribution of continuous variables. Outliers were defined from the box plot as values more extreme than the 3-interquatile range of the box. In the presence of outliers, a new variable was created excluding these values. However, in case of doubt, the dataset was cross-checked with the original data in the rosters. All tests were done first with the original variable, and then redone with the new variable to assess the influence of such outliers. Normal distribution of continuous variables was appraised by a Kolmogorov Smirnoff test. In case of severe departure from normality, the variables were log-transformed.

The α error was set at 5% in all tests. The strategy of data analysis was set in 2 steps. First, a difference at 12 mo of age between the 2 intervention groups was assessed for each primary outcome. These primary outcomes were mean ZP and mean Hb. Differences in anthropometric indicators, i.e., mean weight-for-length Z-score (WLZ) and length-for-age Z-score (LAZ) at 12 mo of age were also examined. A standard t test was used for continuous variables, and a χ^2 test for categorical variables. Similarly, the general trend in main outcomes, between the beginning and the end of the trial, were assessed by applying a paired t test or a McNemar test for categorical variables.

Second, a logistic regression analysis was applied using the EVW model (32). Continuous variables were transformed into categorical variables as indicated below. The dependent variables were as follows: *1*) high ZP at 12 mo of age (ZP > 5 μg/g Hb, coded 0/1) for the first set of models, *2*) anemia (Hb < 110 g/L, coded 0/1) for the second set of models, and *3*) LAZ less than -2 SD, coded 0/1 for the third set of models.[4]

The exposure variable was the type of CF received. The following covariates were inserted into the initial model because they were potential confounding factors or effect modifiers (biological or environmental): *1*) child parameters: ZP > 5 μg/g Hb at baseline (0 = no, 1 = yes), Hb < 110 g/L at baseline (0 = no, 1 = yes), blood smear positive for malaria at age 9 mo (0 = no, 1 = yes), birth weight < 2500 g (0 = no, 1 = yes), LAZ less than -2 Z-score at baseline (0 = no, 1 = yes), sex (0 = girl, 1 = boy), season at entry in the study (0 = harvest season, 1 = other season); *2*) mother's parameters: mother's education lower than primary school (0 = no, 1 = yes), mother living alone (0 = no, 1 = yes), mother's age < 20 y (0 = no, 1 = yes), parity ≥ 3 (0 = no, 1 = yes), BMI (0 = ≥ 18.5, 1 = < 18.5), income $< 10{,}000$ shillings (0 = no, 1 = yes).

All covariates were considered to be potential effect modifiers and introduced in the initial model as product terms involving E (exposure to processed food). The presence of multicollinearity and other numerical problems in regression analyses was appraised by verifying the presence of a high estimated SE for the regression estimates (33). Then a hierarchical backwards elimination procedure was applied to eliminate nonsignificant variables.

Removal of variables was at $P > 0.05$ for the likelihood ratio test. First effect modifications were tested using a likelihood ratio test for the entire collection of interaction terms (32). Then variables were removed one by one according to the likelihood ratio test. The model including the remaining covariates was considered the gold standard. Confounding was then assessed by monitoring changes in the effect measure (odds ratio) for subsets of covariates. The subset of covariates included in the final model was the one allowing the best gain in precision.

RESULTS

Subjects and compliance. Of the 364 infants randomly assigned to a group, 309 participated in the trial, with 157 infants in the intervention group and 152 in the control group. At the end of the trial the respective groups had 133 and 125 participants. The dropout rate did not differ significantly between the 2 groups.

To verify compliance, nutrition officers from the center followed up the mothers at home to make sure the CF was prepared correctly. Compliance was considered to be good if the mother collected the CF, correctly prepared it, and fed it to her infant according to instructions. Surprise visits to the home were made once or twice each week. However, we were not able to fully monitor compliance in the strict sense.

Baseline characteristics. The characteristics of infants, mothers, and household variables in both groups were similar at enrollment of the infants, aged 6 mo (**Table 1**) with the excep-

[4] The weight-for-height indicator was not considered because 99% of the children were in the normal range (mean ± SD).

TABLE 1

Baseline characteristics of infants fed processed or unprocessed complementary foods[1]

	Complementary food		
Variables	Processed	Unprocessed	*P*-value
n	157	152	
Birth weight,[2] *kg*	2.9 ± 0.5	3.1 ± 0.5	0.06
Weight, *kg*	6.7 ± 1.0	6.9 ± 1.0	0.93
Length, *cm*	62.7 ± 3.1	62.8 ± 3.1	0.06
Hemoglobin, *g/L*	91.4 ± 1.9	94.4 ± 2.1	0.27
ZP, *μg/g Hb*	9.9 ± 6.1	9.9 ± 5.8	0.97
WLZ	0.45 ± 1.24	0.72 ± 1.14	0.04
LAZ	−1.53 ± 1.16	−1.54 ± 1.11	0.96
Household size, *n*	5.8 ± 2.3	5.4 ± 2.1	0.11
Maternal BMI, *kg/m*[2]	21.9 ± 2.5	21.9 ± 2.7	0.96
Live children, *n*	2.7 ± 1.9	2.7 ± 1.8	0.86
Mother age, *y*	25.6 ± 7.0	25.3 ± 6.6	0.63
Maternal parity, *n*	3.4 ± 2.3	3.3 ± 2.1	0.63
Sex ratio of infants, M:F	1.01	0.95	

1 Values are means ± SD.
2 Based on 280 infants, 29 infants were home deliveries.

tion of WLZ. Mothers' education ($P = 0.11$), marital status ($P = 0.36$), and family income ($P = 0.43$) were not significantly different between the intervention and control group (χ^2 test).

Nutritional characteristics of the complementary food. The random samples from each month's CF production unit and unprocessed CF had an energy, fat, and protein content that did not differ (**Table 2**). However, the porridge prepared with the processed CF had a greater energy density, significantly higher iron solubility, and a lower concentration of phytates compared with the porridge prepared with the unprocessed CF. There was a small but significant reduction in total iron content in the processed CF compared with the unprocessed CF, probably due to leaching in the course of processing the CF (34). This disadvantage was counterbalanced by the higher amount of soluble iron in the processed CF compared with the unprocessed CF (18.83 vs. 4.76%), respectively.

Food consumption data from the 24-h dietary recall showed no significant difference in daily energy intake, proteins, lipids, and iron intake from the processed and unprocessed CF between the 2 groups of infants (**Table 3**). The mean number of meals, however, was considerably higher in the group fed the unprocessed CF. The energy intake from the CF was 1752 and 1679 kJ in the processed and unprocessed groups, respectively. This was increased to 1922 and 1943 kJ in the 2 groups, respectively, by the addition of oil. Overall, the CF contributed >50% of the total daily energy intake and exceeded the WHO recommendations. Other foods consisted of plain maize flour porridge, porridge made from family food, a mixture of maize, rice, peanuts and finger millet flour, and milk. Only 2 infants were fed fruits (banana or mango). Other foods and breast milk contributed substantially to the total daily energy, lipids, and protein intake. Using a conservative approach and taking a low minimal breast milk contribution, the estimated total energy intake compared with the recommended daily energy requirements was on average 96 and 107% for infants 6–8 mo old and 106 and 103% for infants 9–11 mo old, respectively (Table 3).

Effect of complementary food on growth. The groups did not differ at 12 mo of age (**Table 4**). Weight gains did not differ between the 2 groups with an increase of 1.4 ± 0.6 kg vs. 1.3 ± 0.7 kg for the processed and unprocessed CF groups, respectively ($P < 0.001$). Similarly, the mean WLZ and LAZ did not differ between the 2 groups ($P = 0.12$ and $P = 0.78$, respectively). LAZ declined from age 6 to 12 mo in both groups from −1.60 Z-score to −2.06 ($P < 0.001$). A similar trend was observed in WLZ, which declined from +0.57 to −0.17 ($P < 0.0001$).

Effect of complementary food on Hb and ZP. The concentrations of Hb and ZP did not differ between the groups at 12 mo of age (Table 4). Although Hb increased ($P < 0.014$) and ZP decreased ($P < 0.0001$) between 6 and 12 mo of age, the change did not differ between the groups (Hb, $P = 0.19$; ZP, $P = 0.39$). The majority of the infants (76%) were still anemic according to WHO standards at the end of the study. ZP declined from a mean of 10.1 μg/g Hb at the age of 6 mo to 6.0 μg/g Hb at the age of 12 mo ($P < 0.001$), but without differences between the 2 groups (Table 4).

No significant interaction between covariates and the type of CF was detected (likelihood ratio test for set 1, *P*-value 0.20; likelihood ratio test for set 2, *P*-value 0.11; likelihood ratio test for set 3, *P*-value 0.11) with the logistic regression.

DISCUSSION

The results show that the processed food was not superior to the unprocessed food in improving growth, Hb, and iron status of infants when given under the study conditions. Weight gain

TABLE 2

Composition of the complementary food[1]

	Complementary food		
Variable	Processed	Unprocessed	*P*-value
Energy, *kJ/100 g DM*	1731 ± 11	1731 ± 18	0.89
Protein, *g/100 g DM*	12.87 ± 0.57	12.64 ± 0.56	0.33
Fat, *g/100 g DM*	4.64 ± 0.52	5.08 ± 0.74	0.11
Ash, *g/100 g DM*	2.38 ± 0.08	2.88 ± 0.4	0.001
Total iron, *mg/100 g DM*	4.74 ± 0.41	5.89 ± 0.87	0.0002
Energy density of porridge, *MJ/L*	6.1	1.7	—
Soluble iron, %	18.83 ± 0.72	4.76 ± 0.80	0.0001
Solids, g/L at optimum viscosity, %	35	10	—
Phytates, *g/100 g DM*	0.66 ± 0.02	1.15 ± 0.03	0.04

1 Values are means ± SD, $n = 12$ production batches. DM, dry matter.

TABLE 3

Twenty-four hour dietary recall by mothers of 6- to 12-mo-old infants receiving processed and unprocessed (placebo) complementary food[1]

	Infants receiving processed CF	Infants receiving unprocessed CF	*P*-value
n	71	66	
Total energy intake, *kJ/d*	3427 ± 915	3426 ± 784	0.99
6–8 mo infants, % *REI*[2]	95.7 ± 26.0	105.9 ± 22.7	0.20
9–12 mo infants, % *REI*[2]	106.7 ± 24.0	103.4 ± 22.5	0.49
Energy from project CF + oil, *kJ/d*	1922 ± 793	1943 ± 691	0.47
Energy from other CFs, *kJ/d*	657 ± 333	636 ± 345	0.49
Total protein, *g/d*	18.3 ± 6.3	17.9 ± 5.5	0.68
Total fat, *g/d*	29.9 ± 7.2	31.3 ± 6.4	0.24
Total iron, *mg/d*	6.8 ± 2.7	6.5 ± 2.4	0.55
Meals, *n/d*	1–2	5–6	

1 Values are means ± SD. REI, recommended energy intake.
2 Based on minimum milk production by women in developing countries (4).

did not differ between the 2 groups and stunting increased with age. The control group consumed equal amounts of macronutrients; in this study, the higher energy density did not seem to have any benefits. In our study, there was a very intensive follow-up; at every encounter with mothers, giving the required amounts and adding extra lipids was strongly reinforced. Under those conditions, a well-balanced complementary food with additional lipids can meet the energy needs of young children. Both groups were comparable in energy intake from complementary foods. Age-specific energy and protein intake from CF met the WHO recommendations. The complementary food intake was higher during the study, compared with information obtained from a baseline study in which complementary foods met only 81 and 75% of the recommended energy that complementary foods should provide in the 6–8 and 9–11 mo age groups, respectively.

We cannot exclude, however, that under less supportive conditions, the energy denser food would yield different results. Indirect evidence for this can be found in the considerably higher feeding frequency for the unprocessed food. Two meals were sufficient to provide the necessary amount of processed CF, whereas 5–6 were required for the unprocessed CF. We introduced a bias into the study by continuously emphasizing the amount of CF to be eaten each day. In settings in which time constraints of mothers limit feeding frequency, differences in total intake can be expected. The study also has certain limits because we cannot exclude with certainty that the CF was shared with other family members. However, there are other studies that also documented negative results. In Ghana, the effects of feeding weanimix and 3 other locally formulated, centrally processed CFs on nutritional status of breast-fed infants (6–12 mo of age), were not different between intervention groups in weight or length gain, Hb, and hematocrit values (3).

Stevens and Nelson (35) investigated the effect of feeding 6-mo-old infants a milk formula with no iron compared with one with 12.0 mg Fe/L for 12 mo and found no differences in mean Hb, ferritin concentrations, and growth between the 2 groups of infants. Furthermore, a multicountry study, investigating the effect of supplementation with high energy density CF fortified with minerals and vitamins, on weight and linear growth of 4- to 7-mo-old infants in 4 developing countries, found no significant difference in overall linear growth, although there was an effect of the micronutrients in stunted but not in nonstunted children (36).

Some studies did find a difference, but they differed in a

TABLE 4

Comparison of Hb, ZP, WLZ, and LAZ of infants who were fed processed and unprocessed complementary food at 12 mo of age[1]

Variable	Processed	Unprocessed	Mean difference	*t* test *P*-value	Overall	*t* test[2] *P*-value
n	133	125			258	
12 mo						
Hb, *g/L*	96.6 ± 17.4	96.5 ± 16.2	0.10	0.96	—	—
ZP,[3] *μg/g Hb*	5.8 ± 3.5	6.2 ± 3.1	0.40	0.34	—	—
WLZ[3]	−0.27 ± 0.97	−0.07 ± 0.98	0.20	0.12	—	—
LAZ	−2.08 ± 1.02	−2.04 ± 1.07	0.04	0.78	—	—
Change from 6 to 12 mo						
Hb, *g/L*	4.8 ± 1.8	1.5 ± 2.0	3.3	0.19	3.2 ± 1.3	0.014
ZP,[3] *μg/g Hb*	−4.4 ± 0.5	−3.6 ± 0.5	0.80	0.39	−4.0 ± 0.4	<0.0001
WLZ	−0.67 ± 0.10	−0.81 ± 0.10	0.14	0.31	−0.74 ± 0.07	<0.0001
LAZ[3]	−0.50 ± 0.06	−0.42 ± 0.07	0.08	0.40	−0.46 ± 0.05	<0.0001

1 Values are means ± SD.
2 Comparing values at age 12 mo with values at age 6 mo (baseline) by paired *t* test.
3 *t* test applied on zero-skewness log-transformed variables.

number of important ways. In the study of Chinamma and Golpaldas (37), 2 groups of children aged 6–24 mo were fed either a high-energy, low-viscosity complementary food or a high-energy, high-viscosity food for 6 mo. The former group increased significantly more in weight and length than the latter. The difference between that study and ours is that the children were restricted to 1 experimental meal/d, although they were allowed to consume that single meal ad libitum. In a sense, therefore, 1 group was consuming less experimental food each day. In our study the mothers were encouraged to feed their infants the entire daily amount of CF, which means that they could have increased the feeding frequency up to 5–6 times/d.

Stunting is a very complex multicausal problem, and it is probable that other nutrients were limiting or that the local conditions did not allow a reversal of the trend or stabilization. Similar trends were observed by Martorell et al. (1), whereby 25% of infants at baseline (4 mo old) were already stunted, presumably due to intrauterine growth retardation (IUGR). They concluded that infants who experience IUGR usually never completely catch up in size to their normal-birth-weight peers even when raised under optimal conditions. Similar observations were made in Indonesia (38,39).

Despite an overall significant increase in mean Hb, a large proportion of the infants were still anemic at the end of the study even when low birth weight was controlled for in the analysis. An important cause of anemia in the present population is malaria. At 6 mo, we found malaria parasites in 50% of samples. The Hb concentration was 1.29 g/L lower at mo 12 in infants with a positive blood smear at mo 6 and mo 12 (*t* test $P < 0.0001$), whereas ZP concentration was 1.84 μg/g Hb higher (*t* test $P < 0.0001$). Mortality in the study population was also very high with 19 deaths in the 309 supplemented infants (61 per 1000). Failure to restore Hb concentrations to normal could be explained by the continuous malaria reinfection among infants despite the treatment given when they became ill. Msuya and Curtis (38) indeed showed that in Tanzania, almost all children became reinfected within 2–4 wk after effective malaria parasite clearance with sulfadoxine (fansidar).

Iron status, as defined by erythrocyte ZP, was not significantly different between the processed and unprocessed CF groups, although iron status improved in general. This was rather unexpected because the groups consumed equal amounts of CF, and the laboratory results showed a substantial increase in solubility, a parameter commonly used as a proxy for bioavailability. The iron content in both processed and unprocessed CFs was low, and a minimal bioavailability of 10% is required to provide the recommended daily amount of 0.6–0.7 mg absorbed iron. The reduction in phytates in the processed CF (34%), which improved iron solubility to 19%, might not have been enough to make a clinical difference. For a metabolically significant improvement in bioavailability, Hurrell (39) postulated that phytates must be reduced by >95%. Finally, infants might have met their basic iron needs, but the food content was insufficient to meet increased needs and to permit recovery from iron deficiency (40).

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