Breast Milk Intake Is Not Reduced More by the Introduction of Energy Dense Complementary Food than by Typical Infant Porridge

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Abstract
The effect of different energy densities of complementary foods on breast milk consumption is not well understood. In this study, we tested the hypothesis that provision of fortified spread (FS), a micronutrient fortified, energy-dense (22 kJ/g), ready-to-use food, to Malawian infants would not decrease their breast milk intake more than a traditional corn + soy blended flour (CSB). Forty-four healthy 6-mo-old infant and mother pairs were enrolled in a prospective, parallel group, investigator-blinded, randomized controlled complementary feeding trial. Infants were randomized to receive 25 g/d of FS, 50 g/d of FS, or 72 g/d of CSB. The primary outcome was the difference in breast milk intake after 1 mo of complementary feeding as measured by the dose-to-mother deuterium oxide dilution technique. Outcomes were compared using repeated measures ANOVA. A total of 41 mother-infant pairs completed the study. At enrollment, 88% of the infants had received corn porridge. At baseline, the infants consumed 129 ± 18 g/kg body wt⁻¹·d⁻¹ (mean ± SD) of breast milk. After 1 mo of complementary feeding with 25 g/d FS, 50 g/d FS, or 72 g/d CSB, their breast milk consumption was 115 ± 18 g/kg body wt⁻¹·d⁻¹, a significant reduction; however, the effects of the complementary foods did not differ from one another (F-value model = 4.33, P = 0.0008 for effect of time and P = 0.69 for effect of type of food). The results suggest that complementary feeding of Malawian infants with FS has the same effect on their breast milk intake as complementary feeding with traditional CSB porridge.

Introduction
Among infants in rural Malawi, as in many places in the developing world, 3–4 mo is the typical age for introduction of complementary foods (1). The traditional Malawian complementary food is corn porridge containing ~10% solids (2). By 4 mo of age, Malawian infants begin to show growth faltering, and by 18 mo of age, they are comparatively stunted and underweight and do not record subsequent catch-up growth (3).

A potential intervention to combat growth faltering is the addition of an improved complementary food, a fortified spread (FS), to infants’ diets at 6 mo of age (4). FS is a ready-to-use, energy-dense, micronutrient fortified, lipid paste. The advantages of using FS are that it can safely provide all of the necessary nutrients in a convenient, hygienic food that is targeted within the family for use only by infants. FS has been shown to be beneficial for severely malnourished children both in famine and nonfamine situations (5,6). In clinical trials, a therapeutic formulation of FS has proved to be safe and effective in the rehabilitation of severely malnourished children (7–9). FS was also associated with better recovery growth in underweight and stunted children and less displacement of habitual foods less than a traditional cereal-based porridge (10).

The energy density of FS is 22 kJ/g, much greater than either traditional cereal porridges, which contain 1.5 kJ/g, or oil-fortified porridges, which can provide up to 6 kJ/g. The effect of such an energy-dense complementary food on breast milk intake is unknown. Two previous studies provided evidence that the energy density of complementary food may alter breast milk intake (11,12). In one study, short-term oil-supplementation of a rice-legume gruel given to 20 infants in India found that foods with higher energy density displaced breast milk in excess of the added energy from the complementary food (11). A second study compared breast milk intake in 10 Bangladeshi children consuming traditional and oil-fortified rice/milk porridges and concluded that breast milk intake was decreased by consumption of energy-dense porridge, but overall energy intake was increased (12).

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This study in 6-mo-old Malawian infants receiving 1 of 3 complementary feeding regimens was undertaken to explore how the energy density of complementary food affects breast milk intake. We hypothesized that the addition of FS to these infants’ diets would not displace breast milk intake to a greater extent than a traditional corn porridge.

Subjects and Methods

Study area. The study was carried out in Lungwena, a rural area in southern Malawi where most families are subsistence farmers growing corn and beans and residing in thatched-roof mud huts. The majority of families have access to communal bore-holes for water and cook all meals over open wood fires. Breastfeeding is ubiquitous and breast milk from mothers was not dislocated by study staff.

Subjects. We enrolled all children between 5.50 and 6.49 mo of age who were permanent residents in 1 of 11 villages, who were available for the duration of the study, and whose caretaker had signed an informed consent. Children who had weight-for-height Z-scores < -2.0, the presence of edema, severe illness warranting hospital admission, or a history of peanut allergy, or who were participating in another clinical trial or part of a multiple gestation were excluded. The study was approved by the College of Medicine Research Ethics Committee, University of Malawi, and the Human Studies Committee of Washington University School of Medicine in St. Louis.

Study design. This was a prospective, parallel group, investigator-blinded, randomized controlled trial of 3 complementary feeding regimens. Upon enrollment, mothers answered a brief demographic and health questionnaire. The questionnaire asked if the child received breast milk from other women, foods other than breast milk every day, and if the infant ever received powdered milk. Infants were weighed and measured using an electronic scale (SECA Model 334, precision of 10 g). Mothers were weighed in light clothing. Baseline saliva samples were obtained from mothers and urine samples were obtained from babies. The mothers were then given an accurately measured 10-g dose of deuterated water. Follow-up visits took place on d 1, 3, 4, 13, and 14. Infant urine was collected at each follow-up visit and mother's saliva was collected on d 1, 4, and 14. All visits were conducted at designated meeting places in the participants’ villages.

After completing 14 d of follow-up, infants were randomly assigned to receive 1 of 3 complementary feeding regimens by choosing an envelope that contained 1 of 3 group letters. A research assistant not involved with the study then recorded this letter on the infant’s enrollment form and revealed to the mother which food her child would receive. All other researchers were unaware of which group letters corresponded to which diet.

Breast milk intake was again measured using deuterated water after the infants had received food for 1 mo. All sample collection took place between 15 September and 12 December, 2004, at the end of the dry season.

The primary outcome was the difference in breast milk intake before and after 1 mo of receiving the complementary food. A secondary outcome was the association between the amount of breast milk consumed and the infant’s and mother’s body composition.

The planned sample size of 15 per group provided the study with 80% power and 95% confidence (1-tailed) to verify an equivalence of the energy density of complementary foods, but no other instructions were given. Breast feeding typically occurs on demand in Malawi, and the feeding of complementary foods would likely occur during the prescribed mealtimes. Compliance with the complementary feeding instructions was measured by weekly home visits from a field worker. The field worker asked the mother how much of the food the child was consuming, and asked to see the containers of either FS or CSB that they had been given by the study staff. The contents remaining in the containers were estimated using a standardized procedure. This validated procedure estimated the volume of the container to the nearest 10%; each field worker demonstrated proficiency in this estimation procedure before embarking upon field work.

Stable isotope measurement of breast milk intake. Saliva samples from the mothers were obtained on d 0, 1, 4, and 14, according to the following assumptions were used in the sample size calculation: a standard deviation of 10 g/kg body wt \(^{-1}d^{-1}\) in breast milk intake before and during FS supplementation (9).

Complementary foods. Two groups of infants were randomized to receive either 25 or 50 g of energy-dense FS each day. FS consists of 26% peanut paste, 28% sugar, 19% oil, 25% dry skimmed milk, and 2% micronutrient powder formulated to provide the recommended daily allowance of all micronutrients for 6-mo-old infants (Table 1). Different micronutrient mixes were used to make 25 g/d FS and 50 g/d FS, so that the micronutrient content of the infant food was the same for both doses of FS. FS was made by Project Peanut Butter (Blantyre, Malawi) by special order for this study; it is not commercially available to the public. The energy density of FS was 22 kJ/g (5.3 kcal/g). Mothers were instructed to stir the FS just prior to feeding to create a homogenous paste, and then feed 4 spoonfuls for the 25 g/d FS group and 8 spoonfuls for the 50 g/d FS group to the infant, without mixing the FS with other foods. Mixing FS with other family foods was discouraged so that it was more likely that the entire dose of FS was consumed by the infant. A standard size spoon was provided to all mothers.

The third group received 72 g/d of fortified corn + soy blended flour (CSB) Table 1. This food was similar to the staple ingredient of traditional corn porridge made by mothers in rural Malawi, with the exception that it was consistently fortified with soy flour and micronutrients. The energy density of the CSB porridge was 4.6 kJ/g (1.1 kcal/g). Mothers were instructed to cook 12 spoonfuls of flour in boiling water to achieve the consistency of typical porridge and then feed the food to the child upon cooling. If the child was not able to consume this amount at one time, mothers were asked to save the remaining porridge, keep it warm, and feed it to the child within the next hour.

Mothers were asked not to disrupt the child’s habitual breast feeding pattern with the complementary foods, but no other instructions were given. Breast feeding typically occurs on demand in Malawi, and the feeding of complementary foods would likely occur during the prescribed mealtimes. Compliance with the complementary feeding instructions was measured by weekly home visits from a field worker. The field worker asked the mother how much of the food the child was consuming, and asked to see the containers of either FS or CSB that they had been given by the study staff. The contents remaining in the containers were estimated using a standardized procedure. This validated procedure estimated the volume of the container to the nearest 10%; each field worker demonstrated proficiency in this estimation procedure before embarking upon field work.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Energy and nutrient content of the daily ration of complementary foods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>72 g/d CSB</td>
</tr>
<tr>
<td>Energy, kJ</td>
<td>1190</td>
</tr>
<tr>
<td>Protein, g</td>
<td>10.4</td>
</tr>
<tr>
<td>Carbohydrates, g</td>
<td>NA(^1)</td>
</tr>
<tr>
<td>Fat, g</td>
<td>3.1</td>
</tr>
<tr>
<td>Retinol, (\mu g) RE</td>
<td>139</td>
</tr>
<tr>
<td>Folate, (\mu g)</td>
<td>43</td>
</tr>
<tr>
<td>Niacin, mg</td>
<td>3</td>
</tr>
<tr>
<td>Panthothenic acid, mg</td>
<td>NA</td>
</tr>
<tr>
<td>Riboflavin, mg</td>
<td>0.3</td>
</tr>
<tr>
<td>Thiamin, mg</td>
<td>0.1</td>
</tr>
<tr>
<td>Vitamin B-6, mg</td>
<td>0.3</td>
</tr>
<tr>
<td>Vitamin B-12, (\mu g)</td>
<td>0.9</td>
</tr>
<tr>
<td>Vitamin C, mg</td>
<td>48</td>
</tr>
<tr>
<td>Vitamin D, (\mu g)</td>
<td>NA</td>
</tr>
<tr>
<td>Calcium, mg</td>
<td>72</td>
</tr>
<tr>
<td>Copper, mg</td>
<td>NA</td>
</tr>
<tr>
<td>Iodine, (\mu g)</td>
<td>NA</td>
</tr>
<tr>
<td>Iron, mg</td>
<td>5</td>
</tr>
<tr>
<td>Magnesium, mg</td>
<td>NA</td>
</tr>
<tr>
<td>Selenium, (\mu g)</td>
<td>NA</td>
</tr>
<tr>
<td>Zinc, mg</td>
<td>3.6</td>
</tr>
</tbody>
</table>

\(^1\) Information not available.
sampling protocol described by Haisma et al. (13). Briefly, mothers were asked to not eat or drink for 30 min prior to the sampling. Mothers placed a piece of clean, dry cotton into their mouths until thoroughly soaked. The wet cotton was then placed in a dry 20-mL syringe, and the saliva expressed into cryovials. The saliva sample on d 0, the time of enrollment, was obtained prior to the administration of a fixed dose of 10 g deuterated water to the mother. The exact time of administration of the deuterated water and the times of collection of all subsequent samples were carefully recorded. Urine samples from the babies were obtained on d 0, 1, 3, 4, 13, and 14. Briefly, the babies were cleaned thoroughly, and clean, dry cotton was placed into plastic pants. Once the babies had wet the cotton, it was placed into a clean 20-mL syringe and the urine was expressed into clean cryovials. All samples (breast milk, saliva, and urine) were frozen at −20°C, stored and transported to the laboratory of William Wong in Houston, Texas for stable hydrogen isotopic analysis.

The deuterium enrichment of the samples was determined by isotope-ratio mass spectrometry. Saliva or urine samples (10 μL) were transferred under an atmosphere of nitrogen with a Pencil-Slim micropipette (PS-10, Northwest Scientific Instruments) to a reduction vessel containing 250 mg of zinc turning (Biogeochemical Laboratory, Department of Geological Sciences, Indiana University, Bloomington, IN) (14, 15). After replacement of the stopcock, the sample was frozen with liquid nitrogen and the vessel was evacuated to <10 mPa. With the stopcock closed, the vessel was removed from the vacuum manifold, the bottom third of the vessel was inserted into a Tecan dry-heating block (Model DB-4, Tecne), and the sample was heated to 500°C for 45 min so that the water in the sample was reduced to Hz. When cooled to room temperature, the vessel containing the Hz was attached to an automated sample manifold of a Finnigan Delta-E gas-isotope-ratio mass spectrometer (Finnigan MAT) for 2H/1H ratio measurement. The 2H/1H ratio of the sample was measured against a laboratory Hz working standard and the results were expressed in δH Units after correction for Hz+. The corrected δH values were normalized against Vienna-Standard Mean Ocean Water and Standard Light Antarctic Precipitation, using the equation recommended by the International Atomic Energy Agency (16, 17).

Calculations. Calculations used to determine breast milk intake were performed following the method of Haisma et al. (13). Briefly, using data points generated from the isotope levels of urine and saliva samples and the recorded time elapsed from administration of deuterium oxide to the mothers, curves were generated to reflect the disappearance of the isotope from the mothers’ body water and its appearance and disappearance from the infants’ body water. These curves were fit to the equations below using the Solver function of Microsoft Excel. From the fitted curves, information regarding the mother’s body composition and daily water intake was also estimated. This method allows the calculation of mean breast milk intake over a 2-wk period.

The equation for mothers was

$$E_b(t) = F_{mb}(t) = E_{m0} e^{-K_{mm} t},$$

where $E_{m0}$ is the isotopic enrichment of a sample at time $t$, $E_{m0(0)}$ is the isotope enrichment of the sample at time zero (mg/kg), $t$ is the time elapsed since administration of the isotope expressed (d), and $K_{mm}$ is the water turnover in the mother (g/d).

The equation for infants was

$$E_{i(t)} = E_{i0}(F_{ih}(N/b)(e^{-K_{mm} t} - e^{(0b/Vb)})) /[F_{ih}/N/b - K_{mm}],$$

where $E_{i0}$ is the isotopic enrichment of the sample taken at time $t$ (mg/kg), $F_{ih}$ is the flow of water from the mother to the baby via breast milk (kg/d), $V_{ih}$ is the infant’s distribution space (kg), and $E_{ih}$ is the total water loss in the baby (kg/d). In this method, $V_{ih}$ is assumed to change linearly with weight over the course of the study period, and was related to the infant weight (W) in kg by $V_{ih} = 0.84 W^{0.5}$.

Statistical analysis. Baseline characteristics were tabulated as means ± SD for continuous measures and n (%) for dichotomous measures. Relative infant weight gain was expressed as g/kg body wt⁻¹·d⁻¹. Breast milk consumption was expressed as g/d and g/kg body wt⁻¹·d⁻¹. Absolute infant weight gain was expressed as g. These 3 outcome measures were compared, with respect to time, before and after the intervention, and with respect to complementary feeding group, using repeated measures ANOVA. These analyses were conducted using GLM procedure (SAS/STAT software). Differences with $P < 0.05$ were considered significant.

The association between breast milk intake on enrollment and demographic, anthropometric and dietary characteristics of the subjects was assessed by linear regression modeling (enter mode, SPSS 13.0). Because of the limited sample size, only 4 covariates were considered: gender, infant weight, mother’s percentage body fat, and other foods consumed upon enrollment. These covariates were chosen because there was evidence from other studies that they affected breast milk consumption (13, 18). For each comparison made, $P < 0.05$ was considered significant.

Results

Forty-four mother-infant pairs were initially enrolled in the study and 41 pairs completed the study (Fig. 1, Table 2). No adverse events were recorded.

Thirty-eight (89%) of the mothers reported feeding their babies foods other than breast milk. For all 38, this included corn porridge, to which some mothers added sugar or salt. Four (9%) of the infants also had additional milk in their diet, either from powdered milk or breast milk from other women. Two mothers reported feeding their children corn dough and bean relish. One mother reported feeding her infant commercially prepared cookies and soda. Only 5 (12%) of the infants were exclusively breast-fed. On enrollment, the infants consumed 910 ± 162 g/d of breast milk, or 129 ± 18 g/kg body wt⁻¹·d⁻¹, and had a mean daily water intake from non-breast milk foods and fluids of 168 ± 223 g/d. The mothers consumed 4.7 ± 1.0 kg/d of water.

The infants were fed for 30 ± 4 d between the completion of the first measurement of breast milk intake and the start of the second assessment. After 1 mo of complementary feeding, infants consumed 879 ± 179 g breast milk/d or 115 ± 18 g/kg body wt⁻¹·d⁻¹ and had a daily water intake from non-breast milk foods and fluids of 186 ± 235 g/d. Infants gained 1.9 ± 0.7 g/kg body wt⁻¹·d⁻¹.

FIGURE 1 Subject enrollment flow-chart.
Breast milk intake per weight

Infants

Breast milk intake before CF, kg
0.72 ± 0.06 0.70 ± 0.03 0.64 ± 0.30

Age, mo
5.3 ± 0.3 5.5 ± 0.4 5.5 ± 0.4

Length, cm
64.2 ± 1.7 64.3 ± 1.7 63.6 ± 1.0

Weight-for-Height, Z-score
0.3 ± 1.3 0.2 ± 1.0 0.2 ± 0.8

Weight-for-Age, Z-score
0.3 ± 0.6 0.2 ± 0.9 0.8 ± 0.5

Height-for-Age, Z-score
0.7 ± 0.4 0.6 ± 0.4 0.8 ± 0.6

Days cough reported, n
1.7 ± 2.5 3.2 ± 3.8 7.5 ± 6.0

Ate solid food before enrollment, n(%)
12 (80) 12 (86) 12 (100)

Having another source of milk, n(%)
2 (13) 2 (14) 0 (0)

Infant weight after CF, kg
25 g/d FS 50 g/d FS 72 g/d CSB
25 ± 7 25 ± 7 25 ± 7

Male, n (%)
10 (67) 5 (38) 5 (42)

Weight, kg
7.02 ± 0.66 7.05 ± 0.93 6.41 ± 0.30

Age, mo
5.3 ± 0.3 5.5 ± 0.4 5.5 ± 0.4

Length, cm
64.2 ± 1.7 64.3 ± 1.7 63.6 ± 1.0

Weight-for-Height, Z-score
0.3 ± 0.5 0.3 ± 1.0 0.2 ± 0.5

Weight-for-Age, Z-score
0.3 ± 0.6 0.2 ± 0.9 0.8 ± 0.5

Height-for-Age, Z-score
0.7 ± 0.4 0.6 ± 0.4 0.8 ± 0.6

Days cough reported, n
1.7 ± 2.5 3.2 ± 3.8 7.5 ± 6.0

Ate solid food before enrollment, n(%)
12 (80) 12 (86) 12 (100)

Having another source of milk, n(%)
2 (13) 2 (14) 0 (0)

Compliance with the complementary feeding regimen was good. Mothers reported that infants were consuming all of the complementary food that they were instructed to give and the estimations of the residual food in the containers by the field workers was <5% of the total.

Comparison of breast milk intake (expressed in g/d) among the complementary food groups and over time using repeated measures ANOVA revealed no significant differences (Table 3). When breast milk intake was expressed as g/kg body wt \(^{-1}\) d\(^{-1}\), infants consumed less breast milk after the introduction of complementary food \((F\)-value of model = 4.33, \(P < 0.0008\) for time). However, there was no effect of the type of complementary food \((P = 0.69, \text{Table 3})\). Children receiving 25 g/d FS gained less total weight than children receiving 50 g/d FS or CSB \((P = 0.03, \text{Table 3})\).

Five children enrolled in the study were reported to have never received complementary food; 3 of these infants were assigned to receive 25 g/d FS and 2 infants 50 g/d FS. These 5 children consumed 136 ± 12 g/kg body wt \(^{-1}\) d\(^{-1}\) breast milk before complementary feeding was introduced and 132 ± 22 g/kg body wt \(^{-1}\) d\(^{-1}\) afterward \((P = 0.73)\). The 36 children who were reported to have previously received complementary food decreased their breast milk consumption from 132 ± 20 g/kg body wt \(^{-1}\) d\(^{-1}\) to 117 ± 17 g/kg body wt \(^{-1}\) d\(^{-1}\) \((P = 0.0008\) by repeated measures of ANOVA).

Linear regression modeling of the amount breast milk consumption upon enrollment revealed that infants who were male, heavier, and had mothers with a lower percentage of body fat consumed more breast milk (Table 4).

### Discussion

Adding 50 g of energy-dense FS to the diets of healthy 6-mo-old infants in rural Malawi did not reduce breast milk intake any more than a similar amount of a cereal/legume porridge, suggesting that an energy-dense complementary food does not adversely affect intake when adequate amounts of both foods are available. Addition of either 50 g/d FS or CSB as complementary food in these 6-mo-old infants did not affect energy intake from breast milk. It is not possible to say how the introduction of complementary feeding with study foods affected overall energy intake, because it was not known what quantities of non-breast milk foods were consumed at the time of enrollment. Because FS is 5 times more energy dense than cereals, needs no cooking before use, and is hygienic because it does not support bacterial growth, it is an attractive consideration as a complementary feeding intervention among children at risk for growth faltering in the developing world. This study supports the consideration of FS because it does not compromise breast milk intake.

The results of this study are limited in that they come from a homogenous population in rural Malawi. Caution should be exercised when applying conclusions from this study to other groups of children. The feeding of the complementary foods to the infants was not directly observed. However, indirect measures of compliance by field workers suggested compliance was good. Our research team has been working in the study area for an extended period of time, and members of the Lungwena community have consistently been encouraged to communicate their habits accurately and truthfully, and have never been “punished” for noncompliance. Observed compliance with similar foods in 6-mo-old infants in a previous pilot study in Lungwena was good (4). The absolute weight gain of the children receiving 50 g/d FS was greater than that of the children receiving 25 g/d FS (Table 3), also suggesting that they were compliant with their complementary feeding regimen.

### Table 2: Baseline characteristics of study infants who received complementary feeding with 25 or 50 g/d FS or 72 g/d CSB

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>25 g/d FS (n = 15)</th>
<th>50 g/d FS (n = 14)</th>
<th>72 g/d CSB (n = 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infants</td>
<td>Male, n (%)</td>
<td>Weight, kg</td>
<td>Age, mo</td>
</tr>
<tr>
<td></td>
<td>10 (67)</td>
<td>7.02 ± 0.66</td>
<td>5.3 ± 0.3</td>
</tr>
<tr>
<td></td>
<td>5 (38)</td>
<td>7.05 ± 0.93</td>
<td>5.5 ± 0.4</td>
</tr>
<tr>
<td></td>
<td>5 (42)</td>
<td>6.41 ± 0.30</td>
<td>5.5 ± 0.4</td>
</tr>
<tr>
<td>Length, cm</td>
<td>64.2 ± 1.7</td>
<td>64.3 ± 1.7</td>
<td>63.6 ± 1.0</td>
</tr>
<tr>
<td>Weight-for-Height, Z-score</td>
<td>0.3 ± 1.3</td>
<td>0.2 ± 1.0</td>
<td>0.2 ± 0.5</td>
</tr>
<tr>
<td>Weight-for-Age, Z-score</td>
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<td>0.2 ± 0.9</td>
<td>0.8 ± 0.5</td>
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<tr>
<td>Height-for-Age, Z-score</td>
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<td>0.6 ± 0.4</td>
<td>0.8 ± 0.6</td>
</tr>
<tr>
<td>Days cough reported, n</td>
<td>1.7 ± 2.5</td>
<td>3.2 ± 3.8</td>
<td>7.5 ± 6.0</td>
</tr>
<tr>
<td>Ate solid food before enrollment, n (%)</td>
<td>12 (80)</td>
<td>12 (86)</td>
<td>12 (100)</td>
</tr>
<tr>
<td>Having another source of milk, n (%)</td>
<td>2 (13)</td>
<td>2 (14)</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

1 Values expressed as n (%) for dichotomous measures and means ± SD for continuous measures.
2 Determined over 21 d.

### Table 3: Breast milk intakes and body weights before and after 1 mo of complementary feeding in infants receiving 25 or 50 g/d of FS or 72 g/d of CSB

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>25 g/d FS (n = 15)</th>
<th>50 g/d FS (n = 14)</th>
<th>72 g/d CSB (n = 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant weight before CF, kg</td>
<td>951 ± 189</td>
<td>921 ± 165</td>
<td>839 ± 109</td>
</tr>
<tr>
<td>Breast milk intake after CF, kg</td>
<td>902 ± 193</td>
<td>931 ± 187</td>
<td>797 ± 119</td>
</tr>
<tr>
<td>Breast milk intake per weight before CF, g/kg body wt (^{-1}) d(^{-1})</td>
<td>132 ± 21</td>
<td>127 ± 19</td>
<td>128 ± 15</td>
</tr>
<tr>
<td>Breast milk intake per weight after CF, g/kg body wt (^{-1}) d(^{-1})</td>
<td>115 ± 21*</td>
<td>118 ± 18*</td>
<td>111 ± 14*</td>
</tr>
<tr>
<td>Infant weight before CF, kg</td>
<td>7.02 ± 0.66</td>
<td>7.05 ± 0.93</td>
<td>6.45 ± 0.33</td>
</tr>
<tr>
<td>Infant weight after CF, kg</td>
<td>7.32 ± 0.58**</td>
<td>7.50 ± 0.85*</td>
<td>6.85 ± 0.35*</td>
</tr>
</tbody>
</table>

1 Values are expressed as means ± SD. *Different from before CF, \(P < 0.05\), **Different from the other means in that row, \(P < 0.05\). Comparisons made using repeated measures of ANOVA.
2 Breast milk intakes were measured over a 2-wk period.

### Table 4: Summary of linear regression modeling of breast milk intake by infants at the time of enrollment

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Standardized (\beta)-coefficient</th>
<th>(P)-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant weight</td>
<td>0.53</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Consumption of other foods</td>
<td>0.11</td>
<td>0.37</td>
</tr>
<tr>
<td>Infant sex(^1)</td>
<td>-0.34</td>
<td>0.01</td>
</tr>
<tr>
<td>Mother’s body fat</td>
<td>-0.37</td>
<td>0.007</td>
</tr>
</tbody>
</table>

1 Enter model used, \(r = 0.70, P < 0.0001\) for the model.
2 Negative coefficient indicates male sex is associated with greater breast milk intake.
The baseline, preintervention breast milk intake of 910 g/d, providing 372 kJ/kg body wt \(-1\) d\(^{-1}\) (90 kcal/kg body wt \(-1\) d\(^{-1}\)), was consistent with other studies of similar-age infants that had breast milk intake measured using the dose-to-mother deuterium dilution technique. Two populations of 4- to 9-mo-old infants in Papua New Guinea consumed 936 g/d and 863 g/d (18,19), and 4-mo-old Brazilian infants consumed 723 g/d (20). Our baseline values also agree with intakes of 827 g/d measured by test-weighing among 4-mo-old infants in Denmark (21).

The standard growth rate for infants between 6 and 7 mo is 1.7 g/kg body wt \(-1\) d\(^{-1}\) (22), similar to the rate of 1.9 g/kg body wt \(-1\) d\(^{-1}\) we found in this study. The growth rate of the children receiving 25 g/d FS, which contained only 50% of the WHO recommended total complementary food energy intake, was less than that in the children receiving either 50 g/d FS or 72 g/d CSB. It is possible that mothers of infants receiving 25 g/d FS did not offer their infants adequate amounts of other non-breast milk foods. No conclusions should be drawn from this observation, because the sample size was too small and the duration of the study was too short to assess growth rates. However, it may be wise to explicitly counsel mothers who receive a partial complementary feeding supplement, such as a micronutrient-rich FS, that their child also needs additional complementary foods.

Our results are inconsistent with the notion that the energy density of complementary foods affects the displacement of breast milk, as has been suggested by other studies (11,12). Our findings indicate that the infant’s total energy intake did not differ when complementary feedings of energy-dense FS or low energy density CSB porridge were given. Notable methodological differences between this study and the previous Indian and Bangladeshi studies are that the latter were conducted with older children, aged up to 18 mo, who were studied as inpatients so that all dietary intake could be assessed by weighing. The relationship between breastfeeding and complementary feeding may well be age-dependent and disrupted by the feeding environment. In addition, the Indian study assessed intakes over 48 h with 2 groups of children switching between high and low energy density foods after 24 h; this methodology allowed little time for the children’s appetite to compensate for the change in the energy density of the diet. The dose-to-mother deuterium dilution technique has the advantage of being minimally disruptive to breast-feeding, thus allowing mothers to maintain their on-demand pattern of feeds. The dose-to-mother technique also eliminates errors in estimation that arise from insensible water losses that occur during test-weighing techniques.

Malawian children are continuously carried by their mothers and breast fed as often as they demand it. Of children in this study, 88% were already receiving complementary food, so this is not a study describing the effect of the initiation of complementary feeding on breast milk intake. The 5 exclusively breast-fed children in this study did not show a reduction in relative breast milk intake, supporting the notion that infants modify their intake of food based on their energy requirements rather than the opportunity to eat or their gastric capacity. Another finding that supports the notion that infants consume breast milk in accordance with their energy requirement is that infant weight was a significant predictor of breast milk intake. This is in agreement with other studies using the dose-to-mother technique to assess breast milk intake that found infant weight accounted for over 50% of the variation seen between infants (20).

We found that mothers with a lower fraction of total body fat, indicating a poorer nutritional status, had infants who consumed more milk. Previous work in Bangladesh concluded that mothers with a poorer nutritional status, defined by BMI and skinfold thicknesses, produced breast milk with a lower fat and energy content (23). Also, Gambian mothers fed nutritional supplements who then increased their BMI, an indication that their nutritional status had improved, produced breast milk with a higher fat content (24). Perhaps these Malawian mothers with a lower fraction of body fat and poorer nutritional status were producing breast milk with a lower energy density, and thus their infants consumed more of this milk in an effort to meet their energy requirements.

This study provides evidence that giving 6-mo-old infants energy-dense foods, such as FS, does not reduce breast milk intake when compared with traditional cereal porridges. Further studies exploring the use of energy-dense complementary foods should not be encumbered by concerns that such foods will deleteriously affect breastfeeding in this age group.

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Literature Cited


