3. Energy required from complementary foods and factors affecting their intake

3.1 Estimation of energy required from complementary foods

Once complementary foods are introduced, guidelines are needed on the amounts of energy and nutrients they should provide for children of different ages within the age range 6 to 24 months. In this review, the first step taken to develop such quantitative guidelines was to establish recommendations concerning the amount of energy required from these foods. To define these requirements, we first examined the amount of energy consumed from breast milk by children of this age range in both low-income and affluent countries. We then subtracted the amounts of energy provided by breast milk from the recently revised age-specific estimates of children's average energy needs. These differences were used to estimate the average amounts of energy that would be required from complementary foods. The information used in developing these estimates is described in detail in the following sections.

The resulting estimates of the amount of energy "required" from complementary foods must be accepted with a great deal of caution because of an inherent dilemma with the logic employed. Specifically, it must be recognized that breast-milk energy intakes are likely to be suppressed to some degree in relation to the amount of energy consumed from complementary foods (see sections 1.6.1 and 2.1.4). Thus, when the estimates of energy needed from complementary foods are based on breast-milk energy intakes by children who are not exclusively breast-fed (as is the case for children greater than six months of age in the current analyses), these estimates may be inflated. Because very few children continue to be breast-fed exclusively beyond six months of age, it is not possible to derive more accurate guidelines on the true amount of energy that would be required from complementary foods by children who were previously exclusively breast-fed.

3.1.1 Energy consumption from breast milk

Information on energy consumption from breast milk was obtained through a review of literature identified by Medline searches, previously published review articles, and other references cited in these documents. All studies since 1980 from either developing or industrialized countries were included in the review if they provided quantitative information on breast-milk consumption or total daily energy intake from breast milk. A complete list of these references and reported data for the amounts of breast-milk consumed, energy intake from breast milk ($kcal_{th}$/d and $kcal_{th}$/kg of body weight/d), and energy density of breast milk (when available) are presented in relation to mode of feeding (exclusive breast-feeding or partial breast-feeding) in Annex I for developing countries and Annex II for industrialized ones. When information on the energy density of breast milk was not provided in the original paper, an assumed figure of 0.65 $kcal_{th}$/g was used to calculate energy intake from breast milk, which is similar to the figure of 0.67 $kcal_{th}$/g that was recently proposed by the International Dietary Energy Consultative Group (Prentice et al., 1996).

The mean amount of breast-milk consumed by children in developing countries and their average energy intake from breast milk are presented by age and exclusivity of breast-feeding in Table 7. Similar data are presented in Table 8 for children from industrialized countries. Pooled SDs within each age group were calculated from the square root of the arithmetic means of the variances from all studies. The number of studies and total numbers of subjects within each group are also indicated in the Tables. Because the children's body weights were not available from all studies, the data are also broken down for the subset of studies that provided weight data and for which intakes could therefore be expressed in relation to these weights.

In general, breast-milk consumption and energy intake from breast milk increased during early infancy and reached a peak from 3 to 8 months of age, after which they tended to decline. As expected, exclusively breast-fed children had milk intakes consistently greater than those of partially breast-fed infants. Before 9 months of age there was surprisingly little difference in mean breast-milk consumption by children in low-income countries and more affluent ones. Nevertheless, energy intakes from breast milk by children in industrialized countries were slightly higher, because of the greater apparent energy density of their mothers' milk, although possible methodological differences cannot be excluded. The energy density of breast milk ranged from 0.53 to 0.70 $kcal_{th}$/g in developing countries and from 0.60 to 0.83 $kcal_{th}$/g in industrialized countries. Because the infants from industrialized countries had slightly greater body weights, the mean energy intake from breast milk per kg of body weight was similar in both settings. After 9 months of age breast-milk intakes of children in developing countries tended to exceed those of their counterparts in affluent countries, possibly because of greater energy intake from complementary foods by the latter.

After reviewing these data, we developed estimates of the average energy intake from breast milk by developing country infants less than six months of age, using the respective data from exclusively breast-fed infants only. For children from 6 to 24 months of age we used the pooled data for both exclusive and partial breast-feeders from developing countries. As indicated in Table 7, the estimated mean energy intakes from breast milk were 437 $kcal_{th}$/d for infants 0-2 months of age, 474 $kcal_{th}$/d for those 3-5 months of age, 413 $kcal_{th}$/d for those aged 6-8 months, 379 $kcal_{th}$/d for those aged 9-11 months, and 346 $kcal_{th}$/d for children aged 12-23 months. These intake data were then used to estimate the amounts of energy that would be needed from complementary foods to assure that children of different ages could satisfy their theoretical energy requirements.

3.1.2 Energy requirements of children less than two years of age

There is a growing consensus that the FAO\WHO\UNU recommendations for energy intakes by children less than 2 years of age that were published in 1985 (WHO, 1985b) are overestimates of young children's true energy needs (Butte, 1996; Torun et al., 1996).

Table 7. Intakes of breast milk and energy from breast milk in developing countries, by age group

	Age Group (months)				
	0-2	3-5	6-8	9-11	12-23
PARTIALLY BREAST-FED (PBF)					
ALL STUDIES (16)[a]					
No. of subjects [b].	381	437	533	342	377
Breast-milk intake (g/d):	617±168 (8)[c]	663±155 (9)	660±153 (14)	616±172 (13)	549±187 (9)
Breast-milk energy intake ($kcal_{th}$/d)	376±110 (8)	412±104 (9)	403±99 (14)	379±111 (13)	346±128 (9)
SUBSET[d] (8)					
No. of subjects:	0	91	212	91	182
Breast-milk intake (g/d):	----	750±142 (1)	740±149 (6)	663±187 (5)	526±214 (5)
Breast-milk energy intake ($kcal_{th}$/d)	----	500±97 (1)	459±93 (6)	420±120 (5)	329±150 (5)
Breast-milk energy intake ($kcal_{th}$/kg/d):	----	76±14 (1)	67±16 (6)	56±14(5)	39±18 (5)
Body weight (kg):	----	6.7 (1)	7.0 (6)	7.6 (5)	8.6 (5)
EXCLUSIVELY BREAST-FED (EBF):					
ALL STUDIES (5)					
No. of subjects:	172	259	70	----	----
Breast-milk intake (g/d):	714±131 (3)	784±128 (5)	776±141 (2)	----	----
Breast-milk energy intake ($kcal_{th}$/d):	437±79 (3)	474±80 (5)	483±87 (2)	----	----
SUBSET (4)					
No. of subjects:	140	229	50	----	----
Breast-milk intake (g/d):	690±124 (2)	795±131 (4)	813±126 (1)	----	----
Breast-milk energy intake ($kcal_{th}$/d):	442±78 (2)	488±79 (4)	553±88 (1)	----	----
Breast-milk energy intake ($kcal_{th}$/kg/d):	104±21 (2)	78±12 (4)	73±12 (1)	----	----
Body weight (kg):	4.4 (2)	6.3 (4)	7.6 (1)	----	----
ALL STUDIES (PBF +EBF):					
ALL STUDIES (21)					
No. of subjects:	553	696	603	342	377
Breast-milk intake (g/d):	644±159 (11)	706±146 (14)	674±151 (16)	616±172 (13)	549±187 (9)
Breast-milk energy intake ($kcal_{th}$/d):	393±103 (11)	434±96 (14)	413±98 (16)	379±111 (13)	346±128 (9)
SUBSET (12)					
No. of subjects:	140	320	262	91	182
Breast-milk intake (g/d):	690±124 (2)	786±134 (5)	750±146 (7)	663±187 (5)	526±214 (5)
Breast-milk energy intake ($kcal_{th}$/d):	442±78 (2)	490±83 (5)	472±92 (7)	420±120 (5)	329±150 (5)
Breast-milk energy intake ($kcal_{th}$/kg/d):	104±21 (2)	78±13 (5)	68±16 (7)	56±14 (5)	39±18 (5)
Body weight (kg):	4.4 (2)	6.4 (5)	7.1 (7)	7.6 (5)	8.6 (5)

a Number of studies

b Number of subjects pooled over studies

c Numbers represent arithmetic Mean±SD from various studies, and numbers in parentheses indicate number of studies for each age group.

d Subset indicates data from the subset of studies which provided body weight and/or information on energy intake as $kcal_{th}$/kg.

Table 8. Intakes of breast milk and energy from breast milk in industrialized countries, by age group

	Age Group (months)				
	0-2	3-5	6-8	9-11	12-23
PARTIALLY BREAST-FED (PBF)					
ALL STUDIES (7)[a]					
No. of subjects[b].	175	416	351	108	40
Breast-milk intake (g/d):	640±169 (4)[c]	687±181 (5)	592±182 (6)	436±256 (4)	448±251 (1)
Breast-milk energy intake ($kcal_{th}$/d):	420±132 (4)	471±148 (5)	411±127 (6)	322±186 (4)	313±178 (1)
SUBSET[d] (5)					
No. of subjects:	64	305	245	80	40
Breast-milk intake (g/d):	614±192 (2)	666±204 (3)	614±183 (4)	431±240 (3)	448±251 (1)
Breast-milk energy intake ($kcal_{th}$/d)	430±134 (2)	454±142 (2)	424±123 (4)	307±165 (3)	313±178 (1)
Breast-milk energy intake	71±23 (2)	65±21 (3)	62±18 (4)	36±19 (3)	34±19 (1)
Body weight (kg)	6.0 (2)	6.9 (3)	7.7 (4)	8.6 (3)	9.2 (1)
EXCLUSIVELY BREAST-FED (EBF):					
ALL STUDIES (8)					
No. of subjects:	333	399	139	26	----
Breast-milk intake (g/d):	710±134 (5)	787±128 (7)	803±117 (5)	900±39 (1)	----
Breast-milk energy intake ($kcal_{th}$/d):	490±98 (5)	548±93 (7)	576±71 (5)	585±25 (1)	----
SUBSET (7)					
No. of subjects:	333	291	67	26	----
Breast-milk intake (g/d):	710±134 (5)	773±133 (6)	769±119 (4)	900±39 (1)	----
Breast-milk energy intake ($kcal_{th}$/d):	490±98 (5)	546± 97 (6)	583±72 (4)	585±25 (1)	----
Breast-milk energy intake	104±19 (5)	85±13 (6)	76±10 (4)	67±3 (1)	----
Body weight (kg):	4.7 (5)	6.4 (6)	7.7 (4)	8.7 (1)	----
ALL STUDIES (PBF +EBF):					
ALL STUDIES (15)					
No. of subjects:	508	815	490	134	40
Breast-milk intake (g/d):	679±150 (9)	745±152 (12)	688±156 (11)	529±230 (5)	448±251 (1)
Breast-milk energy intake ($kcal_{th}$/d):	459±114 (9)	516±119 (12)	486±106 (11)	375±167 (5)	313±178 (1)
SUBSET (12)					
No. of subjects:	397	596	312	106	40
Breast-milk intake (g/d):	683±153 (7)	737±163 (9)	681±156 (8)	550±205 (4)	448±251(1)
Breast-milk energy intake ($kcal_{th}$/d):	473±110 (7)	516±114 (9)	503±101 (8)	377±143 (4)	313±178 (1)
Breast-milk energy intake	94±20 (7)	78±16 (9)	69±15 (8)	44±17 (4)	34±19 (1)
Body weight (kg):	5.1 (7)	6.6 (9)	7.7 (8)	8.6 (4)	9.2 (1)

a Number of studies
b Number of subjects pooled over studies
c Numbers represent arithmetic Mean±SD from various studies, and numbers in parentheses indicate number of studies for each age group.
d Subset indicates data from the subset of studies which provided body weight and/or information on energy intake as $kcal_{th}$/kg

The FAO\WHO\UNU recommendations were based on energy intakes by healthy children in affluent countries and included a 5% increment for an assumed underestimation of breast-milk intake (WHO, 1985b). The British Daily Reference Values (Department of Health, 1991), by contrast, do not include this 5% increment. Butte (1996) has recently reviewed relevant literature published since 1980 for the International Dietary Energy Consultative Group to develop estimates of energy requirements of both breast-fed and formula-fed infants based on energy intake, total energy expenditure (TEE), and TEE plus the energy required for growth (i.e tissue deposition). Torun et al. (1996) have completed a similar exercise for children and adolescents from 1 to 18 years of age. Because concerns have been raised about the accuracy of the measurement of dietary intake, it seems that estimates of energy requirements based on TEE plus the energy cost of growth are more appropriate.

The energy requirements of children less than 2 years of age, as estimated by each of the aforementioned sources, are summarized in Table 9. The estimates based on TEE plus the energy cost of growth are considerably less than the earlier FAO/WHO/UNU recommendations based on dietary intake. For the subsequent calculations of energy needed from complementary food we used Butte's data for energy requirements of breast-fed infants and Torun's data for energy requirements of 1-year-old children. These requirements are expressed as energy requirements per day (not per unit body weight per day), because this would allow for extra energy consumption per kg among children with low body weight due to previous nutritional growth retardation.

Table 9. Recommended energy intakes during the first two years of life

	Energy Recommendations					
Age Group (months)	FAO/WHO/UNU 1985[a]		Butte 1996[b]		Torun et al. 1996[c]	
	$kcal_{th}/kg/d$	$kcal_{th}/d$	$kcal_{th}/kg/d$	$kcal_{th}/d$	$kcal_{th}/kg/d$	$kcal_{th}/d$
0-2	116	520	88	404	----	----
3-5	99	662	82	550	----	----
6-8	95	784	83	682	----	----
9-11	101	949	89	830	----	----
12-23	106	1170	----	----	86	1092

a - Numbers derived from the energy and protein requirements in WHO1985b.
b - Based on energy required for total energy expenditure plus growth of breast-fed infants.
c - Based on energy required for total energy expenditure plus growth.

3.1.3 Age-specific estimates of energy required from complementary foods

Tables 10 and 11 summarize the average amount of energy needed from complementary foods by age group, it is calculated as the difference between the recommended total energy intake and the average energy intake from breast milk. Because there is a fairly broad range of energy intake from breast milk, we have also provided estimates of the range of energy required from complementary foods for children receiving low or high amounts of energy from breast milk, and these were defined using the mean –2 SD and the mean +2 SD, respectively. These ranges should not necessarily be considered as representative for all populations because of the limited number of available studies from which they were derived and the non-systematic sampling procedures of individual studies.

As expected, these analyses result in a wide range of estimated energy required from complementary foods. Nevertheless, for the purpose of estimating a population's energy needs from complementary foods, the recommendations derived from the average figure for breast-milk energy intake are probably appropriate, even though individual children will often require more or less energy from complementary foods than the average. It is conceivable that children with low energy intakes from breast milk are those with low individual energy requirements and those with high breast-milk energy consumption are those with greater energy requirements. If true, this would have the effect of reducing the range of energy required from complementary foods. It is more likely though, that children with low breast-milk energy consumption are those who are receiving more energy from complementary foods. Because of these uncertainties, we present the full, unmodified range of possible energy requirements from complementary foods. While this may underestimate or overestimate some children's true energy needs, it would provide a more conservative (that is, greater) range of estimates for the amount of energy needed from complementary foods.

The results of these analyses based on currently available data suggest that breast milk alone provides 76 $kcal_{th}$ per day less than the average theoretical energy needs of infants from 3 to 5 months of age in developing countries, but allows for adequate energy intake by infants of this age in more developed countries. Although this would seem to indicate that some children in developing countries may need additional energy from non-breast-milk sources before six months of age, these estimates must be interpreted cautiously for several reasons. First, infants from developing countries are more frequently of low birth weight. Hence, their energy requirements are likely to be less than the figure derived from reference infants which was applied in this analysis, and the lower observed energy intakes from breast milk by children in developing countries are probably explained on this basis. Second, the figures presented for energy intake from breast milk are undoubtedly underestimates of true intake because most of the studies cited did not correct for insensible losses during test-weighing. Third, the difference in breast-milk energy intake that was reported for children in developing countries and more affluent ones is explained by the energy density of milk, which in turn is determined by maternal body mass index or fatness. Two of the five studies used to estimate "average" milk energy density in developing countries were from malnourished women in Bangladesh and Indonesia. The milk energy intake values would have been quite different with another mix of populations, possibly resulting in greater milk energy intakes and lower energy needs from complementary foods. We are unable to determine what might be an appropriate

Table 10. Energy (kcal$_{th}$) from breast milk and the amount needed from complementary foods by children in developing countries, by age group

Age group (months)	Energy consumed from breast milk[a,b]			Energy needed from complementary foods[c,d]		
	Breast-milk intake			Breast-milk intake		
	Low	Avg	High	Low	Avg	High
0-2	279	437	595	125	0	0
3-5	314	474	634	236	76	0
6-8	217	413	609	465	269	73
9-11	157	379	601	673	451	229
12-23	90	346	602	1002	746	490

a: For age groups 0-2 and 3-5 months, energy consumed from breast milk taken from exclusively breast-fed infants only (Table 7); and for age groups over 6 months from all children regardless of mode of feeding (i.e. pooled for both feeding modes as shown in the ALL STUDIES category, Table 7)

b: The categories Low, Avg and High correspond to energy intake from breast milk being: Low (Mean -2 SD), Average (Mean) and High (Mean +2 SD).

c: Energy needed from complementary foods calculated by difference, i.e. energy requirement (Table 9, Butte, 1996/Torun et al. 1996) minus energy consumed from breast milk (listed in this table).

d: The categories Low, Avg and High correspond to energy intake from breast milk as stated in b.

Table 11. Energy (kcal$_{th}$) consumed from breast milk and the amount needed from complementary foods by children in industrialized countries, by age group

Age group (months)	Energy consumed from breast milk[a,b]			Energy needed from complementary foods[c,d]		
	Breast milk intake			Breast milk intake		
	Low	Avg	High	Low	Avg	High
0-2	294	490	686	110	0	0
3-5	362	548	734	188	2	0
6-8	274	486	698	408	196	0
9-11	41	375	709	789	455	121
12-23	0	313	669	1092	779	423

a: For age groups 0-2 and 3-5 months, energy consumed from breast milk taken from exclusively breast fed infants only (Table 8); and for age groups over 6 months from all children regardless of mode of feeding (i.e., pooled for both feeding modes as shown in the ALL STUDIES category, Table 8).

b: The categories Low, Avg and High correspond to energy intake from breast milk being: Low (Mean-2SD), Average (Mean) and High (Mean+2SD).

c: Energy needed from complementary foods calculated by difference, i.e., energy requirement (Table 9, Butte 1996/Torun et al. 1996) minus energy consumed from breast milk (listed in this table).

d: The categories Low, Avg and High correspond to energy intake from breast milk as stated in b.

representative sample of lactating women in developing countries to prepare appropriate global estimates of milk energy intake. Finally, the results of experimental trials cited above (see section 2.2.4) suggest that introduction of complementary foods prior to six months of age would largely displace energy intake from breast milk.

Given current feeding practices, breast milk does not meet children's theoretical energy needs after six months of age, in both low-income and wealthier countries. Therefore, appropriate complementary foods are almost certainly necessary to supply additional energy after this age. According to our analyses, the average amount (and range) of energy required from complementary foods is 269 (73-465), 451 (229-673), and 746 (490-1002) $kcal_{th}$/d for developing country children from 6 to 8, 9 to 11, and 12 to 23 months of age, respectively. Given the lack of certainty of these estimates, and for the sake of simplicity, the average amounts of energy required from complementary foods are rounded off to 275 $kcal_{th}$/d for children 6 to 8 months of age, 450 $kcal_{th}$/d for children 9 to 11 months of age, and 750 $kcal_{th}$/d for children 12 to 23 months of age. The following sections will discuss how these respective amounts of energy can be successfully delivered to young children.

3.2 Appropriate frequency of feeding and energy density of complementary foods

Having established estimates of the average amounts of energy required from complementary foods at different ages, we will now consider how the frequency of feeding and energy density of these foods influence the amount of food energy children actually consume. Before discussing these issues, relevant methodological concerns will be reviewed briefly.

3.2.1 Methodological issues

There are two primary approaches for studying the relationships between caregiver feeding behaviours and children's energy intakes, neither of which is perfect. Studies using each of these methods are probably needed to understand these relationships fully. One study method is simply to observe current feeding activities and subsequently analyse the relationships between the caregivers' behaviours and the children's food consumption. This approach is extremely valuable because it provides descriptive information on current feeding practices in the home environment. However, because the number of meals offered, timing of meals, and types and preparation of foods are not deliberately controlled by the study protocol, the enormous number of variables makes the statistical modelling extremely complex. Moreover, these descriptive studies only permit an examination of associations between the independent variables (e.g. feeding behaviours, food composition) and total food (energy) consumption. Because of the nature of the research design, it is not possible to draw definitive conclusions regarding the causal direction of any observed associations, nor the reasons for these associations. For example, caregivers may learn over time how much individual children are likely to eat at a particular meal. Thus, positive associations between the amount served and the amount consumed do not necessarily imply a causal relationship. Likewise, positive relationships between the frequency of meals and total daily energy consumption may indicate either that caregivers who feed more frequently are able to encourage children to eat more, or that children with greater appetites "demand" more frequent meals.

An alternative approach is to offer complementary foods of defined composition a specified number of times per day according to a fixed protocol, either in a clinical unit or in children's homes. The total amount of food consumed can then be assessed in relation to the number of meals offered and their composition. The persons feeding the children may either be the usual home caregivers or study aides specially trained to offer food in a consistent manner from one meal to the next. The advantage of this study design is the ability to control both the composition of the diet (to examine the effects of specific food components or organoleptic characteristics on total intake) and the frequency of feeding. By manipulating particular feeding behaviours or components of the diet in a controlled fashion, the experimental design permits causal inferences regarding the effects of these factors on the children's intakes. The disadvantage of this design is the uncertainty regarding the applicability of these results to "natural conditions" in the home.

Regardless of the experimental approach, the research methods are complex, tedious, and costly because they are very labour intensive. Not only is quantitative information regarding food intake needed, but breast-milk consumption must also be monitored to assess the impact of different complementary-feeding regimens on consumption of milk by infants who are still breast-feeding. Preliminary results of studies using the experimental approach are described in the next section. The results of selected descriptive studies of home feeding behaviours in several low-income communities are described subsequently.

3.2.2 Frequency of meals and energy density of complementary foods - results of experimental studies

It is not possible to develop estimates of the minimally adequate energy density of complementary foods without simultaneously considering the frequency of feeding. If meals are provided multiple times during the day, energy requirements can be satisfied with diets having lower energy density. By the same token, if the energy density of the foods is increased, adequate energy intake can be achieved with fewer meals. Both of these issues are treated together in this section.

Relevant clinical studies have been published recently concerning the effects of different frequencies of feeding and composition of meals on total daily energy intakes by fully weaned, recovering malnourished children (Brown et al., 1995a). The ultimate objective of these studies was to develop quantitative feeding recommendations to facilitate designing appropriate complementary foods. As indicated in the previous section, these studies had the advantage of the high degree of control of feeding practices and food composition that was possible in the clinical setting. However, the results must be interpreted with caution due to the nature of the study subjects, all of whom were recovering from recent episodes of severe or moderately severe protein-energy malnutrition, and the fact that they were no longer receiving any breast milk. Thus, these results may not be fully generalizable to non-malnourished breast-feeding children.

The studies examined the effects of three different meal frequencies and four different energy densities on the children's total daily energy intakes. Semi-solid mixed diets were prepared from rice, milk, sugar, vegetable oil, and supplemental vitamins and minerals. Colouring, thickening, and flavouring agents were added to the diets so that they were generally indistinguishable in taste and appearance. The preparations were fed *ad libitum* three, four or five times per day to 18 children aged 6 to 18 months whose total daily amounts of food and energy consumption were measured by weighing the feeding bowls before and after each meal, and subtracting any amount spilled on pre-weighed cloth napkins. Controlling for the level of energy density, the total daily amount consumed was approximately 16% more when the number of meals was increased from three to four per day and 7% more when the feeding frequency rose from four to five meals per day. The proportionately greater increase in intake with the change from three to four meals per day compared with the change from four to five meals per day was statistically significant. Therefore, there may be diminishing returns with still further increases in meal frequency. Importantly, the children reached satiety approximately 15-20 minutes after the meal was initiated, regardless of the meal frequency. Thus, the total daily amount of time required for feeding increased in direct relation to the number of meals. This time cost may be a severe constraint to greater meal frequency, especially when caregivers have multiple competing responsibilities, including other child care tasks, as is common in developing countries. The total amount of time that was required to feed the children each day was unrelated to the energy density of the diets.

These same clinical studies examined the effects of varied energy densities on the children's total daily energy intake (Brown et al., 1995a). The energy densities of the different diets were 0.4, 0.7, 1.0, or 1.5 $kcal_{th}/g$. Controlling for the frequency of feeding, the mean amounts of the diet consumed (g/kg/d) were significantly less with successively greater energy density of the diet (Figure 5). However, the total daily energy intakes ($kcal_{th}/kg/d$) increased significantly with the more concentrated diets. These results indicate that the children were able to adjust their intakes to compensate, in part, for the different energy densities of the diets. There was no clear evidence of a threshold of energy density after which further increases in total energy consumption ceased. Moreover, there were no significant interactions between energy density and feeding frequency. In other words, greater energy intakes occurred with each added meal, regardless of the energy density of the diet, and the intakes increased with each higher level of energy density regardless of the meal frequencies.

Although no other studies were located in which both energy density and frequency of feeding were varied, a total of nine additional studies from developing countries were identified in which young children's energy intakes were measured from similar diets of varied energy density (Table 12). The study diets were provided either as single meals or as multiple servings during one or more days. In all but one of the studies the children's energy intakes were greater when the higher density diets were served. Similar results have been reported from studies of younger infants (Fomon, 1977) and older preschool children in the United States of America (Birch, McPhee & Sullivan, 1989).

Figure 5. Intake of diets of varied energy density by frequency of feeding, young Peruvian children recovering from malnutrition (n=18)

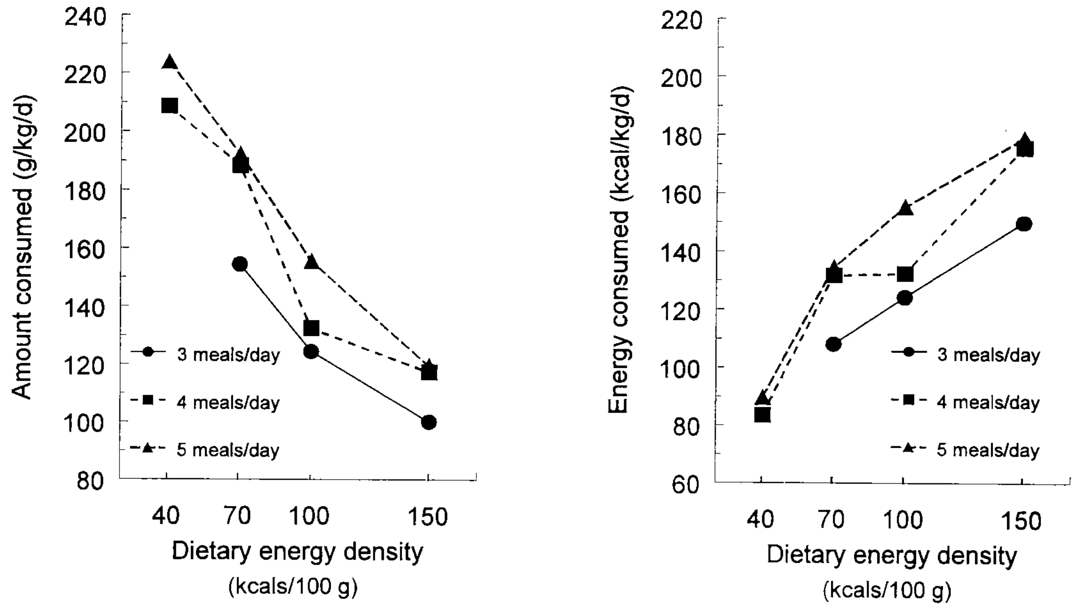


Table 12. Energy consumption by young children in relation to energy density (similar viscosity diets)

Author	Year	Country	Site	n	Age (mths)	Duration	Energy Density ($kcal_{th}/g$) High	Energy Density ($kcal_{th}/g$) Low	Intake ($kcal_{th}/kg/d$ or $kcal_{th}/meal$) High	Intake ($kcal_{th}/kg/d$ or $kcal_{th}/meal$) Low	P
Darling et al.	1995	Tanzania	Hospital (acute diarrhoea)	75	6-25	4 d	0.58	0.38	46[a]	32[a]	0.003
Mitra et al.	1995	Bangladesh	Hospital (acute diarrhoea)	63	6-23	4 d	1.24	0.64	54[a]	37[a]	0.001
Brown et al.	1995a	Peru	Hospital (severe malnutrition)	18	6-18	2 d	1.00	0.40	137[b]	78[b]	0.001
Mensah et al.	1995	Ghana	Hospital (acute diarrhoea)	14	6-15	>1 d	0.99	0.40	42[a]	13[a]	n.s.
		Nigeria		24					49[a]	46[a]	n.s.
Rahman et al.	1994	Bangladesh	Hospital (severe malnutrition)	51	5-18	5 d	1.47	0.92	92[a]	61[a]	0.001
Stephenson et al.	1994	Jamaica	Hospital (severe malnutrition)	15	7-15	4 d	0.97	0.51	105	71	0.001
Sanchez-Griñan et al.	1992	Peru	Hospital (severe malnutrition)	9	7-16	7 d	1.00	0.50	148	110	0.001
Mosha & Svanberg	1990	Tanzania	Home	12	5-24	1 meal	0.74	0.18	229[c]	54[c]	0.05
Lukmanji et al.	1988	Tanzania	Community	21	6-24	1-2 meals	0.75	0.43	134[c]	62[c]	0.001

[a] Intake from study diet only (children also received breast milk and/or other foods);
[b] Controlling for frequency of meals;
[c] $Kcal_{th}$/meal (only study diet provided)

Despite the apparent attempts of the children in the aforementioned study (Brown et al., 1995a) to adjust intakes in response to differing energy density, their total energy intakes still differed during the various dietary periods. It is likely that the children were physically unable to consume enough to satisfy their physiological needs while receiving the lower density diets because of limitations in their gastric capacity, which has been estimated at 30-40 mL/kg body weight (Sanchez-Griñan, Peerson & Brown, 1992; Ashworth, personal communication) although this may be greater in malnourished children. The intakes may have failed to reach a plateau at the higher densities either because the children had not satisfied their requirements for post-malnutrition compensatory growth, even with the highest density diet, or because the adaptive decrease in intake with a high-density diet is not perfectly regulated. For reasons discussed at greater length elsewhere (Brown et al., 1995a), the latter explanation seems more likely.

The results of this study have been used to develop tentative guidelines on the minimum energy density that is needed to allow children to satisfy their theoretical energy requirements. These guidelines obviously depend on assumptions about children's desired level of energy intake. If we assume that the minimum recommended energy density should be sufficient to assure that nearly all fully weaned children can satisfy their theoretical energy needs from a mixed diet, the target level of energy intake should be set at 2 SD above the assumed mean energy requirement for all children of a particular age. Using the aforementioned revised recommendations (Table 9), average daily energy needs of children aged 6-24 months range from 83 to 89 $kcal_{th}$ per kg, with children 9-11 months of age having the greatest energy needs per unit body weight. As per the 1985 FAO\WHO\UNU report, the coefficient of variation in energy requirements is estimated to be 12.5% (WHO, 1985b). Thus, the energy density of the diet of 9-11-month-old children, whose mean theoretical energy requirement is 89 $kcal_{th}$/kg/d, must be sufficient to permit any one of them to consume 112 $kcal_{th}$/kg/d, which is 25% (or 2 SD) greater than the average requirement for all children in this subgroup.

The estimated minimum levels of energy density that would have permitted the average child in the study described above to consume different amounts of energy are shown in Table 13. Data are presented only for children whose weights-for-height were greater than –1 Z-score at the start of the dietary period, because energy intakes were significantly increased among children with greater degrees of wasting. According to this Table, children in this study would have required a minimum energy density of approximately 1.05 $kcal_{th}$/g of diet to be able to consume 112 $kcal_{th}$/kg/d in just three meals. Lower energy densities would be adequate if more meals were provided.

It is important to re-emphasize that the clinical studies described in this section were conducted in non-breast-fed children. Similar studies have not yet been completed in breast-fed infants. Recommendations regarding the frequency of feeding of complementary foods often fail to consider the potentially adverse effects of frequent meals on breast-milk intake. Even if a mother continues to offer the breast often, it is difficult to stimulate a child to nurse at the breast if he or she has been satiated by other

Table 13. Estimated minimum energy density ($kcal_{th}/g$) required to attain different levels of total daily energy intakes at various feeding frequencies, non-breastfed children.*

Level of intake $kcal_{th}$/kg body wt/d	Frequency of feeding (meals/24 hours)		
	3	4	5
		Energy density of diet $kcal_{th}$/g	
70	.52**	<.40	<.40
80	.59**	.44	<.40
90	.65**	.51	.46
100	.77	.57	.52
110	1.02	.64	.59
112	1.05	.65	.60
120	1.17	.72	.65
130	1.33	.97	.77

*Based on studies of fully weaned, recovering malnourished children, using only diet periods of children with initial weight-for-height, Z-score > -1. (Data from Brown et al., 1995)
** All data based on observed intakes except for those indicated with double asterisk, which were imputed.

foods. Recommendations aimed at increasing the intake of complementary foods should take this into account, especially if the nutrient densities of these foods are not as great as those in breast milk. Obviously, at some age the child will be completely weaned from the breast, but the speed at which this occurs may be influenced by the amount and frequency of other foods offered. Additional studies of the effects of different complementary-feeding practices on both total energy and nutrient intakes and on intakes from breast milk and duration of breast-feeding are urgently needed.

To provide an alternative set of estimates of the appropriate energy density and frequency of feeding of complementary foods to young children who are still breast-feeding, we also reviewed the limited available data from controlled studies on the amount of food that fully weaned children could consume at a single meal. Using these figures for maximum single meal intakes, we calculated the minimum energy density that would be required to provide the energy needed from complementary foods, considering different assumed levels of breast-milk energy intake and different meal frequencies. The data on children's functional gastric capacity, or amount of food consumed at single meals, were provided by the authors of two recently published studies from Jamaica and Peru in which meals of varied energy density were fed under supervision and the amounts consumed were recorded. The maximum amount consumed at any meal during the diet period with the lowest energy density diet in each study was considered the functional gastric capacity of an individual child.

In the study from Jamaica (Stephenson et al., 1994), data from non-malnourished children, whose weights ranged from 4.6 kg to 8.8 kg, were analysed for the period when they received a diet with energy density of 0.5 $kcal_{th}$/g. These children consumed a maximum of 28-58 g/kg body weight at a single meal (mean = 45 g/kg body weight). In the study from Peru (Brown et al., 1995a), data from recovering malnourished children, whose weights ranged from 5.0 kg to 9.6 kg, were analysed for the diet period with dietary energy density of 0.4 $kcal_{th}$/g. As explained above, only data for those children with a weight-for-height Z-score > -1 were used. For these children the maximum amount consumed at a single meal ranged from 45 to 91 g/kg body weight (mean = 64 g/kg body weight). From these two sets of information, we concluded conservatively that almost all children should be able to consume as much as 30 g/kg body weight at a single meal. Of course, it must be recognized that the children in these studies were fed by trained nursing aides. It is not certain whether children's caregivers could provide the same levels of intake under usual home feeding conditions.

The figures for functional gastric capacity and published information on average body weights of children at different ages were used to estimate the amounts of food that could be consumed at single meals during each of the age periods. Assuming that the median weight of a well-nourished reference child is 8.3 kg at 7 months, 9.5 kg at 10 months, and 11.5 kg at 18 months (WHO, 1983), the amounts that could be consumed at a single meal are 249 g, 285 g, and 345 g for the respective ages. We then supposed that this amount of food could be consumed at one, two, three or four meals per day in addition to breast-feeding, and we calculated the minimum average energy density that would be required for these meals to be able to provide the energy needed from complementary foods at different ages. To provide a conservative estimate of the amount of energy that would be required from complementary foods to satisfy the total energy needs of nearly all children in a particular age range, the average energy requirement plus 2SD (i.e. 25%) was used. The energy consumed from breast milk for children receiving low, average, or high amounts of breast milk was subtracted from the figure for total energy needed to estimate the amount required from complementary foods. For example, if infants from 6-8 months of age need 275 $kcal_{th}$ per day from complementary foods and they consume a single meal of 249g, the minimum energy density of that meal would have to be 1.10 $kcal_{th}$/g. Table 14 displays the results of these calculations for well-nourished children who receive average, low, or high amounts of breast-milk energy at different ages. Similar calculations were made for growth retarded children (whose body weights and total gastric capacities would be less), assuming that the children's weights were -2 Z-scores weight-for-age at 7, 10, and 18 months. This latter set of calculations probably over-estimates the minimum required energy density slightly because the gastric capacity per unit body weight is greater for malnourished children than for well-nourished children (Sanchez-Griñan, Peerson & Brown, 1992).

As shown in Table 14, these calculations suggest that well-nourished breast-fed infants aged 6 to 8 months would need to receive only three meals per day if the energy density of their complementary foods is at least 0.85 $kcal_{th}$/g, even if their level of energy intake

Table 14. Estimated gastric capacity and minimum dietary energy density required to attain the level of energy needed from complementary foods in one, two, three or four meals/day, by level of breast milk energy (BME) intake and age group, for well-nourished and growth-retarded children*

	6 - 8 months BME				9 - 11 months BME				12 - 23 months BME			
	none	low	avg.	high	none	low	avg.	high	none	low	avg.	high
Average total energy requirement + 2 SD	852	852	852	852	1038	1038	1038	1038	1365	1365	1365	1365
Energy from breast milk	0	217	413	609	0	157	379	601	0	90	346	602
Energy required from comp. foods ($kcal_{th}$)	852	635	439	243	1038	881	659	437	1365	1275	1019	763
Estimated gastric capacity, well-nourished (g)*	249	249	249	249	285	285	285	285	345	345	345	345
Minimum energy density, 1 meal/d ($kcal_{th}/g$)	3.42	2.55	1.76	0.98	3.64	3.09	2.31	1.53	3.96	3.70	2.95	2.21
Minimum energy density, 2 meals/d ($kcal_{th}/g$)	1.71	1.28	0.88	0.49	1.82	1.55	1.16	0.77	1.98	1.85	1.48	1.11
Minimum energy density, 3 meals/d ($kcal_{th}/g$)	1.14	0.85	0.59	0.33	1.21	1.03	0.77	0.51	1.32	1.23	0.98	0.74
Minimum energy density, 4 meals/d ($kcal_{th}/g$)	0.86	0.64	0.44	0.24	0.91	0.77	0.58	0.38	0.99	0.92	0.74	0.55
Estimated gastric capacity, growth-retarded (g)	192	192	192	192	228	228	228	228	273	273	273	273
Minimum energy density, 1 meal/d ($kcal_{th}/g$)	4.44	3.31	2.29	1.27	4.55	3.86	2.89	1.92	5.00	4.67	3.73	2.79
Minimum energy density, 2 meals/d ($kcal_{th}/g$)	2.22	1.65	1.14	0.63	2.28	1.93	1.45	0.96	2.50	2.34	1.87	1.40
Minimum energy density, 3 meals/d ($kcal_{th}/g$)	1.48	1.10	0.76	0.42	1.52	1.29	0.96	0.64	1.67	1.56	1.24	0.93
Minimum energy density, 4 meals/d ($kcal_{th}/g$)	1.11	0.83	0.57	0.32	1.14	0.97	0.72	0.48	1.25	1.17	0.93	0.70

* assumes BW of 8.3 kg, 9.5 kg, and 11.5 kg for well-nourished children in three ascending age groups and BW of 6.4 kg, 7.6 kg, and 9.1 kg for growth-retarded children, and gastric capacity of 30 g/kg BW. Energy needs from complementary foods set at total energy requirement + 2 SD (i.e., + 25%) minus estimated energy intake from breast milk.

from breast milk is low. Malnourished infants of the same age would need complementary foods with slightly greater energy density or would have to receive one more meal per day. Older infants and young children would need increasingly greater levels of energy density or frequency of feeding as they increase in age. According to these results, we tentatively conclude that breast-fed infants aged 6 to 8 months should receive, in addition to breast-feeding, at least two or three meals per day, depending on the population's nutritional status and the likely energy density of complementary foods. There is a possible theoretical advantage of promoting greater energy density and lower meal frequency so that the complementary foods will be less likely to interfere with breast-feeding. However, we were unable to locate any empirical data on these relationships.

These results further suggest that children greater than 8 months of age should receive at least three meals per day. They would benefit from an even greater number of meals if the energy density of the diet is less than 1.03 $kcal_{th}/g$, or if they are malnourished and the energy density of the diet is less than 1.29 $kcal_{th}/g$. As emphasized previously, these two sets of estimates of minimum energy density and frequency of feeding of complementary foods (i.e. the one based on observed intakes and the one derived from estimates of gastric capacity) must be viewed with great caution for the reasons noted above. Nevertheless, the estimates do provide some tentative interim guidelines for the development of complementary-feeding recommendations until additional data are available.

3.2.3 Frequency of meals and energy density of complementary foods - results of observational studies

The relationships among frequency of feeding, dietary energy density, and total daily energy intake can also be examined using data from quantitative studies of dietary intake. For this purpose we re-analysed data from previously completed dietary studies of young children in low-income communities of Peru and Nigeria. The results of these analyses provide interesting insights into specific dietary factors associated with total daily energy intake in these two countries and how these varied between the two locations. The findings have important implications for the design of interventions to improve complementary-feeding practices.

Data were available from 117 Peruvian infants from 6 to 11 months of age. The information was collected during longitudinal studies in Huascar, a low-income community on the outskirts of Lima, Peru. The details of the methods of collection and analysis of data have been reported previously (Lopez de Romaña, Brown & Black, 1987; Lopez de Romaña et al., 1989; Brown et al., 1990; Creed de Kanashiro et al., 1990). The data for the Nigerian children were obtained during longitudinal studies conducted in three villages near Ilorin, Kwara State (Brown et al., 1988; Dickin et al., 1990). Data from 53 children aged 6 to 11 months are included in this report.

The energy intake data from the Peruvian and Nigerian children were analysed using multivariate analysis of covariance. Response variables were total energy intake, energy intake from breast milk, and energy intake from other foods, all measured in $kcal_{th}$ per kg body weight per day. Explanatory variables included: country (Peru vs. Nigeria); presence of fever; presence of diarrhoea; body weight; age; number of breast-feeds; number of other meals; average amount of food offered per kg body weight per meal; and average energy density of food offered.

The children's weight, length, total energy intakes, and selected characteristics of their dietary patterns are shown for both study sites in Table 15. The children's energy intakes per kg body weight were similar to the revised energy requirements presented above (Butte, 1996). However, because the Peruvian and Nigerian children were smaller than expected for age (mean weight-for-age was -0.51 Z-score for the Peruvian children and -1.94 Z-score for the Nigerian children), their total energy intakes (647 ± 201 and 633 ± 167 $kcal_{th}$/d, respectively) were somewhat less than the amounts currently proposed as adequate (682-830 $kcal_{th}$/day, depending on age; see Table 9).

Table 15. Characteristics of children 6-11 months of age and selected food consumption variables in two longitudinal studies of dietary intake and growth (Huascar, Lima, Peru and Kwara State, Nigeria)

	Study Site	
Variable	**Peru ***	**Nigeria****
Age (months)	8.7 ± 1.8	8.8 ± 1.6
Weight (kg)	8.3 ± 1.1	7.0 ± 1.0
Length (cm)	69.1 ± 3.0	67.6 ± 3.3
Total energy intake ($kcal_{th}$/kg/d)	80 ± 26	92 ± 25
Breast-milk energy intake ($kcal_{th}$/kg/d)	43 ± 21	66 ± 21
Non-breast-milk energy intake ($kcal_{th}$/kg/d)	36 ± 38	26 ± 20
No. of breast-feedings (No./12 hr)	4.0 ± 2.0	6.4 ± 1.8
No. of meals (No./12 hr)	3.8 ± 2.5	4.4 ± 1.3
Energy density of meals ($kcal_{th}$/100g)	67 ± 42	26 ± 18

* N= 117 children, 720 d of observation
** N= 53 children, 197 d of observation

The children were fed quite frequently during the 12-hours of observation in their homes. Indeed, it was often difficult to decide exactly when one meal ended and another began, so "feeding episodes" were arbitrarily defined as any intake of non-breast-milk foods separated from other occurrences of food consumption by at least 10 minutes. The Peruvian children received an average of four breast-feeds and nearly four additional meals during the 12-hour observation periods. The Nigerian children received more than six breast-feeds and four other meals on average. The energy densities of the non-breast-milk foods differed considerably in the two populations. Whereas the Peruvian children received mostly non-human milks and soups as complementary foods, with an average energy density of 0.67 $kcal_{th}$/g, the Nigerian children received mostly watery cereal paps that had an average energy density of only 0.26 $kcal_{th}$/g.

The results of the statistical analyses examining the factors that predicted total energy intake and intakes from breast-milk and non-breast-milk sources are shown in Table 16. The selected results shown in the Table are regression coefficients for the number of feeding episodes of non-breast-milk foods and the daily average energy density of these foods. The models control for the children's age, presence of fever, number of breast-feeds per 12 hours, and amount of food offered per meal, all of which were significantly associated with the energy intake variables. Interestingly, the magnitude of association of the two independent variables of primary interest (i.e. the number of meals and energy density of complementary foods) differed for the two sets of children. In Peru, each additional meal was associated with an increase in total energy intake of 6.5 $kcal_{th}$/kg/d, but each $kcal_{th}$ augmentation in energy density was associated with an increase in total energy intake of only 0.11 $kcal_{th}$/kg/d. Thus, if all other factors are held constant, an increased consumption of 10 $kcal_{th}$/kg/d would be expected to occur if the meal frequency were increased by 1.5 meals per day or the energy density were increased by 0.91 $kcal_{th}$/g.

Table 16. Relationship between feeding frequency, energy density of non-breast-milk meals, and total daily energy intake by infants 6-11 months of age* (Huascar, Lima, Peru and Kwara State, Nigeria)

		Regression Coefficients	
Dependent Variables	**Independent Variables**	**Lima**	**Nigeria**
Total energy intake ($kcal_{th}$/kg/d)	No. of meals/ 12 hr	6.5	1.8
	Energy density of meals ($kcal_{th}$/100g)	0.11	0.68
Energy intake from breast milk ($kcal_{th}$/kg/d)	No. of meals/ 12 hr	-1.4	-2.5
	Energy density of meals ($kcal_{th}$/100g)	-0.1	-0.2
Energy intake from non-breast milk ($kcal_{th}$/kg/d)	No. of meals/ 12 hr	7.9	4.3
	Energy density of meals ($kcal_{th}$/100g)	0.1	0.9

* Model controls for age, presence of fever, number of breast-feeds per 12 hour period, and amount of food offered per meal

In contrast with the findings in Peru, each additional feeding episode in Nigeria was associated with an increase of only 1.8 $kcal_{th}$/kg/d, while each $kcal_{th}$ increase in energy density was associated with 0.68 $kcal_{th}$/kg/d greater total energy intake. Thus, to achieve an increase in intake of 10 $kcal_{th}$/kg/d in Nigeria would require either 5.6 more meals per day or an increment in energy density of only 0.15 $kcal_{th}$/g. These results must be accepted with all the caution described above because the original studies were observational and not experimental. Nevertheless, the results imply that different approaches to enhancing energy intake might be appropriate in these two settings. Greater meal frequency might be expected to yield a more positive impact than increased energy density of complementary foods in Peru, especially considering the difficulty in achieving the densities that would be required. On the other hand, enhanced energy density would seem to be a more effective approach in Nigeria than an increased frequency of feeding, particularly in view of the already high combined frequency of breast-feeding and other meals. These results also highlight the potential value of quantitative studies of dietary intake and the importance of defining current feeding practices before initiating programmatic interventions.

3.3 Fat content of complementary foods

Dietary fats provide the young child with essential fatty acids, energy, and fat-soluble vitamins (FAO/WHO, 1994). Fats may also heighten the palatability of the diet, thereby promoting greater total energy intake (Sanchez-Griñan et al., 1995). Although there is general consensus on the minimum requirements for essential fatty acids, there is little information on the minimal and optimal levels of total dietary fat for young children during the period of complementary feeding. These issues will be discussed briefly in this section.

Specific long-chain, polyunsaturated fatty acids (PUFAs) - the n-6 PUFA, arachidonic acid, and the n-3 PUFA, docosahexaenoic acid - are essential precursors of prostaglandins, thromboxanes, leukotrienes, and other mediators of a broad range of cellular processes. Recent studies also indicate that docosahexaenoic acid is critical for normal development of the brain, retina, and other neural tissues. The metabolism and functional importance of long-chain PUFAs have been reviewed recently in detail (Uauy & Hoffman, 1991; Decsi & Koletzko, 1994) and will be discussed only briefly herein.

Arachidonic and docosahexaenoic acids can be synthesized from their respective precursors, linoleic acid and alpha-linolenic acid, but synthetic capacity is limited in premature infants and possibly term infants. Although the concentration of essential fatty acids in human milk is quite variable, breast milk seems to provide a generous supply of these long-chain fatty acids (Jensen et al., 1995), and young breast-fed infants do not require further supplementation. However, there is little information on the essential fatty acid status of older infants and young children who are consuming progressively decreasing amounts of breast milk and increasing amounts of complementary foods with lower fat content. FAO/WHO (1994) have recommended that linoleic acid provide at least 3% of total energy in the diet. Thus, if seed oils like maize oil or soybean oil, which contain more than 50% linoleic acid, are the major source of dietary fat, no more than 6% of total energy would have to be supplied by these sources to meet theoretical requirements for linoleic acid. On the other hand, if fats like palm oil or coconut oil, which contain less than 10% linoleic acid, are the major dietary sources, as much as 30% of energy would be required from these fats to meet theoretical needs.

Fats are the major source of energy for infants and young children who are breast-fed or receiving substantial quantities of animal products. Human milk contains between 40-55% of its energy as fat. Because most mixed diets in low-income countries contain a substantially lower proportion of energy from fat than that which is present in human milk (FAO/WHO, 1994), the fraction of total dietary energy provided as fat gradually decreases as more complementary foods are introduced into the diet. Several issues must be considered when attempting to establish an optimal level of total dietary fat during the period of complementary feeding. First, as described above, a minimal amount of fat must be provided to assure an adequate supply of essential fatty acids. Second, enough fat should be included in the diet so that its energy density is within a desirable range (discussed in detail in section 3.2). Because the metabolizable energy from fat (approximately 9 $kcal_{th}$ per gram) is more than twice as great as the metabolizable energy contents of carbohydrate and protein per unit weight, fat can make a considerable contribution to the energy density of the mixed diet. Moreover, because fat generally does not contribute to increased viscosity of the diet, fat can be used to increase energy density without resulting in an overly thick preparation. However, even though fat may be important to increase the overall energy density of the diet, the fat content should not be so great as to dilute excessively the density of protein and micronutrients per 100 $kcal_{th}$ (see section 3.7) or to induce gastrointestinal intolerance.

Most authors recommend that fat should supply 30-45% of energy intake for children less than 2 years of age (Michaelsen & Jørgensen, 1995), although there is little scientific information to support the necessity of this level of fat intake, so long as the needs for essential fatty acids are met and the energy density of the diet exceeds minimal criteria, as discussed in section 3.2. Thus, it is conceivable that diets with lower fat content may be acceptable. Although concern has been raised that excessive intake of fat may predispose children to risk of future hyperlipidemia and cardiovascular disease, there is also little direct evidence on this issue (Gaull, Giombetti & Woo, 1995; Olson, 1995). Expert groups in many countries have stated that fat intake should not be restricted for children less than 2 years of age (Michaelsen & Jørgensen, 1995). There is considerable diversity of opinion, however, regarding the optimal level of dietary fat during the remainder of childhood. Whereas some groups, such as the American Academy of Pediatrics Committee on Nutrition (1992), have suggested that fat intake should be limited to an average of 30% of total calories after 2 years of age, others have recommended that fat intake should not be restricted until linear growth ceases during adolescence (Working Group of the Canadian Pediatric Society, 1993). Until additional information is available from longitudinal studies, it will not be possible to assess the effect of fat consumption during childhood on subsequent risk of cardiovascular and other diseases in adulthood.

In summary, current guidelines suggest that dietary fat should range from 30% to 45% of total dietary energy for children less than 2 years of age, although lower fat intakes may be compatible with good health and nutrition if the aforementioned caveats are recognized. Accepting the tentative recommendation of 30-45% of total dietary energy as fat, we calculated the proportion of energy that should be provided as fat in complementary foods, using two different assumptions regarding fat and energy intakes from breast milk at different ages. The results of this analysis are described in the following section.

As stated in section 3.1.2, the recommended average daily levels of energy intake for children 6-8, 9-11, and 12-23 months of age are 682, 830, and 1 092 $kcal_{th}$/d. We assumed that the mean fat concentration of breast milk in developing countries may range from 28 g/L, as was seen in a population of lean mothers in Bangladesh (Brown et al., 1986b) and the Congo (Rocquelin et al., 1998) to 38 g/L, as was observed among women with considerably higher body mass indexes in Huascar, Peru (Creed de Kanashiro et al., 1990). The corresponding mean energy densities of breast milk may range from 0.59 to 0.68 $kcal_{th}$/g. Using these two sets of figures, we calculated the amount of energy provided as fat in breast milk for infants consuming average, low (mean –2 SD), or high (mean +2 SD) levels of energy from breast milk. Next, we calculated the number of calories that must be provided as fat in complementary foods so that the proportion of fat in the total mixed diet (i.e. both breast milk and complementary foods) would correspond to either 15%, 30%, or 45% of energy. These levels of energy from fat were then divided by the age-specific number of calories required from complementary foods to obtain the corresponding percentage of calories from fat in complementary foods (Table 17).

Table 17 (upper section) summarizes the data for infants with average volumes of breast-milk intake whose mothers have adequate milk fat contents. The results indicate that for the mixed diet to provide 30% of energy as fat, children would require no additional energy from fat in complementary foods at 6-8 months of age, 13% of energy from fat at 9-11 months, and 21% of energy from fat at 12-23 months. If their mothers have low milk fat contents, the children would require complementary foods with 10-24% of energy as fat at the respective age ranges (Table 17, lower section). By contrast, if the total mixed diet were to offer 45% of energy as fat, children of mothers with adequate milk fat content would need complementary foods that provide 37-43% of energy as fat, and children of mothers with low milk fat concentration would need complementary foods with 46-49% of energy as fat.

In view of current knowledge concerning low fat intakes from mixed diets in developing countries (FAO/WHO, 1994), and the potential difficulties in achieving adequate micronutrient densities with high fat diets (see section 3.7.1), it would seem reasonable to aim for final total diets (i.e. including breast milk and home-available complementary foods) with approximately 30% of energy derived from fat. This implies that complementary foods would need to contain as much as 21% of energy as fat if mothers' milk fat concentrations are in the normal range, or 24% of energy as fat if their milk fat concentrations are low. Thus, a level of 25% of energy as fat in complementary foods would meet this target for all age groups, regardless of maternal milk fat content. This also implies, however, that the mixture of fats from breast milk and other foods would have to contain a sufficient amount of essential fatty acids. Tables have been published on the fatty acid composition of human milk (Jensen et al., 1995) and common foods (USDA, 1979). Additional means may be necessary in some cases to assure adequate energy density of complementary foods (see sections 3.2.2 and 3.7.1). In the case where

Table 17. Percentage of energy needed from fat in complementary foods to provide 15, 30, or 45% of total daily energy intake from fat - Infants of mothers with a) normal breast milk fat concentration, b) low breast milk fat concentration

*a) normal fat concentration**

	% of energy needed from complementary foods								
	age 6-8 months breast-milk intake			age 9-11 months breast-milk intake			age 12-23 months breast-milk intake		
Total percentage of energy from fat	**low**	**avg.**	**high**	**low**	**avg.**	**high**	**low**	**avg.**	**high**
15%	0	0	0	7	0	0	12	0	0
30%	20	0	0	25	13	0	28	21	5
45%	45	37	1	44	41	31	45	43	38

*assumes that breast-milk fat concentration is 38 g/L, breast-milk energy density is 0.68 $kcal_{th}/g$, and breast-milk energy intake is as per Table 7.

b) low fat concentration**

	age 6-8 months breast-milk intake			age 9-11 months breast-milk intake			age 12-23 months breast-milk intake		
Total percentage of energy from fat	**low**	**avg.**	**high**	**low**	**avg.**	**high**	**low**	**avg.**	**high**
15%	2	0	0	9	0	0	13	2	0
30%	24	10	0	27	19	0	29	24	14
45%	46	49	64	46	47	51	45	46	48

** assumes that breast-milk fat concentration is 28g/L, breast-milk energy density is 0.59$kcal_{th}/g$, and breast milk energy intake is as per Table 7.

micronutrient supplements are provided separately or complementary foods are fortified with critical micronutrients, fat intakes from complementary foods that are greater than the level just suggested would be acceptable. In situations where children's intakes of breast milk are very low, slightly greater concentrations of fat in complementary foods may also be desirable.

3.4 Order of breast-feeding and complementary feeding

Once complementary foods have been introduced, they may be given before, after, or simultaneously with breast-feeds. Several authors have argued for a particular, age-specific order of breast-feeding and presentation of complementary foods, but there is very little scientific evidence to suggest that this would have a major influence on the amount and type of foods consumed or on 24-hour breast-milk intake. Drewett et al. (1987) completed a short-term study of this issue among infants, from 4 to 10 months of age, in Great Britain. On three consecutive days the babies were breast-fed exclusively or were given complementary foods either before or after nursing. When foods were provided immediately before breast-feeding, the amount of milk consumed decreased. However, the babies augmented their sucking time at subsequent feeds. Hence, there were no differences in total daily sucking time, regardless of the order of presentation of complementary foods. As was seen with other studies described previously (see sections 1.6.1 and 2.1.4), there was a net positive effect of complementary feeding on total daily energy intake despite a slight decline in energy consumed from breast milk. There were no differences in total daily energy intakes in relation to the order of feeding complementary foods and breast-feeding on those days when complementary foods were provided. Because these studies lasted only 3 days, however, there is still uncertainty regarding possible longer-term impact of the order of consuming breast milk and other foods.

Because of this uncertainty, some programmes recommend offering breast milk before other foods to minimise any negative impact of these foods on the amount of milk consumed (UNICEF, 1993). Other programmes limit this recommendation to children less than 1 year of age, when breast milk ordinarily provides a more critical component of the diet. Additional research is required before a definitive statement can be made in this regard.

3.5 Role of child appetite, food aversions

There is surprisingly little quantitative information on energy intakes by young children during the period of complementary feeding, possibly because of the difficulty in measuring consumption of breast milk and other foods under field conditions. Among recently reviewed, published studies of children's energy intakes from both breast milk and complementary foods, there was general agreement that the level of energy intake by children from 6 to 24 months of age in developing countries is somewhat less than currently recommended (Brown, 1997).

There are several possible factors responsible for the low energy intakes observed among young children in developing countries. These can be categorized as:

- Intrinsic, or child-related, factors
- Dietary factors
- Caregiver behaviour.

Intrinsic factors include both variability in energy requirements and altered physiologic status, such as may be imposed by illness or deficiencies of specific micronutrients, such as zinc. Dietary factors include the energy density of the complementary foods, the volume and frequency of feeding, the macronutrient and micronutrient contents of these foods, their variety, and their organoleptic characteristics, such as taste, aroma, viscosity, and so on. Caregiver behaviours refer to the amount of time devoted to child feeding and the level of supervision and encouragement that are provided. The following sections of this document will examine selected intrinsic factors that influence energy intake, notably child appetite and the impact of illness. Dietary factors that affect intake are discussed in sections 3.2 (energy density), 3.6 (flavour), 3.7 (viscosity), and 3.8 (variety). Caregiver behaviour is examined in section 5.

Caregivers in developing countries often report that the children simply "do not want to eat", although the frequency with which this phenomenon occurs has rarely been examined systematically. The prevalence of poor appetite, as reported by child caregivers, was described during a recent longitudinal study of children's dietary intake, infections, and growth in a low-income community on the outskirts of Lima, Peru (Brown, Creed de Kanashiro & Dewey, 1995). To assess the accuracy of these reports of poor infant appetite, they were first compared with measured energy consumption on days when dietary observations took place. Mean±SD total energy intakes on days with reported anorexia were 81±21 $kcal_{th}$/kg body weight in infants from 1 to 6 months of age and 71±22 $kcal_{th}$/kg in infants greater than 6 months compared with 94±22 and 82±21 $kcal_{th}$/kg in the respective age groups when appetites were reportedly normal ($p<0.001$). Energy intake from non-breast-milk sources was more affected than energy intake from breast milk.

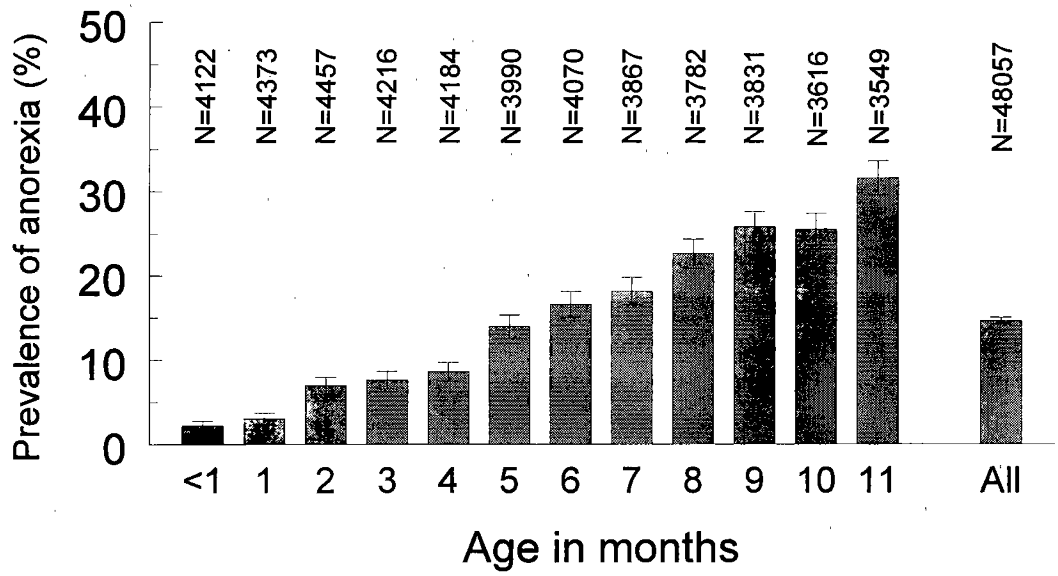
Following this initial confirmation of the validity of the caregivers' reports the epidemiology of reported poor appetite was then assessed in 153 infants who were monitored during their first year of life. The prevalence of reported anorexia increased progressively from 2.2% to 31.7% of days of observation from under 1 month to 11 months of age (Figure 6). The presence of reduced appetite was associated positively with infant age and with the presence of fever, diarrhoea, and respiratory illnesses, and negatively with the consumption of breast milk. Previous analyses of data from a subset of these same children showed that the prevalence of poor appetite was negatively associated with their growth increments from 6 to 12 months of age (Brown et al., 1991). Because of the high prevalence of reported anorexia and its relationship with impaired growth, it seems likely that poor appetite, rather than lack of food or improper child-feeding behaviours, may have explained some proportion of the low energy intakes and growth-faltering of infants in this community. Additional work is needed from other developing country settings.

It has been hypothesized that foods consumed during critical stages of infections may induce a future aversion to that specific food (Rolls, personal communication). Because of the high prevalence of infections in low-income communities, it is conceivable that elevated rates of food aversions may result. Although this is an intriguing hypothesis to explain the low levels of energy intake in developing countries, no empirical data are available to confirm or refute this concept.

3.5.1 Effect of illness on appetite and energy intake

The effects of illness on dietary intakes by children in low-income countries have been studied with a number of different research designs, including clinical observations of hospitalized children (Hoyle, Yunus & Chen, 1980; Sarker et al., 1982; Molla et al., 1983), community-based studies of single episodes of illness (Dickin et al., 1990; Marquis et al.,

Figure 6. Prevalence of reported anorexia in Huascar, Peru, by age (± 99% confidence interval)



1993), and community studies in which longitudinal dietary observations or reported anorexia were linked post-hoc to morbidity surveillance data (Martorell et al., 1980; Brown et al., 1985; Brown et al., 1990; Brown, Creed de Kanashiro & Dewey, 1995). Most of these studies have found some reduction of energy intake during illness, although the quantitative impact of infection is quite variable (Table 18). Clinical studies of children hospitalized for diarrhoea generally report a greater reduction in energy intake during illness than community-based studies. This may be because the illnesses encountered in hospitalized children tend to be more severe or because the high energy density of hospital diets that are generally provided after recovery exaggerated the apparent effects of illness.

Table 18. Impact of diarrhoea on energy intake by young children

Study site	Author	Year	Country	% reduction in energy intake during diarrhoea
Hospital	Hoyle, Yunus & Chen	1980	Bangladesh	42
	Molla et al.	1983	Bangladesh	37
	Sarker et al.	1982	Bangladesh	32
Community	Martorell et al.	1980	Guatemala	20
	Brown et al.	1985	Bangladesh	3
	Brown et al.	1990	Peru	0 for breast-milk 23 for other foods
	Dickin et al.	1990	Nigeria	11
	Marquis et al.	1993	Peru	25

Even among the community-based studies there has been considerable variability in the magnitude of the impact of illness. For example, two reports from Guatemala, which included only children who were completely weaned from the breast, noted an average 15-20% reduction in energy consumption during common illnesses (Mata et al., 1977; Martorell et al., 1980). By contrast, breast-feeding infants and young children in both Bangladesh and Peru, who received about half their energy intake from breast milk, had substantially smaller illness-related decrements in energy intakes (Brown et al., 1985; Brown et al., 1990), possibly because of a protective effect of breast-feeding. Indeed, in the Peru study when energy intakes from breast milk and other foods were examined separately, only the intakes from non-breast-milk sources declined during illness. Thus, part of the difference in the results of previous studies may be explained by the proportions of the children's energy intakes that were derived from breast milk, with greater decrements in intake occurring among those consuming smaller amounts of breast milk.

With the exception of the aforementioned study of the effect of breast-feeding on illness-related reductions in energy intake, most previous studies have not examined the possibility that the relationship between illness and energy consumption may be modified by the nature of the diet. Marquis et al. (1993) explored whether a reduction in dietary viscosity would enhance the level of energy intake during illness. In a community-based study in Peru they compared intakes by groups of children who received either an amylase-treated low-viscosity, potato-based diet or an untreated, higher viscosity, mashed potato diet during and after diarrhoea. Although both groups had lower intakes during illness than following recovery, there was no apparent benefit of the reduced viscosity diet at any stage of illness.

The role of disease severity on energy intake has been examined in two studies. Brown et al. (1995b) examined factors associated with caregivers' reports of poor child appetite during longitudinal observations in Peru. As stated above, initial exploration of the relationship between reported anorexia and quantitative studies of energy intake indicated that the caregivers' reports of low child appetite were associated with a 12-15% reduction in energy intake, depending on age. Reported anorexia was most commonly associated with diarrhoea and respiratory illness. When the illness syndromes were accompanied by fever the likelihood of anorexia was considerably greater than when fever was not present. Diarrhoea-associated anorexia was also more likely to occur when the episode was associated with a higher number of daily bowel movements and during episodes of dysentery and rotavirus infections.

In a descriptive epidemiological study of risk factors for poor appetite among young children hospitalized for diarrhoea, Brown & Perez (1992) reported that low serum bicarbonate and elevated urinary specific gravity at the time of admission were the two characteristics that independently identified children with low food intakes during the first day of hospitalization. Thus, they concluded that the appropriate therapeutic intervention to reduce diarrhoea-related anorexia is to provide adequate rehydration therapy to prevent dehydration and acidosis.

3.6 Flavour, aroma

A number of organoleptic features, such as flavour, aroma, visual appearance, texture, and so on, may affect children's intakes of complementary foods. A study of formula-fed infants in the United States, for example, found that they increased their consumption when sugars with a higher sweetness index were added to their formulas (Fomon et al., 1983). By contrast, preliminary results from a study of semi-solid diets offered to recovering malnourished Peruvian children indicate that replacing starch with sugar did not affect intakes (Brown et al., 1994). However, the children consumed about 10% more when a non-caloric sweetener, saccharine, was added to the high-starch diet.

Unlike sweetening agents, the addition of small amounts of salt to blended foods does not seem to affect consumption by young infants on initial exposure (Fomon, Thomas & Filer, 1970). However, other studies suggest that children develop food preferences in relation to frequency of exposure to particular foods and tastes (Sullivan & Birch, 1990). Thus, development of preference for sweetened or salty foods may occur only after repeated experience with those flavours. Interestingly, there is some evidence that breast-fed infants accept novel foods more readily than formula-fed infants (Sullivan & Birch, 1994), possibly because the former are exposed to a wider range of flavours through breast milk. Much more work is needed on the effects of specific organoleptic characteristics of the diet on children's intake of complementary foods.

3.7 Viscosity

A considerable amount of attention has been devoted recently to the issue of viscosity of transitional foods. This is due to the growing recognition of the importance of dietary energy density as a factor influencing total energy intake (see section 3.2 above), and to the fact that starch-containing staple foods may be extremely viscous when prepared at a concentration that is sufficient to assure adequate energy density. Thus, it may be necessary to increase energy density by using non-starch-containing foods or to reduce the consistency of high-density, starchy foods by other means to make them easier for young children to consume.

Possible ways of augmenting energy density without increasing viscosity are to add fats or non-gelatinous carbohydrates, such as simple sugars, to the diet. However, each of these approaches implies the addition of energy without accompanying protein or micronutrients. Thus, it is extremely important that the entire nutrient profile of the final mixed diet be analysed before issuing blanket recommendations on the advisability of adding sugar or oil to complementary foods. For example, the addition of 1 teaspoon of vegetable oil to 100 g of a typical West African pap would increase its energy density from approximately 0.30 to 0.70 $kcal_{th}/g$, but decrease the percentage of energy as protein from about 9% to about 4% (see Table 19; Brown et al., 1993). If consumed at a sufficient level to satisfy children's energy needs, the oil-supplemented pap would not meet their protein requirements. A similar effect on micronutrient density (in relation to energy content) could have undesirable nutritional consequences if those micronutrients are ordinarily present in low or marginally adequate concentrations.

Table 19. Effects of added oil on energy, protein, and iron densities of maize pap

	Traditional maize pap	Oil-fortified maize pap
Amount of cereal (g/100 g)	7	7
Amount of oil (g/100 g)	0	5
Energy density ($kcal_{th}$/g)	0.28	0.73
Protein density (% energy)	8.9	3.3
Iron density (mg/100 $kcal_{th}$)	0.5	0.2

3.7.1 Methods to reduce viscosity

Several methods have been described to reduce the viscosity of cereal mixtures, such as the addition of amylases (Gopaldas et al., 1986; Svanberg et al., 1987), fermentation (Alnwick, Moses & Schmidt, 1988), and extrusion cooking (Hellström et al., 1981) (described further in section 6.3). Of these, amylases have the greatest and most dramatic ability to reduce viscosity of a cereal porridge rapidly. Use of these enzymes is particularly attractive because they can be produced at the household level in developing countries by germinating local grains and producing malt flour. (See Section 6.4.4 for more information on methods for reducing viscosity).

Despite the dramatic effect of amylase on the viscosity of food, the relative advantages and disadvantages of viscosity reduction are still being debated. The benefits that have been proposed are: increased total energy and nutrient intakes; greater ease of feeding and consequent reduction in feeding time; increased digestibility of the treated foods; and caregiver preferences. These possible advantages of amylase-treated foods must be balanced against their greater material cost, increased preparation time, possible hyperosmolality, and potentially elevated risk of microbial contamination and exposure to food-borne toxins.

A recently commissioned WHO review of several of these issues concluded that amylase-treated diets (or malt-treated diets) failed to produce a consistently positive impact on children's total energy intakes (Ashworth & Draper, 1992). Additional research was recommended, though, because many of the published studies were methodologically flawed. For the present review we examined relevant studies that were published both before and after the earlier WHO document to reassess the effect of viscosity reduction on energy intake (Table 20). Only studies that compared diets with similar composition and energy densities are included in the table, and only results for children from 6 to 24 months are presented. Some studies provided the study diets for only one meal and others for multiple meals on one or more days. The latter design is preferable, because increased consumption of a particular food at a single meal does not necessarily mean that total daily energy and nutrient intakes would be altered. In some cases the study diets were provided

Table 20. Energy intakes of young children in relation to dietary viscosity. (Studies with similar or identical energy densities)

Author	Year	Country	Site	n	Age (mo)	Duration	Viscosity Low	Viscosity High	Energy Density ((kcal$_{th}$/g)	Intake (kcal$_{th}$/kg/d or (kcal$_{th}$/meal) Low Visc	Intake High Visc	P
Mitra et al.	1995	Bangladesh	Hospital (acute diarrhoea)	64	6-23	4 d	"liquid"	"thick" porridge	1.24	54[a]	34[a]	0.001
Rahman et al.	1994	Bangladesh	Hospital (severe malnutrition)	52	5-18	5 d	"thin"	"thick" porridge	1.50	92[a]	69[a]	0.05
Stephenson et al.	1994	Jamaica	Hospital (severe malnutrition)	15	7-15	4 d	"thin" porridge	"thick" porridge	0.97	105	96	n.s.
Marquis et al.	1993	Peru	Community (non-ill, post diarrhoea)	56	9-20	2 d	"liquid"	"semi-solid" puree	1.00	48[a]	67[a]	n.s.
Gopaldas & John	1992	India	Home	56	6-24	1 meal	"pour batter"	"almost solid"	1.63	199[b]	50[b]	0.001
Mosha & Svanberg	1990	Tanzania	Home	12	5-24	1 meal	liquid porridge	thick porridge	0.74	229[b]	189[b]	n.s.
Lukmanji et al.	1988	Tanzania	Community	21	6-24	1-2 meals	"thin" porridge	"stiff" porridge	0.85-1.08	134[b]	240[b]	0.01
Gopaldas Deshpande & John	1988	India	Home	30	6-12	1 meal	"pour batter"	"drop batter"	1.63-1.76	213[b]	109[b]	0.01
Gopaldas et al.	1986	India	Home	30	6-12	1 meal (3 d)	thin gruel	thick gruel	1.00	94[b]	56[b]	0.05

[a] Intake from study diet only (children also received breast milk and other foods),
[b] Kcal$_{th}$/meal (only study diet provided)

exclusively, and in others breast milk and other foods were also allowed. In the case where other foods were offered, only the intakes of the study diets are presented because not all reports included information on intake from all sources.

As indicated in Table 20, the results were quite heterogeneous. Five studies - of which three were carried out by the same research team and included observations of single meals only - reported that reducing viscosity had a significant positive impact on energy intake. On the other hand, three studies found no significant effect of viscosity reduction and one noted significantly increased intakes with the higher viscosity diet. Thus, there does not seem to be a consistent advantage of reduced viscosity on energy intake. Notably, all of the studies that found a positive impact of reducing viscosity included diets with energy densities $\geq$ 1.0 $kcal_{th}/g$, whereas those that found no advantage of reduced viscosity examined diets with energy densities $\leq$ 1.0 $kcal_{th}/g$. Thus, it is possible that reducing the viscosity of the diet may be beneficial only when the diets are initially of high energy density or, possibly, very high viscosity.

Other possible advantages of low viscosity preparations have been considered. Stephenson et al. (1994) noted that the feeding times were significantly shortened when the low viscosity preparations were served. This may be of considerable relevance for caregivers with multiple competing claims on their time. Additionally, Weaver et al. (1995) reported that pre-incubation of starchy foods with amylase-rich flour increased the overall *in vivo* starch digestibility. Whether this observation is of practical importance is uncertain, because most of the energy value of starch that is undigested in the small intestine can be recovered by the colon following fermentation by intra-colonic bacteria (Shulman et al., 1983; Guandalini, 1991).

In summary, there is conflicting evidence regarding the possible benefit of amylase-treated foods on total energy intake. Further research will be needed to determine whether their impact on energy intake may be limited to specific situations, depending on the energy density and viscosity of the original diet. Whether the reduction in feeding time that was observed in one study is sufficient to mitigate the increased time and money required for the preparation or purchase of the amylase source must be assessed in individual settings. The safety concerns that have been expressed must also be taken into consideration (Alnwick, Moses & Schmidt, 1988; Ashworth & Draper, 1992). In particular, possible risks of amylase-rich flour include the increased likelihood of microbial contamination of foods inoculated with home-produced malt flours after cooking, elevated osmolality of treated foods (Wahed et al., 1994), and cyanide toxicity from improperly processed germinated grains. Because of the uncertain benefit of amylase-treated foods and the possible aforementioned risks, there does not presently seem to be sufficiently compelling evidence to warrant extensive promotion of this technique, except under controlled conditions, where the safety of the amylase can be assured.

3.8 Variety, monotony

Because of the limited range of foods available in many developing countries, complementary-feeding regimens may be rather monotonous. It has been postulated that monotony of the diet in developing countries may explain to some degree the low levels of energy consumption that have been observed (Underwood, 1985). This hypothesis was examined in a recently completed clinical study in Peru. During one diet period children were offered a single mixture of rice, milk, vegetable oil, and sugar during each of four meals per day, for four consecutive days. During a second diet period they received four different preparations with similar nutrient content, but varied taste, colour, and consistency. Preliminary results indicate that the children consumed nearly 10% more when they received the varied dietary regimen. These findings are compatible with recent research results concerning sensory-specific satiety in adolescents and adults (Rolls & McDermott, 1991). Thus, increasing the variety of the diet may be another means of enhancing total dietary intake.

3.9 Duration of need for special transitional foods

Although a great deal of information has been presented on the appropriate age for introduction of complementary foods, very little has been written on the age at which special transitional foods are no longer necessary. The need for these special foods is determined by the child's neurological development, as described in section 1.5.1, and by age-specific nutrient requirements and the ability of the family foods to meet these requirements. Individual decisions regarding the appropriate age of introduction of family foods are also influenced by local perceptions concerning child development and cultural beliefs regarding appropriate child-feeding techniques.

As indicated previously (see section 1.5.1), infants as young as 6 months of age can manipulate and successfully swallow at least some solid foods. However, younger children need substantially more time than older ones to consume both solids and semi-solids. Thus, the availability of caregiver time for feeding may also influence the timing of introduction of family foods and the amounts of these foods that are offered.

To provide more information on this topic, we re-analysed previously collected quantitative dietary data from infants in low-income, periurban communities outside of Lima, Peru. All non-breast-milk foods consumed by the infants were classified by form of presentation (that is, whether they were solids, semi-solids, or liquids), food group, and whether they were prepared exclusively for the infant or for the whole family. The proportions of children who consumed more than 5 g per day of any solid foods are shown by age in Table 21. Foods classified as solids included breads, cooked cereals such as rice or noodles, stews, fried items, whole fruits and vegetables, and sweets and puddings. Solid foods were eaten by some children as young as 3 months of age, and more than half the children were consuming solids by 9 months of age. At 1 year of age nearly three-fourths of the children accepted more than 5 g of solid foods per day. Cooked cereals, tubers, puddings, fruits, and meats (generally chicken or organ meat) were the first solid foods offered (Table 21). In most cases the cereals, tubers, and vegetables fed to the children were the same items prepared for the rest of the family. On the other hand, about half the time the meats, sweets, and fruits were prepared especially for the children.

Table 21. Percentage of children consuming more than 5 grams of liquid, semi-solid, and solid food, by age (Huascar, Peru)*

Age (months)	N	Liquid	Semi-solid	Solid	Any form
1	112	48	0	0	48
2	122	56	2	0	56
3	125	52	10	4	55
4	110	50	29	8	60
5	109	50	54	20	80
6	108	56	66	33	88
7	97	53	72	37	91
8	102	58	75	37	94
9	100	65	78	54	98
10	86	72	81	65	98
11	94	75	85	72	99

* Children who consumed 5 grams or less of each category of food during a month were considered non-consumers

These results suggest that most children were physically capable of consuming solid foods by 1 year of age, so there is probably a fairly narrow age window when special transitional foods may be required for physiological reasons such as neurological development, as opposed to nutritional ones. Because the studies from Peru did not collect data on the duration of meals, however, it is uncertain whether early consumption of solids required inordinately long feeding episodes. Thus, additional information from this and other countries on consumption of solid foods, along with data on the time required to prepare and feed specific foods items, would be useful to clarify the age range during which special transitional foods may be necessary. Simultaneously collected information on caregiver beliefs regarding the appropriateness of different foods for children would also be of interest.