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Factors affecting the energy intake from gruel by breast-fed children in developing countries

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Abstract

The main objectives of this paper are to review current knowledge concerning energy intake from gruel in developing countries and define their immediate and underlying determinants.

A conceptual framework for determinants of the energy intake from gruel by breast-fed children living in natural conditions is offered in order to distinguish between immediate factors, underlying factors, and basic causes whatever they are child-related, caregiver-related or diet related factors.

The immediate factors affecting total energy intake from gruels are the feeding frequency, the energy density and the amounts consumed per meal. The feeding frequency (number of gruels/day) mainly depends on factors relative to child caregivers (e.g., occupation, feeding habits, food availability etc.). The energy density of gruels results from the composition (e.g., water and lipid contents) and physico-chemical characteristics of their ingredients, and from their preparation methods. The amounts consumed per meal mainly depend on child appetite and on the organoleptic characteristics of the gruels, in particular their consistency.

It is generally assumed that the gastric capacity of infants and young children ranges from 30 to 40 ml/kg body weight. Actually, a review of published data and preliminary results of surveys recently carried out in various African countries show that energy intakes per meal of gruel amongst 4-23-month-old children greatly vary and are lower than expected considering their supposed gastric capacity.

Effects of immediate and underlying factors previously studied are discussed. However, their relative significance in free-living conditions is still not well known. An in-depth analysis of these factors is necessary in order to elaborate strategies appropriate to the various contexts and likely to improve total energy intakes.

Introduction

According to the conceptual framework on the causes of malnutrition adopted by UNICEF (1990), dietary intake and health status are the immediate determinants of the nutritional status of infants and young children. It is generally assumed that inadequate dietary intake results from household food insecurity and inappropriate child-care practices, and is directly influenced by the presence of disease.

In order to define nutritional interventions aimed at improving infant and young child nutrition, determinants of energy intake have to be analysed in-depth, taking into account specificity and environment of the at-risk populations affected. During the weaning period, energy and nutrient intakes from both breast-milk and complementary foods must be considered. In doing this, one of the main difficulties encountered lies in the interrelationship between them. In fact, an increase of dietary intake from complementary foods does not necessarily result in an improvement of total dietary intake, especially when complementary foods are introduced too early. However, it can be taken as given that during the 6-17-month period when dietary intake from breast-milk needs to be complemented, energy and nutrient intakes from appropriate complementary foods have to be increased.

In most developing countries, complementary foods are mainly liquid or semi-liquid foods such as gruels. Increase of energy intake from gruel is of particular concern insofar as it induces an increase of nutrient intake at the same time. Therefore, the main objectives of this paper are to review current knowledge concerning the energy intake from gruel in developing countries and define their immediate and underlying determinants.

1. Proposed conceptual framework for determinants of the energy intake from gruel

There is little reliable quantitative information on energy intake from complementary foods by breast-fed children in free-living conditions. However, some recent reviews have identified the possible determining factors and categorised them as child-related, diet-related, and caregiver-related factors (Brown, 1997; WHO, 1998).

When consumed as complementary food by infants and young children, gruel can be considered as a special transitional food which is characterised by its homogeneity and its liquid or semi liquid consistency. A conceptual framework for determinants of energy intake from gruel by breast-fed children is offered (figure 1) in order to distinguish between immediate factors, underlying factors, and basic causes. In this first part, these factors and basic causes and the possible ways they operate will be identified only. The effect of those which have already been studied will be analysed in the third part.

1.1. Immediate determining factors

Three immediate factors determine the level of the daily energy intake from gruel: the number of meals per day, the amount of gruel consumed at each meal and the energy density of each gruel. It can therefore be calculated using the following equation:

$$EI_d = \Sigma^{n}_{i=1} Ca_i \times ED_i$$

with: EI_d = Daily energy intake (kcal/d) from gruel
i = Rank of the gruel *(n = total number of gruels distributed per day)*
Ca_i = Consumed amount (g) of the i^{th} gruel
ED_i = Energy density (kcal/g) of the i^{th} gruel

The number of meals per day is part of the feeding habits which result from the caregiver's education, beliefs and income. It is also the consequence of the mother's perception of the child's aptitude for ingesting food.

Energy density is part of the gruel characteristics and depends on the nature of foods and processes used for preparing gruels.

The amount of gruel consumed per meal is, amongst the three immediate determining factors of the energy intake from gruel, undoubtedly the one which depends on the most numerous underlying factors. In fact, it depends on child's aptitude for ingesting food (i.e., gastric capacity, appetite, and possible food aversions), feeding habits, and gruel characteristics, particularly organoleptic ones such as consistency, flavour or aroma.

1.2. Underlying factors

Three main categories of underlying factors can be distinguished. The first is relative to the gruel proposed, the second to the caregiver and the third to the child.

Besides energy density, gruel characteristics which have effects on energy intake are those which determine its appetibility, that is to say its tendency to correspond to the infant's and the mother's expectations. Amongst them, we can identify consistency which is most often appreciated by viscosity measurements and other organoleptic characteristics. In addition, dry matter content and nutrient composition, which determine its energy density, can also influence its appetibility.

Caregivers' dependent factors can be subdivided into two sub-categories. First, those which determine the methods of preparing gruels, in particular the choice of food ingredients and processes. Second, those corresponding to feeding habits. In addition to the daily frequency of gruel feeding, the latter include breast-feeding patterns, nature and feeding time of other complementary foods, intervals between meals, and level of supervision and encouragement provided during gruel consumption.

The main child-related underlying factors correspond to its aptitude for ingesting food. The main factors are appetite, that is to say acceptance of food proposed by the mother, and gastric capacity. In some cases, children can manifest an aversion for specific food, especially when this food was previously proposed to them during a period of illness.

1.2. Basic causes

In addition to these immediate or underlying factors, three kinds of basic causes can be distinguished.

The first one includes household characteristics (i.e., standard of living and purchase power, size and structure of the household, ethnic origin of household members) and mother's characteristics (age, primary and secondary occupations, level of education, nutritional knowledge, technological know-how) which have a significant influence on gruel preparation methods and determine feeding habits.

The second one corresponds to food availability and depends on the agro-ecological context and, when foods are not produced by the mother or the household, on the price of ingredients likely to be incorporated into the gruels. They condition the gruel preparation methods that are chosen by caregivers according to their education, beliefs and income.

The third one corresponds to a child's characteristics, both permanent (i.e. genetic factors and gender) and temporary (i.e., weight, nutritional and health status) which determine their aptitude for ingesting food.

2. Energy intakes from gruel by infants and young children in developing countries

Published data on gruel consumption are scarce and no reviews on energy intake from gruel by infants and young children in free-living conditions have been performed. However, some data can be taken from various previous studies (Table 1).

Table 1: Published data on traditional gruel consumption during a single meal by infants and young children in free-living conditions

Country *(Reference)*	Age *(month)*	Nature of the gruel	[c] *(1)*	Mean amount consumed	Energy intake (kcal)
India *(Gopaldas et al., 1986)*	6-11	Rice + Sugar + Oil	10%	56 ml	38
			25%	56 ml	104
India *(John and Gopaldas, 1988)*	6-23	Wheat+Soybean+Sugar+Oil	20%	55 ml	89
India *(Gopaldas et al., 1988a)*	6-11	Corn + Sugar + Oil	15%	42 ml	50
		Sorghum + Sugar +Oil	10%	65 ml	46
India *(Gopaldas et al., 1988b)*	6-11	Wheat + Sugar + Oil	20%	62 ml	109
Tanzania *(Lukmanji et al., 1988)*	6-11	Corn + Sugar + peanut	8%	128 g	55
Tanzania *(Mosha and Svanberg, 1990)*	5-11	Corn + peanut	5%	154 g	28
India *(Gopaldas and John, 1992)*	6-11	Wheat + Sugar + Oil	20%	26 ml	42
Tanzania *(Kingamkono, 1988)*	9-23	Corn + Sugar	14%	161 g	81
Tanzania *(Lukmanji et al., 1988)*	12-23	Corn + Sugar + peanut	8%	150 g	64
Tanzania *(Mosha and Svanberg, 1990)*	12-23	Corn + peanut	5%	330 g	60
India *(Gopaldas and John, 1992)*	13-17	Wheat + Sugar + Oil	20%	25 ml	41

(1) concentration of the starchy component into the gruel

Depending on the environment and on the diet, the mean amounts of gruel consumed ranged from 26 to 154 g (or ml) by meal in 6-to-11-month-old infants and from 25 to 330 g (or ml) with 12-23-month-old children. Assuming that the median body weight of 6-11-month old and 12-23-month-old infants is 8.9 and 11.2 kg, respectively, this means that amounts of gruel consumed per meal by young children in free-living conditions ranged from 3 to 18 g/kg body weight during their second semester of life and from 2 to 29 g/kg body weight during their second year of life. In fact, it is generally assumed that the gastric capacity of infants and young children ranges from 30 to 40 ml/kg body weight (WHO, 1998). As in most studies gruels were given *ad libitum*, these values are considerably lower than expected. The energy intake per gruel ranged from 28 to 109 kcal per meal for 6-11-month-old infants and from 41 to 64 kcal per meal for 12-23-month-old children.

Recent observational studies carried out in different African settings by our team confirm the low level of energy intake from gruel by young children living at home (Table 2).
Mean amounts of gruel consumed per meal ranged from 74 g in a district of Ouagadougou (Burkina Faso) for a low-energy-dense gruel prepared from a locally processed blend (millet + soybean + peanut + sugar) and 141 g in a district of Brazzaville (The Congo) for home made, low-energy-dense gruels prepared mainly from fermented corn. When expressed per kilogram of body weight, the mean amounts of gruel consumed per meal ranged from 10.6 g in urban districts of Senegalese cities for a gruel prepared from a locally processed blend (millet + cowpea + peanut + sugar) to 20.6 g in Brazzaville. Thus, mean amounts of gruel consumed by young children less than two years old in different African contexts can vary by twice as much depending on the setting and on the nature of the gruel. It can be noted that the average of the mean amounts consumed per meal observed during these nine dietary surveys is about 14 g/(meal x kg) which corresponds to less than half of the gastric capacity generally assumed for young children.
The energy intakes ranged from 31 to 111 kcal/meal and 4.5 to 15.7 kcal/(meal x kg) in the above mentioned districts of Ouagadougou and Brazzaville for a high-dense gruel prepared from a locally processed flour for infant (corn + soybean + sugar + CMV + amylase), respectively. Considering that the mean energy requirement within the 6-24-month period of age is 89 kcal/kg of body weight (Butte, 1996), it means that, for the children observed, a single meal of gruel in average met 5 to 18% of the daily energy requirement. Thus, depending on contexts, 2 to 7 meals should be given to meet a third of the daily energy requirement of the children consuming mean amounts of these gruels. This calls for greater concern and efforts towards improving knowledge on variation factors of energy intake from gruels in order to use them as a significant component of infants' diet.

Table 2: Preliminary results of dietary surveys on gruel consumption by infant and young children in free-living conditions in some African countries

Country *(setting)*	Age *(month)*	Type of gruel	*n*	Amount consumed		Energy intake (kcal)	
				g/meal	g/(kg x meal)	/meal	/(kg x meal)
Burkina Faso *(rural area)*	4-23	Home made	*34*	98	13.0	46	6.0
Burkina Faso *(urban district)*	6-9	locally processed blend	*139*	74	10.9	31	4.5
		locally processed infant flour	*180*	46	6.2	46	6.2
Cameroon *(urban district)*	4-11	Home made	*60*	99	12.7	57	7.4
The Congo *(urban district)*	4-11	Imported infant flour	*50*	98	15.1	94	14.5
		Home made	*252*	141	20.6	87	12.7
	6	locally processed blend	*73*	135	19.0	66	9.3
		locally processed infant flour	*64*	109	15.4	111	15.7
Senegal *(urban districts)*	6-36	locally processed blend	*203*	95	10.6	87	9.7

n: number of gruel meals observed

3. Current knowledge on the effects of various factors affecting the energy intake from gruel by infants and young children

3.1. Child-related factors

Gender

Up to now, no data have been published on the effect of a child's gender on energy intake from gruels. Preliminary results of recent dietary surveys carried out by our research team in rural and urban areas of Burkina Faso, Cameroon, The Congo, and Senegal has showed that, in most cases, gender has no significant effect on energy intakes per kg body weight from gruels. However, energy intakes were significantly higher (6.8 *vs* 5.2 kcal per meal and per kg body weight) for boys than for girls in an urban district of Ouagadougou (Burkina Faso) with an high-energy-dense gruel amongst 6-8-month-old infants.

Age

Effect of age on energy intakes from gruels has not been extensively studied. Data from the above mentioned dietary surveys indicate that energy intakes of 6-23-month-old children do not vary in an significant way with child age when expressed on a kg body weight basis.

However, in a rural area in Burkina Faso, energy intakes from traditional gruels by 4-8-month-old infants was significantly less than those by 9-17-month-old children (4.7 *vs* 7.1 kcal per meal and per kg body weight).

Effects of illness

Effects of illness on dietary intake by infants and young children have been studied using different research designs including clinical studies of hospitalised children and dietary observations during single episodes of illness or during longitudinal studies comprising a morbidity surveillance.

In most of these studies, a reduction of total energy intake was observed but the magnitude of the impact of illness varies considerably (Table 3). The highest reduction occurred for children hospitalised for diarrhoea. Among the studies realised in normal conditions at home, the most significant reduction was observed for fully weaned infants. Other studies carried out with children receiving about half their energy intake from breast-milk, found that illness-related decrements in energy intakes affected complementary food intakes more than breast-milk intakes.

Table 3: Impact of diarrhoea on energy intake by young children

Country	Age *(month)*	Diet	% reduction in energy intake	Reference
Hospitalised Children				
Bangladesh	6-35	BM+gruel	42 (total)	Hoyle et al., 1980
Bangladesh	12-47	BM+various CF	35	Sarker et al., 1982
Bangladesh	11-24	BM+various CF	98 (CF)/31 (total)	Sarker *et al.*, 1983
Longitudinal studies at home				
Peru	6-11	BM+various CF	0 (BM) / 23 (CF)	Brown *et al.*, 1990
Guatemala	15-23	Low calorie supplement	19	Martorell *et al.*, 1980
Bangladesh	5-30	BM+various CF	3	Brown *et al.*, 1995
Single episodes of illness at home				
Nigeria	5-28	BM+gruel+other CF	0 (BM, gruel) / 48 (total)	Dickin *et al.*, 1990
Peru	9-20	BM+gruel+other CF	0 (BM) / 25 (gruel)	Marquis *et al.*, 1993

In addition, a longitudinal studies carried out in Peru found that caregivers' reports of low child appetite were commonly associated with diarrhoea and respiratory illness and resulted in a 12-15% reduction in energy intake (Brown *et al.*, 1995).

Nutritional status

Unlike effects of illness on energy intakes, relation between nutritional status and child aptitude for ingesting gruel is little known because no studies were designed with this particular objective.

Donnen *et al.* (1996) observed that, amongst 3-23-month-old hospitalised children, those with a weight-for-age Z score below -2 consumed significantly more (16 and 60% depending on the type of gruel) energy per day - on a kg body weight basis - from gruels than those whose Z scores were equal or higher than -2.

Preliminary results from an experimental study (Mouquet and Trèche, unpublished) aimed at comparing energy intakes from 4 gruels differing in energy density and/or consistency show that energy intakes by 6-8-month-old children with weight-for-age Z score below -1.5 was 13 to 39% higher - depending on the type of gruels - than those whose Z scores were equal or higher than -1.5.

In both the last studies mentioned, differences of energy intakes were higher for energy-dense gruels than for gruels with a low energy density. Hence, children with low weight-for-age Z scores seem to be inclined to consume more energy from gruel than those having a better nutritional status.

3.2. Caregiver-related factors

Time constraints

Effects of time constraints of mothers on the gruel consumption by their children can be observed during the preparation of the gruel and at the time of giving it to the child.
As preparation of gruel is time consuming, mothers are not only inclined to shorten the period of gruel consumption by introducing family foods very early but also to limit the daily number of preparations during the consumption period.
On an other hand, time constraints of the mother can influence the level of supervision and encouragement to ingest gruel during each meal. We will examine the impact of feeding frequency on daily energy intake and the relation between duration of meals and energy intakes.

- Feeding frequency

Surprisingly, no studies of the effect of feeding frequency of gruel on energy intake have been carried out with non-malnourished, breast-fed infants living at home. However, a clinical study on the effects of different gruel feeding frequencies on total daily energy intake by fully weaned 6-8-month-old infants recovering from severe or moderately severe protein energy malnutrition was carried out in Peru by Brown *et al.* (1995). Semi-solid diets of different energy densities composed of rice, milk, sugar, vegetable and supplemental vitamins and minerals were fed *ad libitum* three, four or five times daily. Controlling for the level of energy density, the total daily amount consumed was approximately 16% higher when the number of meal was increased from three to four and 7% higher when the feeding frequency rose from four to five.

Similar studies in breast-fed children of various age whether receiving other complementary foods or not are needed to estimate whether increasing number of meals with gruels significantly increases energy intake from gruels and total energy intake. But it is likely that the answer is context dependent. In fact, multivariate analysis of covariance performed on data from two observational studies carried out in low-income communities of Peru and Nigeria (WHO, 1998) have permitted the estimation of regression coefficients between energy intakes and number of meals and between energy intakes and energy density of meals in 6-11-month-old infants (Table 4).

Table 4: Relationship between feeding frequency, energy density of complementary foods (CF), and energy intakes by 6-11-month-old infants in Peru and Nigeria.

Dependent variables	Independent variables	Regression coefficients	
		Peru	Nigeria
Energy intake from CF (kcal/(kg x d)	Number of meals / 12hr	7.9	4.3
	Energy density of meals (kcal/100g)	0.1	0.9
Total energy intake (kcal/(kg x d)	Number of meals / 12hr	6.5	1.8
	Energy density of meals (kcal/100g)	0.11	0.68

In Peru, where the mean number of meal was 3.8 and the mean energy density of CF was 67 kcal/100g, each additional meal was associated with an increase in energy intake from complementary foods of 7.9 kcal/(kg x d) and an increase of total energy intake from of 6.5 kcal/(kg x d) while in Nigeria (mean number of meals = 4.4; mean energy density of CF = 26 kcal/100g), the two corresponding increases were respectively of 4.3 and 1.8 kcal/(kg x d). By comparison, each ten kilocalories augmentation in energy density of Peruvian complementary foods was associated with an increase in energy intake from complementary foods of 1.0 kcal/(kg x d) and an increase of total energy intake of 1.1 kcal/(kg x d) while in Nigeria the two corresponding increases were respectively of 43 and 6.8 kcal/(kg x d). Thus, the best strategy to improve energy intakes in Peru appears to be to increase the number of meals while, in Nigeria, increasing energy density of gruels seems to be much more effective.

- Duration of meal

The time spent giving a gruel to a child can be considered both as an indicator of the level mother's encouragement of the child for ingesting gruel and as an indicator of the difficulty for a child to ingest a particular gruel. Thus, possible relationship between duration of meal and energy intakes are difficult to analyse. Two studies recently carried out by our research team provided useful data on this topic.

In Senegal (Dieng and Trèche, unpublished), the duration of meal and energy intakes were measured during 206 meals given twice a day to 103 children (6 to 24 months old). The gruels were prepared by mothers from the same millet/cowpea/peanut/sugar blend but they were free to add sugar or other ingredients. There was no significant correlation between duration of meal and energy intake. However, a significant correlation ($r=-0,35$; $P<0,01$) was found between energy intakes and the duration for ingesting 10 g of gruels.

In Burkina Faso (Mouquet and Trèche, unpublished), duration of meal and energy intake were measured during the consumption of 4 types of gruel prepared from a millet / soybean / peanut / sugar blend at different energy density and/or consistency by adding amylases or oil. Each type of gruel was given by mothers twice daily during a three-day period at thirty 6-8-month-old infants after having been prepared in standardised conditions by experimented field workers. Significant ($P<0,001$) correlations were found not only between energy intakes and the duration for ingesting 10 g of gruels (r ranged from -0,36 to -0,53 depending on the type of gruel) but also between energy intakes and total duration of the meal (r ranged from +0,27 to +0,54 depending on the type of gruel).

The significant negative correlation between energy intakes and ingestion speed (duration for ingesting 10 g of gruel) found in both studies indicates that ingestion speed is a good indicator of the child's aptitude for ingesting a particular gruel. A positive correlation between energy intakes and total duration of meals was found only in Burkina Faso with infants of a narrow age range consuming similar gruels: further investigations are necessary to define in which conditions increasing the time spent by mothers to give gruel can have a significant impact on energy intake.

Breast-feeding pattern and other complementary food consumption

Breast-feeding pattern and other complementary food consumption can influence energy intakes from gruels not only by modifying gruel feeding frequency by also by limiting the child aptitude for ingesting gruel at each meal.

Although some programmes recommend offering breast-milk before other foods to minimise any negative impact of complementary foods on the amount of milk consumed (UNICEF, 1993), 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 (WHO, 1998).

Preliminary analysis of data recently obtained from Senegal (Dieng and Trèche, unpublished) shows that energy intake from gruels were not modified when the last breast-milk feed was given either an hour or more before gruel or in the preceding 60 minutes.

In addition, energy intakes from gruels depend only slightly on their position in the gruel order of consumption. From the data mentioned above obtained from Senegal and Burkina Faso by our research team, it appears that, in Senegal, the energy intake from the first and the second gruels given in a same day were not significantly different and that, in Burkina Faso, mean energy intake from the second gruel given during a day was 9% lower than that from the first gruel.
Hence, in free-living conditions it seems that the moment when gruels are given only slightly modifies the energy intakes from gruels.

Variety/monotony of the diet

Monotony of the diet in developing countries has been mentioned by Underwood (1985) as a possible cause of low levels of energy consumption often observed. In order to examine this hypothesis, children were offered, for four consecutive days, either a single mixture of rice, milk, oil, and sugar during each of four meals daily or four different preparations with similar nutrient content, but varied taste, colour, and consistency (WHO, 1998). Results indicate that the children consumed nearly 10% more when they received the varied dietary regimen.

Thus, increasing the variety of the diet may be another means of enhancing total dietary intake.

3.3. Gruel characteristics

Energy density

Low energy density of gruels was mentioned as a possible cause of malnutrition affecting infants and young children at the beginning of the seventy's by Nicol (1971), Naismith *et al.* (1973), Rutishauser (1974), and Waterlow and Payne (1975). But it is only during the twelve last years that some fifteen experimental studies aimed at comparing energy intakes from gruels with different energy density has been published. As shown in recent reviews (Trèche, 1996; WHO, 1998), all of these studies but one (realised with a small effective of 6-15-month-old children suffering from acute diarrhoea and with two gruels differing from one another in very low energy density; Mensah *et al.*, 1995) have demonstrated that consumption of gruels with the highest energy density results in higher energy intakes. But these studies have been carried out in a limited number of environments, some of them with non breast-fed children and only two - performed in Tanzania (Lukmanji *et al.,* 1988; Mosha and Svanberg, 1990) - with children in free-living conditions.

In addition, Rahman *et al.* (1995) showed that energy intakes from gruels and total energy intakes from complementary foods were, respectively, 85% and 34% higher in 6-35-month-old child group with acute shigellosis receiving an high-energy-dense gruel liquefied by amylase flour than in a comparable child group receiving an gruel diluted with water to a similar viscosity.

Recently, preliminary results of two recent studies performed in The Congo (Trèche *et al.*, (1997) and in Burkina Faso (Mouquet et Trèche, unpublished) confirmed that improving energy density of gruels consumed in free-living conditions results in a significant increase of energy intakes.

One of the objectives of the study carried out in an urban district of Brazzaville was to verify whether the use of amylase-containing flour for gruel preparation allows higher energy intakes from gruels at the age of 6 months. 80 infants were selected at random and were randomly assigned to two experimental groups. Mothers of the two groups of infants were supplied with maize/soybean experimental flour with (A) or without (C) amylase when their infant reached 18 weeks of age, until the age of 32 weeks. They were instructed on how to prepare gruel with the flour, but they were left free to use it at their convenience. Amylase in flour A and sugar in both flours were added in adequate amounts to produce gruels indistinguishable in taste and viscosity when prepared at the energy density of 55 kcal/100 g (control gruel) and 135 kcal/100 g (amylase-containing gruel). At 24$\pm$2 weeks of age, a 24-hour quantitative food consumption study was done.
The mean energy density per 100 g of prepared gruel was 114 kcal with the amylase-containing flour (A) *vs* 61 kcal with the control flour (C). The infants' energy intake from experimental flour was 69% higher per meal (15.7 *vs* 9.3 kcal/(kg x meal) and 56% higher per day (31.0 *vs* 19.9 kcal/(kg x d)) in group A than in group C (Table 5).

Table 5: Amount of gruel consumed and energy intake from experimental flour for the control group (C) and the group receiving amylase-containing gruels (A)

	Group A		Group C		P<
	n	mean±SD	n	mean±SD	(1)
Mean per meal					
Amount of gruel (g)	64	108.6 ± 46.0	73	135.4 ± 65.0	0.05
Energy intake (kcal/kg)	64	15.7 ± 7.5	73	9.3 ± 4.9	10^{-6}
Mean per day(2)					
Amount of gruel (g)	31	215.0 ± 102.1	33	289.6 ± 146.1	0.05
Energy intake (kcal/kg)	31	31.0 ± 18.0	33	19.9 ± 10.3	0.05

(1) *Test de Mann-Withney* (2) *for infants consuming gruels prepared from experimental flour*

In Burkina Faso, two gruels prepared from a local blend (Millet + cowpea + peanut + sugar) with or without amylases were alternatively given two times per day during three-day periods to thirty 6-8-month-old infants living at home. The two gruels had very different energy densities (33 and 100 kcal/100g) but a similar consistency. The gruel with the highest energy density was consumed less than that with the lowest energy density (6.2 *vs* 9.8 g per meal and per kg body weight) but permitted to almost double the mean energy intake from gruels (6.2 vs 3.3 kcal per meal and per kg body weight).

Hence, it is obvious that increasing energy density of gruels may result in an important increase of energy intakes from gruels by infants in free-living conditions. Recently, the minimum energy densities required to attain the level of energy needed from complementary foods depending on the number of meals per day and the level of breast-milk energy intake have been estimated for well-nourished children of different age group (WHO, 1998) (Table 6). In order to reach the minimum energy density required with at least two meals whatever the level of breast-milk intake in 6-8 month-old infants and for average breast-milk intake in 9-11-month-old infants, an energy density of 120 to 130 kcal/100g is necessary.

Table 6: Minimum energy density required for gruels

Age group	Level of BM intake	Number of meals per day			
		1 meal	2 meals	3 meals	3 meals
6-8 months	Low (1)	255	**128**	85	64
	Average	176	88	59	44
9-11 months	Low (1)	309	155	103	77
	Average	231	**116**	77	58
12-23 months	Low (1)	370	185	123	92
	Average	295	148	98	74

(1) Low level of breast-milk (BM) intake corresponds to mean- 2 SD)

Consistency

There are two reasons for drawing a particular attention to gruel consistency. First, unless special hydrothermic or enzymatic processes are used, reaching the recommended energy density values for gruels prepared from commonly used blends, particularly in Africa, lead to so thick consistency that the food prepared can not be qualified as gruel anymore. Second, various studies have shown that, within the range of acceptable consistency for gruels - most often characterised by their viscosity (Mouquet, 1998) - differences in consistency can result in differences in energy intake.

A considerable amount of attention has been devoted to the effect of gruel consistency on energy intake since the beginning of the 80s (Church, 1979; Ljunjqvist *et al.*, 1981) insofar as energy density and consistency of gruels prepared mainly from high-starch staple foods are strongly related. Recent reviews (Ashworth and Draper, 1992; Trèche, 1996; WHO, 1998) of the 11 published studies aimed at comparing energy intakes from gruels with different viscosities have concluded that the effect of reducing the viscosity of gruels on energy intakes is not constant. 7 out of 11 studies demonstrated that energy intakes were significantly higher with the gruels with the lowest viscosity. 3 of them showed no evidence of any difference of energy intake. The last one (Lukmanji *et al.*, 1988) showed higher energy intake from a thick gruel than with a thinner porridge but their energy densities and composition were not similar.

Recently, Rahman *et al.* (1995) showed that energy intake from gruels and total energy intake from complementary foods were, respectively, 68% and 24% higher in a 6-35-month-old child group with acute shigellosis receiving an high-energy-dense gruel liquefied by amylase-containing flour than in a comparable child group receiving a thick gruel of the same energy density.

Starch content / Sweetness

To assess whether dietary starch content affects total energy intake, Brown *et al.* (1994) offered three different gruels composed of rice, milk, oil and sugar (74 kcal/100g) *ad libitum* four times daily for 3 days to 17 recovering malnourished children from 11 to 20 months of age. The three diets had similar viscosities and contained 56% of energy as carbohydrates with different starch content. Mean energy intakes from high-starch diet (83% of CHO as starch and 17% as sucrose) and low-starch diet (67% of CHO energy as starch and 33% as sucrose) were similar. But energy intakes from a high-starch diet with added saccharin to match the sweetness of the high-sucrose diet were significantly higher (11% increase) that those observed with the two other ones. Thus, increasing sugar content at the expense of starch content does not seems to increase energy intakes but increasing sweetness of a high-starch diet seems to do so.

Fat concentration

To assess whether variations in dietary fat and carbohydrate contents affect total daily energy intakes, eighteen 6-23-month old infants recovering in hospital from previous severe malnutrition were offered two gruels (120 kcal/120g) *ad libitum* four times daily for 4 days (Brown, 1997). The two diets had similar viscosities, flavour and colour but different fat contents. The mean energy intakes from the high-fat diet (45% of energy as fat and 44% as carbohydrates) was 10% higher than those from the low-fat diet (17% of energy as fat and 72 as carbohydrates) indicating that an increase of fat content in gruels may result in an increase of energy intake.

Nature and processing of ingredients

The nature of gruel ingredients and some processes (e.g. milling, toasting, fermentation) directly determine its taste and aroma and indirectly influence other nutritional and organoleptic characteristics. Hence, they are likely to modify appetibility of gruels and consequently the amount of gruel consumed. However, until now, no studies have been published on this topic. These points should be closely looked at in order to explain the differences in energy intakes from gruels consumed in different settings (Table 2).

Conclusion

The mean amounts of gruels consumed by meal by 6-23-month-old children in free-living conditions are generally two times less than expected in regard of their estimated gastric capacity (30 to 40 ml/kg body weight). Hence, taking into account the low energy density of the gruels generally fed to children, the mean energy intake per kg of body weight from a gruel meal probably does not exceed 10 kcal. As the daily number of meals with gruels is generally two or three and cannot be easily increased because of caregivers' time constraints, daily energy intake from gruels in average can only meet a low percentage (20% to 30%) of their energy requirement.

In addition, energy intakes greatly varies from a gruel to another for a same child, from a child to another within the same setting, and from a setting to another. So far, insufficient data on the energy intake from gruel fed to children in free-living conditions have been gathered from dietary surveys to conclude about the relative significance of the within-child, between-children or within-setting, and between-settings variability.

Nevertheless, some determining factors of the levels of energy intake are identified. A conceptual framework for determinants of the energy intake from gruel by breast-fed children can be proposed in order to distinguish between immediate factors, underlying factors, and basic causes and between child-, caregiver- and diet-related factors. Whatever they are immediate factors, underlying factors or basic causes, they can be classified as child-, caregiver- and diet-related factors. Most of them have effects at different levels but, according to their nature, some, such as child-related factors, are most likely to influence the within-child or between-children variabilities, while others, such as caregiver- or diet-related factors, mainly influence the between-setting variability.

In the present state of scientific knowledge, the relative significance of the three immediate factors (i.e. number of meals with gruels per day, energy density, and amount of gruel consumed per meal) is still badly known. There is only a strong evidence that the relative importance of the first two ones is context dependent. But, it can be hypothesised that the most influent factors of daily energy intake from gruels are the number of meals with gruels per day, energy density of gruels and the child's weight. Temporary child illness and consistency of gruels within the range currently observed are also probably influent factors. The others factors likely to explain 10% to 30% of the variability observed are mainly other gruel characteristics, such as fat content and sweetness, and other caregivers-related factors such as level of encouragement during meal and diet monotony.

Amongst these factors, the diet-related ones (i.e. energy density, consistency, fat content, sweetness) appear to be the easiest to influence. This needs to carry out further studies in free-living conditions to verify their relative significance, setting up of appropriate household recipes or technological processes usable in infant flour small-scale production units, and better collaboration and understanding between scientists and agents working in the fields of health and food science.

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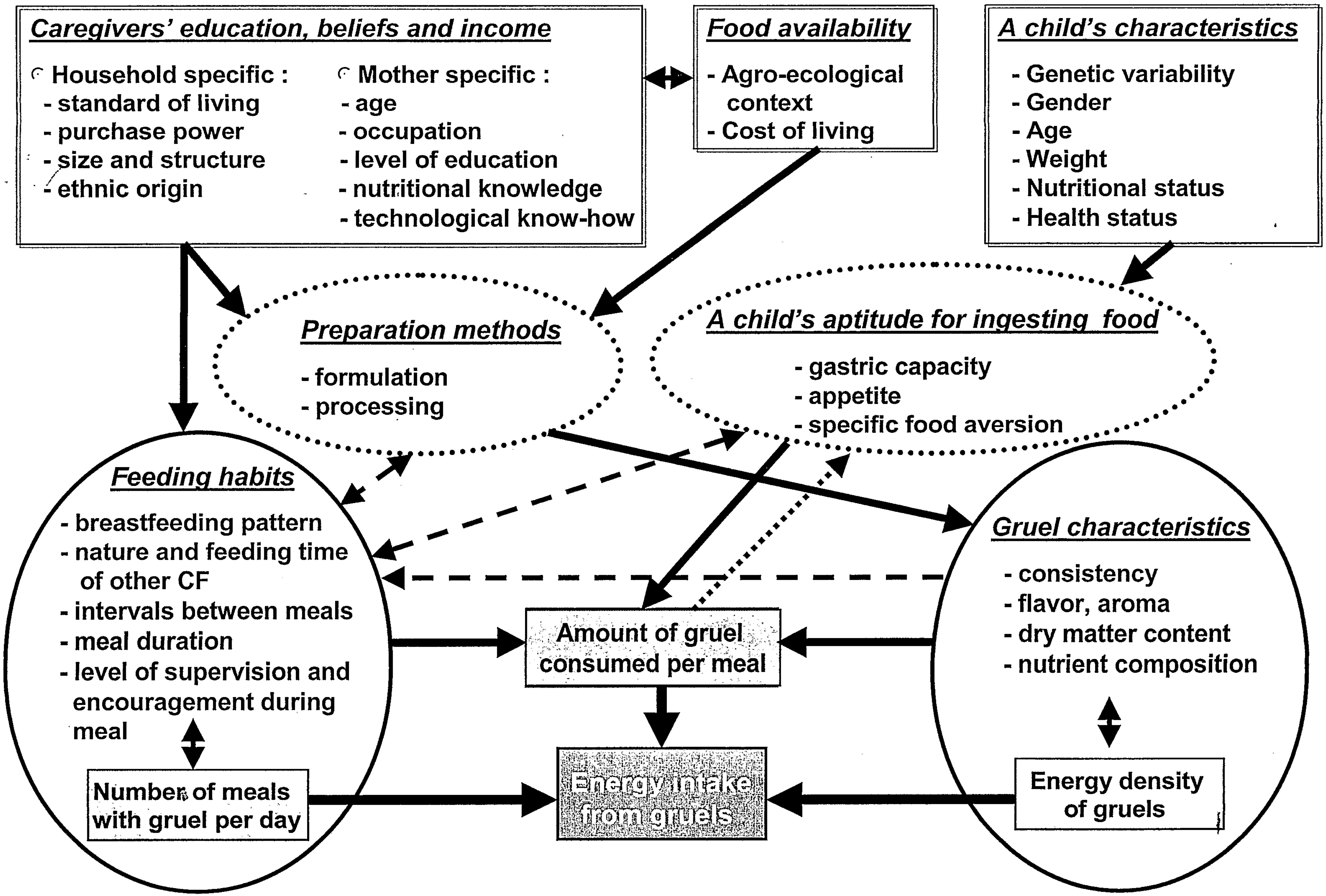

Figure 1 : Conceptual framework for determinants of daily energy intake from gruels