Dietary factors in malnutrition: quality and quantity of diet in relation to child development

By M. Church, *The Health Education Council*, 78 *New Oxford Street, London WC1A 1AH*

Introduction: food as a factor in malnutrition syndromes

Until some 45 years ago the origin was obscure of the childhood syndrome typically including oedema, 'flaky paint' skin rashes, dyspigmented hair and hepatomegaly. Suggested causes at that time included renal failure and multivitamin deficiency. Williams (1933) not only called the syndrome kwashiorkor, the local Ghananian name for it, but established that it was cured by milk and not by vitamins. Thus a nutritional cause for kwashiorkor was claimed with a further tentative suggestion that '... some amino acid or protein deficiency cannot be excluded'.

The view that kwashiorkor was caused specifically by protein deficiency gradually became the accepted view with little definite dietary evidence. Childhood malnutrition, which later became known as protein calorie malnutrition and more recently protein energy malnutrition (PEM), includes a range of conditions from kwashiorkor through to marasmus, in which oedema, skin and hair changes are rare and is characterized by stunting, wasting and very little subcutaneous fat. The classic dietary hypothesis held for many years was that kwashiorkor was caused by protein deficiency and marasmus by energy deficiency.

Factors in the persistence of the 'low protein' theory

The general acceptance of the 'low protein' theory as the cause of kwashiorkor was greatly enhanced by the WHO report of Brock & Autret (1952), which was based on their survey of malnutrition in Africa shortly after the war. The accepted estimates for protein requirements at that time ((US) National Research Council, 1974) for a 1-year-old child were 13·2 net protein energy as a percentage of total energy. This level is nearly 2·5 times the current estimates of 5·4 net protein energy as a percentage of total energy.

Many traditional vegetable-based diets are protein deficient as judged by the high level of requirement, whereas very few are now reckoned to be so by the lower level. Waterlow & Payne (1975) argue this to be an important factor in the persistence of the 'low protein' theory.

McLaren (1975) in his stimulating review of this topic entitled 'The great protein fiasco' also stresses the reinforcing effect of large nutrition-intervention programmes by the United Nations and other agencies, which were based on high-protein foods such as dried skim milk or on high-protein mixtures such as maize, soya and dried skim milk. In many countries large industries were developed to

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manufacture and promote high-protein 'child' foods at low cost, which added further momentum to the 'low-protein' theory.

Dietary evidence for PEM

Disquiet with this classical hypothesis of PEM developed in the 1960s and became explicit by the late '60s and early 1970s. Until the 1960s most dietary evidence was qualitative and even since then there has been remarkably little quantitative information. This is not surprising since childhood weighed-food-intake studies are difficult and especially so under the conditions which predispose to malnutrition.

Gopalan (1968) in a prospective study of children in a poor community was unable to find quantitative or qualitative differences in diet between those who

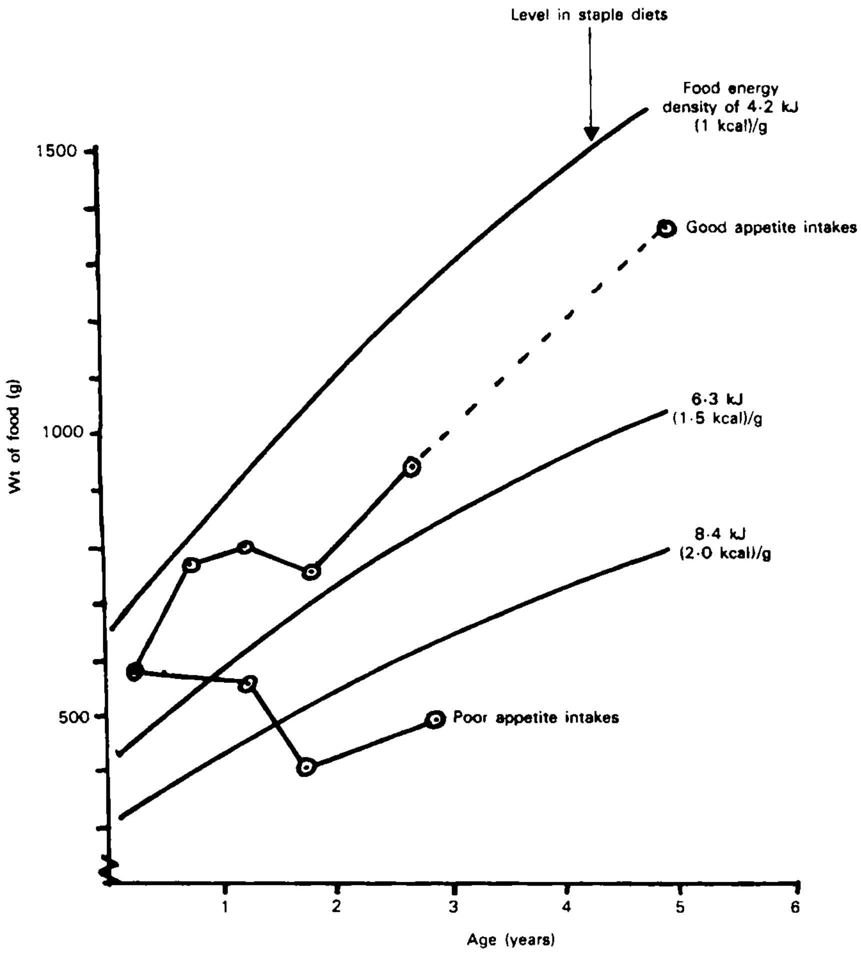

Fig. 1. *Ad. lib.* food intakes of children on traditional staple diet (Rutishauser, 1974; Binns, 1975) compared with amounts of food with differing energy density. The energy density of the average UK diet is 8·4 kJ (2·0 kcal/g).

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developed kwashiorkor or became marasmic. He suggested that individual variability in ability to adapt could account for his findings.

Waterlow & Rutishauser (1974), reviewing the existing dietary information from six countries: Ghana, Guatemala, Jamaica, Polynesia and Uganda, showed that energy intakes were strikingly low and protein intakes were low only secondarily. Only in the Thailand diet was the protein level below the estimated requirement level. In other words if the children had been able to eat enough of the same food to cover their energy needs their protein requirements would have been met.

Rutishauser (1974) in a careful prospective study of children in Uganda followed from birth to 3 years of age showed that energy and protein intakes began to fall below recommended levels from 3 months of age onwards but total energy derived from protein was not low. An important dietary factor was low energy concentration of the traditional weaning diet, which was served infrequently in small amounts. Intakes were further reduced by the frequent episodes of poor appetite.

Rutishauser & Frood (1973) suggested that the bulkiness and low energy density of traditional Ugandan low-fat weaning diets were factors contributing to low energy intakes of children in the weaning period. Even given the food *ad lib.* for an experimental period the children failed to achieve recommended intakes. A study of children in Papua New Guinea (Binns, 1975) given sweet potato *ad lib.* showed a similar shortfall. The results of these two studies are illustrated in Fig. 1. The lowest curve shows the much lower weights of food that would need to be eaten by children in the UK on diets with an average energy density of approximately 8·4 kJ (2·0 kcal)/g (Ministry of Health, 1968). The pattern of 'fall-off' of food intake is characteristic and strikingly exaggerated on days of poor appetite, which occurred (in the Uganda study) on average 1 d in 3 d.

In both the Rutishauser's (1974) and Binn's (1975) studies the same children achieved adequate intakes of energy with high-energy liquid supplementary diets: a milk mixture in Uganda and a 'concentrated soup of peanuts, pandanus nuts, margarine and fish' in Papua New Guinea respectively.

Nutrient density and viscosity in relation to child development and the weaning process

When the term 'bulk' is applied to food it implies weight, volume and viscosity. Of these features 'bulk' is usually equated with weight since it is most easily measured. Not only is volume more difficult to measure, especially for solids, but the specific gravity of most cooked foods is nearly 1·0. Viscosity has no simple measuring technique and viscometry, which is an integral aspect of food science, has tended to be ignored by nutritionists. Food viscosity is, however, from a physiological and developmental viewpoint, a vital factor. For instance, is it chewable, swallowable, drinkable? Can it be eaten out of a spoon, a fork or by hand? The mouth is evidently a most sensitive viscometer and most of these questions are seldom consciously asked, but the choke reflex is good evidence that food is rejected if there is a serious possibility of it becoming stuck in the oesophagus. Furthermore at various phases of development only food of the right viscosity can be adequately dealt with as shown in Table 1. Some of the features are primarily physiological and neurological, such as the ability to suck, chew or swallow whereas others relate to skills such as eating and drinking, which are vital to the young child often fighting for its own share from a communal family dish.

Table 1. *Feeding and stages of development*

Stage	Foetal	Birth	Infant phase (6–12 months)	Toddler phase (2 years)
Appropriate form of food and water	Intravenous	Liquid	Semi-solid gruel or pap	Mixed family foods
Means of feeding	Placenta	Breast- or Bottle-feeding	Feeding by mother, by hand or utensil	Self-feeding
Child skills	None	Ability to suck and swallow	Development of chewing	Coordination of hand–mouth feeding skills
Psychological stages	Confluence and passivity	Dependence on mother	Decreasing dependency	Growth of independence, identity
Developmental stages	Weaning from the womb	'In arms' phase	Crawling phase	Walking

Adequate weaning from milk to a solid mixed diet is obviously fundamentally dependent on foods of suitable viscosity. Illness has a regressive effect, which is clinically well recognized and is illustrated in Fig. 2. The more severe the illness the further the regression requiring the appropriate means of feeding back to the intravenous route. Recovery involves passing rapidly through the normal developmental phases.

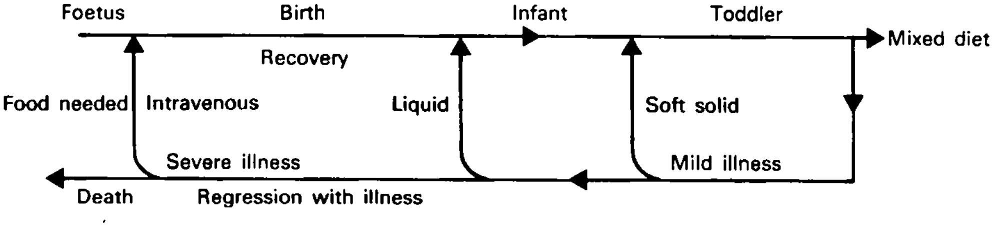

Fig. 2. A schematic diagram of the effect of illness on feeding.

Thus, if there is an inherent problem in the weaning diets of children these will be re-encountered each time a child is ill. This is a possible nutritional reason for the strong association between malnutrition and infection and especially gastro-enteritis. Food viscosity is dependent on the nature of the ingredients, dilution and temperature as illustrated in Fig. 3. Clearly there is wide variability, and fat or the solubility of food have the most profound effect. Hence milk containing fat, soluble

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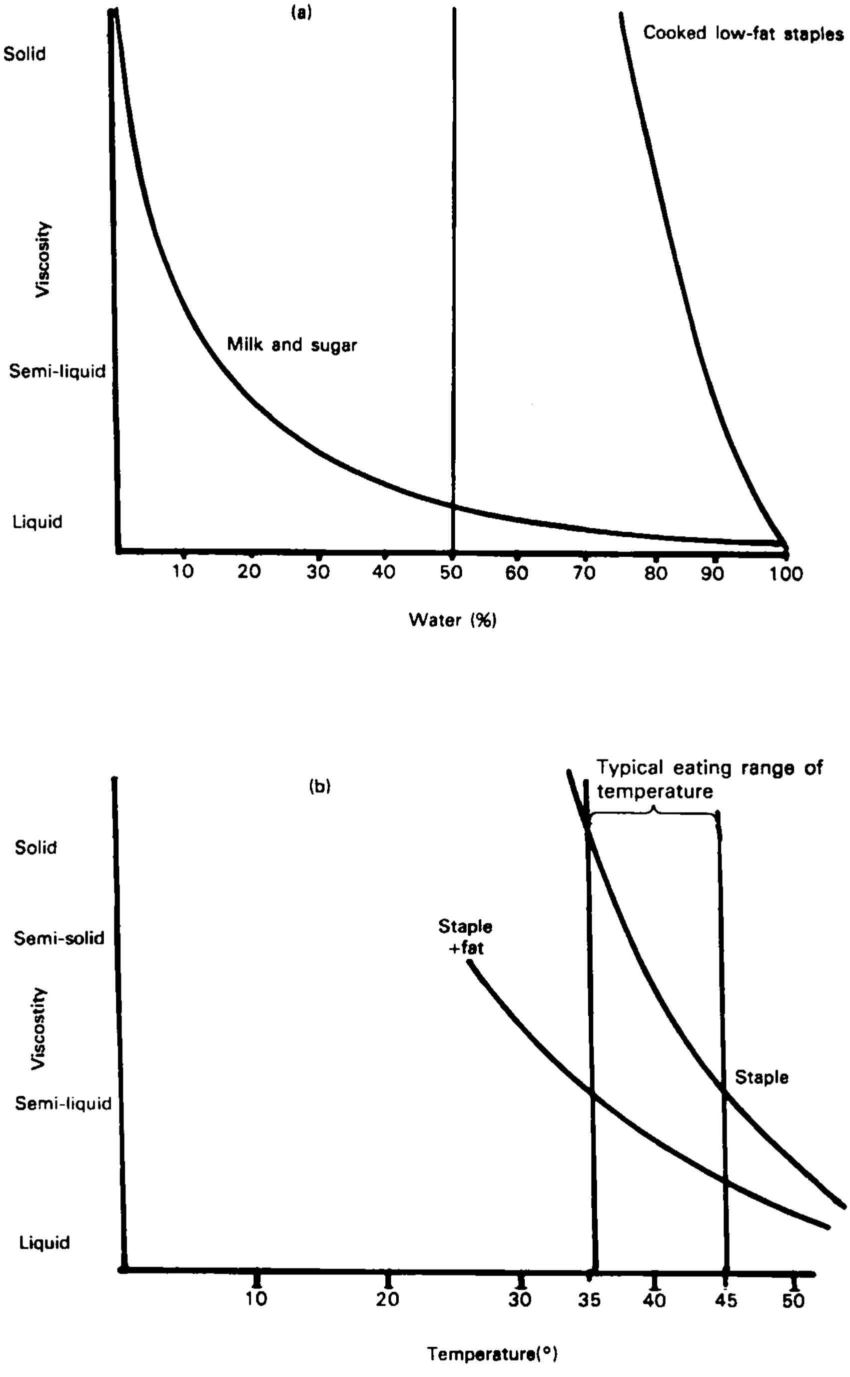

Fig. 3. Factors affecting the viscosity of food. (a) The viscosity of cooked foods is most basically affected by dilution with water but varies enormously with different ingredients and with temperature. The most important factors are solubility of the ingredients and the amount of fat. The range of variability is illustrated by the curves for milk and cooked staples. (b) All foods become thicker with cooling but the addition of fat dramatically reduces the rate of change.

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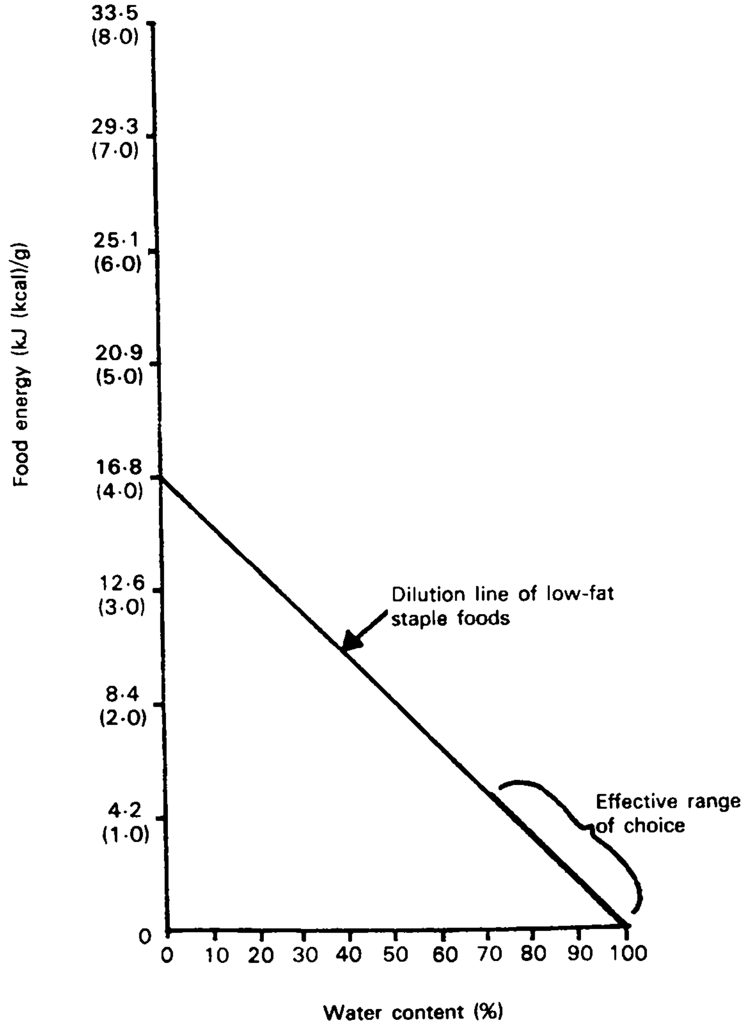

Fig. 4. Food energy density and the effects of dilution with water. Low-fat staple foods showing limited range of choice.

carbohydrate and soluble protein shows one extreme and is still drinkable at 200 ml water/l. The other extreme is shared by all low-fat cooked staple foods in which viscosity rises very rapidly so that they are handleable at between 700 and 800 g water/kg. Conversely to be drinkable they have to have approximately 950 g water/kg. Furthermore the effect of heat and cooling is most dramatic on low-fat cooked staples, all of which rapidly become more solid on cooling.

These viscosity curves show clearly the well-recognized dilemma of children being weaned on to low-fat traditional diets. Much below 700 g water/kg these foods are too thick to eat and yet as served have rarely more than 4·2 kJ (1 kcal)/g. They are softest when hottest and difficult to handle, but as they cool they rapidly thicken. If they are made dilute enough to be drinkable they will have approximately 950 g water/kg and have approximately 1·1 kJ (0·25 kcal)/g. The range of choice is very narrow as shown in Fig. 4.

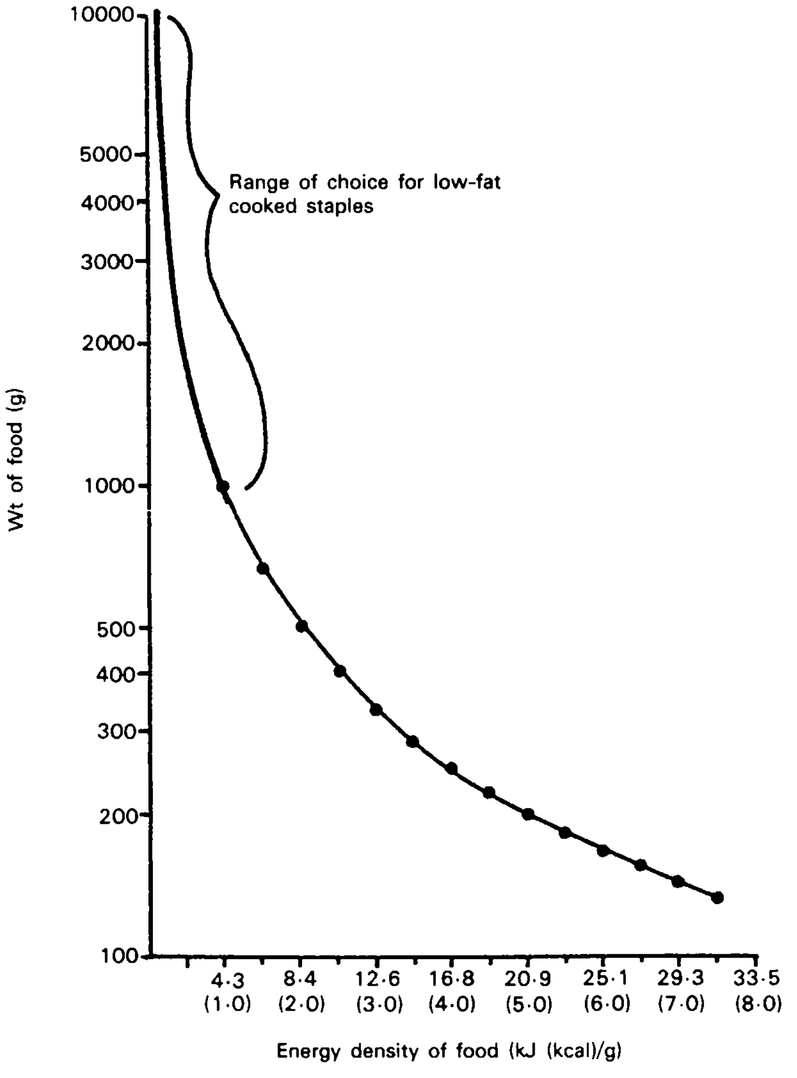

Fig. 5. The different weights of food that provide 4·3 MJ (1000 kcal) at different levels of energy density.

Fig. 5 further illustrates the dilemma by showing the weights of food that are needed to achieve 4·2 MJ (1000 kcal). For instance a 1-year-old child on a typical maize gruel of 1·1 kJ (0·25 kcal)/g will need 4 l. On the other hand, of the thick family pap 1000 g will have to be eaten.

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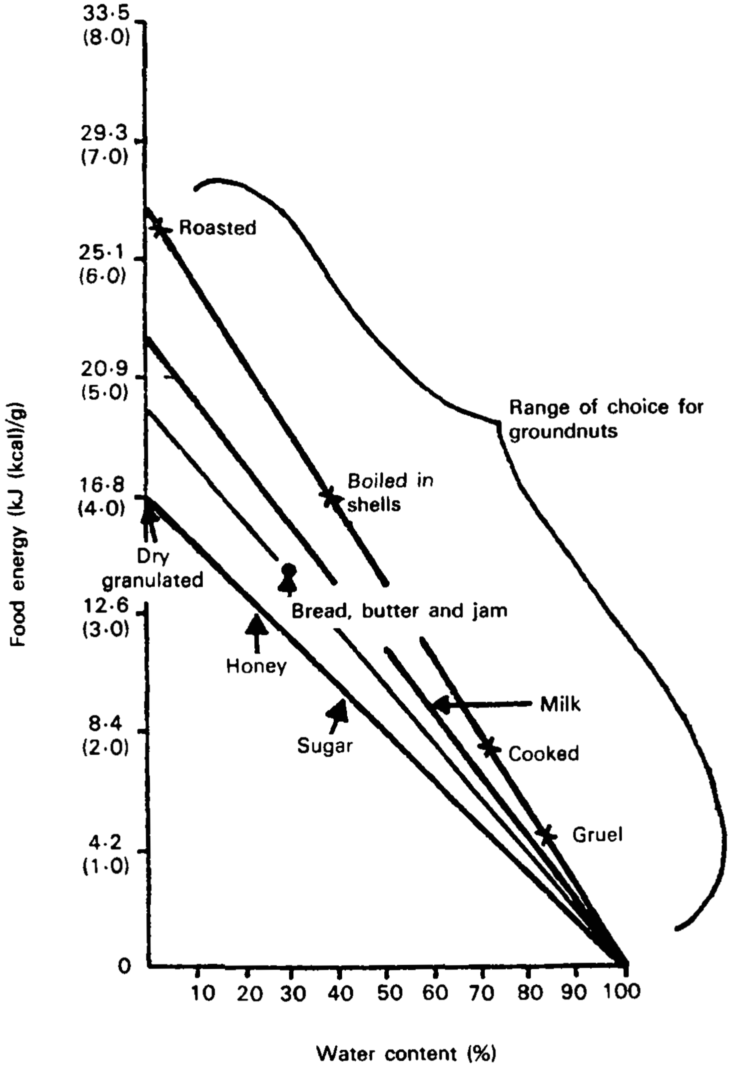

Fig. 6. Food energy density and the effects of dilution with water. This shows the range of choice with the addition of fat or soluble ingredients.

Fig. 6 shows how the range of choice is enormously increased either with fat as an ingredient of food or if it is soluble. Thus it is not surprising that sugar and fat are the ingredients of diet which increase so rapidly as people move from the constraints of low-fat traditional staple diets. As shown in Fig. 3 this is almost certainly primarily due to the effect of fat and solubility on viscosity.

These effects have obviously been recognized and cherished for a long time. For example the 'promised land' of the ancient Hebrews was a 'land flowing with milk and honey'.

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Thus what is evident is that fat not only adds energy to food by its relative energy density (38 kJ (9 kcal)/g compared with 17 kJ (4 kcal)/g for carbohydrates and proteins) but makes foods palatable over a wide range of water content. The groundnut (*Arachis hypogaea*) is a good example, being palatable roasted, with 20 g water/kg and an energy density of 26 kJ (6·3 kcal)/g. Furthermore as a drinkable gruel groundnut soup still has an energy density which is higher than the low-fat staples which will have cooked to a handleable consistency at the same water content.

Sometimes foods cooked for the family are unsuitable and thus unavailable for small children for much more obvious reasons such as beans having thick skins or fish having bones. (In these situations a common practice is to serve the flavourful soup of a stew and restrain the other ingredients.) These kinds of problems need to be solved by practical local food preparation techniques for these foods to become part of the weaning diet.

In conclusion it has been proposed that one of the most important features of low-fat traditional staple foods is that they cook to a thick consistency at high water contents and are thus bulky and of low energy density. It has been argued that many of the problems faced by children being weaned to such diets relate to these qualities, which also explain the consistent finding of low energy intakes of such children, which are severely affected by infection and poor appetite.

The inclusion of fats and soluble foods such as sugar to the diet make a much wider range of palatable foods available with a much more gradual transition from liquidity to solidity. These are food features, which are inherently appropriate for the weaning period and reduce the risks of children becoming malnourished.

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