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Optimizing the introduction of complementary foods in the infant's diet: a unique challenge in developing countries

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Abstract

Being one of a series of technical support papers pertaining to the South African paediatric food-based dietary guidelines, this paper specifically deals with two of the guidelines proposed for the age group 6–12 months regarding the introduction of complementary foods in the infant's diet. Studies have shown that most of South African infants receive solid foods at the age of 4 months or earlier while only a small percentage are breastfed exclusively until 6 months. The untimely and inappropriate introduction of complementary foods have been shown to be risk factors for both under- and over-nutrition with resultant under- or overweight, stunting and micronutrient deficiencies. Optimal timing for the introduction of complementary foods will depend on the infant's physiological and developmental status. Small, frequent meals of easily digestable, smooth, semisolid nutrient- and energy-dense complementary foods should initially be offered while gradually increasing variety in both the type and texture of food. Protein and carbohydrate intake should increase with the infant's age while preference should be given to foods rich in micronutrients. It should be observed that certain foods, such as fresh cow's milk and egg white, because of their allergenic properties, as well as fat-free and high-fibre foods, excessive fruit juice and low nutrient value drinks such as tea are not recommended. Timely introduction of appropriate complementary foods is vital for the immediate and long-term health of the infant and caregivers should be accordingly advised on feeding at this age.

Keywords: infants, complementary foods, South African food-based dietary guidelines.

Following the 1996 recommendations of a Food and Agricultural Organization/World Health Organization (FAO/WHO) expert panel for the development of food-based dietary guidelines (FBDGs) unique and specific to the needs of the populations of different countries, a South African FBDG Working Group and ultimately also a Paediatric Working Group was formed with the task of the latter being the

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development of FBDGs for children younger than 7 years. A set of preliminary FBDGs, chosen to address the most pressing paediatric public health issues, namely protein-energy malnutrition, micronutrient deficiencies and infectious diseases, were formulated for age group subcategories 0–6 months, 6–12 months and 1–7 years. Being one of a series of technical support papers pertaining to the South African Paediatric FBDGs, this paper specifically deals with two of the guidelines proposed for the age group 6–12 months regarding the introduction of complementary foods in the infant's diet. The FBDGs concerned are worded as follows:

- 'From six months start giving your baby small amounts of solid foods'; and
- 'Gradually increase your baby's meals to five times a day'.

The United Nations Children's Emergency Fund (UNICEF) (1998) recommendations regarding complementary foods and feeding include the following statement: 'As breastfeeding continues after 6 months, it is time to introduce complementary foods, i.e. foods that are readily consumed and digested by the young child and that provide additional nutrition to meet all the growing child's needs. Although exclusive breastfeeding provides the best start, after six months and as long as breastfeeding is continued, the child needs more vitamins, minerals, proteins and carbohydrates than are generally available from breast milk alone. Any non-breast milk foods or nutritive liquids that are given to young children during this period are defined as complementary foods, and complementary feeding is the process of introducing these foods'.

However, in different cultures worldwide, the time of initiating the weaning process and the time of finally terminating breastfeeding, the variety, quantity and quality of complementary foods provided, as well as the manner in which it is provided, differs greatly. While infants in more affluent societies are often introduced to a variety of liquid and semisolid foods before the age of 6 months, complementary foods given to infants in less affluent societies and especially in rural areas, usually lack variety in texture and taste, have inadequate nutritional value and are often introduced too soon or too late (Steyn *et al*. 1993; Igbedioh *et al*. 1996; Faber *et al*. 1997; Tessema & Hailu 1997; Mamabolo *et al*. 2004).

Malnutrition in relation to complementary feeding practices in South Africa

In South Africa, more than 80% of infants in rural areas and more than 50% in urban areas receive solids by 4 months of age, with many already being introduced to complementary foods before the age of 3 months (Steyn *et al*. 1993). Usually the main reasons given for the early introduction of complementary foods relate to the mother's perception of the adequacy and the quality of her milk (Faber *et al*. 1997).

In a recent study of infants from birth to 12 months in the Limpopo province (Mamabolo *et al*. 2004), it was reported that only 4% of the 170 infants were still exclusively breastfed at 6 months of age. Solids, comprising mainly of maize- and sorghum meal, were introduced as early as 1 month in 17% of the subjects. Concurrently, the frequency of stunting in the 6–12-month age group was found to be 35%.

Earlier studies such as The South African Vitamin A Consultative Group (SAVACG) (1995) and the National Food Consumption Survey (NFCS) (Labadarios *et al*. 2001) indicated that, on average, 9% of South African pre-schoolers were underweight, and more than 21% were stunted. As stunting is an indication of long-term malnutrition (SAVACG 1995), it can be deduced that the high prevalence of stunting could at least be partly due to poor feeding practices in the period following the introduction of complementary foods (Faber *et al*. 1997; Mamabolo *et al*. 2004).

On the other hand, the prevalence of overweight and obesity among young children should not be overlooked, as shown in the NFCS, indicating that 6% of South African children between the ages of 1 and 9 years were overweight. Especially children born to well-educated mothers seem to be at greater risk (Labadarios *et al*. 2001).

In a recent study conducted in Kwa-Zulu Natal, it was shown that 38% of infants at 6 months of age had a weight-for-height Z score ≥2SD. Although this figure declined to 16% at 1 year of age, over-nutrition in this age group is a cause for concern (Faber 2002).

Furthermore, the poor micronutrient content of foods introduced at an early age is implied in results of the SAVACG study and the NFCS, showing that, for South Africa as a whole, children's diets were deficient in iron, selenium, calcium and zinc as well as most vitamins, especially Vitamins A, C, D, E and B2, B3 and B6 (SAVACG 1995; Labadarios *et al*. 2001).

The optimum age of introducing complementary foods

Current evidence is conclusive regarding 6 months as the appropriate age for introduction of complementary foods (Lanigan *et al*. 2001). While several independent studies have failed to establish any significant benefit associated with the introduction of complementary foods before 6 months of age (Mehta *et al*. 1998; Kramer & Kakuma 2003), malnutrition is well documented in countries such as Nigeria (Igbedioh *et al*. 1996) and Ethiopia (Tessema & Hailu 1997), where prolonged breastfeeding, well beyond the age of 6 months, is practised without complementing it with suitable foods.

Another important consideration in determining the ideal age for introducing complementary foods is gastro-intestinal permeability, associated with immature cells of the gut epithelium and believed to be the greatest in early infancy. Permeability of the small infant's gut for intact protein molecules is considered an important risk factor for the development of food allergies and the introduction of solid foods before the age of 4 months has been associated with a high incidence of atopic dermatitis (Host 2001).

Furthermore, there are clear developmental stages correlating with an infant's ability to ingest various forms of food (Glinsmann *et al*. 1996). One of the developmental milestones which make 6 months the ideal age to introduce complementary foods is the development of the mechanism whereby solid foods are transferred from the front of the tongue to the pharynx, enabling the infant to take pureed, semi-solid food from a spoon, while the protruding movement of the tongue when food is placed upon it decreases (Pridham 1990). Tooth-eruptions, usually starting with mandibular incisors, and the inclination to put objects in the mouth as part of a quest to explore, are further indications of a readiness for complementary foods (Behrman *et al*. 2000).

Beyond 6 months, infant behaviour displaying feeding skills signals a child's readiness to progress to new types of food, textures and feeding modes. These skills include the ability to sit without support, taking food from a spoon, handling thicker or lumpier foods and foods that require chewing, self-feeding with fingers or from a spoon, and cup drinking (Pridham 1990).

Regarding the introduction of complementary foods to the preterm infant, Norris *et al*. (2002) quote the British Department of Health recommending that 'a reasonable compromise may need to be adopted such that weaning can be advised when the infant weighs at least 5 kg, has lost the extrusion reflex and is able to eat from a spoon'. Furthermore, gestational age and developmental stage of the infant, type of milk feed, gender, current weight and weight gain are viewed as important considerations in the timing of introduction of complementary foods in the infant's diet. Delaying the introduction of complementary foods until the age of 6 months post term may render the infant nutritionally vulnerable, especially as the nutritional requirements of the preterm infant are higher per kg bodyweight than that of the term infant (Norris *et al*. 2002).

Foods recommended as suitable complementary foods

Young infants have immature digestive and excretory systems and are not equipped to handle a large variety of foods. Their need is for energy-dense foods which are easily digestible and readily metabolized (Glinsmann *et al*. 1996). Suitable foods of a semisolid pureed consistency should be introduced one at a time, allowing the infant to become used to one new taste or flavour, before introducing the next. New foods should be offered in small quantities which are gradually increased as the infant becomes used to it (Lucas 1999).

Carbohydrate-rich foods such as fruits, vegetables and grains are usually the first complementary foods to be introduced and become even more important as the child grows older when staple grains very often form the basis of the everyday diet. These foods are sources of complex carbohydrates, sugars, micronutrients and a mixture of dietary fibres. Introducing fruit and vegetables in the infant's diet facilitates dietary balance and diversification in addition to providing micronutrients and energy (Glinsmann *et al*. 1996; Lucas 1999). Vitamin A and C-rich fruits and vegetables should be given daily to ensure adequate intake of these nutrients. Vitamin A-rich vegetables and fruit being mainly carrots, butternut, pumpkin, peas, peaches, mango and pawpaw, while richest sources of vitamin C are tomato, citrus fruit and guava (Glinsmann *et al*. 1996; Lucas 1999).

It should be borne in mind, however, that a vegetarian or vegan diet, unless very well-planned, cannot meet all nutrient needs at the age of 6–12 months unless nutrient supplements or fortified products are used (Daelmans *et al*. 2003). One such product is maize-meal, fortification of which has been mandatory in South Africa since October 2003 (South African Department of Health 2003).

At the age of 7–8 months the infant should be introduced to protein-rich complementary foods such as the yolk of a soft boiled egg, finely minced home-cooked meat or chicken and boneless fish. Diets with an adequate fat intake should be provided to meet the need for energy, to facilitate the absorption of fat soluble vitamins and to provide essential fatty acids. Lipids added to complementary foods should preferably be plant-based, such as canola-, flax seed- or olive oil (Prentice & Paul 2000; Daelmans *et al*. 2003). Appropriate protein-rich foods to support growth of vegan infants, would be tofu, pureed legumes and soy yoghurt (Mangels & Messina 2001).

At 9 months, the ideal diet would consist of breast milk and a variety of solid foods including cereal, fruit, vegetables, meat, chicken and fish. Food for finger feeding would be finely cut soft meat or chicken and small pieces of soft fruit or vegetables and grated cheese. Appropriately prepared family meals are quite suitable for the infant 9 months or older (Pridham 1990; Glinsmann *et al*. 1996; Daelmans *et al*. 2003). However, literature warns against the danger of foods which may cause choking such as raw carrots, nuts and grapes which may obstruct the trachea as a result of their shape and consistency (Daelmans *et al*. 2003).

Foods not recommended as complementary foods

While an adequate intake of vitamin C-rich fruits may enhance the uptake of non-heme iron from foods such as cereals, literature warns against the excessive intake of fruit juice. Besides displacing nutrient-dense solid foods and milk, large quantities could also lead to malabsorption of sugars such as fructose or sorbitol commonly found in fruit juice, and may lead to gastrointestinal problems such as diarrhoea, abdominal pain and bloating (Lucas 1999; Daelmans *et al*. 2003). Fruit juice is not recommended before the age of 9 months (Trahms 2004). Drinks with a low nutrient value such as tea, coffee and sugary drinks should be avoided as they displace more nutrient-rich foods (Lucas 1999; Daelmans *et al*. 2003), and it should also be remembered that polyphenols, such as tannins in tea, and phosphates in cow's milk inhibit the bio-availability of dietary iron (Glinsmann *et al*. 1996; Sive *et al*. 1999).

Because of their allergenic properties, egg white and cow's milk should not be introduced before the age of 12 months. In the presence of a family history of atopic disease, wheat, fish and soy should also be avoided during the first year of life, while peanut products should be avoided for the first 3 years (American Academy of Pediatrics Committee on Nutrition 1992; Sive *et al*. 1999).

It was found that iron-fortified cereal does not meet the infant's iron requirements if whole cow's milk is used during the 6–12-month period. Nutritionally significant iron loss could occur with ingestion of fresh cow's milk by increasing gastrointestinal blood loss (American Academy of Pediatrics Committee on Nutrition 1992). Additionally, low-fat cow's milk is yet more inappropriate, because of its low-fat content (American Academy of Pediatrics Committee on Nutrition 1992). Guidelines developed for healthy adult diets are not necessarily appropriate for infants and small children and restrictions intended to reduce the risk of adult disease, could retard growth and development in infants and very young children (Zlotkin 1996). Commercial full-fat soy milk has a fat content equal to that of reduced fat (2%) cow's milk and is, therefore, apart from the fact that the high-phytate content also reduces the bio-availability of zinc and iron, unsuitable for infant feeding (Mangels & Messina 2001). A diet high in fibre and complex carbohydrates and low in fat does not meet the nutrient and energy needs of rapidly growing infants. Nutrition in this age group should promote growth and development rather than focussing on the prevention of adult degenerative disease (Glinsmann *et al*. 1996; Zlotkin 1996). In view of an infant's limited capacity for food intake, adequate dietary energy levels would be hard to achieve if low-fat foods such as 2% or skimmed milk are included in the infant's diet. Fibre has a bulking effect which will lead to early satiety, preventing the infant from taking in enough nutrient-dense foods. Furthermore, the phytate in bran and wholegrain cereals will impede the absorption of important minerals such as iron from the diet (Glinsmann *et al*. 1996). Restricted-fat and high-fibre diets are therefore not appropriate for infants and children under the age of 2 years.

What about salt and sugar?

Sodium is an essential mineral responsible for several physiological functions of which the most important is the maintenance of the extra-cellular fluid compartment and normal blood pressure (Whitmire 2004). In later infancy, the moderate use of salt in selected foods is appropriate and it is neither safe nor reasonable to try to eliminate salt from the infant's diet (World Health Organization 1998). The recommended intake of sodium for infants 6–12 months of age is 370 mg day^{-1} (85 mg of which is supplied by 600 mL of breast milk) (The Dietary Reference Intakes 2003). While addition of extra table salt to complementary food is discouraged (Trahms 2004), complete salt restriction in cooking for infants is not recommended in South Africa (Dr P. Jooste, Medical Research Council, Cape Town, South Africa, personal communication).

Iodized table salt is an important source of iodine which forms an integral part of the thyroid hormones triiodothyronine (T_3) and thyroxin (T_4) regulating various physiological processes including the functioning of the neurological system (Sauberlich 1999). Iodine-deficiency is associated with brain damage and is considered to be the single most important cause of preventable mental defect in the world. However, iodine deficiency is rarely observed where iodized table salt is used (Sauberlich 1999). Excess sodium could lead to expansion of the extra-cellular fluid compartment and to a small but significant elevation in blood pressure (Lucas 1999).

Although one study among West African infants indicated that intakes of complementary foods increased progressively in relation to the level of sweetness of the preparations, the risk of excessive sugar intake, such as displacement of more nutrient-rich foods and promotion of dental caries, outweighs the perceived benefit of increased food intake (Dewey & Brown 2003). It has been shown that any fermentable carbohydrate, including sugar, which stays in contact with the teeth, can contribute to dental caries (Glinsmann *et al*. 1996). However, in developing countries where the heavy burden of infectious disease increases the demand for higher energy intake, sugar may still have a role in meeting energy requirements although enrichment of food with oil or margarine would increase energy intake more effectively. Honey is not recommended as a source of energy as the infant's immune system is unable to prevent botulism spore development. Honey and corn syrup have been identified as food sources of *Clostridium botulinum* spores which germinate and produce toxin in the bowel lumen (Trahms 2004).

The use of processed complementary foods

With the increase in employment of women, the demand for pre-cooked products requiring less time to prepare is growing. This should be weighed against the disadvantages of processed complementary foods, being the cost, which is still high relative to home prepared foods, and the fact that introduction of culture-specific family foods is delayed. A child given processed foods and introduced to family foods later on may reject the family food in favour of the processed foods. Therefore, despite certain advantages including the ease of providing an appropriate balance of nutrients, potential time saving and the possibility of reducing microbial contamination, processed foods should not be the sole component of a complementary feeding program and it is recommended that food suitable for the infant is drawn from the family pot (Dewey & Brown 2003).

Supplementary formula feeding

Where formula feeding is practised, illiteracy, innumeracy and language barriers are among the reasons why instructions on how to mix formula are not properly understood. Some mothers even deliberately add more water to save formula, thus resulting in feeds with inadequate energy density (Faber *et al*. 1997). Offering additional milk feeds can jeopardise sustained breastfeeding, as reduced stimulation and less regular emptying of the breast would decrease production of breast milk (Dewey & Brown 2003). Formula feeds, unhygienically prepared, also carry the risk of gastro-intestinal infection (Faber *et al*. 1997).

Quantities of complementary food to offer

A limited gastric capacity and simultaneous large requirement for energy and nutrients create the need for small, frequent, energy- and nutrient-dense meals to provide in the increasing requirements of the growing infant (Dewey & Brown 2003). Balance in energy and nutrient intake during infancy is considered critical for normal childhood growth and development as well as health in adulthood. As both under- and over-nutrition have important clinical and public health implications, it is advised that the focus on under-nutrition and food security should expand to also include trends in overweight and obesity (World Health Organization 2000). Therefore, both the type and quality as well as the quantity of complementary food offered should match the infant's nutritional requirements (Dewey & Brown 2003).

Nutritional requirements of the 6–12-month-old infant

Energy requirements

According to Dewey & Brown (2003), the 2002 FAO recommendations for energy intake during infancy, described as appropriate estimates of the energy needs of healthy US breastfed infants, are 5–13% less than those published in 1998 in a WHO/UNICEF document on complementary feeding and are intended to replace the latter (Table 1) (Dewey & Brown 2003).

Following the FAO recommendations, energy intakes of respectively 200 kcal day^{-1} and 300 kcal day^{-1} for the age groups 6–8 months and 9–11 months, should be derived from complementary foods, based on an assumed average breast milk intake of ±630 mL day^{-1} (Table 1) (Dewey & Brown 2003).

In developing countries, however, the heavy burden of infectious and parasitic disease borne by infants and children, accounts for a higher energy requirement. Disease such as diarrhoea has a growth limiting effect, affecting appetite and energy expenditure, as an increase in metabolic rate is the normal reaction to fever. With concurrent micronutrient deficiencies, as often occur in developing countries, energy is used even less efficiently than under more favourable conditions (Prentice & Paul 2000).

Catch-up growth

Catch-up growth, placing high demands on energy needs, may occur at any stage of growth for a variety of reasons. It is most commonly observed during recovery periods after illness, after addressing causes of growth failure and post-natally after severe intrauterine growth restraint (Hack *et al*. 2003).

However, growing evidence indicates that upward centile crossing of weight in the first 2 years of life puts children at risk for obesity with comorbid metabolic disturbances such as insulin resistance, non-insulin-dependent diabetes mellitus, hypertension and cardiovascular disease. This risk also pertains to catch-up growth among term-born infants following intrauterine growth restriction and/or growth failure during infancy (Hack *et al*. 2003).

Table 1. Energy requirements from complementary foods, based on WHO/UNICEF 1998 recommendations, the proposed FAO 2002 recommendations and the DRIs for infants 6–12 months with an assumed average daily intake of ±630 mL breast milk or substitute formula (Dewey & Brown 2003; The Dietary Reference Intakes 2003)

Age group (months)	Total energy requirements per day			Assumed daily energy intake from ±630 mL breast milk or substitute formula	Required daily energy intake from complementary foods		
	WHO/UNICEF 1998	FAO 2002	DRIs		WHO/UNICEF 1998	FAO 2002	DRIs
6–8	682 kcal (2.85 MJ)	615 kcal (2.57 MJ)	676 kcal (2.84 MJ) Girls 743 kcal (3.12 MJ) Boys	413 kcal (1.73 MJ)	269 kcal (1.12 MJ)	202 kcal (0.84 MJ)	263 kcal (1.11 MJ) Girls 330 kcal (1.39 MJ) Boys
9–11	830 kcal (3.47 MJ)	686 kcal (2.87 MJ)	676 kcal (2.84 MJ) Girls 743 kcal (3.12 MJ) Boys	379 kcal (1.59 MJ)	451 kcal (1.88 MJ)	307 kcal (1.28 MJ)	263 kcal (1.11 MJ) Girls 330 kcal (1.39 MJ) Boys

WHO, World Health Organization; UNICEF, United Nations Children's Emergency Fund; FAO, Food and Agricultural Organization; DRI, dietary reference intakes.

In the Avon longitudinal prospective study of pregnancy and childhood (Ong *et al*. 2000), children undergoing catch-up growth in the first 2 years of life were heavier and taller than other children at 5 years, had a greater body mass index, total fat mass and central fat distribution which are variables of childhood size linked to metabolic markers for risk of disease in adulthood and are predictive of adult obesity.

Energy density of complementary foods

The required energy density of complementary foods, expressed as kcal g^{-1} of food, can be calculated by dividing the estimated total energy requirement from complementary foods by the amount of complementary foods given, also taking into account that infants have an assumed gastric capacity of 30 g kg^{-1} body weight per meal (Dewey & Brown 2003). Although not described in the literature, it is proposed that the calculation can be made as follows (Box 1):

The lower the energy density of a meal, the greater is the quantity of food required to provide in the infant's energy needs as illustrated in Table 2. It should also be noted that the energy density of each meal can be increased from ±0.6 to ±1.0 by adding one teaspoon of oil/butter or margarine or one heaped teaspoon (13 g) of mashed avocado to 100 g of porridge, vegetables or fruit. Once meat or chicken is added to a meal, the energy density increases to ±1.0 kcal g^{-1} of food, without addition of any extra oil or margarine (FoodFinder 3 2002). It should be noted that these calculations are theoretical, serving to illustrate the concept of energy density and not meant to be rigidly prescriptive of quantities to be consumed.

Box 1.

Energy required from complementary foods (Table 1) ÷ No of meals served per day = energy required from 1 meal

Energy required from 1 meal ÷ quantity served per meal = required energy density of meal

Example:

If 3 meals are served per day:

330 kcal day^{-1} from complementary foods (boy 6–12 months, Table 1) ÷ 3 meals per day = 110 kcal per meal

110 kcal ÷ 150 g (quantity of 1 meal) = 0.73 kcal g^{-1} (required energy density of food)

Table 2. Examples of meals of varying energy density supplying ±110 kcal per meal (FoodFinder 3 2002)

Meal constituents	Total quantity	Energy density
125 g soft maize-meal porridge with 5 g margarine	130 g	0.85 kcal g^{-1}
100 g apple, stewed without sugar + 50 g frozen peas, boiled and mashed	150 g	0.73 kcal g^{-1}
40 g mashed banana + 100 g plain, unsweetened low-fat yoghurt	140 g	0.78 kcal g^{-1}
50 g boiled, mashed potato + 50 g boiled, mashed butternut squash + 5 g canola oil	105 g	1.05 kcal g^{-1}
80 g boiled, mashed potato + 80 g boiled, mashed butternut	160 g	0.69 kcal g^{-1}
30 g cooked beef topside mince + 30 g boiled, mashed potato + 30 g boiled, mashed butternut squash	90 g	1.22 kcal g^{-1}
30 g finely chopped cooked chicken + 70 g mashed, boiled carrot + 13 g mashed avocado	113 g	0.97 kcal g^{-1}

Literature states that if most households were able to prepare meals with an energy density of 1.0 kcal g^{-1}, children in all age groups should be able to consume enough energy if they received at least three meals per day (Dewey & Brown 2003). Excessive addition of lipids, and hence an indiscriminatory increase in energy density of complementary foods with resultant energy intake in excess of dietary needs, is likely to lead to rapid weight gain and obesity. In addition, concentrations (quantity/kcal) of micronutrients in the diet may be over-diluted with excessive addition of lipids, and the energy density of complementary feeds may also affect the quantity of complementary foods taken. Furthermore, because of self-regulatory energy intake, infants will also tend to reduce their breast milk intake when given a large amount of energy from other foods (Dewey & Brown 2003).

Macronutrient requirements

Lipids

The amount of lipids that should be provided by complementary foods depends on the infant's intake of breast milk and can be calculated to provide together with breast milk 30–45% of total dietary energy as lipids. According to Dewey's (Dewey & Brown 2003) calculations, a child in the 6–8 months age group with an average to high intake of breast milk (600–895 mL day^{-1}) will not need any lipids coming from complementary foods, assuming that the mother is well-nourished. However, with a breast milk intake of only 300 mL day^{-1}, the infant would need 19% of the energy value of complementary foods to be coming from lipids to ensure that 30% of the total energy value of the diet is supplied by lipid. Breast milk is a relatively more abundant source of lipids than most complementary foods and the easily digested fat in human milk is particularly well-suited to the needs of rapidly growing infants (Dewey & Brown 2003).

The arachidonic acid (AA): docosahexapentanoic acid (DHA) ratio in breast milk is commonly 1:1 and AA and DHA are, respectively, referred to as the most important n-6 and n-3 long chain poly unsaturated fatty acids in breast milk (Uauy *et al*. 2000). These fatty acids can, to a certain extent, also be synthesised in the human body from their precursor fatty acids, linoleic and α-linolenic acid (ALA) (Luukkainen *et al*. 1996; Uauy *et al*. 2000). Therefore, despite the relatively low content of poly unsaturated fatty acids of complementary foods usually offered, they do raise the plasma levels of AA through synthesis from dietary fats, usually from meat, chicken or added plant oils (Zlotkin 1996). However, as complementary foods usually supply very little n-3 fatty acids such as ecosapentanoic acid (EPA) from marine sources and ALA (Uauy *et al*. 2000), it seems that the infant can rely solely on breast milk as the source of the all important DHA (Luukkainen *et al*. 1996), unless precursor fatty acids (ALA) are obtained from plant oils such flax seed-canola or soybean oil (Ettinger 2004). However, excess n-6 fatty acids (as from safflower oil) in the diet prevents the conversion of ALA to the longer EPA and DHA fatty acids (Ettinger 2004). The optimum ratio for n-6 : n-3 fatty acids for humans is estimated at 2:1 to 3:1 (Ettinger 2004).

Table 3. The daily nutrient requirements, expressed as DRIs or RDAs, for infants 6–12 months of age (The Dietary Reference Intakes 2003)

Nutrient	DRI/RDA per day for infants 6–12 months	Assumed daily nutrient intake from 600 mL breast milk or substitute formula	Amount of nutrient needed from complementary foods to meet daily requirements
Energy	676 kcal girls, 743 kcal boys	400 kcal girls, 400 kcal boys	276 kcal girls, 343 kcal boys
Fat (total)	30 g	21.2 g	8.8 g
n6 PUFA	4.6 g	5.3 g	–
n3 PUFA	0.5 g	–	0.5 g
Protein (RDA)	13.5 g	9.6 g	3.9 g
Calcium	270 mg	152 mg	118 mg
Phosphorus	275 mg	88 mg	187 mg
Magnesium	75 mg	20 mg	55 mg
Iron (RDA)	11 mg	0.56 mg	10.44 mg
Zinc (RDA)	3 mg	2.24 mg	0.76 mg
Fluoride	0.5 mg	–	–
Iodine	130 µg	108 µg	22 µg
Selenium	20 µg	–	–
Chromium	5.5 µg	n.a.	–
Vitamin C	50 mg	26.8 mg	23.2 mg
Vitamin A	500 µg	86.4 µg	413 µg
Vitamin D	5 µg	1.2 µg	3.8 µg
Vitamin E	5 mg	2.4 mg	2.6 mg
Vitamin K	2.5 µg	12 µg	–
Thiamine	0.3 mg	0.056 mg	0.244 mg
Riboflavin	0.4 mg	0.164 mg	0.236 mg
Niacin	4 mg	1.2 mg	2.8 mg
Pyridoxin	0.3 mg	0.036 mg	0.264 mg
Folic acid	80 µg	20 µg	60 µg
Vitamin B12	0.5 µg	0.12 µg	0.38 µg
Pantothenic acid	1.8 mg	1.2 mg	0.6 mg
Biotin	6 µg	3.2 µg	2.8 µg

DRI, dietary reference intakes; RDA, recommended dietary allowance.

Protein

The amount of protein required from complementary foods can be calculated by subtracting the protein coming from breast milk from the total daily protein requirement for each of the age intervals 6–8 and 9–11 months. A total intake of 13.5 g day^{-1} or 1.52 g kg^{-1} day^{-1} is the current recommended dietary allowance (RDA) for the 6–12-month age group (Table 3) (The Dietary Reference Intakes 2003). Assuming an average breast milk intake of 600 mL per day, with a protein content of 16 g L^{-1}, the amount of protein supplied by breast milk would be 9.6 g day^{-1}. Protein needed from complementary foods would therefore increase from approximately 2.5 g day^{-1} at 6 months to approximately 6 g day^{-1} at 12 months (Dewey & Brown 2003; The Dietary Reference Intakes 2003).

Carbohydrate and fibre

Breast milk supplies 40% of its energy in the form of lactose (Dewey & Brown 2003) and together with carbohydrate-rich foods such as a variety of fruit, vegetables and suitable grains, such as rice and maize, infants will get all the carbohydrate and fibre they need. In view of the bulking effect of fibre and the high-phytate content of wholegrain foods discussed earlier, added dietary fibre is not recommended for infants (Glinsmann *et al*. 1996).

Micronutrient requirements

Vitamin A

According to Dewey (Dewey & Brown 2003), the amount of vitamin A, folate, vitamin B12, vitamin C, iodine and selenium, needed by the breastfed infant from complementary foods before 12 months, is zero or close to zero, because human milk contains generous amounts of these nutrients if a mother is well-nourished (Dewey 2001). In contrast to this, vitamin A deficiency was found to affect one third of South African children under the age of 6 years and has been identified as a significant public health problem in this country (SAVACG 1995). In view of this finding, Dewey's recommendation may not be appropriate for children in developing countries. Supplementation programmes, such as provided by the South African Department of Health, can be of great benefit.

Iron

In spite of progress worldwide in improving child health and survival rates, the problem of iron deficiency anaemia persists, affecting the lives of 30–40% of children (Glinsmann *et al*. 1996). Evidence exist that the adverse effects of anaemia persist throughout childhood, even if the condition is corrected by iron supplementation (Sive *et al*. 1999).

In developing countries where poverty may restrict the intake of meat and other iron-rich foods such as fortified cereals, breastfeeding extending well beyond the first year may be the first line of defence against iron deficiency anaemia, although the iron content of human milk is relatively low (Dewey & Brown 2003). In addition, the enrichment of staple cereals such as maize may do much to alleviate the problem (South African Department of Health 2003).

Zinc

Relating to immune function and growth, the consequences of zinc deficiency are likely to be extensive but not necessarily easily recognized as such. The amount of zinc in human milk declines with prolonged breastfeeding while foods with high natural zinc content such as meat, organ meat and shellfish are not generally fed to children in developing countries. Additionally, phytate in a predominantly staple-cereal-based diet may inhibit the uptake of zinc (Behrman *et al*. 2000). Inclusion of foods rich in zinc such as meat and chicken in the infant's diet from 7 months onwards should be encouraged. Mandatory fortification of maize-meal in South Africa makes this food an alternative source of zinc and other nutrients such as vitamins and iron. Dietary Reference Intakes for nutrients and energy (from the USA) for infants 6–12 months old are summarized below (Table 3) (The Dietary Reference Intakes 2003).

Responsive feeding

It should be remembered that the intake of complementary foods is influenced by a number of independent factors including the child's appetite, the caregiver's feeding behaviour and characteristics of the diets themselves (Dewey & Brown 2003).

Therefore, positive mealtime interaction and parental mealtime behaviour modelling are extremely important in fostering healthy eating habits and social development (Ramsay *et al*. 1993). Parents should make mealtimes enjoyable and avoid force feeding or coercion, but feed with responsiveness to a child's expressed needs. A relaxed mealtime environment and positive communication are most important in developing a healthy parent–child feeding partnership (Ramsay *et al*. 1993; Host 2001). If the parent models enjoyment of a varied, nutritious diet, the infant will more than likely adopt a positive attitude to learning to enjoy new foods (Ong *et al*. 2000; Daelmans *et al*. 2003; UNICEF 1998).

Conclusion

The introduction of nutritionally adequate complementary foods at the right time in sufficient quantities poses a unique challenge to mothers, caregivers and health professionals. Evidence is conclusive that few infants who are fed only breast milk beyond the age of 6 months remain healthy and grow well with growth faltering being most evident in infants between 6 and 12 months if the introduction of complementary foods is delayed for too long (Daelmans *et al*. 2003). In view of the above, it is evident that a well-planned complementary diet plays a significant role in the prevention of dietary errors and imbalances of which the detrimental effects often persist throughout childhood and onwards (Dewey & Brown 2003).

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