1. Introduction

1.1 Objectives and organization of review

The ultimate objective of this document is to provide the background information that is necessary for the development of scientifically sound feeding recommendations and appropriate intervention programmes to optimize children's dietary intake and enhance their nutritional status. The review is intended primarily for health professionals and others concerned with the nutrition, health, and well-being of children in developing countries. Although much of the information may also be relevant for young children in industrialized countries, the document focuses on the particular needs of children in low-income settings, and the recommendations have been formulated with consideration of the economic and environmental constraints that are common in developing countries. The presentation assumes that the reader has some familiarity with basic concepts of nutrition science.

The document is organized into nine major sections. This introductory chapter provides the rationale for the current review and defines some of the more important terms that will be used throughout the report. Additional background information is presented on the maturation of physiological processes relevant to child feeding. The next chapter discusses the importance of breast-feeding in child-feeding regimens and discusses the appropriate age of introduction of complementary foods and duration of breast-feeding. The third chapter provides a broad range of technical information on different aspects of complementary feeding, including the energy required from complementary foods at different ages, appropriate feeding frequency, the energy density of complementary foods, and the importance of organoleptic characteristics of these foods as determinants of intake. The following chapter presents similar analyses regarding the protein and micronutrient contents of complementary foods. Chapter five discusses the important role of caregiver behaviours in child feeding, and the following one provides information on food processing and food safety. The seventh chapter presents a brief summary of available global information on child-feeding practices and the subsequent one describes the range of current programmatic interventions to promote improved child feeding. The last chapter presents a summary of current conclusions regarding appropriate child feeding and a discussion of future research needs.

Several topics will not be reviewed fully in this publication, either because they have limited relevance for developing countries or because they have already been dealt with in detail elsewhere. In particular, the current presentation generally assumes that children are being breast-fed initially, as is the case in most developing countries, so there is little discussion of appropriate feeding of non-breast-fed infants. In any case, it would be very difficult to provide very young non-breast-fed infants with a diet of adequate nutritional quality unless highly processed foods are provided, and these are unlikely to be affordable. Also, little information is presented in the document on the management of severely malnourished children, but a publication of the World Health Organization will deal

thoroughly with this topic (WHO, in press). Finally, there is no specific information in the current review on the dietary management of children during illness. In most cases, however, the same complementary foods that are appropriate for asymptomatic children can be used safely during common childhood illnesses. Again, more information is available elsewhere on this issue (Brown & Bentley, 1988; Griffiths et al., 1988; Brown, 1994; Brown, Peerson & Fontaine, 1994; Ashraf et al., 1996; WHO, 1996a; ESPGAN, 1997).

1.2 Rationale for review

Childhood malnutrition remains a common problem in much of the developing world. A recent comprehensive report on the global nutritional situation, which was prepared by the World Health Organization using data collected from 1980 to1992, indicates that more than one-third of children less than five years of age in developing countries have heights-for-age less than –2 standard deviations (SD) with respect to international reference data (de Onís et al., 1993). It is difficult to compare these results with earlier assessments, because of inconsistencies in the study methods and sampling techniques. Nevertheless, the proportion of children who are undernourished does not appear to have changed very much during the past 20 years since these figures were first analysed (ACC/SCN, 1987; ACC/SCN, 1989; ACC/SCN, 1992; ACC/SCN, 1994). However, because of considerable global population growth during this period, the number of malnourished children continues to escalate.

Early growth retardation is associated with a broad range of adverse functional consequences. For example, malnourished children have impaired immune function (Chandra, 1991), and increased rates (Tomkins, 1981; Sepulveda, Willett & Muñoz, 1988) and severity of enteric (Palmer et al., 1976; Black, Brown & Becker, 1984; Bairagi, 1987) and other infections (Victora et al., 1990) than those who are better nourished. Malnourished children also have a higher risk of dying prematurely, and recent analyses indicate that as much as one-third to one-half of childhood mortality can be attributed to malnutrition (Pelletier, 1994; Schroeder & Brown, 1994). In addition to this elevated mortality risk, delayed motor development (Pollitt et al., 1994), and impaired cognitive function and school performance are also associated with the process of early nutritional stunting (Lasky et al., 1981; Sigman, 1989; Martorell et al., 1992). Thus, improvements in young children's nutrition are desirable not only for their expected positive impact on their physical growth, but also to reduce the risk and complications of infections and to maximize psychomotor development and school performance.

On the surface, the foregoing surveillance statistics seem to leave little room for optimism. However, contemporary research on factors that influence children's dietary intake and growth performance is providing new insights into the etiology of childhood malnutrition. These findings suggest that novel programmatic approaches may be more successful in improving child feeding and reducing the current high rates of malnutrition than many historical efforts. Therefore, this is an opportune time to review the newly available

information and to reconsider current programmatic activities to promote optimal feeding and nutritional status of young children.

Examples of recent scientific evidence with particular relevance for improved child feeding include the following. First, results of longitudinal growth studies and data from nutritional surveillance activities both indicate that growth-stunting occurs within a fairly narrow "age window" from several months after birth to about 2 years of age. This coincides with the time when foods other than breast milk are generally introduced into the diet. Thus, targeting interventions to this age group may be more cost-effective than traditional programmes that include a broader age range of preschool children. Second, new information is available from several observational studies and intervention trials concerning the optimal age of introduction of complementary foods. These indicate the importance of exclusive breast-feeding during the early months of life and the potential hazards of introducing complementary foods too soon. Third, quantitative data have been published recently on the adequate energy density of foods for young children. These provide useful guidelines on the proper formulation of complementary foods. Fourth, several studies have found that the content and bioavailability of specific nutrients in the diet, often referred to as "dietary quality", may be more limiting to growth than energy intake *per se* in many populations. Again, these results have implications for the design of dietary regimens and/or nutritional supplements for children in the critical age range. Each of these issues, and others, will be presented in greater detail in subsequent sections of this report, and their possible implications for child feeding and nutrition intervention programmes will be discussed.

1.3 Definitions of terms used in review

The words used to describe various aspects of child feeding are not always applied consistently by different authors. To avoid any misinterpretations of the current report, working definitions of key terms are provided in this section. Other definitions will be introduced, as needed, in specific sections of the text. The word *infants* refers to all children less than 12 months of age. *Young children*, or *preschool children*, is used for children less than five years of age, including those less than 12 months of age. *Infant* or *child feeding* refers to the whole complex of dietary, behavioural, and physiological processes involved in the child's ingestion of food. Definitions used herein to denote different breast-feeding practices conform to those of the Interagency Group for Action on Breastfeeding (Labbock & Krasovec, 1990). Specifically, the term *exclusive breast-feeding* is used when all fluid, energy, and nutrients are provided by breast milk, with the possible exception of small amounts of medicinal supplements. *Almost exclusive breast-feeding* refers to the use of only water or other non-nutritive liquids in addition to otherwise exclusive breast-feeding. *Partial breast-feeding* is used to indicate mixed feeding with breast milk and other sources of energy and nutrients.

The period during which other foods or liquids are provided along with breast milk is considered the period of *complementary feeding*. Any nutrient-containing foods or liquids

other than breast milk given to young children during the period of complementary feeding are defined as *complementary foods*. Because of the non-restrictive definition of complementary foods that is used in this document, it must be recognized that some complementary foods, such as sugar water or poorly prepared milk formulas, may be detrimental to young children's health. This definition differs from that implied by previous WHO documents, which describe complementary feeding to mean, "the child has received both breast milk and *solid (or semi-solid)* food" (WHO, 1991; emphasis added).

The words used to describe different aspects of complementary feeding are illustrated in Figure 1. Panel A of the Figure portrays the absolute contribution of breast milk and other foods to total energy intakes at different ages, and panel B presents the same information as percentage of total energy intake. As shown in the Figure, we have subdivided the complementary foods into two categories. When complementary foods are specifically designed to meet the particular nutritional or physiologic needs of the young child, these are described as *special transitional foods*, or simply *transitional foods*. When complementary foods given to the young child are the same as those consumed by the rest of the family members, they do not have a special designation, or may be considered *family foods*. Thus, in this document the term *special transitional foods* is used in the same way that many previous papers have used the term "weaning foods" which we do not use for the reason described below.

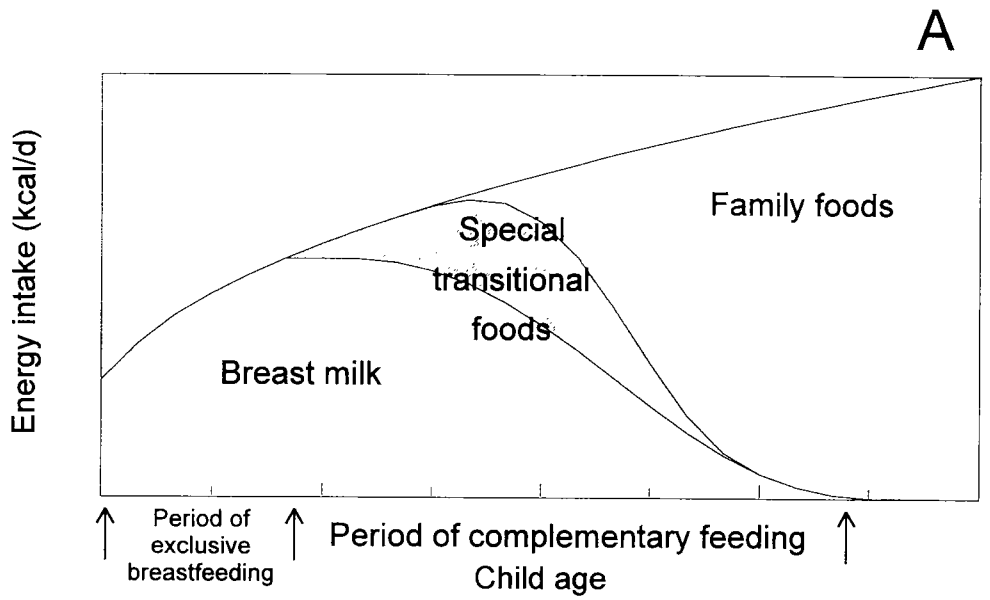
The term *weaning* is used in an intentionally limited sense to indicate complete cessation of any breast-feeding. We purposefully avoid using the term "weaning foods" so as not to imply that complementary foods are meant to displace breast milk or initiate the withdrawal of breast-feeding.

1.4 The socioeconomic context of child feeding and the UNICEF model of child care

Although this document will focus primarily on the food-related and nutrition-related aspects of complementary feeding programmes, it is important to emphasize the obvious fact that child feeding takes place in a broader context of multiple social, political, economic, and cultural forces. Many of these sociocultural factors that influence child feeding in particular settings have been discussed in more detail in the recent Colloquium on Care and Nutrition of the Young Child (Garza, 1995), so they will be reviewed only briefly herein. Chapter 5 provides additional information on caregiver feeding behaviours and the contextual issues that influence them.

Complementary feeding is an essential element in the care of young children. According to the conceptual framework on the causes of malnutrition adopted by UNICEF as a foundation for its country programming (UNICEF, 1990), nutrient intake and the presence or absence of disease are the direct determinants of child survival, growth, and development (Figure 2). Dietary intake and the incidence of illness are, in turn, influenced by the underlying factors of household food security, available health care services, and

Figure 1. Contribution of different food sources to young children's energy intake in relation to age



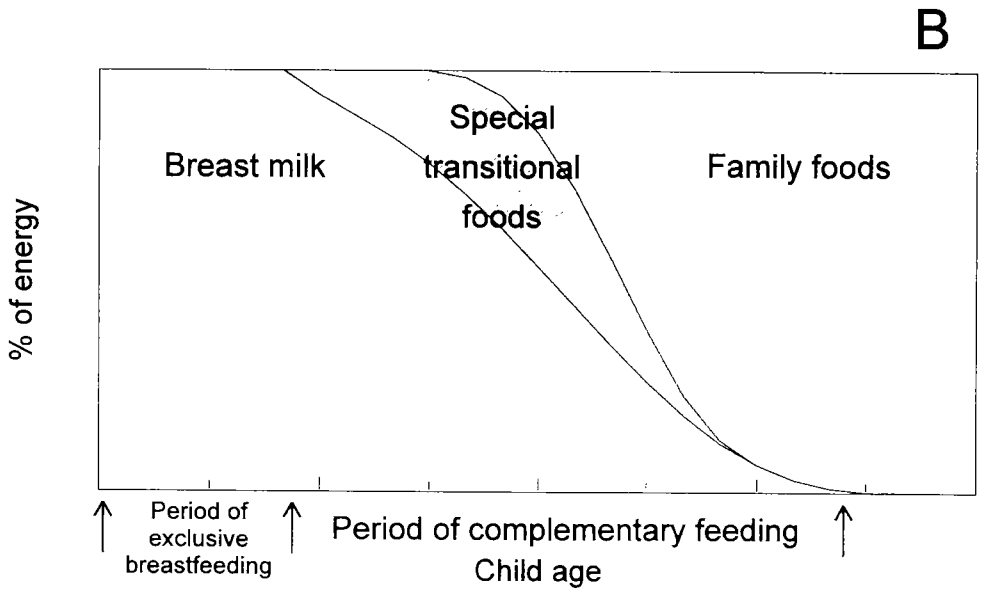
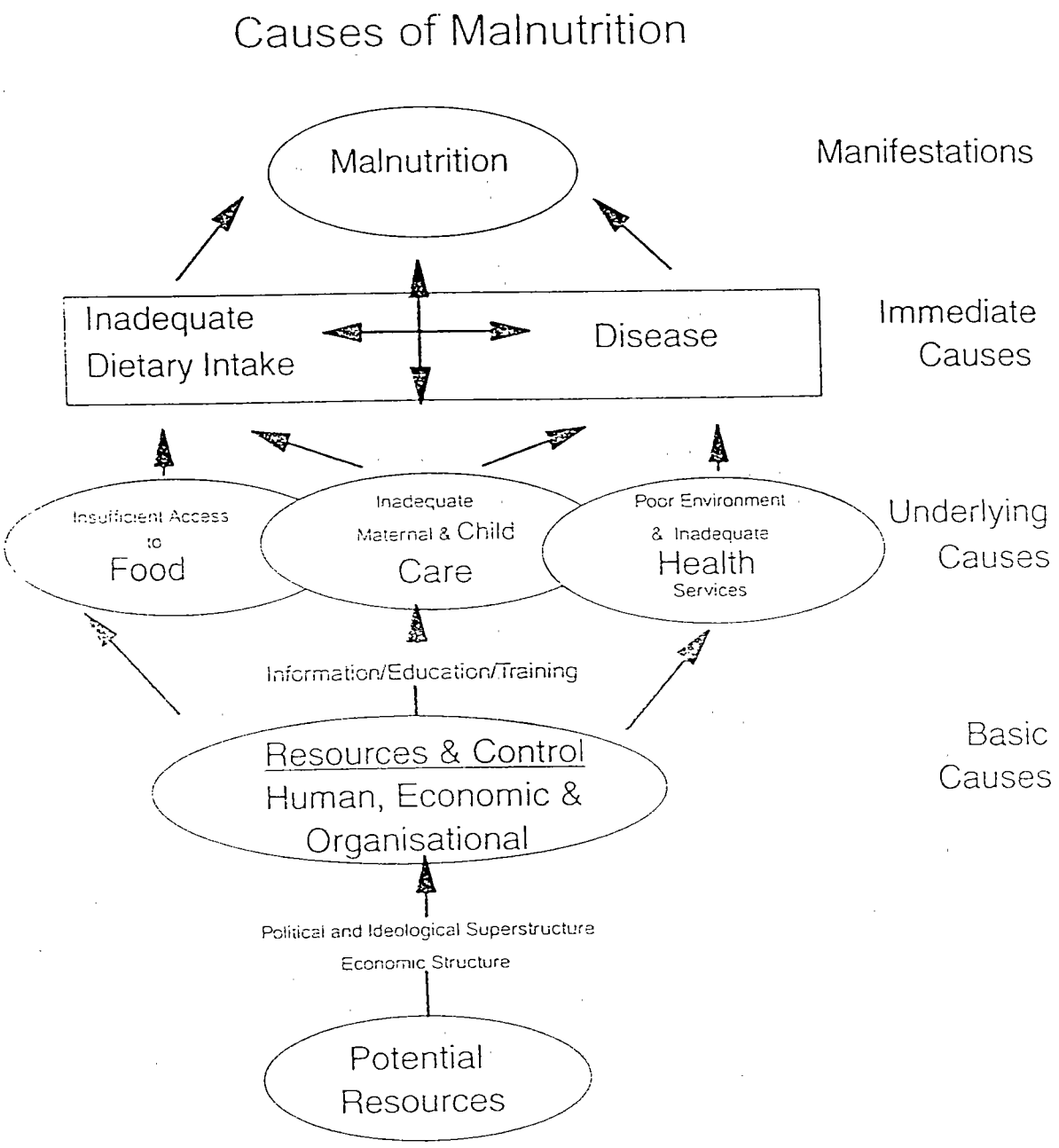


Figure 2. UNICEF conceptual framework for determinants of nutrition status



child-care practices. Child-care practices are themselves determined in part by the ability of caregivers (and others) to gain access to economic, human and organizational resources that are necessary to provide adequate complementary foods and care. The theoretical placement of child care as one of the three critical determinants of adequate nutrition, along with access to food and health services, represents an important breakthrough in the understanding of good nutrition as more than just a problem of food security and health.

Table 1 lists some of the potential social and economic factors that influence complementary-feeding practices by the level of society at which they operate. This list is useful for discussion purposes, but obviously does not take into account the overlap and interplay of these factors at different levels of society (e.g. legislation protecting women's rights will influence community-level institutions, which will influence household-level decision-making). Establishment of programmes to improve complementary feeding should be preceded by an assessment of these factors, both to explore the extent to which they may constrain successful programmatic implementation, and to identify any possible opportunities for modification when appropriate.

Table 1. Examples of socioeconomic determinants of complementary feeding practices

Macro level (regional, national, international)
Macroeconomic issues
Labour laws
Corporate business practices
Civil disturbances and natural disasters
Community level
Culture and religion
Urban vs. rural settings
Child care services
Workplace rights and benefits
Household level
Income, wealth, and resource control
Autonomy of the caregiver
Household composition and alternate caregivers
Caregiver level
Health and nutritional status
Labour force participation
Education
Psychosocial factors

1.5 Physiological development and young child feeding

Successful child-feeding practices are those that:

- Provide a sufficient amount of food of adequate quality to satisfy nutrient requirements
- Protect the airway against aspiration of foreign food substances

- Do not exceed the functional capacity of the gastrointestinal tract and the kidneys.

Maturational changes of the neurological, gastrointestinal, and renal systems may influence the possibilities for successful child feeding at different ages. These issues will be reviewed briefly in the following sections.

1.5.1 Neuromuscular system

Maturation of the neuromuscular system exerts a profound influence over possible approaches to infant feeding. A number of feeding reflexes that are present at various stages of development may facilitate or interfere with the introduction of different types of foods. For example, both the rooting reflex and the suck and swallow mechanisms, which are present at birth, facilitate nursing (Sheppard & Mysak, 1984; Stevenson & Allaire, 1991); but the gag reflex may interfere with early introduction of solids. The locus of sensitivity to stimulation of the gag reflex moves from the mid-portion to the posterior third of the tongue by seven months of age, so feeding solids becomes easier with increasing infant age. Some of these important reflexes and age-related oral skills are listed in Table 2 along with possible implications for the types of foods that can be safely consumed (Table adapted from Milla, 1991; Stevenson & Allaire, 1991). These observations do not necessarily mean that the individual types of foods described should be introduced into the diet at the ages when the relevant reflexes appear or disappear, but merely that the child is physically more capable of handling the particular type of food at those stages of development.

Table 2. Neurological development of infants and young children and implications for types of foods that can be consumed at different ages (Adapted from Milla, 1991; Stevenson & Allaire, 1991)

Age (months)	Reflexes/skills present	Types of food that can be consumed*
0-6	Suckle/suck and swallow	Liquids
4-7	Appearance of early "munching" Increased strength of suck Movement of gag reflex from mid to posterior 1/3 of tongue	Pureed foods; crackers
7-12	Clearing spoon with lips Biting, chewing Lateral movements of tongue and movement of food to teeth	Mashed chopped foods; finger foods
12-24	Rotary chewing movements Jaw stability	Family foods

* This indicates types of foods that can be consumed and swallowed successfully; it does not necessarily imply when these foods should be offered.

Four different types of age-related methods by which infants ingest and "process" food have been described: suckling, sucking, munching, and chewing (Stevenson & Allaire, 1991; Gisel, 1991). At birth, the confined space of the newborn's nasopharynx forces the tongue to move in an extension-retraction pattern (Stevenson & Allaire, 1991). When

extended, the tongue is cupped around the "teat" formed by the nipple, surrounding areola and underlying breast tissue. Milk is expressed from this "teat" by posteriorly directed peristaltic waves of the tongue followed by upward pressure from the lower gum, a sequence of events referred to as "suckling" or "stripping" (Woolridge, 1986). This process is facilitated by the maternal milk ejection reflex, or "letdown reflex", which causes active expulsion of milk. True "sucking" refers to the negative pressure that is generated when the border of the mouth (including the lips, gums, and tongue) forms a seal against the breast and the back of the tongue is lowered along with the mandible to create a vacuum in the pharyngeal space.

When semi-solid or pureed foods are first introduced, infants usually suck or suckle these foods from the spoon or hand of the feeder. By about five months of age, up and down mandibular movements referred to as "munching" first become apparent. These movements permit consumption of some solid foods, such as crackers or toasted cereal products, regardless of whether teeth have appeared (Stevenson & Allaire, 1991). Lateral movements of the tongue, which push food to the molars, do not emerge until 8-12 months; and full rotary chewing movements allowing disposal of fibrous foods, such as meats and some fruits and vegetables, are not present until 12-18 months of age.

Although these oropharyngeal maturational events indicate the minimum ages when the infant can physically manage food, the efficiency of consumption of different types of foods varies considerably with age. Thus, even though a young child may be physically capable of consuming a particular food, the time required to complete a feeding episode may be excessive unless the consistency of the food is appropriate for the child's stage of development. In a fascinating set of studies of healthy infants from 6 to 24 months of age, Gisel (1991) found that most children were able to consume a broad spectrum of textures, including solids (toasted cereal: "Cheerios"), viscous gelatins, and purees (apple-sauce). However, the younger children required three to four times as long to consume the solid foods as the viscous ones and twice as long to consume the viscous gelatins as the less viscous purees. During half of the observations the six-month-old children did not consume any of the solid foods, although all of the older children were able to consume some of the solids on at least some of the occasions when they were offered. The duration of feeding decreased with age for the solid and viscous foods, but not for the purees, and the improvement in efficiency was much greater for the solid foods than for the viscous ones. In general, the children's sex, current breast-feeding status, or presence of teeth did not affect these differences.

Gisel concluded that full maturity of consumption (defined as the age at which feeding duration became constant) was achieved for purees by 10 months, but the efficiency of consumption of solids continued to improve through 24 months of age. Interestingly, the investigator noted that children up to 10 months sucked in response to apple-sauce, but munched and/or sucked on the cereal. Often the children would first let the cereal soften in their saliva before swallowing it. They intermittently suckled or munched on the gelatins until 10 months, but tended to munch thereafter. True chewing was not observed

in this study, although the author speculated that the food textures offered may not have been tough enough to elicit rotary chewing.

It has been hypothesized that there are "sensitive" or "critical" periods in children's development when complementary foods must be introduced (Illingworth & Lister, 1964). The "sensitive" period is defined as the optimal time for new behaviours to be learned most efficiently, and the "critical" period is the time after which it is no longer possible for that behaviour to be mastered. Although this theory is intriguing with regard to timing of child-feeding practices, there is no empirical evidence from human infants that introduction of food during sensitive early periods governs children's later acceptance of food (Walter, 1994).

It has also been claimed that breast-feeding contributes positively to the development of clear speech. However, early research on this topic yielded conflicting results and was often beset by serious methodological problems, both with regard to objective assessments of phonological development and careful classification of infant-feeding practices. More recent studies have failed to demonstrate associations between feeding practices and development of speech (Smith & Gerber, 1993), but none has specifically examined the relationship between speech and the age of introduction of complementary foods.

1.5.2 Digestion and absorption

The process of maturation of gastrointestinal function has been reviewed elsewhere (Lebenthal & Leung, 1989), so this topic will be discussed only briefly herein. Normal digestive function changes considerably during the first year of life. For example, intra-intestinal concentrations of the pancreatic enzymes, amylase, lipase, and trypsin, are considerably less during the first few months of life than during later childhood and adulthood (Zoppi et al., 1972; Lebenthal & Lee, 1980). Similarly, the secretion of bile salts is only marginally adequate to permit micelle formation during early infancy, resulting in reduced efficiency of fat absorption (Watkins, 1974) although bile production increases throughout infancy. As explained below, these age-related changes probably have limited importance with regard to complementary feeding of normal infants.

Although pancreatic amylase secretion is less during early infancy than during later childhood, most cooked starches are absorbed almost completely (de Vizia et al., 1975). Even during the initial months of life, intra-colonic bacteria are capable of converting energy from any carbohydrates that are unabsorbed in the small intestine into short-chain fatty acids, which can be absorbed from the colon (Shulman et al., 1983; Guandalini, 1991). This so-called "colonic salvage" of incompletely absorbed carbohydrate prevents loss of most of the carbohydrate energy. Other alternate pathways for the assimilation of carbohydrates during infancy have also been described (Heitlinger et al., 1983; Lebenthal & Leung, 1989).

Although inefficient digestion and absorption of fat during early infancy may be

accompanied by some excess loss of energy in the faeces, this is not generally associated with other adverse consequences. Thus, there are no particular implications with regard to the design of the infant's usual diet except to assure access to adequate energy intake to compensate for any excess faecal losses. Moreover, by the time non-breast-milk foods are appropriately introduced into the diet later in infancy, there is little evidence that the level of gastrointestinal maturation adversely influences the efficiency of intestinal fat absorption to an extent that is nutritionally important (Watkins, 1974).

There is very little information on the efficiency of assimilation of micronutrients by young children of different ages. Nevertheless, experience suggests that healthy young children can absorb adequate amounts of micronutrients at the age when complementary foods should ordinarily be introduced if these foods have adequate nutrient density and do not contain factors that interfere with absorption. On the other hand, alterations in intestinal permeability have been encountered frequently among children in unhygienic environments in low-income settings (Lunn et al., 1991; Goto et al., 1994), and the nutritional implications of these intestinal changes are not well understood. One study in the Gambia found that children's growth velocity was negatively associated with the degree of abnormal intestinal permeability (Lunn et al., 1991). Thus, altered intestinal function due to infection or other causes may interfere with utilization of nutrients provided by the diet. Research is needed on the assimilation of micronutrients from mixed diets by infants of different ages and health status.

1.5.3 Renal function

Most aspects of renal function of normal, full-term neonates are either nearly fully developed at birth or mature rapidly within a short period of time thereafter (Guignard, 1982). Thus, recommendations on complementary feeding do not ordinarily need to be modified to account for the level of renal development. Nevertheless, because the maximal urinary concentrating capacity of the newborn kidney is somewhat less than in older children (Edelman, 1960), there has been some discussion in the clinical literature about the safe maximal level of solute consumption, especially under conditions of low fluid intake or excessive fluid losses (Ziegler & Fomon, 1971). By the time children reach the recommended age of introduction of complementary feeding, this issue is of less concern. Moreover, because the protein and electrolyte contents of breast milk are quite low compared with non-human milks, the issue of renal solute load is of concern primarily for non-breast-fed infants. A simple method for estimating the renal solute load, based on total fluid intake and level of consumption of protein and electrolytes, has been described (Ziegler & Fomon, 1971). These estimates can be applied when extra-renal fluid losses are elevated, as occurs, for example, in hot, humid environments or when diarrhoea is present, to assure that the solute load of the mixed diet does not exceed renal excretory capacity.

1.6 Functional outcomes of child-feeding practices

Different approaches to child feeding can influence a broad range of outcomes with regard

to the well-being of both the child and the caregiver. Each of these outcomes must be borne in mind when assessing the potential impact of child-feeding decisions. Because a particular child-feeding intervention may have different impacts on each of these disparate outcomes, the results must be considered simultaneously when establishing child-feeding recommendations. For example, earlier introduction of non-breast-milk foods may result in increased total intake and greater reserves of some nutrients, but may also increase the risk of infections and have detrimental effects on nutrient bioavailability and children's physical growth. Inevitably, controversy arises regarding the relative benefit of specific feeding practices when only one or another of these outcomes is considered. The range of concerns that must be borne in mind will be noted briefly in the following sections.

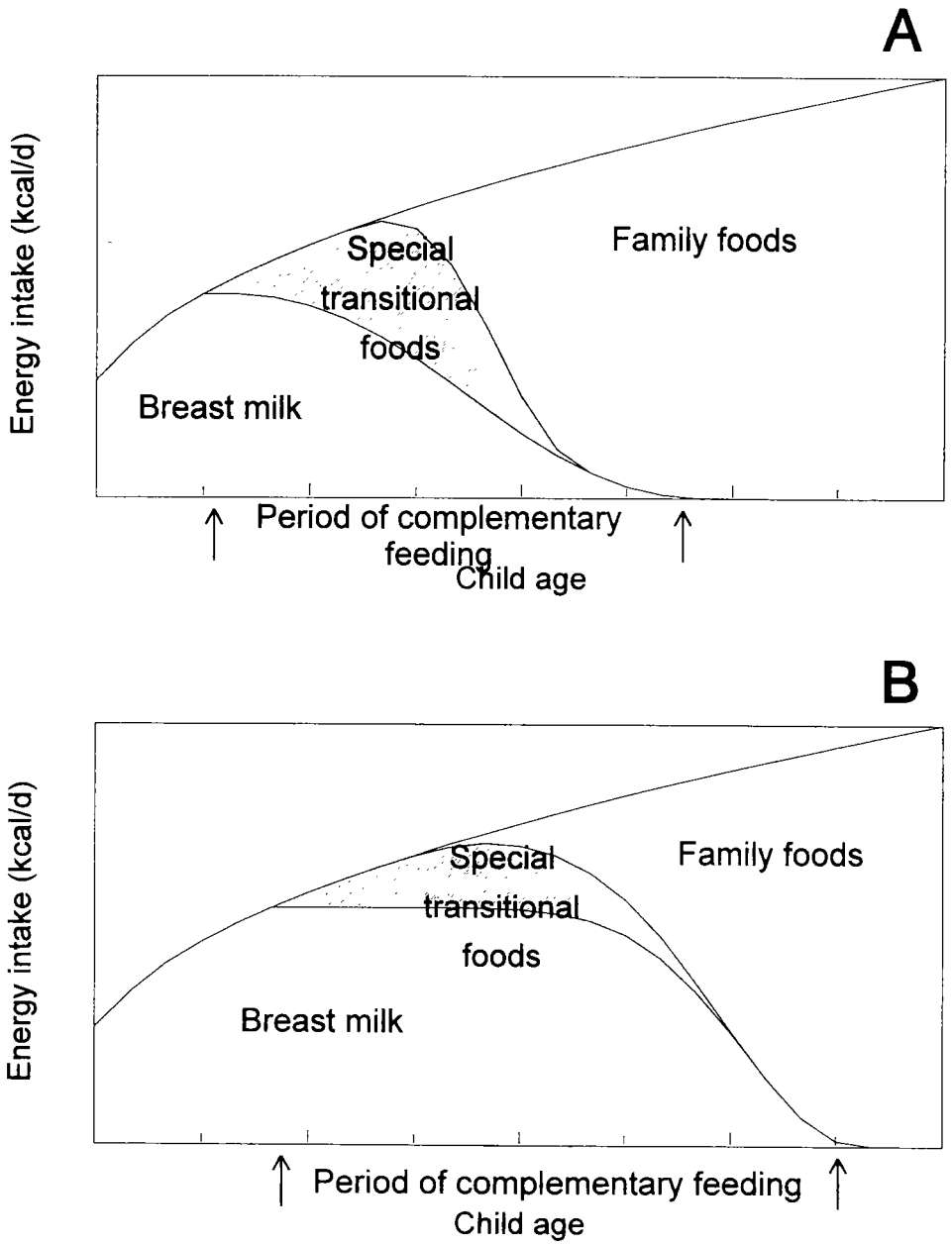
1.6.1 Child-related outcomes

The impact of different feeding practices on children's well-being can be judged in terms of their effects on children's energy and nutrient intakes, physical growth, micronutrient status and reserves, susceptibility to infections, physical activity, and behavioural development. Because available information is limited for many of these outcomes, this document focuses primarily on energy and nutrient intakes. As indicated above, particular feeding practices may have a positive impact on some of these outcomes while having a negative effect on others. Thus, child-feeding programmes must ultimately promote those practices that are likely to have the greatest net benefit for children's nutritional status, overall health and development, and that are feasible for caregivers to implement.

Of particular interest is the possible negative impact of complementary-feeding practices on children's breast-milk consumption. Figure 3 demonstrates two possible relationships between the introduction of complementary foods and the consumption of energy from breast milk. Panel A illustrates the common pattern in which complementary foods are introduced earlier than desirable and there is a simultaneous decline in breast-milk energy intake as complementary foods are introduced. Panel B depicts the theoretical situation in which complementary foods are introduced later and breast-milk energy intake is maintained at a constant level while intake of complementary foods is increasing. It is currently unknown whether specific complementary-feeding practices or types of complementary foods may be more likely to sustain maximal breast-milk energy consumption for longer periods of time.

Several reports have provided descriptive information on the relationships between energy intake from complementary foods at different ages and energy intake from breast milk. Although these analyses do not permit definitive conclusions regarding the causal direction of any associations identified, they are nevertheless useful indications of the likely direction and magnitude of the observed associations between these two sources of energy intake. Table 3 summarizes data from Thailand, Peru, Honduras and the United States of

Figure 3. Possible relationships between intake of energy from complementary foods and breast milk



America of the changes in energy intake from breast milk as energy intake from complementary food increases for children of different ages. As indicated in the Table, each unit of energy intake of complementary foods by Thai infants less than 1 month of age was accompanied by a decreased intake of energy from breast milk of 1.7 units. This implies that Thai children who received complementary foods very early in life had a lower total energy intake than those who did not receive complementary foods. With increasing age, the magnitude of the negative association between energy intake from complementary foods and energy intake from breast milk appears to diminish. Thus, older infants who received complementary foods had greater total energy intakes despite the reduction in energy intake from breast milk (see also discussion in sections 2.1 and 2.2). Additional research will be needed to determine whether the apparent negative impact of complementary foods on breast-milk consumption by young children can be mitigated by specific feeding techniques or types of foods.

Table 3. Differences in energy intake from breast milk ($kcal_{th}$) for each $kcal_{th}$ of energy consumed from complementary foods, by age group

Age group (months)	Thailand (Drewett et al., 1993)	Peru (un-published)	Honduras (Cohen et al.,1994)	USA (Stuff & Nichols, 1989)
<1	-1.7			
1-2	-0.6	-0.8		
3-5	-0.7	-0.5		
6-8	-0.6	-0.4	-0.6	-0.8
9-11	-0.3			
12	-0.3			

1.6.2 Caregiver-related outcomes

Not only do child-feeding practices have diverse impacts on child-related outcomes, but they may also have different implications for the caregiver. Whereas continued breast-feeding may have positive effects on children's nutritional status, it may have detrimental effects on maternal nutrient reserves (Adair & Popkin, 1992). Likewise, feeding recommendations that promote more frequent meals may be achieved only at the cost of additional time and other resource commitments by the caregiver (Cohen et al., 1995a). On the other hand, frequent breast-feeding prolongs the duration of lactational infertility (McNeilly, Glasier & Howie, 1985) which may have beneficial implications for maternal nutrition and health. Thus, all of these factors must be balanced when developing optimal feeding guidelines, and recommendations must be specific to the children's and caregivers' particular needs in individual settings.