Reviews/Analyses

Contaminated weaning food: a major risk factor for diarrhoea and associated malnutrition*

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Infections and the malnutrition associated with them are responsible for a significant proportion of the 13 million deaths among infants and children under 5 years of age worldwide each year. After respiratory infections, diarrhoeal diseases are the commonest illnesses and have the greatest negative impact upon the growth of infants and young children. The causes of diarrhoeal diseases have traditionally been ascribed to water supply and sanitation. In attempts to prevent such diseases, efforts by governments and nongovernmental organizations have been focused on and sometimes limited to improving water supply and sanitation as well as promoting and protecting breast-feeding.

Based on studies reported in the literature, this review article demonstrates that weaning foods prepared under unhygienic conditions are frequently heavily contaminated with pathogens and thus are a major factor in the cause of diarrhoeal diseases and associated malnutrition. In the light of the evidence presented, it appears that current efforts are not sufficient to prevent diarrhoeal diseases: education of mothers in food safety principles, particularly weaning food, must also receive high priority. Educational programmes based on the hazard-analysis-critical-control-point approach, taking into consideration also sociocultural factors, should be integrated into all national infant feeding or food and nutrition programmes.

Introduction

Contaminated weaning foods account for a substantial proportion of diarrhoeal diseases among infants and young children, especially in developing countries. Worldwide (excluding China) it is estimated that 1400 million episodes of diarrhoea occur annually in children under the age of 5 years. In 1990, over 3 million of such children died as a result.[a] Up to 70% of diarrhoeal episodes could be due to pathogens transmitted through food (*1*).[b] Nevertheless, the importance of food safety[c] in the prevention of diarrhoeal diseases is often overlooked or neglected. It is often observed that the strategies for prevention of diarrhoeal diseases and associated malnutrition are limited to promotion of breast-feeding or improving water supply and sanitation, neglecting the need to educate foodhandlers, particularly mothers, in food safety (*2*). Not infrequently, studies of why children suffer from diarrhoea overlook the *relevant* factors related to food safety.

The present review provides evidence that food contamination is one of the major contributors to diarrhoeal diseases and the malnutrition associated with them and that in the prevention of diarrhoeal diseases in infants and children food safety is as important as breast-feeding or provision of safe water supplies and sanitation. Every effort should be made to improve the hygiene quality of foods. Edu-

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[a] *Global health situation and projections—estimates.* Unpublished document WHO/HST/92.1.

[b] **Esrey, S.A. & Feachem, R.G.** *Interventions for the control of diarrhoeal diseases among young children: promotion of food hygiene.* Unpublished document WHO/CDD/89.30.

[c] This term is taken here to be all conditions and measures that are necessary during the production, processing, storage, distribution, and preparation of food to ensure that it is safe, sound, wholesome, and fit for human consumption. See ref. *59.*

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cation of foodhandlers, particularly mothers, in food safety principles, through primary health care and infant feeding programmes, should be regarded as an important strategy for the prevention of diarrhoeal diseases (*3*).

Weaning age: a critical period

Breast milk is a nutritious and generally safe food for newborn infants, and exclusive breast-feeding, i.e., giving the infant no fluid or food other than breast milk, protects against diarrhoea by minimizing the infant's exposure to foodborne and waterborne pathogens. Breast-feeding may also reduce the severity of diarrhoeal illnesses and has an influential effect on preventing diarrhoea-associated deaths (*4–6*). However, when the infant reaches 4–6 months of age, breast milk needs to be supplemented, and later on (>2 years of age) substituted by appropriate foods until the child is gradually introduced to family food. With the introduction of weaning foods, which in many countries are prepared under unhygienic conditions, infants who until then have only consumed breast milk may be exposed to infective doses of foodborne pathogens. Many studies report that the incidence of diarrhoeal diseases is especially high after weaning is initiated (*7*). In a study of infants and children in a Guatemalan Mayan village, Mata noted that the prevalence of many infections increased during the weaning period (*8*). Rowland & McCollum reported that there is particularly high incidence of diarrhoeal diseases between 7 and 18 months with a peak at 9 months of age (*9*). Similarly, Black et al. found that the prevalence of diarrhoea was highest during the second 6 months of life (*10, 11*) and declined with increasing age thereafter. The declining incidence of foodborne illnesses with increasing age is explained by the probable acquisition of immunity from repeated exposure to the pathogens. A review by Snyder & Merson indicated that the median incidence of diarrhoeal diseases was three-to-six episodes per year, the highest incidence being during the second half of infancy (*12*).

For various reasons, weaning is initiated in many cultures at an even earlier age than is nutritionally necessary, i.e., 4–6 months of age. Recent surveys indicate that exclusive breast-feeding is a very infrequent practice, and water, various infusions, rice water, and similar foods are often introduced to young infants at a very early age.[d] Consequently, contaminated weaning food may increase the risk of diarrhoeal diseases even during the very early months of life.

Foodborne pathogens

Infants and young children are very susceptible to foodborne diseases and, if they consume contaminated foods, are likely to contract infections or intoxications leading to illness and often death. While foodborne diseases may be caused by either chemical or biological agents, those of biological origin are of specific interest in this article, since they are responsible for a considerable proportion of diarrhoeal diseases. However, it should be noted that infants and children also are sensitive to various chemical contaminants of foodstuffs, e.g., lead, and such contamination is a major public health concern in several countries.[e]

Various pathogens have been identified as causing diarrhoeal diseases. Some of these include bacteria such as *Escherichia coli*, *Shigella* spp., *Salmonella* spp., *Vibrio cholerae* O1 and *Campylobacter jejuni*; protozoa such as *Giardia lamblia, Entamoeba histolytica, Cryptosporidium* spp.; and also enteric viruses such as rotavirus (*13–16*).[f] In addition, *Bacillus cereus, Staphylococcus aureus, Clostridium perfringens*, and helminths are common foodborne pathogens that cause diseases frequently accompanied by diarrhoea.

Infections due to pathogenic *E. coli* are probably the commonest illnesses in developing countries and produce up to 25% of all diarrhoeal episodes. Transmission of *E. coli* has been specifically associated with weaning foods.[f] *C. jejuni* causes 5–15% of diarrhoeas in infants wordwide. Shigellosis is a major health problem in developing countries and causes 10–15% of acute diarrhoeas in children under 5 years of age.[f] Cholera remains an important cause of morbidity and mortality in many developing countries, mainly in Asia, Africa and, recently, South America. Between the start of the epidemic in Peru in January 1991 and the end of May 1992, cholera has, worldwide, affected 800 000 people and killed 20 000 (WHO unpublished data, 1992). Rotavirus is commoner in children aged 6–24 months and is responsible for 20% of all diarrhoeal deaths among under-5-year-olds (*17*); the virus is of concern in both developing and industrialized countries. In addition, intestinal parasitic infections are prevalent

[d] *Breast-feeding and the use of water and teas. CDD Update*, No. 9, 1991 (unpublished WHO document).

[e] **UNEP/FAO/WHO**. *Assessment of chemical contaminants in food*. Unpublished UNEP/FAO/WHO document, 1988.

[f] *A manual for the treatment of diarrhoea for use by physicians and other senior health workers*. Unpublished document WHO/CDD/SER/80.2, Rev. 2.

worldwide and in some countries may even be more important than bacterial infections. Amoebiasis, giardiasis, cryptosporidiasis, and ascariasis are among the commonly occurring foodborne parasitic infections (*18*). Amoebiasis is one of the commonest parasitic intestinal diseases that can be fatal (*18*), and a high prevalence of amoebiasis has been reported among children of weaning age (*19, 20*).

Implications of foodborne diseases

Foodborne diseases can cause severe and/or long-lasting damage to health, including acute, watery and bloody diarrhoeas (leading to severe dehydration or ulceration), meningitis, as well as chronic diseases affecting the renal, articular, cardiovascular, respiratory, and immune systems (*21–23*). One study has reported that about 2% of adults infected with an arthritogenic strain of salmonella may consequently suffer from reactive arthritis (*22*). A proportion of patients, especially children, who are affected by enterohaemorrhagic *E. coli* can develop haemolytic uraemic syndrome (HUS), which is characterized by acute renal failure (*24, 25*). However, the most serious implications of foodborne infections are their effects on nutritional status.

The association between diarrhoeal diseases and malnutrition has been the subject of extensive studies, and these have been reviewed by Tomkins & Watson (*26*). Despite the complex nature of the interaction between infectious diseases and malnutrition, it is generally accepted that infectious diseases can affect children's growth once weaning is initiated (Fig. 1) (*8, 27, 28*). An infectious disease can lead to a reduction in food intake owing to anorexia. In addition, in certain cultures parents may also contribute to a reduction in their child's food intake by withholding or substituting certain foods during illness (*29*). A poor food intake, aggravated by loss of nutrients from vomiting, diarrhoea, malabsorption, and fever over an extended period (persistent diarrhoea), leads to nutritional deficiencies with serious consequences for the growth and immune system of the infants and children. Thus, an infant whose resistance is suppressed becomes vulnerable to other diseases (including respiratory infections) and is subsequently caught in a vicious cycle of malnutrition and infection (Fig. 2 and 3). Many infants and children do not survive under the circumstances. Annually, about 13 million children under 5 years of age die in developing countries; in the majority of cases, these deaths are due to infections and associated malnutrition (*26*).

Fig. 1. **Growth pattern of a child with frequent episodes of diarrhoea and other infections.** The horizontal bars indicate the duration of the infectious disease. Source: **Mata, L.J.** Nutrition and infection. *Protein Advisory Group bulletin*, **11**: 18–21 (1971).

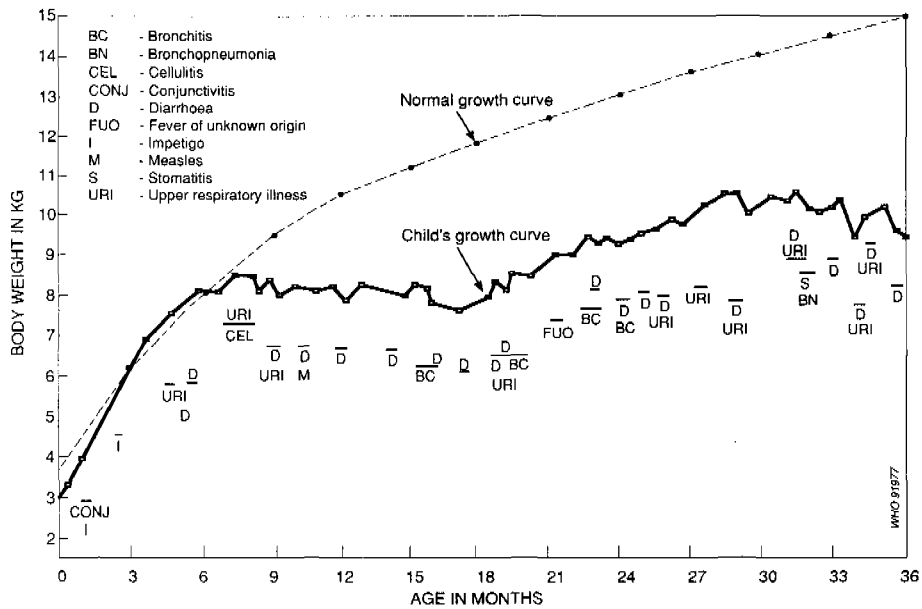


Fig. 2. **Diarrhoea and malnutrition combine to form a vicious cycle leading to declining health status, and too often death.** Source: *Readings on diarrhoea—student manual.* Unpublished document WHO/CDD/SER/90.13.

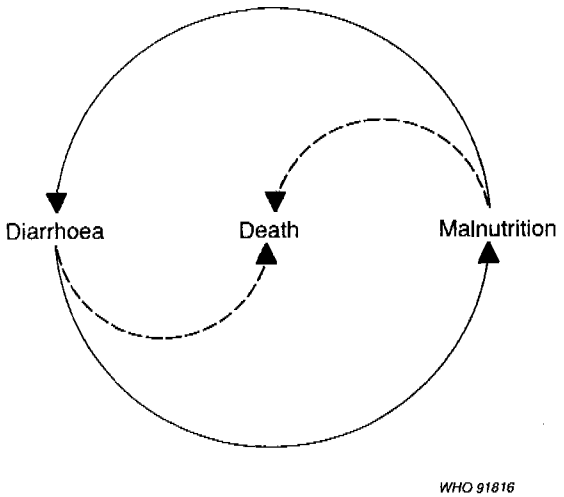
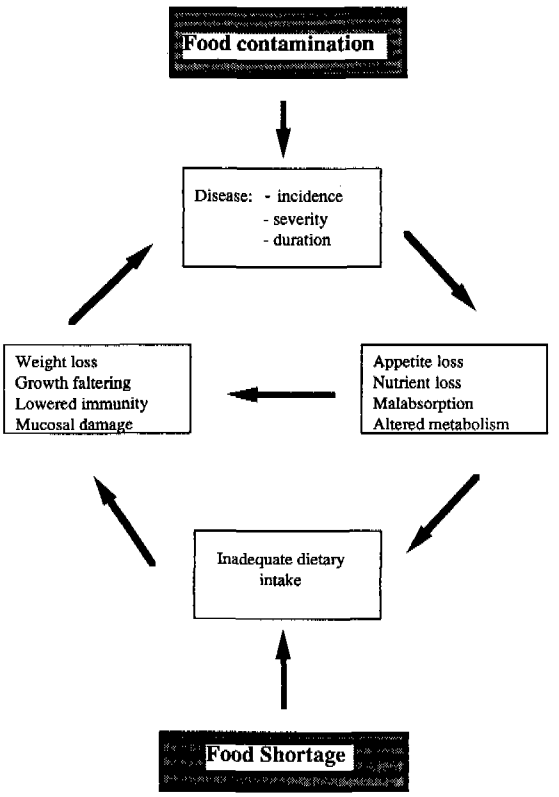


Fig. 3. **Malnutrition and infection cycle.** Adapted from **Tomkins, A. & Watson, F.** *Malnutrition and infection: a review.* (ACC/SCN State of the Art Series, Nutrition Policy Discussion Paper No. 5). United Nations, 1989.



There is very little evidence that any nutritional impact is caused by infections among exclusively breast-fed infants (*26, 27, 30*). This underlines again the importance of exclusive breast-feeding for the prevention of malnutrition, particularly during the first 4–6 months of life. Breast milk compensates for the loss of water and nutrients that occurs during diarrhoea. In view of the protective effects of breast milk against diarrhoea and malnutrition, continued breast-feeding for at least 2 years is recommended (*5, 6*).

Many studies have demonstrated that infections may induce growth faltering during the weaning period. In one study, for example, the relationship between morbidity and growth in the first 2 years of life among a cohort of 126 neonates was studied in a Gambian township (*27*); the mean weight-for-age exceeded the National Center for Health Statistics (NCHS) standards in the first half of infancy, but there was a mean deficit of 1.2 kg by 1 year of age. It was estimated that diarrhoeal diseases were responsible for half this deficit—and respiratory illnesses for a quarter—and the effect of diarrhoeal diseases on growth after the onset of weaning was four times that in exclusively breast-fed infants. Enterotoxigenic *E. coli* was the commonest organism isolated in infants aged 6–12 months who had diarrhoea. *E. coli* from contaminated weaning foods was considered to be responsible, in part, for the diarrhoea-induced weight faltering. In Keneba, Gambia, it was also demonstrated that diarrhoea was the main cause of weight faltering in children aged 6 months to 3 years (*27*). Similar results have been obtained in other studies. In longitudinal studies of the effects of infectious diseases on physical growth of infants in Huascar, an underprivileged peri-urban community in Lima, the average weights during the first five-to-six months of life approximated those of the NCHS reference population; thereafter, the average weight declined relative to the reference data, and the rates of stunting and wasting increased progressively during the first year of life (*31*). A study of the population of a Guatemalan village also revealed that the incidences of infectious diseases, particularly diarrhoeal diseases, were extremely high during the weaning period (6–24 months) and that infectious diseases

were an important cause of weight loss, arrested height, and impaired physical growth (*20*).

Studies have also been carried out on the effect of infections and dietary intakes on children; for example, Martorell et al. report a greater reduction in dietary intake during diarrhoeal illnesses than during respiratory illnesses (*32*).

Many investigations indicate that of all the common childhood illnesses, only diarrhoeal diseases have a significant negative effect on growth. Studies by Martorell et al. in Guatemala suggest that children who suffered from diarrhoea for a short period exhibited a substantially greater increase in length and weight than children who were ill with diarrhoea for a longer period (*33*). In addition, children had a lower weight gain during periods of enterotoxigenic *E. coli* diarrhoea (*34*). Among rural Mexican children, an investigation of the relationship between childhood illnesses and growth increments in length and weight reported that, while upper and lower respiratory infections did not affect incremental gains in weight, a high frequency of diarrhoeal infections reduced weight gain (*35*). Village-based surveillance data from longitudinal studies in rural Bangladesh have demonstrated that, of the common illnesses, only diarrhoeal diseases had a significant inverse relationship on increase in weight (over a 2-month period) and on length (over 1 year); diarrhoeal diseases accounted for 20% of the difference in linear growth between the study children and the international reference population during the first 5 years of life (*36*). The greatest impact on nutritional status was observed for infections caused by enterotoxigenic *E. coli* and *Shigella* spp. Diarrhoea associated with *E. coli* constituted 30% of diarrhoeal disease episodes and affected the bimonthly weight gain. Shigellosis (prevalence, 15%) had a negative effect both on bimonthly and annual linear growth (*36*).

Nutritional deficiency diseases, such as protein–energy malnutrition, iron-deficiency anaemia, and vitamin A deficiency, have been reported in connection with foodborne parasitic infections such as giardiasis and ascariasis. For example, in one study of a 14-month-old boy in Guatemala it was noted that the child exhibited normal growth until weaning (which started at 6 months of age); introduction of semi-solid foods at that time was accompanied by bouts of diarrhoea and reduced growth rate. When he received treatment, the child was found to have oedematous protein–energy malnutrition (kwashiorkor) and to be infected with *G. lamblia* (*37*).

Contaminated weaning food

Numerous studies have shown that weaning foods prepared under unhygienic conditions are frequently heavily contaminated with pathogenic agents and are a major risk factor in the transmission of diseases, especially diarrhoeal diseases. For example, Black et al. in Bangladesh showed that 41% of samples of food items fed to children of weaning age contained *E. coli* (*38, 39*). Milk and foods prepared separately for infants were more frequently and heavily contaminated with *E. coli* than foods prepared for adults, such as boiled rice. The level of contamination was related to the storage of weaning foods at high ambient temperatures. About half of drinking-water samples also contained *E. coli*, but colony counts were approximately 10 times lower than those in food samples. A major important finding was the correlation between the proportion of a child's food samples contaminated with *E. coli* and the number of annual episodes of diarrhoea associated with enterotoxigenic *E. coli*. Bacterial contamination of weaning foods and drinking-water has also been studied in rural Bangladesh by Henry et al. (*40*). Of about 900 samples of food and drinking-water that were analysed for faecal coliforms, "wet" foods, such as milk and rice (particularly "*panta bhat*"), which made up a large proportion of a child's weaning diet in the 6–23-month age range, contained the highest levels of faecal coliforms, while during the rainy season, when ambient temperatures increased, so also did the level of contamination. These results indicate that the food was contaminated with faecal matter and thus may be a vehicle for pathogens usually transmitted via the faecal/oral route, including *Shigella* spp. and *V. cholerae*.

Also, studies conducted elsewhere provide evidence for the significant contamination of weaning foods. Barrel & Rowland found that a very high proportion of the food consumed by infants and young children in a rural area of Gambia contained pathogens. In the rainy and hot season, when diarrhoeal illness is at its height, a third of the foods were contaminated immediately after their preparation with unacceptable levels of one or more pathogens, and this increased to 96% of foods after 8 hours' storage (*41*). In Myanmar, food consumed by children aged 6–29 months was examined for four enteric bacterial pathogens. Of 775 samples of food tested, 505 were positive for *E. coli*, 28 for *V. cholerae* non-O1, and 6 for *Salmonella* spp. *E. coli* and *V. cholerae* non-O1 were isolated from 29 and 5 drinking-water samples, respectively, from a total of 113 such samples (*42*). In Peru, menu items given to infants were analysed at the time of consumption; milk and food specially prepared for infants (cereals or purées) were most frequently contaminated, whereas foods eaten by an entire family, e.g., soups, stews, and fried foods, were less often contaminated. For most food items, the frequency of

contamination was related to the time elapsed from initial preparation. Specific pathogens found in food included *Salmonella* spp., *Aeromonas hydrophila*, *V. cholerae* non-O1 and enterotoxigenic *E. coli* (*14*).

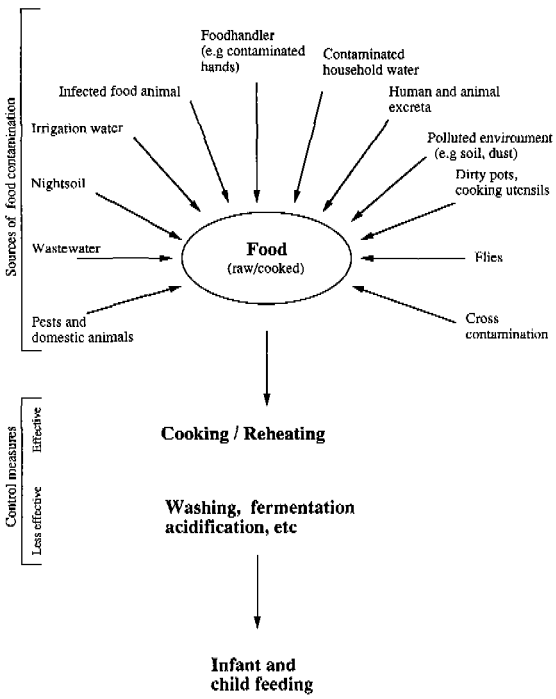
Since weaning foods are frequently selected from items in adults' diets, the hygienic quality of adults' food is also of relevance. Hazard-analysis-critical-control-point (HACCP) studies[g] conducted in households in the Dominican Republic showed that cooked food products (particularly beans, rice, dried milk) if subjected to time/temperature abuse[h] contained high amounts of *B. cereus*, *S. aureus* and also faecal coliforms (*44*, *45*). In Guatemala, heavy contamination with coliforms, *B. cereus* and staphylococci was found in tortillas before and after cooking (*46*). A total of 18% of foods in El Salvador were contaminated with *E. coli* (*47*). Finally, in an investigation of a large urban epidemic of cholera in Guinea, it was determined that peanut sauce supported the growth of *V. cholerae* and was the probable vehicle for transmission of the disease (*48*).

Improper food handling

The sources of food contamination are numerous: nightsoil, polluted water, flies, pests, domestic animals, unclean utensils and pots, dirty hands, and a polluted environment caused by lack of sanitation, domestic animals' droppings, dust and dirt, etc. Raw foods themselves are frequently the source of contaminants, since some foodstuffs may naturally harbour pathogenic agents or have been obtained from infected animals (Fig. 4).

Unclean pots, cooking utensils, baby bottles, teats, etc. are a potential source of contamination. A study in rural Kenya showed that 44% of dishes were unsafe from a hygienic point of view (*49*). Hazard analyses carried out in households in the Dominican Republic reported that kitchen knives and blenders were contaminated with *Salmonella* spp. (*44*), and several studies have indicated that babies bottles are not always effectively washed or boiled (*44*, *50*).

Fig. 4. **The sources of food contamination are numerous; however, with appropriate food safety measures the hygienic quality of infant food (including drinking-water) can be controlled.**



Evidence that flies contribute to the transmission of the diarrhoeal disease agents has been reviewed by Esrey.[i] Many pathogens that cause diarrhoea in humans, including *V. cholerae*, *Shigella* spp., campylobacter, *E. coli*, poliovirus, and *Entamoeba histolytica*, can be recovered from flies, and many pathogens can survive on the integument of flies for up to 10 days. Pathogens can also be carried in the gut of flies and deposited on food when they regurgitate or deposit excreta. Although, Esrey was unable to conclude that they play a role in the transmission of diarrhoeal diseases, flies are a potential source of contamination of food and water. Several studies have also reported the presence of infected domestic animals in household premises (*44*), presenting an additional risk factor for the contamination of food.

[g] This is a novel approach in the prevention and control of foodborne diseases; it consists of identifying the hazards associated with the different stages of food processing/handling, assessing the related risks, and determining the operations where control procedures will be effective. See ref. *43*.

[h] Time/temperature abuse refers to situations where the minimum time/temperature requirement to reduce the contaminant(s) to safe levels has not been respected and/or the food is stored under time/temperature conditions that permit bacterial proliferation.

[i] **Esrey, S.** *Interventions for the control of diarrhoeal diseases among young children: fly control.* Unpublished document WHO/CDD/91.37.

Touching food with contaminated hands has been the cause of many outbreaks of foodborne diseases. For those pathogens that have a low minimum infective dose and for which the human body is the main reservoir, e.g., *Shigella* spp., *S. typhi*, contaminated hands are a particularly important risk factor. In one cholera outbreak in Guinea the contaminated rice-based meal responsible was prepared by a person who had cleaned the bed sheets and washed the body of a cholera victim, including evacuating the victim's bowel contents with enemas (*48*). There are more likely to be multiple cases of cholera in families or households if the index case is a woman or a foodhandler (*51*). Nevertheless, the washing of hands after defecation or changing infants' nappies, and prior to the preparation of food, is frequently neglected or ignored. Studying the food preparation habits of migrants living in the outskirts of Lima, Bryan et al. observed that mothers did not always wash their hands after changing babies' nappies, and when they did it was often in the same pan of water used to prepare food and wash utensils (*50*). Capparelli & Mata reported that the dirty hands of women who prepared tortillas were one of the main sources of contamination of food among rural Guatemalan Indians (*46*). Also, in Lagos it was noted that out of 265 cooks only 43 washed their hands before preparing a meal (in the presence of an observer) (*52*); had no observer been present, the number would probably have been lower.

Foodstuffs such as vegetables, fruits, and seafoods can become contaminated with pathogens during cultivation. Use of untreated wastewater and nightsoil in agriculture and polluted seawater increases the risk of contamination (*53, 54*). Outbreaks of foodborne cholera, typhoid fever, viral hepatitis, amoebiasis, ascariasis, and fascioliasis caused by using contaminated wastewater and nightsoil are well documented (*55, 56*).

Contamination of weaning food with faecal matter has been frequently reported, and lack of basic sanitation certainly is a contributing factor. Water used for the preparation of food itself is a source of pathogenic agents, and in rural areas, water is very often contaminated.

Some pathogens exist naturally in the environment, e.g., earth, and are consequently endogenous contaminants of food. One example is *B. cereus*, the spores of which are often found in foods, such as rice and dried milk. In the United Kingdom, it occurs in 70% of samples of uncooked rice (*57*); if a meal based on ingredients such as rice and/or dried milk undergoes time/temperature abuse during post-preparation storage, *B. cereus* spores that may have survived the cooking process can germinate and produce toxin. Another example is provided by *Clostridium botulinum*, a natural contaminant of soil, which can therefore be present in some foodstuffs. Some foods of animal origin may harbour pathogenic bacteria or parasites, and surveys in some industrialized countries show that up to 80–100% of all poultry meat may be contaminated with campylobacter and/or salmonella (*58*).

In addition to the above-mentioned sources, there is also the imminent risk of cross-contamination during food handling. This can occur either by the direct contact between raw and cooked foods or indirectly through insects, rodents, contaminated hands, surfaces, or utensils.

Pathogenic agents can therefore contaminate food in many different ways, at various stages in the food chain, including during the preparation of food. Under the unfavourable conditions that exist in many countries, especially in slum and rural areas, the risk of contamination of weaning foods during their preparation is even greater. However, in terms of the causes of foodborne diseases, the most critical factors are the following: the preparation of food several hours prior to consumption, combined with inadequate storage conditions; and insufficient cooking or reheating of stored food (*59*).

Whatever the source of the food contamination, foodborne pathogens and some of their toxins can be destroyed by appropriate heat treatment, and adequate cooking or reheating can reduce their numbers to safe levels. However, contrary to popular belief, normal cooking does not necessarily eliminate all the microorganisms. In the preparation of porridge or gruels, for example, prolonged cooking is often avoided, since sustained cooking produces a food that is too glutinous and viscous for young infants to consume. Consequently, depending on the extent of the initial contamination and the duration of cooking, a number of pathogens may survive the cooking process. Many foods are a rich medium for microorganisms, encouraging their growth and eventually the production of toxins. Under favourable conditions, a single bacterium can multiply to 500 million bacteria in 10 hours. Bearing in mind that the minimum infective dose of pathogens varies from a few (10 or less) to as many as 10^4 or 10^6, the survival of even a small number of pathogens in freshly prepared food can become health threatening, particularly if the food is stored at ambient temperature for several hours or overnight, as is often the case. For some microorganisms, cooked foods are an even more favourable milieu than raw foods, since cooking reduces the number of competitive flora. If food is contaminated by such a microorganism after cooking, e.g., by contaminated hands, and is then stored at inappropriate temperatures for an extended period of time (≥4 hours), it is more likely to cause

disease. In this context, it is important to remember that the reservoir of many pathogenic micro-organisms, e.g., *S. aureus*, is the human body. The proportion of healthy humans who carry staphylococci at any one time varies from 30% to 50%, with 15–35% being persistent carriers (*60*). Also, while adequate heating is effective in reducing the number of bacteria, including those that are pathogenic, certain toxins, such as those produced by staphylococci or certain strains of *B. cereus*, are heat stable and are not destroyed by cooking.

There are some traditional practices that are advantageous from the food safety point of view. For example, in many African countries it is customary to give infants fermented cereal products such as *ogi* (Nigeria), *ugi* (United Republic of Tanzania, Uganda, Kenya) and *mahewu* (South Africa, Zimbabwe) (*61*). As a result of fermentation by lactic bacteria and yeasts, the pH of the food decreases to ≤4.3, at which levels microorganisms associated with spoilage or disease cannot multiply. Such techniques of food preservation are not only a helpful means of preserving food, especially if fuel for cooking is in short supply or if mothers are compelled to prepare food in advance and the means for its safe storage are lacking, but also offer many nutritional benefits (*61–63*). Several studies carried out in Africa have demonstrated the importance of this traditional technology in controlling and improving the microbiological quality of weaning food (*64, 65*). Mensah et al. showed that there were lower quantities of contaminated fermented porridge than unfermented, and that after several hours of storage the level of contamination was significantly lower in fermented porridge (*64*).

In addition to some of the above-mentioned studies, there are a few others that demonstrate the relationship between contamination of weaning food and the occurrence of diarrhoeal diseases. One such study carried out in Kenya, which shows the relationship between food contamination and diarrhoea, is worth discussing in some detail. Contamination of infant food was investigated in Kiambu, a district on the outskirts of Nairobi, where the rates of diarrhoeal diseases were low compared with other areas of the country. The level of contamination of infant food was also relatively low and in over 75% of occasions the food was eaten almost immediately after being prepared. During the weaning period, mothers took direct responsibility for feeding their infants and in most cases the food was cooked for relatively long periods. Of note is that when high levels of contamination occurred the handling of food after preparation was found to have been involved. For example, when food was cooked to high temperatures the mothers would add either cold milk or leftovers to cool it—a process that could reintroduce pathogens (*66*). A correlation between contamination of weaning food and diarrhoeal diseases can also be deduced from studies of the risks associated with early weaning. For example, Elegbe & Ojofeitimi found a higher rate of recovery of enteric pathogens from the stools of children who were fed weaning food than from their counterparts who were exclusively breast-fed (*67*). Also, Gordon et al. made the following observation. Children born in spring and during the hot dry season, shortly before and at the height of diarrhoea prevalence, had the lowest death rates for diarrhoeal diseases during the first year of life. They were predominantly breast-fed at the time of major risk. Children born in autumn, with weaning beginning in the hot dry season at the time of greatest risk, had the highest death rates of any cohort determined by month of birth (*68*).

Finally, it should be mentioned that there are also studies that have failed to demonstrate a clear correlation between weaning food contamination and diarrhoeal morbidity (*69*). One possible explanation for this is that food is often analysed only for a limited number of pathogens and not for all those potentially present.

The emphasis in this review has so far been on the biological contamination of weaning foods, because of the extent and gravity of the consequences for infants and children as well as of the role that those preparing infant foods can play. However, the chemical contamination of food also needs to be discussed, since many outbreaks of chemical intoxication have arisen as a consequence of errors made by those handling food due to their ignorance or negligence. For example, in a number of instances food has been contaminated because of unsafe packing and leakage of pesticides during storage or transport or because food was stored in containers that previously contained pesticides, but which were not adequately washed before being re-used. Also, seeds have been consumed that were intended for planting and which had been treated with fungicides; fish have been caught in ponds where rice treated with pesticide was growing; or cereals have been harvested too soon after being treated with pesticide. The problems presented by intoxication with marine biotoxins are also increasing in many parts of the world, and if seafoods constitute a part of the diet of infants and children, they too will be affected if such food is contaminated.

Sociocultural constraints

Although the risk factors for foodborne disease are well known, their prevention may be impeded or

hampered by many social and cultural constraints. Social infrastructure, ignorance, incorrect beliefs and practices, taboos, poverty, insufficient food, lack of safe water and sanitation, shortage of fuel, and time are some of the many factors that aggravate the situation.

Food habits and beliefs have major implications for food safety. Unfortunately, in many societies the relationship between diarrhoea and food contamination is not understood. For example, in Uganda some parents believe that diarrhoea is caused by false teeth (*70*). In Orissa, in India, 65% of mothers believed that diarrhoea is caused by the casting of the evil eye, 44% by indigestion, 10% by eating "hot foods" such as mango and egg, 8% by teething, and 35% by food eaten by breast-feeding mothers; many mothers blamed their own breast milk for causing diarrhoea (*71*). In many cultures, babies' stools are not considered to be dirty or contaminating (*72*). For example, in one community-based study of the etiology of diarrhoea in Papua New Guinea, children whose mothers did not perceive babies' faeces to be important in causing diarrhoea had a 7.4 times greater risk of having diarrhoea than children whose mothers recognized their importance. Also, the risk of contamination of food was 6.8 times greater for those children whose mothers did not recognize the importance of this route (*73*).

Many customary kitchen practices and food preferences contribute to lack of safety in food preparation. These include a predilection in some societies for raw fish and undercooked meats, the storage of perishable food at ambient temperature, and cooks' failure to wash their hands before preparing food (*74*). Bryan et al. reported that many migrants living in a settlement on the outskirts of Lima did not have a refrigerator to store their food; however, those who had refrigerators either did not know that cooked foods should be stored in them in the interval between meals or it was their usual practice not to refrigerate cooked foods (*50*). Cultural beliefs as well as taboos add to these problems. In much of Latin America, hands are thought to be "heated" by contact with pressing irons and pottery kilns or by working with "hot" substances such as mineral lime. Exposing "hot" hands to cold water is believed to cause cramps and rheumatism, so people refrain from washing them, often for many hours (*74*).

Insufficient water is also an important reason for not washing hands or utensils properly. According to some studies, improvement in water availability has a higher impact in reducing the rate of diarrhoeal morbidity than improvements in water quality alone (*75*). Lack of excreta disposal facilities increases the risk of contaminating food with faecal matter.

Undoubtedly, availability of time is one of the major factors that governs the feeding patterns of infants. If, in addition to caring for infants and children, mothers have to work outside the home, the greater demand on their time competes with their care/nursing capacity; in such circumstances, they do not always prepare food according to correct safety principles. Moreover, to be able to attend to their activities outside the home, some mothers may initiate weaning earlier than the prescribed age of 4–6 months (*76*). This may lead to an increased risk of foodborne diseases.

Food preparation (cooking) can consume a great proportion of household fuel energy. In many developing countries shortage of fuelwood affects the nutritional status of rural households, particularly that of infants and children. To meet the daily nutrient requirements of infants and children (who have small stomachs), they have to be fed several times per day. When there are shortages of fuel and/or time, either for feeding or collecting fuelwood, households tend to economize on both fuel consumption and time by adopting food preparation practices that may be detrimental to the child's health. For example, it has been repeatedly observed that in order to save on fuel/time, food is prepared in quantities larger than are required for one meal—sometimes also insufficiently cooked—and is then stored until the next meal, often at ambient temperature. If there is a shortage of fuel, weaning food may be served cold or without adequate reheating. In addition to the risk of infections, insufficient cooking also causes nutritional problems since weaning food may be less palatable or digestible; for example, some pulses contain trypsin inhibitors that prevent the absorption of proteins, but which could be destroyed with adequate cooking (*77*).

Finally, in cases of food shortages, the availability of the food is prioritized to the detriment of its quality, and safety aspects are often neglected. Sometimes ingredients are used that are not fit for consumption. Lack of some ingredients modifies the physico-chemical properties in such a way that the food (which is otherwise safe) encourages the rapid growth of microorganisms. For example, an outbreak of cholera in an African village was associated with leftover millet gruel in which the sour milk that is traditionally added had become unavailable because of drought (*48*).

Significance of foodborne diseases for health care systems

In addition to the human suffering that foodborne diseases cause in terms of death or ill health, tremen-

dous economic costs are incurred by health care systems and society. Episodes of diarrhoeal disease, which in some countries occur on average about 10 times per child during the first year of life, are one of the most frequent reasons for the hospitalization of children. In some areas such disease accounts for 30% or more of paediatric hospitalizations (*78*). For example, in Bangladesh, diarrhoeal syndromes have been reported to account for 52% of all hospitalizations (*10, 13*); and in one study of hospitalized cases of infants and children with symptoms of intoxication in Mali, 44% of the cases were foodborne and occurred with the highest frequency among under-5-year-olds (*79*). Increasing health care costs are clearly a tremendous economic burden for many countries, particularly those with limited resources (*80*).

Health education in food safety: a cost-effective intervention

To prevent the suffering of millions of children and parents, and to contribute to the breaking of the vicious cycle of disease, under-development and poverty, an urgent and cost-effective intervention is required. Currently, there is no vaccine capable of providing general protection against foodborne infections, and it is unlikely that there ever will be. Attempts are being made to develop vaccines for specific foodborne diseases such as cholera and shigellosis; however, these efforts are still at the research or experimental stage. Diarrhoeal diseases have traditionally been linked to contaminated water supplies and lack of sanitation, and great efforts have been concentrated in preventing them by improving water supplies and excreta disposal facilities. A review of the impact of improved water supplies and excreta facilities in the control of diarrhoeal diseases among young children has shown that, even under the most favourable circumstances, the rate of morbidity was reduced only by 27% (*75*). In Europe, which by and large has safe drinking-water and effective excreta disposal facilities, the incidence of foodborne diseases has increased threefold since 1984 and it is believed that in some industrialized countries such diseases affect about 10% of the population (*81, 82*).[j, k] While there are numerous reasons for this increase, outbreaks of foodborne disease are almost always caused by one or more errors during the final preparation of food.

To prevent foodborne diseases, a multidisciplinary approach is needed. Environmental conditions need to be improved, including the provision of safe water supplies and sanitation as well as the creation of the social infrastructure to permit mothers to improve their care/nursing capacity. However, such measures might take many years to achieve, and on their own will not be sufficient to prevent foodborne diseases. Foodhandlers (including all mothers) need to be educated to learn how to protect infants and children from foodborne hazards. Since the nutrition of infants and young children depends closely on the education of their mothers on food safety, this is one the most important interventions to be considered. A programme to educate mothers on food safety principles should therefore be considered to be an integral part of every primary health care system and should be incorporated into national infant feeding or food and nutrition programmes.

Experience with education programmes on other issues, such as the promotion of appropriate feeding for improving nutritional status, has shown that they are feasible and cost-effective interventions. Compared to some other interventions, the costs involved in health education are relatively low, while they produce long-lasting changes in the health-related behaviour of the target group (*86, 87*).

In view of the worldwide dramatic increase in the incidence of foodborne diseases, immediate action to protect the most vulnerable groups of society, i.e., infants and children, is called for. Reviews of published data on foodborne diseases show clearly that one of the most critical practices leading to increased risk of foodborne diseases is storing cooked foods at ambient temperature for several hours, and serving such foods without appropriate reheating. Therefore, as an immediate action to prevent foodborne diseases, a health education programme focusing on the problem related to time/temperature abuse should be launched, using diverse channels, including primary health care centres.

Since sociocultural settings vary among countries, in the long term the design of health education programmes should be based on a detailed analysis of the hazards associated with food habits, the social and economic situation, and the technological facilities available in the target society. Such an approach should involve two types of studies. The first should be concerned with collecting sociocultural information, for which the assistance of anthropologists or sociologists is required to investigate the customs, beliefs and rituals that lead to specific food safety problems, and to provide the sociocultural informa-

[j] *WHO Surveillance Programme for Control of Foodborne Infections and Intoxications in Europe, fifth report.* Robert von Ostertag Institute, Berlin. Unpublished document, 1992.

[k] **Hoogenboom-Vergedaal, A.M.M.M. et al.** *Epidemiological and microbiological study with reference to gastroenteritis in humans in the Amsterdam and Helmond regions in 1987 and 1988.* Unpublished document (in Dutch).

tion needed to plan an educational programme acceptable to the population. The second is the hazard-analysis-critical-control-point approach, i.e., the systematic identification of hazards at each step during the preparation of food, assessing the risks and determining the operations where control procedures will be effective. For this purpose, the expertise of food scientists is required.

In conclusion, it is clear that the prevention of diarrhoea in infants and children requires a multidisciplinary approach, including the promotion and protection of breast-feeding as well as the safe preparation and handling of weaning food. In view of this, the education of mothers on food safety principles is one of the most important interventions in promoting the health and nutritional status of infants and children.

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Résumé

Diarrhée et malnutrition: les aliments de sevrage contaminés sont souvent en cause

Les maladies infectieuses et la malnutrition qui les accompagne sont responsables d'une partie importante des quelque 13 millions de décès de nourrissons et d'enfants de moins de cinq ans qui surviennent chaque année dans le monde. Les maladies diarrhéiques sont les maladies les plus fréquentes, après les infections respiratoires, chez les jeunes enfants et ce sont elles qui ont les conséquences les plus graves sur la croissance.

Le lait maternel est un aliment nutritif et généralement sûr pour les nouveau-nés. Lorsqu'il constitue leur seule alimentation, il est protège grâce à ses propriétés immunologiques et en leur évitant d'être exposés aux germes pathogènes contenus dans la nourriture. L'allaitement au sein peut aussi réduire la gravité des maladies diarrhéiques et le nombre des décès associés à ces maladies. Toutefois, lorsque l'enfant atteint l'âge de quatre à six mois, le lait maternel ne suffit plus à répondre à ses besoins nutritionnels et doit être complété, puis remplacé, par des aliments appropriés jusqu'à ce que l'enfant commence à partager la nourriture familiale, vers l'âge de deux ans. Lors du sevrage, l'exposition aux agents pathogènes présents dans la nourriture constitue un danger. En effet, les nourrissons et les enfants sont particulièrement sensibles à ces germes et risquent fort de tomber malades s'ils consomment des aliments contaminés.

L'incidence des maladies diarrhéiques augmente dès le début du sevrage et atteint un maximum dans la seconde moitié de la petite enfance. Il est très rare que les infections aient des conséquences nutritionnelles négatives chez les enfants nourris exclusivement au sein. Par contre, des épisodes de diarrhée répétés peuvent provoquer de graves retards de croissance et d'autres troubles nutritionnels pendant la période de sevrage. Avec la diminution de la résistance aux infections, les enfants se trouvent pris dans un cercle vicieux d'infections et de malnutrition dont l'issue est souvent fatale.

Les aliments contaminés pourraient être à l'origine de 70% des 1,4 milliard d'épisodes diarrhéiques dont sont victimes chaque année dans le monde les enfants de moins de cinq ans. Les aliments de sevrage préparés dans des conditions non hygiéniques contiennent souvent de grandes quantités de germes pathogènes ou sont contaminés par des matières fécales. A elle seule, la présence d'*Escherichia coli* dans ces aliments est responsable de près de 25% des cas de diarrhée.

Les sources de contamination sont diverses. Toutefois, une analyse détaillée des infections d'origine alimentaire a montré que dans la grande majorité des cas, celles-ci se produisent dans les circonstances suivantes:

— les aliments sont préparés plusieurs heures avant d'être consommés et sont conservés dans des conditions inadéquates;
— ils sont insuffisamment cuits ou réchauffés.

Si ces erreurs étaient évitées lors de la préparation des aliments, le nombre d'infections d'origine alimentaire serait grandement diminué. Des croyances erronées contribuent souvent aussi à cette situation. Par exemple, certaines mères ne considèrent pas les excréments de leurs enfants comme sales et négligent de se laver les mains avant de préparer les repas. La rareté ou la mauvaise qualité de l'eau, le manque de combustible pour la cuisson, l'absence de réfrigérateur et le manque de temps pour préparer les aliments sont également des facteurs importants qui rendent difficile l'application des principes d'hygiène alimentaire.

Dans les pays en développement, certaines familles ont tendance à adopter des méthodes de

préparation des aliments qui peuvent être néfastes pour la santé des enfants. Par exemple, pour économiser du temps et du combustible, les aliments sont souvent préparés pour plusieurs repas à la fois et conservés à la température ambiante. Les aliments de sevrage sont parfois servis froids ou sans avoir été suffisamment réchauffés; à la saison chaude, leur conservation à la température ambiante est encore plus dangereuse.

Pour prévenir les maladies diarrhéiques, les gouvernements et les organisations non gouvernementales se contentent souvent de faire porter leurs efforts sur l'approvisionnement en eau et l'assainissement et de favoriser l'allaitement maternel, *alors qu'une approche multidisciplinaire plus large est indispensable. L'environnement,* notamment les conditions d'approvisionnement en eau et l'assainissement, de même que l'infrastructure sociale, doivent être améliorés de façon à permettre aux mères de mieux prendre soin de leurs enfants (y compris en favorisant l'allaitement au sein). Etant donné que les aliments de sevrage contaminés sont responsables d'un grand nombre de cas de diarrhée, l'enseignement des principes d'hygiène alimentaire devrait être prioritaire. Les personnes appelées à manipuler les aliments doivent apprendre comment protéger les nourrissons et les enfants des risques d'infection alimentaire. L'enseignement des principes d'hygiène alimentaire aux mères de famille constitue l'une des plus importantes interventions stratégiques qui puissent être entreprises pour prévenir les maladies diarrhéiques et améliorer l'état sanitaire et nutritionnel des nourrissons et des enfants.

References

1. **Esrey, S.A.** Food contamination and diarrhoea. *World health*, pp. 19–20, January–February 1990.
2. **Henry, F.J.** Combating childhood diarrhoea through international collaborative research. *Journal of diarrhoeal diseases research*, **9**(3): 165–167 (1991).
3. **Tomkins, A.** Recent developments in the nutritional management of diarrhoea. 1. Nutritional strategies to prevent diarrhoea among children in developing countries. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **85**: 4–7 (1991).
4. Research on improving infant feeding practices to prevent diarrhoea or reduce its severity: Memorandum from a JHU/WHO Meeting. *Bulletin of the World Health Organization*, **67**: 27–33 (1989).
5. **de Zoysa, I. et al.** Why promote breast-feeding in diarrhoeal disease control programmes? *Health policy and planning*, 6: 371–379 (1991).
6. Infant feeding—the physiological basis. *Bulletin of the World Health Organization*, **67**(suppl.) (1989).
7. **Barrel, R.A.E. & Rowland, M.G.M.** Infant foods as a potential source of diarrhoeal illness in rural West Africa. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **73**: 85–89 (1979).
8. **Mata, L.** *The children of Santa Maria Cauqué: a prospective field study of health and growth.* Cambridge, MA, MIT Press, 1978.
9. **Rowland, M.G.M. & McCollum, J.P.K.** Malnutrition and gastroenteritis in the Gambia. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **71**: 199–203 (1977).
10. **Black, R.E. et al.** Longitudinal studies on infectious diseases and physical growth of children in rural Bangladesh. I: patterns of morbidity. *American journal of epidemiology*, **115**: 305–314 (1982).
11. **Black, R.E. et al.** Longitudinal studies of infectious diseases and physical growth of children in rural Bangladesh. II: incidence of diarrhea and association with known pathogens. *American journal of epidemiology*, **115**: 315–324 (1982).
12. **Snyder, J.D. & Merson, M.H.** The magnitude of the global problem of acute diarrhoeal disease: a review of active surveillance data. *Bulletin of the World Health Organization*, **60**: 605–613 (1982).
13. **Black, R.E. et al.** A two-year study of bacterial, viral, and parasitic agents associated with diarrhea in rural Bangladesh. *Journal of infectious diseases*, **142**: 660–664 (1980).
14. **Black, R.E. et al.** Incidence and etiology of infantile diarrhea and major routes of transmission in Huascar, Peru. *American journal of epidemiology*, **129**: 785–799 (1989).
15. **Huilan, S. et al.** Etiology of acute diarrhoea among children in developing countries: a multicentre study in five countries. *Bulletin of the World Health Organization*, **69**: 549–555 (1991).
16. **Gomes, T.A.T.** Enteropathogens associated with acute diarrheal diseases in urban infants in São Paulo, Brazil. *Journal of infectious diseases*, **164**: 331–337 (1991).
17. **de Zoysa, I. & Feachem, R.G.** Interventions for the control of diarrhoeal diseases among young children: rotavirus and cholera immunization. *Bulletin of the World Health Organization*, **63**: 569–583 (1985).
18. **WHO Expert Committee.** The public health significance of intestinal parasitic infections. *Bulletin of the World Health Organization*, **65**: 575–588 (1987).
19. **Shetty, N. et al.** Intestinal amoebiasis and giardiasis in southern Indian infants and children. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **84**: 382–384 (1990).
20. **Mata, L. et al.** Effect of infection on food intake and the nutritional state: perspectives as viewed from the village. *Journal of clinical nutrition*, **30**: 1215–1227 (1977).
21. **Archer, D.** Diarrheal episodes and diarrheal disease: acute disease with chronic implications. *Journal of food protection*, **47**: 322–328 (1984).
22. **Archer, D. & Young, F.** Contemporary issues: diseases with a food vector. *Clinical microbiology reviews*, **1**: 377–398 (1988).
23. **Davies, P.A. & Gothefors, L.A.** Bacterial infections in the fetus and newborn. *Major problems in clinical pediatrics*, vol. 26. Philadelphia, W.B. Saunders, 1984.

24. **Gross, J.R.** Vero-cytotoxin-producing *Escherichia coli* 0157. *PHLS microbiology digest*, **7**: 119–123 (1990).
25. **Taylor, M.** The hemolytic uraemic syndrome: a clinical perspective. *PHLS microbiology digest*, **7**: 133–140 (1990).
26. **Tomkins, A. & Watson, F.** *Malnutrition and infection: a review.* (ACC/SCN State of the Art Series, Nutrition Policy Discussion Paper No. 5). London, London School of Hygiene and Tropical Medicine, 1989.
27. **Rowland, M.G.M. et al.** Impact of infection on the growth of children from 0 to 2 years in an urban West African community. *American journal of clinical nutrition*, **47**: 134–138 (1988).
28. **Mata, L.J.** Nutrition and infection. *Protein Advisory Group bulletin*, **11**: 18–21 (1971).
29. **Ekanem, E.E. & Akitoye, C.O.** Child feeding by Nigerian mothers during acute diarrhoeal illness. *Journal of the Royal Society of Health*, **5**: 164–165 (1990).
30. **Scrimshaw, N.S. et al.** Diarrhea and nutrient requirements. In: Chen, L.C. & Scrimshaw, N.S., ed. *Diarrhea and malnutrition — interactions, mechanisms, and interventions.* New York, Plenum Press, 1983, pp. 269–286.
31. **Lopez, G. et al.** Longitudinal studies of infectious diseases and physical growth of infants in Huascar, an underprivileged peri-urban community in Lima, Peru. *American journal of epidemiology*, **129**: 769–784 (1989).
32. **Martorell, R. et al.** The impact of ordinary illnesses on the dietary intakes of malnourished children. *American journal of clinical nutrition*, **33**: 345–350 (1980).
33. **Martorell, R. et al.** Acute morbidity and physical growth in rural Guatemalan children, *American journal of diseases of children*, **129**: 1296–1301 (1975).
34. **Martorell, R. et al.** Diarrheal diseases and growth retardation in preschool Guatemalan children. *American journal of physical anthropology*, **43**: 341 (1975).
35. **Condon-Paoloni, D. et al.** Morbidity and growth of infants and young children in a rural Mexican village. *American journal of public health*, **67**: 651–656 (1977).
36. **Black, R.E. et al.** Effects of diarrhea associated with specific enteropathogens on the growth of children in rural Bangladesh. *Pediatrics*, **73**: 799–805 (1984).
37. **Solomon, N. et al.** Weanling diarrhea: a case report, clinical nutrition cases. *Nutrition reviews*, **48**: 212–214 (1990).
38. **Black, R.E. et al.** Contamination of weaning foods and transmission of enterotoxigenic *Escherichia coli* diarrhoea in children in rural Bangladesh. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **76**: 259–264 (1982).
39. **Black, R.E. et al.** Enterotoxigenic *Escherichia coli* diarrhoea: acquired immunity and transmission in an endemic area. *Bulletin of the World Health Organization*, **59**: 263–268 (1981).
40. **Henry, F.J. et al.** Bacterial contamination of weaning foods and drinking water in rural Bangladesh. *Epidemiology and infection*, **104**: 79–85 (1990).
41. **Barrel, R.A.E. & Rowland, M.G.M.** Infant foods as a potential source of diarrhoeal illness in rural West Africa. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **73**: 85–89 (1979).
42. **Khin Nwe, O.O. et al.** Bacteriologic studies of food and water consumed by children in Myanmar, 1: the nature of contamination. *Journal of diarrhoeal disease research*, **9**: 87–90 (1991).
43. **Bryan, F.** *Hazard analysis critical control point evaluations: a guide to identifying hazards and assessing risks associated with food preparation and storage.* Geneva, World Health Organization, 1992.
44. **Michanie, S. et al.** Critical control points for foods prepared in households in which babies had salmonellosis. *International journal of food microbiology*, **5**: 337–354 (1987).
45. **Michanie, S. et al.** Critical control points for foods prepared in households whose members had either alleged typhoid fever or diarrhea. *International journal of food microbiology*, **7**: 123–124 (1988).
46. **Caparelli, E. & Mata, L.J.** Microflora of maize prepared as tortillas. *Applied microbiology*, **29**: 802–806 (1975).
47. **Soundy, J. & Rivera, H.** Acute diarrhoeal diseases: longitudinal study in a sample of Salvadorean population, II—analysis of the faeces and foods. *Revista del Instituto de Investigaciones Medicas*, **1**: 307–316 (1972).
48. **St Louis, M. et al.** Epidemic cholera in West Africa: the role of food handling and high risk foods. *American journal of epidemiology*, **131**: 719–728 (1990).
49. **van Steenbergen, W.M. et al.** Machakos project studies: agents affecting health of mother and child in a rural area of Kenya, XXIII. Bacterial contamination of foods commonly eaten by young children in Machakos, Kenya. *Tropical and geographical medicine*, **35**: 193–197 (1983).
50. **Bryan, F. et al.** Hazard analyses of foods prepared by migrants living in a new settlement at the outskirts of Lima, Peru. *Journal of food protection*, **51**: 314–323 (1988).
51. **Roberts, D.** Growth and survival of *Vibrio cholerae* in foods. *PHLS microbiology digest*, **9**: 24–31 (1992).
52. **Ekanem, E.E. et al.** Food hygiene and childhood diarrhoea in Lagos, Nigeria: a case–control study. *Journal of diarrhoeal diseases research*, **9**: 219–226 (1991).
53. **Geldreich, E.E. & Borndner, H.** Fecal contamination of fruits and vegetables during cultivation and processing for market. *Journal of milk and food technology*, **34**: 184–195 (1971).
54. **Ercolani, G.L.** Bacteriological quality assessment of fresh marketed lettuce and fennel. *Applied and environmental microbiology*, **31**: 847–852 (1976).
55. **Bryan, F.L.** Diseases transmitted by foods contaminated by wastewater. *Journal of food protection*, **40**: 45–46 (1977).
56. **Mara, D. & Cairncross, S.** *Guidelines for the safe use of wastewater and excreta in agriculture and aquaculture.* Geneva, World Health Organization, 1989.
57. **Rowland, M.G.M.** Bacterial diarrhoeas: contaminated food and water. In: Gracey, M., ed. *Diarrhoeal*

disease and malnutrition—a clinical update. Edinburgh, Churchill Livingstone, 1985, pp. 47–62.
58. **Roberts, D.** Sources of infection: food. *Lancet*, **336**: 859–861 (1990).
59. WHO Technical Report Series, No. 705, 1984 (*The role of food safety in health and development*: report of a Joint FAO/WHO Expert Committee on Food Safety).
60. **Bergdoll, M.** *Staphylococcus aureus*. In: Doyle, M., ed. *Foodborne bacterial pathogens*. New York, Marcel Dekker Inc., 1989, pp. 463–524.
61. **Tomkins, A. et al.** Fermented foods for improving child feeding in eastern and southern Africa: a review. In: Alnwick, S. et al., ed. *Improving young child feeding in eastern and southern Africa; household-level food technology. Proceedings of a Workshop held in Nairobi, Kenya, 12–16 October 1987*. Ottawa, International Development Research Centre, 1988, pp. 136–167.
62. **Nout, M.J.R.** Fermentation of infant food. *Food laboratory news*, **20**: 11–13 (1990).
63. **King, J. & Ashworth, A.** Contemporary feeding practices in infancy and early childhood in developing countries. In: Falkner, F., ed. *Infant and child nutrition worldwide—issues and perspectives*. Boca Raton, FL, CRC Press, 1991, pp. 141–174.
64. **Mensah, P.P.A. et al.** Fermentation of cereals for reduction of bacterial contamination of weaning foods in Ghana. *Lancet*, **336**: 140–143 (1990).
65. **Odugbemi, T. et al.** Study of the pH of *ogi*, Nigerian fermented weaning food, and its effect on enteropathogenic *Escherichia coli, Salmonella typhi* and *Salmonella paratyphi*. *Journal of tropical medicine and hygiene*, **94**: 219–223 (1991).
66. **Pertet, A.M. et al.** Weaning food hygiene in Kiambu, Kenya. In: Alnwick, S. et al., ed. *Improving young child feeding in eastern and southern Africa: household-level food technology. Proceedings of a Workshop held in Nairobi, Kenya, 12–16 October 1987*. Ottawa, International Development Research Centre, 1988, pp. 234–239.
67. **Elegbe, A. & Ojofeitimi, E.O.** Early initiation of weaning foods and proliferation of bacteria in Nigerian infants. *Clinical pediatrics*, **23**: 261–264 (1980).
68. **Gordon, J.E.. et al.** Weanling diarrhea. *American journal of the medical sciences*, **245**: 345–377 (1963).
69. **Lloyd-Evans, H.A. et al.** Food and water hygiene and diarrhoea in young Gambian children: a limited case–control study. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **78**: 209–211 (1984).
70. **Bwengye, E.** Uganda: newborn, false teeth and diarrhoea. *Dialogue on diarrhoea*, **39** (December): 6 (1989).
71. **Mohapatra, S.S.** Beliefs of rural mothers about diarrhoea in Orissa, India. *Dialogue on diarrhoea*, **39** (December): 7 (1989).
72. **Fukumoto, M. & Del Agulla, R.** Why do mothers wash their hands? *Dialogue on diarrhoea*, **39** (December): 5 (1989).
73. **Bukenya, G.B. et al.** The relationship of mothers' perception of babies faeces and other factors to childhood diarrhoea in an urban settlement of Papua New Guinea. *Annals of tropical paediatrics*, **10**: 185–189 (1990).
74. **Abdussalam, M. et al.** Food-related behaviour. In: Hamburg, D. & Sartorius, N., ed. *Health and behaviour: selected perspectives*. Cambridge, Cambridge University Press, 1989, pp. 45–65.
75. **Esrey, S.A.** Interventions for the control of diarrhoeal diseases among young children: improving water supplies and excreta disposal facilities. *Bulletin of the World Health Organization*, **63**: 757–772 (1985).
76. **Simpson-Hebert, M. & Makil, L.P.** Breast-feeding in Manila, Philippines: preliminary results from a longitudinal study. *Journal of biosocial science*, **9** (suppl.): 137–146 (1985).
77. **Brouwer, M.S. et al.** Nutritional impacts of an increasing fuelwood shortage in rural households in developing countries. *Progress in food and nutrition science*, **13**: 340–361 (1989).
78. **Claeson, M. & Merson, M.** Global progress in control of diarrheal diseases. *Pediatric infectious disease journal*, **9**: 345–355 (1990).
79. **Sidibe, T. et al.** L'intoxication accidentelle chez l'enfant. *Médicine d'Afrique noire*, **38**: 128–130 (1991).
80. Health expenditure as percentage of gross national product (GNP), by groups of countries, 1960 and 1986. *World health statistics annual 1991* (UNDP Human Development Report 1990).
81. **Todd, E.C.D.** Preliminary estimates of costs of foodborne disease in Canada and costs to reduce salmonellosis. *Journal of food protection*, **52**: 586–594 (1989).
82. **Archer, D.L. & Kvenberg, J.E.** Incidence and cost of foodborne diarrheal disease in the United States. *Journal of food protection*, **48**: 887–894 (1985).
83. **Bryan, F.L.** Factors contributing to outbreaks of foodborne diseases. *Journal of food protection*, **41**: 816–827 (1978).
84. **Roberts, D.** Factors contributing to outbreaks of food poisoning in England and Wales 1970–1979. *Journal of hygiene*, **89**: 491–498 (1982).
85. **Todd, E.C.D.** Factors that contributed to foodborne disease in Canada 1973–1977. *Journal of food protection*, **46**: 737–747 (1983).
86. **Ashworth, A. & Feachem, R.G.** Interventions for the control of diarrhoeal diseases among young children: weaning education. *Bulletin of the World Health Organization*, **63**: 1115–1127 (1985).
87. **Feachem, R.G.** Interventions for the control of diarrhoeal diseases among young children: promotion of personal and domestic hygiene. *Bulletin of the World Health Organization*, **62**: 467–476 (1984).