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INTERVENTIONS FOR THE CONTROL OF DIARRHOEAL DISEASES AMONG YOUNG CHILDREN: PROMOTION OF FOOD HYGIENE

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SUMMARY

This review examines whether interventions to promote improved food hygiene, namely, better handling, preparation, and storage of food, can reduce diarrhoeal morbidity or mortality rates among young children. Although we conclude that improper practices in the preparation, handling, and storage of food and poor feeding methods can account for a substantial proportion of all diarrhoeal episodes, there is little epidemiological information available to help in designing appropriate interventions. We therefore encourage investigators to conduct studies to identify practices that are risk factors for faecal contamination of weaning foods and are therefore likely to be associated with increased or decreased diarrhoeal incidence; such practices should then be targeted by diarrhoeal diseases control programmes. Subsequently, intervention studies based on the results of this research should be conducted to measure the impact of specific interventions which aim to modify the identified risk-related practices.

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INTRODUCTION

Bacteria, viruses, and protozoa that cause diarrhoea can be passively carried in or on food and lead to infection and disease if ingested in sufficient numbers. In addition, some bacterial enteric pathogens can multiply in specific foods under appropriate conditions of temperature, pH and moisture content, so that an initially small number of pathogens can increase to produce the large doses that are necessary to cause certain bacterial diarrhoeas.

Other agents of disease, in addition to the infectious agents of diarrhoea, can be transmitted by way of food. For instance, harmful chemicals, plant toxicants, marine biotoxins, mycotoxins, and bacterial causes of other diseases (such as botulism) can be ingested through food. These contaminants are not known to be a major cause of diarrhoea in young children. There are social and economic, as well as other health consequences associated with both the transmission and the reduction of foodborne infectious diseases. For instance, diarrhoea may lead to malnutrition, regardless of the source of infection. Efforts to reduce or eliminate foodborne diarrhoea may lead to a change in dietary practices which, if the change is detrimental, may also lead to malnutrition. Dietary change is an important aspect of the promotion of food hygiene, and should not be neglected in any intervention.

The promotion of food hygiene is closely related to the control of zoonotic reservoirs and to education with respect to personal and domestic hygiene, breast-feeding, and weaning. These potential interventions are analysed in other papers in this series. This review examines the nature and extent of poor food hygiene and its contribution to foodborne diarrhoea among young children. For the purposes of this document, food hygiene refers to those practices involved in the preparation, handling, and storage of food that are known or expected to reduce the transmission of enteric pathogens.[a] The potential role of food hygiene promotion in controlling childhood diarrhoea in developing countries is explored, and areas of research are outlined. This paper is the thirteenth in a series of reviews of potential diarrhoea control measures (3-6, 23-24, 29-35).

[a] The term "food hygiene" is not here synonymous with the term "food safety", which is the official term used by the World Health Organization for all of the conditions and measures that are necessary mainly after harvesting (the term "harvesting" includes slaughter/milking, etc.) and during storage, processing, distribution, and preparation of food to ensure that it is safe, sound, wholesome, and fit for human consumption.

EFFECTIVENESS

For the promotion of food hygiene to be an effective diarrhoea control measure it must be true that

either

poor food handling, preparation, and storage practices contribute to the transmission of diarrhoea-causing pathogens and thereby increase diarrhoeal morbidity or mortality rates among young children	Hypothesis 1

and

food handling, preparation, and storage practices can be improved by appropriate educational and legislative measures	Hypothesis 2

or

appropriate educational and legislative measures to improve food handling, preparation, and storage practices can reduce diarrhoeal morbidity or mortality rates among young children	Hypothesis 3

The effectiveness of measures to improve food hygiene is suggested by a demonstration of the correctness of hypotheses 1 and 2 or the correctness of hypothesis 3. Most of the available literature focuses on the first hypothesis, and there is relatively little information on hypotheses 2 and 3. In some other reviews in this series, theoretical estimates for hypothesis 3 have been calculated. This is not possible for food hygiene because of the lack of information on hypotheses 1 and 2. The evidence for and against each hypothesis is examined below.

Hypothesis 1: Poor food handling, preparation, and storage practices contribute to the transmission of diarrhoea-causing pathogens and thereby increase diarrhoeal morbidity or mortality rates among young children.

For this hypothesis to be true, two sub-hypotheses must also be true. First, foodborne diarrhoea must constitute a sufficient proportion of all diarrhoea among young children such that a reduction in the foodborne component will be translated into a detectable reduction in total diarrhoeal morbidity or mortality rates. Second, it must be established that poor food hygiene contributes substantially to the ingestion of pathogens in food by young children, and thus to foodborne diarrhoea.

Information on the precise extent of foodborne diarrhoeal disease in young children is lacking in both developed and developing countries. Some evidence suggests, however, that foodborne diarrhoea may constitute a considerable proportion of all diarrhoea. For example, many outbreaks of diarrhoea in developed countries have been traced to the consumption of pathogens in food. Some of these outbreaks, especially those involving large numbers of people, have been carefully investigated. In addition, all of the major infectious agents of diarrhoea have been isolated from a variety of foods. Moreover, during the warmer months, when bacteria can multiply more rapidly in stored food, the incidence rate of bacterial diarrhoeas is highest in most countries. Finally, the infective dose of some pathogens may be reduced if those pathogens are ingested in foods rather than fluids (21, 25, 41).

Extent of the problem: developed countries

Numerous foodborne outbreaks of diarrhoea occur every year in the developed countries. It is generally recognized that the numbers of reported outbreaks and cases (Table 1) substantially underestimate the true magnitude of the problem, probably because of restrictive definitions of foodborne outbreaks, a failure of sick individuals to seek medical attention, and a failure on the part of the responsible authorities to investigate suspected outbreaks, especially if they are small and are not known to have caused any deaths. In the USA, two or more persons must experience a similar illness after ingestion of a common food, and the food must be implicated as the source of the illness, before a foodborne outbreak is declared (49). Clearly, an episode of foodborne diarrhoea in single-member households could not be an outbreak under this definition.

Many cases and outbreaks go unreported, especially those that occur in the home. It has been estimated that actual foodborne cases may be 25 to 100 times more frequent than reported cases (54, 37). Apparent differences in the rates of foodborne diarrhoea among countries may reflect only differences in definitions, reporting, and investigative procedures.

Proportions of bacterial foodborne diarrhoea outbreaks of known etiology and location that occur in the home, reported by 6 selected countries, are presented in Table 2. These data represent a minority of all foodborne outbreaks. The proportions by country are 7-44%, with a mean of 40%, which reflects the high proportion of home outbreaks in Japan. The median for all 6 countries is 26%, suggesting that home foodborne diarrhoea outbreaks are common. These figures include foodborne diarrhoea outbreaks for all ages and may therefore underestimate the proportion of such illness that originates in the home among young children. Foodborne diarrhoea due to certain pathogens appears to be especially common in the home (Table 2). For instance, outbreaks caused by Salmonella spp., Staphylococcus aureus, and Vibrio parahaemolyticus may be more likely to occur in the home than outbreaks caused by Bacillus cereus or Clostridium perfringens. The information on Campylobacter jejuni, Escherichia coli, Shigella, streptococci, Vibrio cholerae, and Yersinia enterocolitica is too scanty to infer any relationships.

In the USA in 1982, an etiological agent was confirmed in only 220 (34%) of 656 foodborne disease outbreaks (49). In the same year and country, the proportion of foodborne outbreaks that occurred in the home was 18% for bacterial diarrhoeas (Table 2), but 29% for disease outbreaks of unknown etiology (49). In England and Wales during 1980-84, 59% of all foodborne outbreaks involved only single-member households (50). The proportions of all diarrhoea cases in developed countries that are foodborne, whether in aggregate or by agent, are unknown.

Extent of the problem: developing countries

The proportion of diarrhoea that is foodborne may be lower in developing than in developed countries, because of the more varied and frequent opportunities for other modes of transmission and because the zoonotic agents (particularly Salmonella and Campylobacter), which are especially associated with foodborne transmission, are relatively less important. The rates of foodborne cases, however, are likely to be higher. Knowledge of the extent of the problem in the developing countries is even more limited than in the case of developed countries, and data are available for only a few countries in Asia and Latin America. Some of these are summarized in Table 3. The numbers have little meaning and are an outcome of the very recent and faltering efforts in these countries to document foodborne diarrhoea. For instance, in Thailand, where figures are high compared with other Asian countries, there were no reported cases of foodborne diarrhoea prior to 1976, and reported figures increased 7-fold from 1976 to 1979. The Dominican Republic and El Salvador clearly must have some foodborne diarrhoea although

Table 1. Total reported outbreaks, cases and deaths from bacterial foodborne diarrhoea in selected developed countries

Country (year)	Number of outbreaks	Number of cases	Number of deaths	References
Australia (1976)	-[a]	346	-	47
Canada (1973-77)	555[c]	4 791[c]	2[c]	72-73
England & Wales (1970-79)	646[c]	9 455[c]	-	38, 59
England & Wales (1981)	-	10 665	44[b]	19
England & Wales (1983)	588	15 168	42[b]	20
Japan (1963-78)	676[c]	21 606[c]	9[c]	46
The Netherlands	-	-	-	8
(1979)	-	6 498	-	
(1980)	-	7 169	-	
New Zealand (1976)	-	480	-	47
Scotland (1973-80)	618[c]	152[c]	3[c]	62
USA (1979)	112	6 797	6	13
USA (1982)	130	5 471	19	49

[a] No information reported

[b] *Salmonella*-related deaths only

[c] Annual average

Table 2. Proportion of bacterial foodborne diarrhoea outbreaks, of known etiology and location, that occur in the home for selected developed countries[a]

Country Year Reference	CANADA (1973-77) 72	ENGLAND & WALES (1970-79) 59	JAPAN (1963-78) 46	THE NETHERLANDS (1979) 8	 (1980)	SCOTLAND (1973-80) 62	USA (1979) 13	 (1982) 49	TOTAL (by pathogen)
Pathogen									
B. cereus	-[b]	8%[c] (53)	-	-	-	0% (11)	-	0% (8)	6%
C. jejuni	-	-	-	-	-	-	-	50% (10)	50%
C. perfringens	-	6% (387)	-	-	-	4% (83)	20% (15)	0% (22)	6%
E. coli	-	- (3)	19% (325)	-	-	-	-	0% (2)	19%
Salmonella spp.	-	21% (396)	46% (1010)	-	-	8% (173)	31% (32)	22% (55)	35%
Shigella	-	-	-	-	-	-	43% (7)	25% (4)	36%
S. aureus	-	30% (132)	42% (2743)	-	-	18% (11)	50% (22)	14% (28)	41%
Streptococci - group A,D,G	-	-	-	-	-	-	0% (1)	0% (1)	0%
V. cholerae non-01	-	-	-	-	-	-	100% (1)	100% (1)	100%
V. parahaemolyticus	-	- (8)	45% (5901)	-	-	-	100% (2)	33% (3)	45%
Y. enterocolitica	-	- (1)	-	-	-	-	-	50% (2)	33%
Total (by country)	33% (190)[d]	16% (980)	44% (9979)	37% (105)[e]	8% (215)[f]	7% (278)	38% (80)	18% (130)	

[a] Percentages are the proportion of all bacterial foodborne diarrhoea outbreaks, of known etiology and location, that occur in the home; numbers in parentheses are the total number of bacterial foodborne diarrhoea outbreaks of known location, except where noted otherwise.

[b] No information.

[c] Includes *Bacillus* spp.

[d] Included in addition to these pathogens are outbreaks due to *Brucella abortus* (1 outbreak), *Clostridium botulinum* (24 outbreaks), suspect *Pseudomonas aeruginosa* (1 outbreak), and suspect yeast and molds (29 outbreaks).

[e] Includes 32 of the above pathogens, 9 chemical agents, and 64 outbreaks of unknown etiology.

[f] Includes only 53 of the above pathogens, 11 chemical agents, and 151 outbreaks of unknown etiology.

there are no reported cases. Table 3 shows how little is known about the magnitude of foodborne diarrhoea in the developing countries and indicates which countries are beginning to make efforts to document the problem.

Table 3. Total reported cases of foodborne diarrhoea in selected developing countries

Country (year)	Total reported cases	Reference
Argentina (1974)	83	14
Dominican Republic (1974)	0	14
El Salvador (1974)	0	14
Fiji (1976)	54	47
Malaysia		
(1970-79)	470	42
(1979)	641	
Martinique (1974)	30	14
Mexico (1974)	225	14
Nicaragua (1974)	6	14
Panama (1974)	24	14
Philippines (1976)	860	74
Singapore (1977)	624	58
Surinam (1974)	20	14
Thailand (1979)	12 741	15
Bangkok(1979)	885	
Non-Bangkok (1979)	11 856	
Tonga (1976)	17	47 47
Western Samoa (1976)	17	47

It seems probable that, in these countries, most food is prepared and consumed in the home, particularly in low-income households. Thus, the home may be responsible for the large majority of all foodborne diarrhoea outbreaks. Even in urban and middle-income areas, much of the food, particularly for the young child, is likely to be prepared and consumed in the home.

In the absence of field data, indirect estimates may be made of the proportion of diarrhoea that is foodborne in developing countries. There is a theoretical upper limit to the proportion of diarrhoea that is foodborne since rotavirus and other viral agents of diarrhoea are not usually associated with food and can account for a substantial proportion of total diarrhoea. It has been estimated that rotavirus accounts for 6% of diarrhoea cases and 20% of diarrhoea deaths among children under 5 years of age in developing countries (23).

All bacterial and parasitic agents of diarrhoea can be transmitted by vehicles other than food. Transmission associated with deficiencies in water supply, sanitation, and personal hygiene is of major importance, and other reviews in this series have evaluated the impact on diarrhoea rates of interventions to limit these non-food transmission routes. Interventions to improve water supply and sanitation may reduce diarrrhoea incidence rates by 16-37% (29) and hygiene education may cause a reduction of 14-48% (31). Fly control appears to be ineffective in most settings (S.A. Esrey, in preparation). Control of zoonotic reservoirs appears to play only a minor role, particularly among young children (D. Silimperi, in preparation).

On the basis of the predicted impacts of controlling transmission associated with poor personal hygiene, and water supply and sanitation, food as a vehicle may contribute to the transmission of between 15 and 70% of all diarrhoea episodes. This range is so wide as to be of little value, but the available data do not permit more precise estimates. It must be stressed that, especially within the home, there are likely to be numerous interconnections and interactions among factors such as water, sanitation, flies, animals, personal hygiene, and food that are responsible for diarrhoea transmission.

Concerning the sub-hypothesis that foodborne diarrhoea must be of sufficient proportion to effect a detectable reduction in total diarrhoea morbidity or mortality rates, it is plausible, though unconfirmed, that foodborne diarrhoea constitutes a sizable proportion of all diarrhoea among children in developing countries. It is also likely, though not demonstrated, that most foodborne transmission in developing countries takes place within the home.

<u>Inadequate food hygiene and its role in foodborne diarrhoea</u>

In view of the second sub-hypothesis, which states that inadequate food hygiene is an important cause of foodborne diarrhoea, it is appropriate to concentrate in this paper on preparation, handling, and storage practices in the home. Although in some settings in some countries, public or commercial food outlets (such as street vendors) also play a major role, the majority of children under 5 years of age may be little affected by these food outlets because infant and child foods are mainly prepared and stored within each individual household.

Many specific deficiencies in food hygiene can contribute to the transmission of pathogens in developed countries. Some outbreaks, particularly those in which a pathogen has been identified, can be categorized according to the incriminated food handling, preparation, or storage practices. Specific pathogens may be associated with specific food hygiene practices. In the USA in 1982, the 5 most common practices responsible for bacterial foodborne diarrhoea outbreaks, in order of frequency, were (i) improper holding temperature, (ii) inadequate cooking, (iii) poor personal hygiene by food handlers, (iv) contaminated equipment, and (v) an unsafe source of food (Table 4).

Table 4. Bacterial foodborne diarrhoea outbreaks, by contributing food hygiene practice, USA, 1982[a]

Bacterium	Contributing food hygiene practice					
	Improper holding temperature	Inadequate cooking	Contaminated equipment	Food from unsafe source	Poor personal hygiene	Other
B. cereus	5				1	
C. jejuni				1		1
C. perfringens	19	8	3			2
E. coli	1					
Salmonella	16	18	6	6	7	4
Shigella	1				4	
S. aureus	20	3	4	1	9	1
Streptococcus	1				1	
V. cholerae non-01		1				
V. parahaemolyticus				2		
All bacteria	63	30	13	10	22	8

[a] Data (49). Numbers are number of outbreaks.

The relationship between the transmission of specific pathogens and food hygiene practices is even less well understood in developing countries. Table 5 shows those practices by which transmission of pathogens (indicated by a plus symbol) could have occurred. The published literature deals more with the relationship between food hygiene practices and the presence or concentration of indicator organisms in the food than with the association between food hygiene practices and diarrhoea outbreaks or rates. Aerobic plate counts indicate the overall level of microbial activity. Several types of indicator organism are commonly used and include those that are specifically indicators of faecal contamination (such as *E. coli*, faecal coliforms, enterococci, faecal streptococci and the *Enterobacteriaceae* in general) and those that indicate bacterial contamination that is not necessarily of faecal origin (such as *Staphylococcus*, *Pseudomonas aeruginosa*, and total coliforms). For studies of diarrhoea, only faecal indicator organisms are truly relevant. Unfortunately, there is a scarcity of information about faecal indicators in home-prepared foods in developing countries and almost no data on the relationships between the concentration of faecal indicator organisms and the presence of specific pathogens.

Table 5. Food hygiene factors and food contamination in selected developing countries

Country	Bangladesh	El Salvador	Ethiopia	The Gambia		Guatemala	India
Reference	10	67	44	60	7	12	52
Indicator organisms examined	E. coli	E. coli E. intermedia	Enterotoxigenic bacteria	B. cereus Cl. welchii E. coli S. aureus	B. cereus Cl. welchii E. coli S. aureus	S. faecalis Bacillus spp. E. coli Klebsiella spp. Staph. spp. Total coliforms	E. coli Salmonella Shigella S. aureus
Food hygiene factors							
Handling practices							
Infected person							+
Contaminated raw food			+	+		+	
Cross contamination							
Contaminated equipment				+			
Contaminated water	+	+		+		+	+
Unsafe source			+				
Preparation practices							
Inadequate cooking	+	+		+	+	+	+
Inadequate reheating				+		+	
Inadequate cooling							
Extra large quantity prepared		+					+
Storage practices							
Failure to keep at high enough temperature							
Lapse of time between preparation and serving		+	+		+	+	+
Food left at ambient temperature	+	+		+	+	+	
Use of leftovers							

[a] A plus symbol indicates those practices by which transmission of pathogens could have occurred. Other practices were not necessarily investigated.

Table 5. Food hygiene factors and food contamination in selected developing countries (continued)

Country	India	Indonesia	Kenya	Nigeria	Philippines	Uganda
Reference	64	69	75	28	36	57
Indicator organisms examined	B. cereus Coliforms Staphylococci Total bacteria	aerobic counts anaerobic counts	Enterobactericeae S. aureus	E. coli Klebsiella spp. P. mirabilis Salmonella Shigella S. aureus S. epidemialis	Enterobacteriaceae S. aureus	E. coli
Food hygiene factors						
Handling practices						
Infected person					+	
Contaminated raw food	+					
Cross contamination						
Contaminated equipment				+		+
Contaminated water			+		+	
Unsafe source						
Preparation practices						
Inadequate cooking		+			+	+
Inadequate reheating						
Inadequate cooling						
Extra large quantity prepared					+	
Storage practices						
Failure to keep at high enough temperature						
Lapse of time between preparation and serving			+	+		
Food left at ambient temperature			+	+		
Use of leftovers						

[a] A plus symbol indicates those practices by which transmission of pathogens could have occurred. Other practices were not necessarily investigated.

Faecal indicators do not necessarily mean that pathogens are present. In the following discussion, we use the terms "contaminated food" or "contamination" to indicate the presence of microbial activity that is either faecal or non-faecal in origin. Thus, contaminated food may or may not contain pathogenic enteric bacteria. The term "pathogen-containing food" indicates the presence of a known pathogenic agent of diarrhoea. It must be kept in mind that raw food, hands, utensils, and surfaces are seldom sterile and that contamination of ingested food is therefore the rule not the exception.

Studies in developing countries have indicated that contamination of raw food, utensils, and water used in food preparation occurs regularly. Undercooking, failure to reheat previously cooked food, and preparation of the day's meals well in advance of consumption (because of time constraints, fuel scarcity, and fuel cost) also contribute to the contamination of food. Storage practices, such as leaving food at ambient temperature, also play a major role. Many of these factors are related. Thirteen studies link various food hygiene practices with indicator organisms in food in developing countries (Table 5). A discussion of the different practices of handling, preparing, and storing food is presented below, making inferences from these and other reports.

Handling practices. The contamination of the hands of mothers and children has been investigated. In India (52), there was no significant difference in the proportion of low-income mothers (42%) and high-income mothers (44%) with contaminated hands. In the Philippines (36), a high proportion of mothers' and children's hands were contaminated with S. aureus and Enterobacteriaceae. Although S. aureus commonly occurs on the skin and mucous membranes and is difficult to remove, usually less than 50% of people in temperate areas carry this organism (39).

Efforts to promote hand-washing, particularly among young children, have been reviewed elsewhere (31). A reduction in the incidence of diarrhoea of 14-48% may be expected from using this practice, but in the studies reviewed, hand-washing was carefully monitored, and such reductions may not always be realized.

It has been copiously documented that the infectious agents of diarrhoea can be found in foods. Bacterial pathogens present at high levels in raw food may survive cooking in sufficient quantity to lead to the ingestion of an infectious dose (see below). Fruits and vegetables may be infected by a range of bacterial and protozoal pathogens. Such infection is especially likely to occur if the crops have been fertilized with raw or partially treated sewage or nightsoil. This practice is common in some countries and is becoming more widespread (11). Undercooked meats and unprocessed milk can transmit both zoonotic and anthroponotic pathogens.

In Guatemala, dry maize used to prepare tortillas had an average bacterial count of 10^5/g (12). In the Gambia, millet flour was reported to have a bacterial count of 10^9/g (60). In Nigeria, local weaning food, powdered milk samples, and raw foods such as rice, wheat, and beans had bacterial counts of up to 10^6/ml (27). Whether these high bacterial counts are a cause for concern is not known because no information on the presence or absence of pathogens can be inferred from bacterial counts.

Milk products used for infants, however, have been demonstrated to contain pathogens. In the USA, Salmonella newbrunswick was isolated from instant non-fat dried milk (18), which had been contaminated after drying. In Austria, Salmonella isangi was isolated from a powdered infant milk that infected 18 known infants (70). In India, B. cereus and S. aureus were isolated from dried and reconstituted milk products (64). In Nigeria, several enteric pathogens, most commonly enteropathogenic E. coli, were isolated from commercial milk formulas in bottles and from teats (16). Enteric pathogens were isolated more frequently from traditional weaning gruels, which often contained commercial milk formulas, than from commercial milk formulas alone.

It may not always be possible to eliminate or reduce the levels of contamination in raw food. A study in Lebanon (1) evaluated the effectiveness of reducing the contamination of fruits and vegetables by washing. In general, washing was not effective in reducing the number of samples positive for various bacteria, including E. coli. For instance, 50% of washed lettuce samples, but only 29% of unwashed samples, were positive for E. coli. Vegetables were washed using tap water, but the tap water had not been tested for the presence of E. coli. For parsley also, a greater proportion of washed samples was positive.

Street vendors have been shown to be carriers of pathogens or to sell food that is contaminated (43, 44, 71, 76). Even though young children may not consume food from street vendors, they may be affected if other family members become ill after ingesting infected food acquired from this source.

Indicator organisms, and in some instances pathogens, have been isolated from the equipment and utensils used to prepare and consume foods. For instance, in the Gambia, children's empty feeding bowls had total viable counts of 10^{5-6} bacteria (60). These bowls had been washed with fresh well water, scrubbed with palm leaves, and left to dry in the sun.

Cross-contamination can readily occur when an organism has entered the kitchen environment in uncooked food (45). Non-pathogenic E. coli K12 was experimentally introduced to homes through frozen chickens (22). An analysis of swabs taken from utensils, preparation areas, and towels after the chickens had been prepared in the kitchens showed that E. coli K12 was ubiquitous. A comparison was also made of objects that had been cleared (but not washed-up) or washed-up after preparation. After clearing, 64% of kitchens were found still to be contaminated with E. coli K12, compared with 37% after washing-up.

Four methods of sterilizing cups, spoons, bottles, and teats were studied in Uganda (57). The methods were: boiling utensils for less than 5 minutes, boiling utensils for more than 5 minutes, washing utensils in boiling water, and soaking utensils in hypochlorite. The method of infant feeding was more important in reducing bacterial counts than sterilization itself. Unsterilized cups and spoons were less contaminated than sterilized bottles and teats. Attempts to sterilize, despite the inconsistency and inadequacy of the methods used, helped to reduce contamination. In Nigeria (28), a comparison of different methods of sterilizing teats used by literate and illiterate mothers revealed that the use of detergents and hypochlorite was more effective than detergents with or without hot water, or detergents with salt water. Literacy had little effect unless detergents and hypochlorite were used, and then it was beneficial.

Pathogens such as Salmonella can persist on utensils for several hours, even if the utensils are dry (22). Twenty per cent of swabs taken from kitchen utensils in hospitals, restaurants, and canteens in England revealed E. coli, Ps. aeruginosa, and Klebsiella (63). In Australia, Salmonella was often found on abattoir workers' hands (66), knives (56), cutting boards, tables, and gloves (65). In the kitchen areas of English homes, Enterobacteriaceae were found in a wide variety of locations (sinks, floors, cutting boards, and food shelves), although most of the isolates were considered non-pathogenic (61). Recent work in the Dominican Republic, Peru, and Thailand has also demonstrated the ubiquity of bacteria on utensils and foods in cooking areas (F. Bryan, personal communication).

Contaminated water may play a significant role in the contamination of food. Of the 7 studies examining this issue (Table 5), all reported that water used for the preparation of food was contaminated (10, 12, 36, 52, 60, 67, 75). When milk was reconstituted with boiled well water, it was less contaminated than when unboiled well water was used (60). Similar findings were reported in the Philippines (36) and India (52). The provision of water of improved quality has been reviewed (29) and it was concluded that it may result in a 17% reduction in diarrhoea incidence. Whether some of this reduction is mediated through the consumption of less contaminated food is not known. In studies that compared contamination levels of food and water, food was more contaminated. In Bangladesh (10), the geometric mean colony count of E. coli was 7 times higher in prepared food than in water. In El Salvador (67), 18% of 520 different food samples were contaminated with E. coli or E. intermedia compared with 10% of chlorinated water samples from a central system.

In summary, poor food handling practices contribute to the contamination of food. Efforts to promote hand-washing and cleansing of utensils may result in reduced contamination. Cups and spoons are likely to be less contaminated than bottles and teats. Efforts to clean the food preparation area may reduce cross-contamination. Unfortunately, contamination is often defined in the literature in terms of total bacterial counts, and there is scant information on the concentrations of faecal indicators or pathogens. In the Philippines, E. coli was isolated from vegetables and meat, but no samples contained enterotoxigenic E. coli (26). In the USA, no differences in total aerobic counts, coliforms, or enterococci were found when chickens positive for Salmonella spp. were compared with chickens that did not yield Salmonella spp. (77). In Brazil, a study of 7 foods failed to show an association between the presence of S. aureus and faecal indicator organisms (53). Contamination may, therefore, have little or no health significance.

Preparation practices. Freshly prepared foods may be highly contaminated because the foods are undercooked or inadequately reheated. In Guatemala, freshly prepared tortillas had 10^3 total bacteria/g (12). In the Philippines (36), the majority of foods examined (milk, rice, and rice plus other food) were contaminated with S. aureus and Enterobacteriaceae.

Inadequate reheating of foods allows bacteria not only to survive but also to proliferate, particularly if the food is stored at ambient temperature. In Guatemala (12), tortillas reheated after 24 hours at ambient temperature contained 10^5 bacteria/g, and after 48 hours had counts of 10^7/g. Although in both instances the bacterial counts decreased compared with the counts just prior to reheating, they were nonetheless high.

Some cooking methods do not eliminate bacterial contamination of food. In the Gambia (7), steamed foods were less contaminated than boiled foods during the wet season (7.1% vs 10.5%, respectively), but not in the dry season (2.5% vs 0.0%). Foods were considered to be contaminated if they met the following criteria: 10^4 B. cereus/g, 10^3 Cl. welchii/g, 3×10^2 S. aureus/g, or E. coli in 0.1 g or less. In this study, simmering of gruels did not eliminate contamination (60). Dried lake fish had a lower total coliform count than fresh marine fish in the Nairobi market (9).

Storage practices. In the developing countries, where refrigeration facilities are usually lacking, foods have to be stored at ambient temperature, allowing bacterial pathogens to proliferate. Since some freshly cooked foods are contaminated, the practice of storing foods for consumption later in the day may be particularly unsafe. Furthermore, the storage of pathogen-containing cooked foods may deposit pathogens on kitchen surfaces, which can then contaminate other foods and utensils.

In the Gambia (7), foods were examined at various intervals (up to 8 hours) after preparation. The percentage of samples containing unacceptable levels of contamination (defined above) increased from 35% at 0-1 hour after preparation to 96% at 8 hours in the wet season. The corresponding figures for the dry season were 7% and 71%. Other reports of bacterial multiplication during storage come from Bangladesh (10, 12, 52, 75), India (52), and Kenya (75). These studies suggest that storage for longer than 3 hours is associated with marked increases in bacterial counts. Clearly, food that is prepared for one meal should be consumed as quickly as possible after cooking. Ideally, only sufficient food for one meal should be prepared at a time. However, this requires that food be prepared and cooked more often, which may be costly and impractical because of the scarcity of time and fuel.

Failure to improve storage practices may partly or wholly offset the benefits of improvements in handling and preparation. Improved food storage practices may be expected to have a larger impact on the transmission of bacterial pathogens with a high infectious dose (such as E. coli or Salmonella) than of those with a low infectious dose (such as Shigella). Storage is unlikely to have any effect on the transmission of viral and protozoal enteric pathogens, which cannot multiply in food.

In summary, we may conclude that food in developing countries is frequently contaminated and that this contamination may be linked to specific food hygiene practices. However, we know almost nothing about the link between food hygiene practices and either the presence and concentration of enteric pathogens in food or the risk of diarrhoea.

Hypothesis 2: Food handling, preparation, and storage practices can be improved by appropriate educational and legislative measures.

In theory, one can imagine a variety of policies and approaches towards improving food hygiene in the developing countries. In particular, food-related educational information can be disseminated through multiple channels, such as radio, newspapers, posters, clinicians, and village health workers. We are aware of only one study, in Bangladesh, that reported on an attempt in several villages to increase hand-washing prior to preparing food (68). The prevalence of hand-washing decreased following the intervention compared with the baseline period, but the decrease in the control group was even larger. We are aware of no evidence that food hygiene practices have been changed at the local or national level by promotional campaigns and educational activities launched by governmental agencies. Public education to alter behaviour in such fields as oral rehydration therapy, family planning, smoking, and AIDS has succeeded in some countries, and there is evidence of the effectiveness of some weaning education programmes (5). It is perfectly plausible, therefore, that carefully designed programmes to bring clear and feasible messages about food hygiene to mothers could lead to changes in food hygiene in the home. Unfortunately, we have little epidemiological basis for the selection of these messages.

Hypothesis 3: Appropriate educational and legislative measures to improve food handling, preparation, and storage practices can reduce diarrhoea morbidity or mortality rates among young children.

Few data are available that associate different hygiene practices with diarrhoea rates among young children. Some evidence suggests that food contamination plays an important role in increasing diarrhoea rates. For instance, secondary attack rates among household contacts of index cholera cases in Bangladesh are higher when the index case is an adult female (presumably the food preparer) than when the index case is not (51, 55). Furthermore, diarrhoea rates tend to rise at the age when supplementary foods are introduced (7, 10), and they may peak during the season when food contamination levels are highest (7).

A few studies have investigated the links between food hygiene practices and diarrhoea. In a peri-urban slum area near Santiago, Chile, the presence or absence of acute diarrhoea among children under 7 years of age was not related to the cleanliness of kitchen utensils, presence of food leftovers, or frequency of hand-washing (2). In Micronesia, consumption of food prepared by a food handler who had recently had diarrhoea was a risk factor for diarrhoea and cholera (40). In Uganda (57), when mothers attempted to sterilize utensils, 49% of infants had diarrhoea severe enough to warrant a visit to a doctor or clinic. The corresponding figure in the group that did not sterilize utensils was 69%. Sterilization was defined as boiling utensils, washing them in water that had been boiled, or soaking them in hypochlorite. In Bangladesh (17), the risk of diarrhoea was less if hands were washed prior to preparing food than if they were not.

Other studies have investigated possible associations between levels of food contamination and diarrhoea. In Bangladesh, a significantly positive correlation (r=0.35) between the proportion of a child's food samples containing E. coli and the annual incidence of enterotoxigenic E. coli diarrhoea was reported (10). No significant correlation was found for diarrhoea due to rotavirus, Shigella, and all causes whether known or unknown. By contrast, a study in the Philippines (36) reported no significant relationship between food contamination and the percentage of days with diarrhoea in the week following bacteriological testing of food. Negative findings have also been reported from Indonesia (69) and the Gambia (48).

In Mexico, newly arrived American students were more likely to have diarrhoea if at least half their meals were taken in cafeterias, restaurants, or from street vendors than if they ate at home at least 50% of the time (71). This association was not found among students who had lived in Mexico for at least one year. E. coli counts, from cooked and uncooked foods, were high in food samples from restaurants, street vendors, and small grocery stores. No foods from students' homes were sampled. In another study in Mexico (76), however, the percentage of students with diarrhoea increased as the percentage of food consumed in the home increased.

The results of these studies are somewhat contradictory. Both contaminated and pathogen-containing foods have sometimes, but not always, been associated with increased diarrhoea rates. There are several possible reasons for this finding. First, overall diarrhoea rates may not change when foodborne diarrhoea is reduced. There are two situations in which this would occur: (i) in areas where diarrhoea morbidity rates are low, as in the study in the Philippines (36), a reduction in diarrhoea might be too small to measure; and (ii) reductions in diarrhoea due to a specific pathogen may not be reflected in overall diarrhoea rates (10). Although in both instances foodborne diarrhoea may be reduced, it may be difficult to detect a reduction in overall diarrhoea rates. Second, some studies have measured food contamination by bacterial indicators that are not specifically faecal. There is no reason to suppose that contamination measured in this way is correlated either with faecal pathogens or with risk of diarrhoea. Where faecal indicators such as E. coli have been used, faecal contamination may be inferred, but the correlation, if any, with the presence of faecal pathogens remains to be demonstrated. Third, host immunity may prevent infection from occurring even when pathogens are ingested. In areas where children are continually exposed to the same pathogens, diarrhoea incidence may not fall even if foodborne transmission is reduced. Fourth, since diarrhoea is transmitted by many routes, a reduction in food contamination may be offset by the ingestion of pathogens from other sources (such as water, hands, dirt, or objects). This would pertain particularly to the weaning child who is beginning to move about and coming into closer contact with a contaminated environment.

FEASIBILITY AND COST

The feasibility and cost of promoting food hygiene in the developing countries are difficult to assess. It is by no means clear what type of food hygiene programme would be most likely to reduce childhood diarrhoea rates. There is a lack of documented experience from developing countries of the various educational and legislative measures that could be taken. Very few governments have launched programmes in this area, and no evaluations of such programmes have been reported.

CONCLUSIONS

The paucity of firm evidence from developed countries, and the even greater lack of information from developing countries, means that conclusions about the role of food hygiene promotion in diarrhoea control must be extremely tentative. The limited evidence is fully consistent with the possibilities that a substantial proportion of the diarrhoea episodes among young children in developing countries are foodborne and that foodborne transmission is related to specific deficiencies in food hygiene, including handling, preparation, and storage.

There is no evidence of which we are aware that food hygiene practices can be changed at the national level by promotional campaigns and educational programmes launched by governmental agencies. However, there is evidence of the effectiveness of weaning education programmes (5), and public education in such fields as oral rehydration therapy, family planning, and smoking has succeeded in some countries. It is plausible, therefore, that carefully designed programmes to bring clear and feasible messages about food hygiene to mothers could lead to a change in food hygiene practices. Whether such a change would lead to a measurable fall in diarrhoea incidence rates remains an important question for research.

In view of these numerous uncertainties, and the prospect that interventions to promote food hygiene practices may be of considerable importance in the control of diarrhoeal diseases, a well-planned programme of research is urgently needed. The

Diarrhoeal Diseases Control Programme of the World Health Organization has identified the following research priorities. First, studies are required to determine food preparation, handling, and storage techniques and feeding methods that are associated with an increased or decreased risk of faecal contamination of foods. In most instances, it will not be possible to relate these practices to the risk of contamination of foods with specific diarrhoeal pathogens or to the risk of diarrhoea. It is suggested, therefore, that the enumeration of indicators of faecal contamination be used as evidence for the potential of the foods to transmit diarrhoeal diseases. The aim of these studies should be to identify the practices that are likely to be associated with increased or decreased diarrhoeal incidence and that can be targeted by diarrhoeal disease control programmes. The laboratory work generated by the risk factor studies will require careful standardization of techniques and preparation of field and laboratory staff. Second, and of highest priority, are intervention studies designed to measure the impact of promoting specific changes in food preparation, handling, and storage practices and feeding methods which aim to reduce the faecal contamination of foods. These studies should measure the impact on behaviour, and if possible on growth and diarrhoeal morbidity, and should be conducted in various cultural, socioeconomic, and environmental settings.

This programme of research will take several years and will require strong central planning and leadership. To be successful, it will require a multi-disciplinary approach, in which experts in epidemiology, nutrition, microbiology, the social sciences (especially medical anthropology and economics), and communications work together as equal partners. It is a priority area for diarrhoeal disease control and deserves to be adequately funded and vigorously implemented.

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