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# FOOD SAFETY ISSUES

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## **Food technologies and public health**

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**FOOD SAFETY UNIT  
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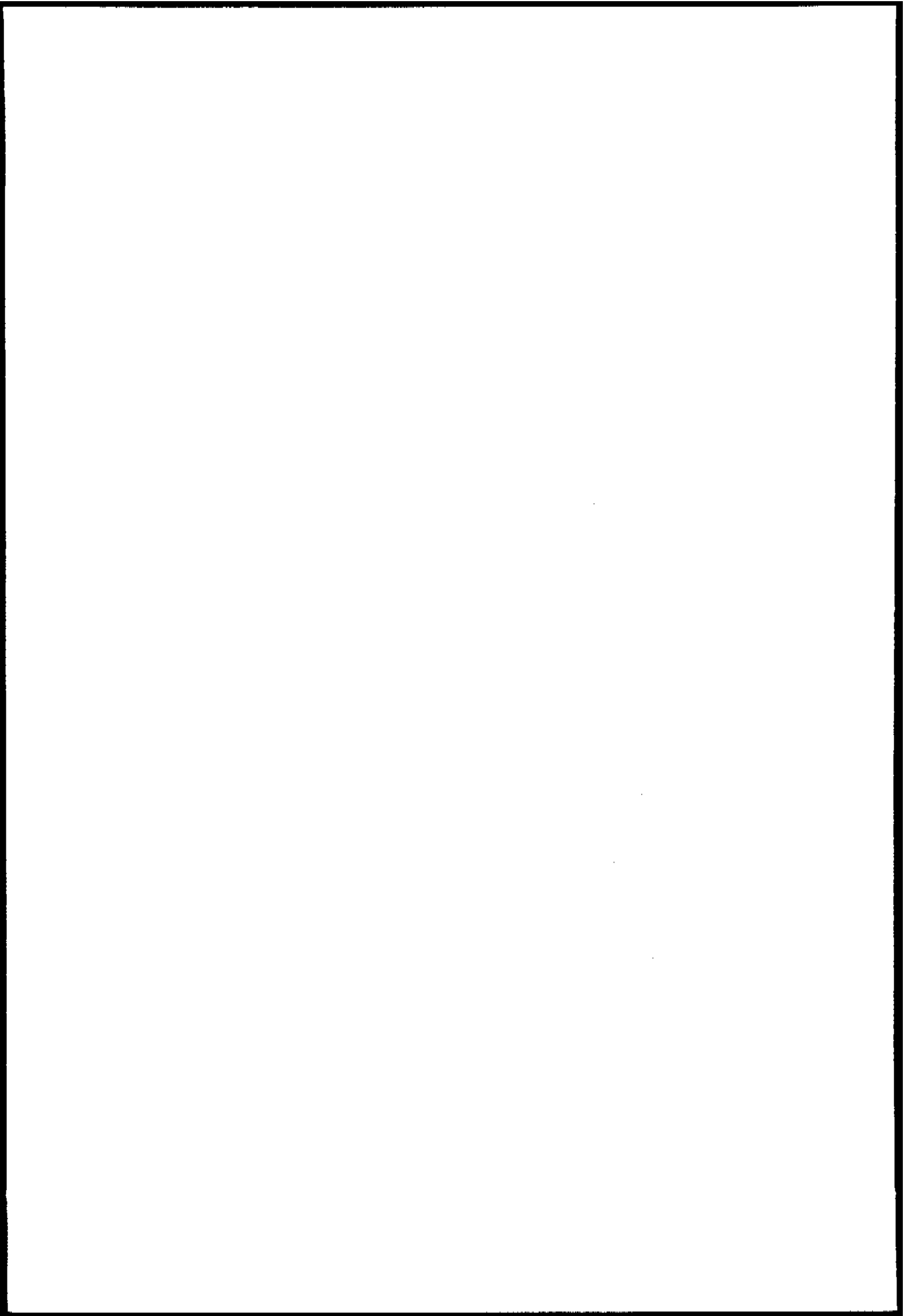
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# Food Technologies and Public Health

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## FOOD TECHNOLOGIES AND PUBLIC HEALTH

*Since the dawn of history, food technologies have played a vital role in the life and survival of human kind. Recent advances in this area have made this science indispensable for health and socioeconomic development. In spite of this, the importance of food technologies in the prevention of diseases, and subsequently health, remains largely unrecognized in most public health circles, and at times they are even thought to be the cause of foodborne diseases.*

*This paper highlights the contribution of food technologies to health from the perspective of food safety and underlines the need to consider them as "health technologies" in their own right.*

### 1. Introduction

Health technologies may be divided into those for curative and preventive purposes. In the latter group, a number of food technologies play a fundamental role, and one which unfortunately is not always recognized in public health circles.

Food technologies play a pivotal role in improving the nutritional quality of food, ensuring its safety, and preventing foodborne disease. They reduce losses due to spoilage or contamination, and are thus vital in the prevention of malnutrition and starvation.

Food technologies also have important socioeconomic implications. They facilitate and promote trade in food, provide employment for a large section of the population, facilitate the work of women in preparing the family's food, and give them the opportunity to participate fully in social life. They increase the consumer's pleasure and provide a greater choice of products.

The role of food technologies in life and health is broad. This paper describes the nature and extent of foodborne diseases and highlights the contribution of food technologies in their prevention.

## 2. Burden of foodborne disease

Diseases caused by contaminated food<sup>1</sup> constitute one of the most widespread health problems and are an important cause of reduced economic productivity (1). The majority of foodborne diseases are caused by biological agents, i.e. bacteria, viruses and parasites (see Box 1) and are manifest with gastrointestinal symptoms such as diarrhoea (watery, bloody or persistent), abdominal pain, nausea and vomiting. Infections caused by pathogens such as *Vibrio cholerae*, *Escherichia coli*, *Campylobacter jejuni*, *Salmonella* spp, *Shigella* spp, *Entamoeba histolytica*, *Cryptosporidium* spp, and rotavirus have diarrhoea as the major clinical symptom, and are therefore also known as *diarrhoeal diseases*.

**Box 1. Pathogenic organisms of public health importance which may be transmitted through contaminated food**

<b>Bacteria</b>	<b>Protozoa</b>
<i>Bacillus cereus</i>	<i>Cryptosporidium</i> spp
<i>Brucella</i> spp	<i>Entamoeba histolytica</i>
<i>Campylobacter jejuni</i>	<i>Giardia lamblia</i>
<i>Clostridium botulinum</i>	<i>Toxoplasma gondii</i>
<i>Clostridium perfringens</i>	
<i>Escherichia coli</i> spp (pathogenic strains)	<b>Trematodes</b>
<i>Listeria monocytogenes</i>	<i>Clonorchis sinensis</i>
<i>Mycobacterium bovis</i>	<i>Fasciola hepatica</i>
<i>Salmonella typhi</i> and <i>paratyphi</i>	<i>Fasciolopsis buski</i>
<i>Salmonella</i> (non-typhi) spp	<i>Opisthorchis felineus</i>
<i>Shigella</i> spp	<i>Opisthorchis viverrini</i>
<i>Staphylococcus aureus</i>	<i>Paragonimus westermani</i>
<i>Vibrio cholerae</i>	
<i>Vibrio parahaemolyticus</i>	<b>Cestodes</b>
<i>Vibrio vulnificus</i>	<i>Diphyllobothrium latum</i>
<i>Yersinia enterocolitica</i>	<i>Echinococcus</i> spp
	<i>Taenia solium</i> and <i>saginata</i>
<b>Viruses</b>	
<i>Hepatitis A virus</i>	<b>Nematodes</b>
Norwalk agents	<i>Anisakis</i> spp
Poliovirus	<i>Ascaris lumbricoides</i>
Rotavirus	<i>Trichinella spiralis</i>
	<i>Trichuris trichiura</i>

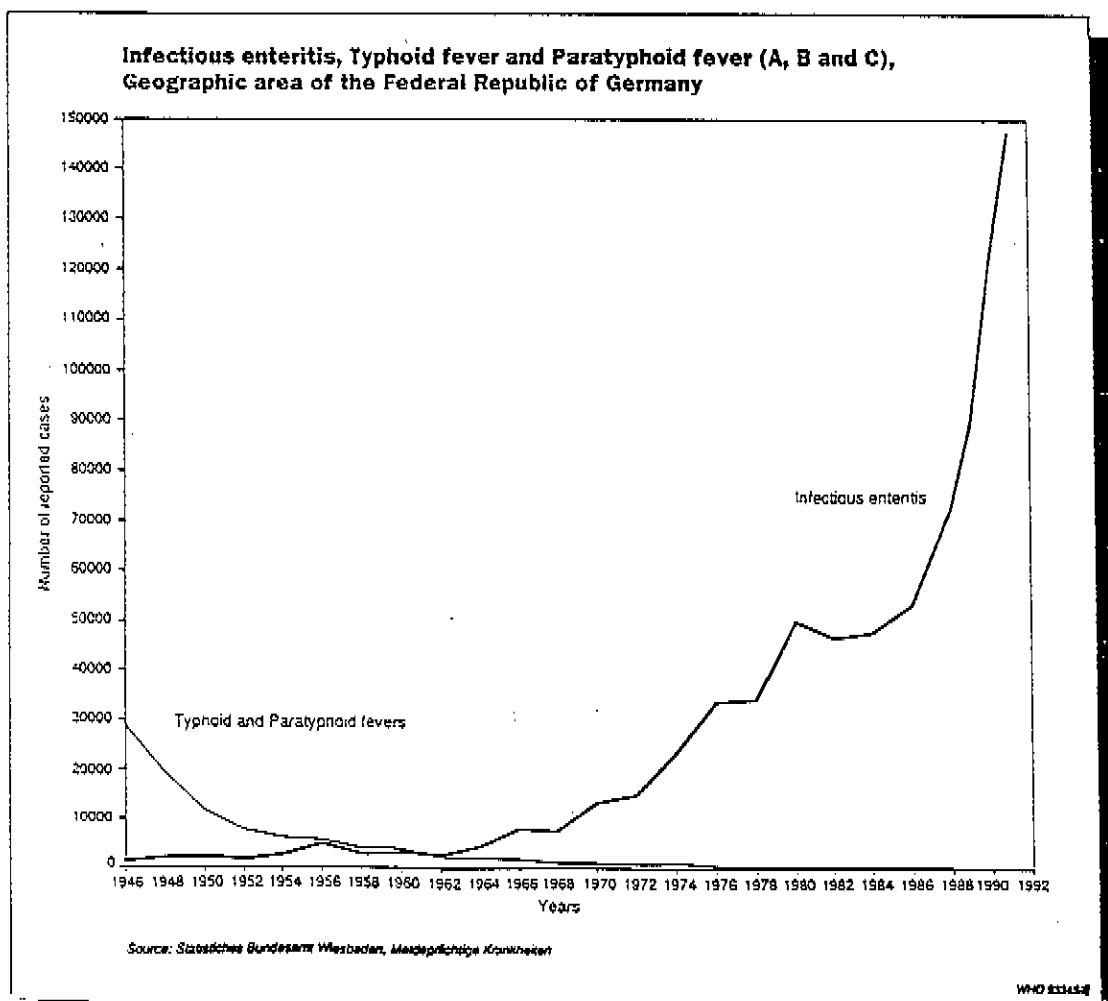
<sup>1</sup> including drinking-water

The variety and extent of foodborne diseases are such that no country is able to provide accurate data on their incidence or prevalence, and surveillance programmes, where they exist, mostly collect information on only a low number of incidences. It is therefore not possible to give any global estimate of the real magnitude of the problem. In some cases, the etiology is multifactorial in nature and disease becomes manifest only after a long period of exposure, as in the case of certain cancers. Consequently, many of the health problems resulting from food contaminants do not figure in statistics on foodborne disease.

Furthermore, even when there is a reporting system, only a small proportion of episodes of foodborne diseases ever comes to the attention of public health authorities. In industrialized countries, reported cases probably account for less than 10% of real incidence, but in developing countries underreporting is much higher, and it is estimated that less than 1% of foodborne disease episodes are notified (1).

A wide range of foodborne diseases are prevalent in developing countries. These include: cholera, salmonellosis, campylobacteriosis, shigellosis, typhoid, poliomyelitis, brucellosis, amoebiasis and *E. coli* infections. Although the real magnitude of the problem is unknown, statistics available from a few of these show an increasing trend (Figure 1).

Figure 1



Diarrhoeal diseases are a major cause of morbidity and mortality in infants and children under the age of five and, on average, children in developing countries suffer 2 - 3 episodes of diarrhoea per year, in some cases as many as 10 episodes. Up to 70% of such episodes in children under the age of five have been attributed to contaminated food. Weaning foods contaminated with pathogenic strains of *E. coli* are considered as the cause of 25-30% of diarrhoeal disease episodes in developing countries (2). A serious consequence of diarrhoeal disease is the effect on the nutritional status and immune systems of infants and children. Repeated episodes lead to a reduction in food intake, aggravated by loss of nutrients due to malabsorption and vomiting, fever and impaired resistance to other infections (often respiratory), and the child becomes caught up in a vicious cycle of malnutrition and infection. Many do not survive under these circumstances, and some 13 million children under the age of five die each year in this way (2).

The elderly and the immunosuppressed are also very susceptible to the health effects of foodborne infections, and case fatality rates, for example of salmonellosis, are significantly higher (as much as 10 times) in this population group (2,3).

The problem is not limited to the developing countries but is also considerable in industrialized countries. [The annual incidence of foodborne disease in the United States of America (USA) has been estimated to be in the order of 6 - 80 million cases, the latter figure corresponding to about one third of the population (4).] Studies in industrialized countries have estimated that each year 5 - 10% of the population suffer from a foodborne disease (2).

During recent years, the reported incidence of foodborne disease has increased significantly, an increase which is partly due to epidemics of salmonellosis. In many countries *Salmonella enteritidis* is the dominant pathogen and poultry, eggs and food containing eggs have been identified as the predominant source. In certain countries, 60 - 80% of poultry meat is reported to be contaminated with *Salmonella enteritidis* (5).

Many industrialized countries are also experiencing outbreaks of diseases due to relatively newly-recognized types of foodborne pathogens such as *Campylobacter jejuni*, *Listeria monocytogenes* and *E. coli* 0157:H7. Campylobacteriosis has increased to such an extent that it is now the leading foodborne disease in several of these countries. As with salmonellosis, the main vehicles for transmission are poultry meat and raw milk.

Infection due to *E. coli* 0157:H7 is also emerging as an important public health problem both because of the gravity of the disease as well as its increasing trend.

Brucellosis occurs worldwide but in North America and Western Europe the incidence has decreased significantly. However, in some countries brucellosis still remains an important health problem, notably in the Mediterranean countries (Egypt, Greece, Italy, Morocco, Tunisia), the Middle East (Iran, Iraq, Saudi Arabia), Mexico, Peru, some regions of China, the former USSR and India. Countries in the Middle East are experiencing an increasing trend (6).

*Clostridium botulinum* causes the severe intoxication, botulism, which may lead to respiratory paralysis, with a fatality rate of 35 - 65%. Botulism is a major concern of public health authorities, for outbreaks are usually due to faulty preservation of food, a significant proportion of which happens in the home.

Listeriosis, caused by *Listeria monocytogenes* is particularly dangerous for the elderly, pregnant women/foetus, neonates, and immunoimpaired persons. The clinical manifestations include septicaemia, meningitis, encephalitis, osteomyelitis, endocarditis, abortion, and stillbirth or malformation of the fetus. The overall fatality rate is 30%, but may be as high as 70%. The pathogen is ubiquitous, and is found in a wide range of foods, including milk and milk products, seafood, meat, meat products, and vegetables. Some 1 - 10% of humans are carriers (7).

*Vibrio parahaemolyticus* and *V. vulnificus* cause acute gastroenteritis and in the latter case, also septicaemia and liver disease. They are constituents of the normal bacterial flora of the marine or estuarine environment, particularly in warm climates, in which fish and other seafood, including oysters, may become contaminated.

Parasites constitute another group of pathogens of major public health importance (8). Some protozoans cause persistent diarrhoea: *Giardia lamblia*, *Cryptosporidium spp.*, *Entamoeba histolytica*. *Cryptosporidium spp.* by their opportunism affect particularly those with immature or impaired immune systems, for example in early childhood, and those with acquired immune deficiency. *Toxoplasma gondii* presents a special danger to pregnant women and the foetus. With the increase in the number of people with impaired immunity, this pathogen is becoming an important cause of morbidity or mortality in this group of population. Raw or undercooked meat, as well as raw vegetables contaminated with cat faeces, is the major route for transmission of this infection (8).

Among the helminths causing severe, acute and long-lasting damage, a few examples may be mentioned. *Trichinella spiralis*, a nematode, is transmitted principally through raw or undercooked pork, as well as game (e.g. bear, wild boar). Of the cestodes, *Taenia solium* and *T. saginata* are transmitted through raw or undercooked pork and beef respectively which is infested with the larvae of the parasite. Persons infected with *Taenia solium* are also potential transmitters of cysticercosis, in which cerebral lesions may lead to neurological and mental symptoms (8). Certain trematodes (or flukes) are transmitted by fish, crustaceans from fresh or brackish water, and snails, and may cause serious infections. The liver flukes *Opisthorchis* and *Clonorchis* cause mechanical obstruction of the biliary tract, recurrent pyogenic cholangitis, and cholangiocarcinoma. *Paragonimus* infection can lead to collapse of pulmonary tissue and bronchiectatic change (9).

Foods may also contain toxic chemical substances, some occurring naturally as in the case of cyanogenic glycosides in cassava, or being produced by the metabolic activity of moulds, as with the mycotoxins. Others may contaminate food through a polluted environment (polychlorinated biphenyls, radionuclides, toxic metals such as lead, cadmium

or mercury). Some chemicals, such as pesticides, may be present in excessive amounts in foods as a result of poor agricultural practice. Box 2 presents examples of chemical agents of concern to public health authorities.

**Box 2. Examples of chemical agents of public health importance**

Toxic metals (e.g., lead, mercury, cadmium)	Pesticides
Polychlorinated biphenyls (PCBs)	Mycotoxins
Radionuclides	Plant toxicants
	Marine biotoxins

Mycotoxins are of concern for two reasons, their acute toxicity and their potential carcinogenicity. Epidemiological studies have shown a strong correlation between the high incidence of liver cancer in some African and South-East Asian countries (12-13 cases per 100 000 annually and exposure to aflatoxins (10). Ochratoxin A has also been associated with Balkan endemic nephropathy, a fatal kidney disease prevalent in several Balkan countries (11). Contamination of food with mycotoxins is particularly important in countries with hot and humid climates where conditions are more favourable for the growth of moulds.

Serious health consequences may also result from consumption of foods contaminated with toxic metals such as lead, methylmercury or environmental chemicals. For example, clinical and epidemiological studies, made following the foodborne outbreaks of methylmercury intoxications in Iraq (1971-2) and Japan (1950-1960), indicate that severe derangement of the developing central nervous system may occur as a result of prenatal exposure to methylmercury (12).

### **3. Socioeconomic consequences of contamination of food**

In addition to their effects on health, the economic and social impact of food contaminants may be of serious consequence. The diseases caused by food contaminants can in themselves be very costly in terms of loss of income and manpower and medical care costs. For example, the cost of salmonellosis alone was estimated to be about US\$ 1000 million in 1987 in the USA (13).

The impact of food losses due to contamination is also considerable, with world-wide losses of grain and legumes estimated as least 10% of production. For non-grain staples, vegetables and fruits, the loss is believed to be as high as 50% (14). Annually, some 1000 million tonnes of cereals are at risk of contamination with mycotoxins (15). In Nigeria, the Food and Drug Administration destroyed contaminated food worth more than £100 000 in 1977 (16,17). Food contamination affects trade in two ways. Firstly, contaminated food may be rejected if the level of contaminants is above the limits permitted by importing countries. For example, during a three month period from January to March 1980, food imports valued at about US \$ 20 million were rejected in the USA on account of food contamination with moulds and aflatoxins (1). Secondly, a country's reputation in food safety may cause a decrease in trade as well as in tourism. The epidemic of cholera in Peru cost the country over US \$ 700 million in 1991 due to the loss of food exports and tourism, in addition to medical care costs (18).

#### 4. Food technologies of major public health importance

A first approach to ensure the safety of food is naturally to prevent contamination during production. This may be possible for certain contaminants. For example, contamination of milk with *Brucella spp* can be prevented by appropriate animal health measures (e.g. vaccination of animals). Levels of pesticide residues can be controlled by their proper application and good agricultural practice. Biotechnology can be used to produce plants which are more resistant to disease and thus require reduced use of pesticides, and it may be particularly important in the case of production of plants which contain naturally occurring toxins, e.g. cassava. For many chemical contaminants (e.g., PCBs), preventing contamination - for example through environmental measures - may be the only practical means of keeping their concentrations at safe levels.

Preventing contamination, however, is not always possible. Some toxic substances are natural components of foods or present in the environment where crops grow or animals live. Despite all efforts at good agricultural practice, certain raw foodstuffs may still become contaminated with pathogenic organisms particularly in countries where food animals are not vaccinated, untreated wastewater is used for irrigation or where human excreta is used as fertilizer. The hot and humid climates of many developing countries favour the growth of moulds and the production of mycotoxins. Improper handling during later stages in the food chain (i.e., transport, storage, distribution and preparation) may also increase the level of contaminants.

Application of food technologies is thus essential to prevent foodborne diseases. In addition to controlling pathogens, most food technologies are also effective against spoilage microorganisms and they are therefore often applied with the double objective of ensuring food safety and extending the shelf life of food products.

From a public health viewpoint, food technologies may be divided into three groups, depending on their potential for preventing, reducing (killing) or controlling contaminants:

- those used to render food safe (i.e. reducing contaminants present in food);
- those used to keep contaminants under control; i.e., preventing the growth of Organisms or the production of toxins; and
- those used to prevent contamination during or after processing.

In practice, combinations of two or more such technologies are frequently applied to achieve the objective desired. For example, raw milk is pasteurized to render it safe. It is aseptically packed to prevent re-contamination.

Food technologies broadly comprise those which entail a physical treatment (e.g., heating or freezing) and those which use chemicals (e.g., salt as preservative). In the former, the foods are safe as long as surviving pathogens are kept under control and no contamination occurs after processing. In the latter, the control of contaminants persists as long as the chemical agents continue their activity in the food.

Any consideration of the role of food technologies in ensuring food safety must also take into account the techniques for analyses of food and identification of pathogens or toxic chemicals. This is an important matter which is a subject in itself. Progress achieved in food technologies and in the safety of food products could not have been possible without parallel advances in techniques for food analyses.

The spectrum of food technologies contributing to food safety is broad, and the following are only a few examples to illustrate their potential for the prevention of disease.

#### 4.1 Technologies used for rendering food safe

**Heat treatment.** For thousands of years this has been the most effective and best method for man to combat undesirable organisms in food. All organisms have a range of temperature in which they live and/or grow. Many pathogenic bacteria are mesophilic, which means that they grow best at moderate temperatures of 30-45°C, with a minimum of 5-15°C and a maximum of 35-47°C. As the temperatures of foods are increased above this range, bacterial growth will be inhibited and cells will eventually die. By heating food above the temperature of viability for a sufficient length of time it is possible to ensure microbial safety of food by killing and reducing the number of pathogens or their heat labile toxins. During this process, spoilage organisms will also be inactivated and, for this reason, heat treatments are often also used to extend the shelf-life of food products.

Boiling, cooking, frying, baking and roasting are steps in many food preparation and food manufacturing processes at household and industrial levels. They lead to physico-chemical changes which increase the digestibility of certain foods - and thus nutritional quality - and improve texture, taste, smell and appearance. Many think of cooking only in relation to these effects and overlook its importance in ensuring the safety of food. As a consequence, the need for adequate cooking is often neglected, and it may even be omitted for foods which present a risk of being contaminated. Analysis of foodborne disease outbreaks in many countries shows that insufficient heat treatment of food during the preparation of a meal is one of the main causative factors (1).

Cooking, baking, roasting or frying foods of animal origin (meat, eggs and seafood) is imperative to kill pathogens and is also important for vegetables and fruits which cannot be peeled and which are likely to be contaminated because of use of wastewater for washing or untreated excreta as fertilizer.

In situations where disinfected or otherwise 'safe' water is not accessible, or when pasteurized milk is not available, boiling is essential. Water can be a source of pathogens and when its safety is not assured by means such as chlorination or filtration, boiling is an essential technology. Boiling milk is similarly important when pasteurized milk is not available.

Heat treatment is also widely applied at industrial level. Of the different applications available, pasteurization and commercial sterilization deserve specific attention because of their potential role in preventing certain foodborne diseases. The importance of pasteurization<sup>2</sup> has been repeatedly demonstrated in connection with milk and other dairy products. Raw milk, and in some instances products made with raw milk, are major sources of contaminants. Pasteurization effectively destroys the great majority of these contaminants and prevents diseases which they cause. The Joint FAO/WHO Expert Committee on Milk Hygiene stated that: *there can be no complete assurance to the safety of fluid milk for human consumption unless pasteurization or some other effective method of heat treatment has been applied* (19).

Although pasteurization of milk was originally introduced to prevent the transmission of brucellosis and bovine tuberculosis, experience from countries where this technology is routinely applied has demonstrated its value in preventing other diseases transmitted by milk or its products, e.g. salmonellosis, campylobacteriosis, cryptosporidiosis (see Box 3).

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<sup>2</sup> The term 'pasteurization' usually refers to a process involving heat treatment at a prescribed time-temperature combination to kill vegetative forms of pathogens that may be present, while causing minimal changes in the composition, flavour, and nutritive value of food. However, with advances and the development of new food technologies, the term is sometimes used for non-thermal technologies as well, leading to the same effect.

In Scotland, during the eight years prior to introducing legislation requiring heat treatment of milk for sale, 27 major outbreaks of milk-borne salmonellosis occurred in the general community compared to a single outbreak in the subsequent eight-year period. Similarly, many outbreaks of milk-borne campylobacteriosis have been prevented: in the three years prior to compulsory heat treatment six outbreaks occurred while in the subsequent three years only one was reported. Properly pasteurized milk which is adequately protected from re-contamination has not been associated with any outbreak. In the two occurring after the introduction of compulsory heat treatment, it is likely that the milk was not properly pasteurized or was re-contaminated (20). Despite the existence of this technology, infections due to consumption of raw milk or products made from it are frequently reported. In many developing countries, pasteurized milk is not readily available, and if people do not boil the raw milk before consumption they are at risk. In some industrialized countries, the trend to consume "health foods" has led to an increase in consumption of raw milk, with the negative effect of exposing consumers to milk-borne pathogens.

Although pasteurization is often more commonly associated with milk and other dairy products (e.g., cream), it is also applied to a wide variety of food products such as ham, eggs, and beverages (e.g., fruit juices). Eggs are a potential source of *Salmonella* and recent epidemiological evidence has proven that in addition to surface contamination, some serotypes of *Salmonella enteritidis* may be present in the yolk of intact eggs. Raw eggs are therefore a potential health hazard and, in view of this, the use of pasteurized egg products is gaining public health importance (21).

Commercial sterilization, another type of heat treatment used in canning to render food safe, kills all pathogenic and non-pathogenic vegetative cells, as well as the spores of pathogens, and is therefore of great importance for elimination of spore-forming pathogenic bacteria such as *Clostridium botulinum*.

As spoilage bacteria are also killed during commercial sterilization, this process ensures safe and shelf-stable products. This means that they can be stored at room temperature without the product becoming unsafe or spoiled. Sterilization thus presents a great advantage for products which have to be transported or stored for lengthy periods at ambient temperatures, and it is used by canning industries for production of diverse shelf-stable food products and ready-to-eat meals.

### Box 3 Examples of milk-borne diseases that can be prevented by pasteurization

Bovine tuberculosis
Brucellosis
Campylobacteriosis
Cryptosporidiosis
Diphtheria
Listeriosis
Poliomyelitis
Q fever
Salmonellosis
Streptococcal infections
Typhoid and paratyphoid fevers

Sterilized foods are thus of particular value to people with immunodeficiency in whom even the smallest exposure to pathogens entails a health risk.

**Freezing** is mainly used to prevent growth of microorganisms (both spoilage and pathogenic organisms) as well as to stop physico-chemical deterioration of food. However, it is of interest in this context because certain parasites, i.e., helminths, are killed by freezing which can thus be used for killing helminths such as *Trichinella* and *Taenia* in meat or *Anisakis* and *Clonorchis* in fish. In countries where it is a tradition to eat raw or undercooked fish or meats, for example, in China, Japan and Scandinavia, freezing can be an important technology for preventing foodborne helminthiasis (9).

**Irradiation.** At low doses (up to 0.5 kGy), irradiation may be used to destroy larvae parasites in meat (e.g., *Trichinella spiralis*, *Taenia saginata*), or to inactivate metacercariae of *Clonorchis* and *Opisthorchis* in fish. At higher doses (3-10 kGy), this technology can be effective in destroying bacteria such as *Salmonella*, *Shigella*, *Campylobacter*, *Vibrio*, *Yersinia* and other non-spore forming pathogens which may contaminate meat, poultry and seafood. Irradiation can also be used to reduce the concentration of microorganisms in spices and dried vegetables and thus prevent contamination of foods to which these are added (9,14,22).

The importance of irradiation in killing pathogens in meat, poultry and food of aquatic origin cannot be overemphasized, particularly when these foodstuffs are eaten raw or undercooked, as is frequently the case in many cultures. Pork meat has been estimated to cause half to three-quarters of the infections with *Toxoplasma gondii* in the United States of America (23). Infections with protozoa and helminths are extremely common in certain tropical countries and irradiation of meat and meat products can eliminate these risks. Similarly, irradiation can reduce the risk of poultry-borne salmonellosis or campylobacteriosis and the risk of *Vibrio parahaemolyticus* gastroenteritis, salmonellosis and shigellosis transmitted through shrimps and seafood.

Irradiation technology can also be used to reduce the level of spoilage microorganisms, to delay sprouting or maturation, and to disinfest grains. In

#### Box 4. Examples of foodborne diseases that can be prevented by food irradiation

- Campylobacteriosis
- Cholera
- *E. coli* infections
- Listeriosis
- Salmonellosis
- Shigellosis
- *Vibrio parahaemolyticus* gastroenteritis
- *Vibrio vulnificus* septicaemia
- Yersiniosis
  
- Toxoplasmosis
  
- Clonorchiasis
- Opisthorchiasis
- Paragonimiasis
  
- Trichinellosis

this, it has two distinct advantages: the prevention of food losses, and a reduced need for certain chemicals which could be a potential health risk. Irradiation is an alternative to fumigants such as ethylene bromide and ethylene oxide, the use of which has been banned or restricted for health or environmental reasons.

**Disinfection** with chemical agents is one of the most important technologies applied in the public health control of disease, notably in the treatment of water supplies. Water, whether used for drinking or as a processing aid or ingredient, is directly or indirectly a source of pathogenic organisms. Disinfection with chemical agents, together with other treatments (coagulation, filtration, softening and carbon absorption), ensures its microbial safety and prevents contamination of food. Chlorine, one of the most widely-used chemical agents for disinfection purposes, is effective in preventing waterborne diseases, (e.g., cholera, typhoid fever, shigellosis, salmonellosis, amoebiasis and hepatitis A).

**High Pressure Technology.** This is now under development and makes use of high pressures (up to 1000 MPa) to kill microorganisms. As the technology has little effect on chemical constituents, it keeps the natural flavour of food intact. In the future, this technology may provide a new method for rendering certain foods safe.

Sometimes food technologies used for decontamination can be very simple. For example, the **grating** and **mincing** of cassava tubers during *gari* preparation is crucial for the detoxification of cassava. The disruption of tissues which occurs during this process increases the contact of an endogenous enzyme (linamarase) with the substrate linamarin, and leads first to the production of cyanohydrins and later on of cyanide, which is subsequently removed from the product during "garification" or roasting in a hot pan (24).

#### 4.2 Technologies used to control contaminants

The minimum infective dose required for bacteria to cause disease varies with the organism; however, in most cases high doses are required. For example, diseases caused by pathogenic strains of *E. coli* require a minimum infective dose (MID) of about  $10^6$  bacteria. Certain food technologies are important because they can prevent the growth of pathogenic bacteria to disease-causing levels or the production of toxins. These make use of one or a combination of several factors which affect the growth of bacteria, such as temperature, gaseous environment, acidity, water activity or the presence of other substances with bacteriostatic effects. Depending on the factors involved, different food technologies can be applied.

##### *Temperature*

**Cold holding, chilling, hot holding.** Microorganisms grow within a specific temperature range, known as the 'danger' zone. Outside this zone, growth is slowed down or stopped. For most pathogenic bacteria the danger zone is between 10° and 60°C. By keeping food at temperatures above 60°C (**hot holding**) or below 10°C (**cold holding**)/

**chilling**), it is possible to prevent or slow down the growth of most pathogenic bacteria or the production of toxins. Experience with outbreaks of foodborne disease world-wide shows that a major cause of outbreaks is because of lack or inappropriate application of these technologies (1). In poor populations, lack of refrigerators for cold storage or fuel for hot holding pose additional difficulties in the application of these technologies. In many cases, foods prepared in advance are left at room temperature for several hours, during which time bacteria proliferate and reach MID levels. However, certain bacteria (e.g. *Listeria*, *Yersinia* and *Cl. botulinum type E*) can grow at temperatures below 10°C. Therefore, it should be borne in mind that chilling may not always be a suitable technique to prevent bacterial growth.

### *pH*

Microorganisms are sensitive to pH, and their growth or survival is affected by the acidity of the food. There is a range of pH within which microorganisms can reproduce: outside this range their growth is inhibited.

**Acidification** with vinegar (acetic acid) or other types of acid foods or agents is a simple technology which makes use of the sensitivity of pathogens to low pH. Where cooking fuel is scarce or costly, or there are no refrigerators, this technology is effective in preventing or slowing down growth of acid-sensitive bacteria such as *Vibrio cholerae*.

**Fermentation** is a technology by which growth and survival of microorganisms (including pathogens and those causing spoilage) are regulated by low pH, competition for nutrients, and/or bacteriocins resulting from the metabolic activity specific to non-pathogenic bacteria (e.g., lactic acid bacteria) or yeasts. Fermentation by lactic acid and bifidus bacteria is receiving increasing interest because of its claimed therapeutic properties. The preparation of many traditional foods in different parts of the world is based on fermentation (2). In many African countries it is customary to give infants fermented cereal products, such as *ogi* (Nigeria) and *ugi* (United Republic of Tanzania, Uganda, Kenya). These are considered to be helpful in improving the hygienic quality of foods, particularly when, due to the sociocultural constraints, heat treatment of food cannot be applied. Experience in Zimbabwe has shown that *mahewu*, a fermented drink, was less likely to transmit foodborne cholera than other foods available in the community. However, the sensitivity of foodborne pathogens to pH differs, and bacterial toxins are not denatured by fermentation. The microbial safety of fermented food, therefore, depends on a variety of factors, including the nature of pathogens present, the way fermentation is carried out, and the final pH of the products. Some fermented foods have in fact been implicated in cases of botulism, as have been foods which were insufficiently acidified.

### *Water activity*

In their natural state, many foodstuffs contain sufficient water to support the growth of microorganisms. By decreasing the amount of water in food or its availability to microorganisms (for example, by binding to other substances such as salt or sugar or by freezing), the growth of microorganisms can be prevented. A number of food technologies are based on these principles.

**Use of salt or sugar** or other water-binding agents is a well established method of preventing growth of microorganisms and food preservation. Salted fish and marmalades are examples of foods which are preserved by this method.

**Drying** has been used since ancient times to preserve foods and for the prevention of pathogen growth. The light weight and reduced volume of the dried products facilitates their transport. A variety of methods are used for drying foods, spray and freeze drying being among the most modern. Solar drying is a simple technology still used in developing and developed countries. Drying of cereals and grains is particularly important for prevention of mould growth and production of mycotoxins.

**Freezing** prevents the growth of microorganisms by reducing the availability of water (reduced water activity) and by low temperature, and is effective against both spoilage and pathogenic organisms. Most bacteria survive freezing process and upon thawing, particularly at temperatures corresponding to the danger zone (10-60 °C), surviving bacteria can grow. Also, in reconstituted dried products, microbial growth can occur. Food safety measures recommended for fresh foods are, therefore, also applicable for both thawed and reconstituted products.

### *Antimicrobial agents*

In addition to substances used to reduce water activity (e.g. salt or sugar) or for acidification (e.g. organic acids), other agents with specific antimicrobial effects may also be used to prevent the growth of microorganisms. These usually fall under one of the following main categories:

- curing salts, such as nitrites used in meat products (e.g., ham) to prevent growth of *Cl. botulinum* as well as to give them an attractive reddish colour;
- bacteriocins, e.g., nisin produced by lactic acid bacteria, are active against pathogens such as *Listeria monocytogenes*, *Cl. botulinum*, *Staphylococcus aureus*; and
- gases used as preservatives (e.g., CO<sub>2</sub> used in modified atmosphere packaging, which acts in two ways - as an antimicrobial agent, and by replacing oxygen which is required for growth of certain microorganisms).

The effects of antimicrobial agents on microorganisms are often selective and they are generally used to control specific organisms. Their effectiveness also depends on other environmental factors, e.g., temperature and pH.

Some technologies are based on a combination of these factors. For example, microbial safety of **smoked foods** is achieved by a combination of heat treatment, drying and sometimes antimicrobial agents which are present in the smoke.

#### 4.3 Technologies to prevent re-contamination during or after processing

**Packaging**, whether in metal, glass, paper or plastic, is important in preventing contamination of food after processing and during storage. The success of many food technologies used for rendering food safe depends on the packaging, and many products could not be put on the market without proper packaging.

Advances in this area have played an important role in health. For instance, lead-soldered cans were once an important source of dietary lead but, nowadays, non-lead soldered cans are available and their use can significantly reduce the lead content of canned foods.

In addition to preventing contamination by pathogenic organisms or chemicals, appropriate packaging protects foods against moisture, and thus prevents chemical and physical changes during storage and thus prevents the growth of undesirable organisms including moulds.

**Disinfection of equipment** is an essential measure for industrially-produced foods and it is crucial for preventing contamination of food during processing. Disinfection of certain equipment may be carried out by heating and ultraviolet light. Other types of equipment are disinfected with chemical agents such as chlorine, iodine, or quaternary ammonium compounds which are effective against most or all of the microorganisms present on the surface of equipment. Disinfection is usually preceded by a thorough cleaning with water and a suitable detergent to remove traces of food, and followed by a thorough rinsing.

**Hygienic design of food processing equipment** is essential for prevention of contamination during processing. If equipment is of poor design, it will be difficult to clean and ensure that it is free from harmful microorganisms. Residues of food remaining in crevices and dead areas would then serve as culture media for the multiplication of microorganisms. The materials used to construct food machinery should fulfil specific requirements, and those coming into contact with the food should be inert to the product as well as to detergents and disinfectants under operating conditions (25).

## 5. Safety of processed foods

If appropriate technologies are used at industrial and household levels, most dangerous contaminants, particularly those of biological origin, can be reduced or controlled, and a wide range of foodborne diseases (particularly those of a diarrhoeal nature) prevented. Despite this, they not only remain one of the most widespread health problems but are on the increase all over the world. It may be asked why, while these technologies exist and could be used to reduce or control contaminants in foods, so many people still suffer or die from foodborne disease.

Epidemiological data (1) on the incidence of foodborne diseases show that the majority occur as a result of:

- failure to apply food technologies; and/or
- faulty application of food technologies.

Many developing countries lack the necessary facilities for processing foods, e.g., pasteurizing milk, drying grains, and disinfecting water. Application of heat treatment or chilling at household level is also hampered due to lack of fuel or facilities for cold storage. Available technologies are not always used because food handlers and consumers are not aware of their importance for health protection. Several studies have shown that despite the availability of refrigerators, cooked foods are often stored at room temperature (26,27). Sometimes foods may be consumed raw because consumers are not aware of the risks involved. In addition to the habit of eating raw eggs, meat, fish and shellfish, many consumers are turning towards uncooked or unprocessed foods in the erroneous belief that these are healthier.

Lack of understanding, misinformation and prejudice about certain novel technologies also hinder their application, in spite of the benefits which these could bring. One notable example is food irradiation. Despite the extensive studies made with regard to the wholesomeness of irradiated products, as well as the scientific community's seal of approval, some decision makers and some groups of the public still remain opposed to their use. They ignore the fact that this technology has the potential to prevent numerous foodborne diseases.

Most food technologies have been developed empirically, based on trial and error at household or artisanal level. Advances in food and related sciences have helped us to understand the underlying mechanisms of food technologies and the factors which determine food safety. However, this knowledge has tended to remain with scientists and has not been properly communicated to consumers. Even professional food handlers

working in food service and catering establishments are not always educated in the basic aspects of food science related to food safety.

Most outbreaks of acute foodborne disease caused by biological agents could have been prevented if food handlers had only known and observed basic principles of food safety (1). Most food preparation practices involve the application of one or more technologies. Cooking, freezing, salting, smoking and fermentation are all used for the domestic preparation of meals and their mode of action needs to be understood if the food product is to be safe. In absence of this, any change from the normal conditions of food preparation (e.g., increase in temperature, presence of a new pathogen in the food or environment, increase in the quantity of food to be prepared, or less time for food preparation) sets the scene for an outbreak. Outbreaks commonly occur during holidays or at banquets when food has to be prepared in large quantities and often in advance. The summer months, in temperate climates, also bring an increase in the incidence of many foodborne diseases because the ambient temperature increases, favouring bacterial growth.

The problem of Konzo in some regions of Africa is an example of how a change in the socioeconomic setting resulted in a food safety problem, mainly because of lack of understanding on the part of food handlers about the significance of their actions when processing cassava. Epidemics of Konzo, a form of myelopathy characterized by an abrupt onset of spastic paraparesis, have been known to occur in Sub-Saharan Africa. Studies of outbreaks in the Bandundu region of Zaire have attributed them to exposure to cyanide from consumption of insufficiently-processed cassava. Cassava contains natural cyanogens, and the traditional processing in Africa includes a period of soaking during which the cyanogens are removed. However, in the mid-1970s a new road to the capital was constructed. This made cassava an important cash crop. To respond to the higher demand, women who were processing cassava reduced the soaking time from three days to one. This resulted in a higher content of cyanogen, which led to outbreaks of Konzo in the dry season, because during this period the diet lacks supplementary foods with sulfur-containing amino acids essential for cyanide detoxification (28).

With economic growth, traditional food technologies are being increasingly applied at industrial level. In countries where the food control infrastructure and systems for investigation of foodborne disease are weak or non-existent, industrially produced foods may be contaminated or even adulterated. Where food control and investigation of foodborne disease are relatively efficient, food industries are more vigilant as they have an vested interest in ensuring the safety of their products. In addition to the controls exercised by government officials, many industries are equipped with control laboratories with trained food scientists who verify the quality of their products.

Nevertheless, even in industrialized countries accidental food contamination may happen and endanger the lives of a great number of people. A prominent example is the massive outbreak of salmonellosis due to re-contaminated pasteurized milk which affected some 169 000 - 198 000 people in USA (29).

During recent years, techniques used in quality assurance have progressed and improved tremendously. An important development in this area is the Hazard Analysis Critical Control Point system which has revolutionized quality assurance programmes. Wider application of this system would unquestionably lead to greater assurance of the safety of industrial food products (30,31).

## 6. Food technologies and public health policies in times of epidemics of foodborne diseases

The impact of food technologies on the economies of countries is immense. Epidemics of foodborne disease may jeopardize the export of agricultural products from affected areas, on the grounds of actual or presumed contamination and this leads to tremendous economic losses.

To alleviate the losses caused by restriction of food imports from countries affected by the cholera epidemic, the World Health Organization developed a policy whereby it urges Member States not to apply to cholera-affected countries restrictions that cannot be justified on public health grounds, in particular as regards importation of products from the countries concerned. This policy reflects the importance of food technologies for ensuring food safety and protecting trade in foods (32), and runs as follows:

*No specific restrictions are called for, where the physical or chemical characteristics, or the processing of the food are such that Vibrio cholerae 01 are unlikely to be present, even if earlier contamination of the food cannot be excluded. Examples of such foods include:*

- acid foods (pH  $\leq$  4.5) <sup>3</sup>
- irradiated foods (minimum dose 1 kGy) <sup>3,4</sup>
- foods that have been subjected to a heating process, e.g. cooking, pasteurization, sterilization/canning <sup>3,4</sup>

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<sup>3</sup>Handled according to the relevant Codex Standards and Codex Codes of Hygienic/Technological Practice.

<sup>4</sup>Provided that post-processing contamination is prevented.

*In addition, no risk of cholera is to be expected from foods with reduced water activity ( $a_w$ ). Such foods include:*

- *dry foods, e.g. dried vegetables, coffee beans, cereals and pulses, dried milk (also dried animal feed meals)*
- *salt-preserved foods, e.g. salted fish*
- *sugar-preserved foods, e.g. jams and marmalades*

*In the case of certain fresh foods there is a possibility that they may be contaminated with Vibrio cholerae O1 if they are derived from a cholera-affected area. Importing and exporting countries may, by agreement, decide to take precautionary measures with respect to seafood if it is caught/harvested in:*

- *water contaminated by sewage suspected to contain Vibrio cholerae O1, or*
- *water identified as being an environmental reservoir of Vibrio cholerae O1*

*If undamaged fresh fruits and vegetables are in transit under normal conditions of temperature and humidity for at least ten days, the probability of survival of the vibrio is low, as is the risk to health. But importing and exporting countries may agree on specific requirements concerning vegetables and fruits grown close to the soil, particularly when untreated night-soil has been used as fertilizer.*

*Vibrio cholerae O1 may survive in contaminated frozen foods for longer periods. Such foods pose a risk to the consumer if they are eaten raw or are allowed to contaminate other foods.*

## **7. Conclusion**

Foodborne diseases constitute a substantial risk to health. Most are largely preventable by proper application of appropriate food technologies. Their importance is often not fully realized by consumers and public health authorities. As a result, too many preventable illnesses and deaths continue to occur.

However, their safe and effective use requires an understanding of their mechanisms. At industrial level, application of the Hazard Analysis Critical Control Point system combined with controls effected by health/food control authorities are effective in assuring safety of food products. In homes, such control is not possible and in food service and catering establishments, the possibility for control is also limited. Therefore, consumers and food handlers need to be educated in the safe application of food technologies, a subject which seems to receive insufficient emphasis in health education programmes.

It is time now to recognize food technologies as health technologies in their own right.

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