FOOD SAFETY

F.K. Käferstein
International Food Safety Consultant,Switzerland

Y. Motarjemi
Nestlé S.A., Vevey, Switzerland

G. Moy
Food Safety Program, World Health Organization, Geneva, Switzerland

Keywords: Agriculture, agrochemicals, biogenic amines, biological contamination, chemical contaminants, chemical hazards, Codex Alimentarius (CA), Codex Alimentarius Commission (CAC), DDT, diarrhea, dioxins, environmental pollution, food, food additives, food allergy, food intolerance, food handlers, food irradiation, food safety, foodborne disease, genetically modified foods (GMFs), marine biotoxins, mycotoxins, nutritional hazards, pathogen, pesticides, plant toxicants, polychlorinated biphenyls (PCBs), radionuclides, risk, toxic metals, veterinary drugs, ADI, BSE, FAO, GEMS/Food, JECFA, JMPR MRL, PTWI, WHO, WTO

Contents

Summary

The German word for food is *Lebensmittel*, which literally translates to "a substance that supports life." Unfortunately, food is not always life supporting; if contaminated, food may acquire health-damaging or even life-destroying properties. Therefore, to fulfill its role, it is of paramount importance that food is not only available and nutritious but also safe.

Efforts to reduce the devastating consequences of food contamination and spoilage started long before written records. However, despite considerable advances in food science and technology, the safety of our food supply remains, at the beginning of the third millenium, a cause of concern. Every day, millions of people on this globe suffer the dire consequences of food contamination and foodborne diseases. In many instances, such diseases result in chronic or permanent disabilities and, at times, death.

This topic level contribution attempts to summarize in succinct form the biological and chemical hazards that may compromise food safety. It lists the significant factors responsible for food contamination and discusses the resulting health and economic consequences. The article also discusses briefly such hotly debated issues as BSE, food irradiation, and genetic modification of foods. However, the list of possible foodborne diseases and food safety issues is truly extensive, and readers are referred to more comprehensive sources for a more complete account of the health and economic burden posed by foodborne hazards.

The application of present-day knowledge and technology could prevent many, if not most, cases of contamination, growth, and survival of pathogens and their resulting health and economic consequences. However, to arrive at this goal, the necessary political will must be mobilized to make food safety a high public health priority, both at national and international levels.

1. Introduction

In every part of the world, people wage a constant battle against food contamination, foodborne diseases, and food wastage. Efforts to reduce these survival-threatening, devastating consequences of food contamination certainly started in prehistoric times. Cooking, smoking, simple sundrying, and fermentation were probably the first methods

used. Despite considerable advances in food science and technology, the safety of our food supply is, at the beginning of the third millennium, a cause of concern.

In 1983, a group of internationally renowned experts, convened jointly by the Food and Agriculture Organization of the UN (FAO) and the World Health Organization (WHO), concluded that illness from contaminated food was perhaps the most widespread health problem in the contemporary world and an important cause of reduced economic productivity. In 1992, FAO/WHO sponsored the International Conference on Nutrition, which recognized that hundreds of millions of people suffer from communicable diseases caused by contaminated food and drinking water. This Conference declared that access to nutritionally adequate and safe food is a right of each individual. In the same year, the UN Conference on Environment and Development recognized that food was a major vehicle for the transmission of environmental contaminants, both chemical and biological, to human populations throughout the world, and urged countries to take measures to prevent or minimize these threats. In 2000, the World Health Assembly, the supreme governing body of WHO, unanimously adopted a strongly worded resolution that recognizes food safety as an essential public health function.

A wide range of biological and chemical agents (hazards) causes foodborne diseases, with varying degrees of severity ranging from mild indisposition to chronic and/or life-threatening illness. Some important foodborne hazards are shown in Table 1.

		Transmission [a] by				
Hazards	**Important reservoir or carrier**	**water**	**food**	**person to person**	**Multiplication in food**	**Examples of some incriminated foods**
BACTERIA						
Bacillus cereus	Soil	–	+	–	+	Cooked rice, cooked meats, vegetables, starchy puddings
Brucella spp	Cattle, goats, sheep	–	+	–	+	Raw milk, dairy products
Campylobacter jejuni	Chickens, dogs, cats, cattle, pigs, wild birds	+	+	+	–[b]	Raw milk, poultry
Clostridium botulinum	Soil, mammals, birds, fish	–	+	–	+	Fish, meat, vegetables (home preserved), honey
Clostridium perfringens	Soil, animals, man	–	+	–	+	Cooked meat and poultry, gravy, beans
E. coli enterotoxigenic	Man	+	+	+	+	Salad, raw vegetables
E. coli enteropatogenic	Man	+	+	+	+	Milk
E. coli enteroinvasive	Man	+	+	0	+	Cheese
E. coli enterohaemorrhagic	Cattle, poultry, sheep	+	+	+	+	Undercooked meat, raw milk, cheese
Listeria monocytogens	Environment	+	+	–	+	Cheese, raw milk, coleslaw
Mycobacterium bovis	Cattle	–	+	–	–	Raw milk
Salmonella typhi and *paratyphi*	Man	+	+	±	+	Dairy products, meat products, shellfish, vegetable salads

Salmonella (non-*typhi*)	Man and animals	±	+	±	+	Meat, poultry, eggs, dairy products, chocolate
Shigella spp	Man	+	+	+	+	Potato/egg salads
Staphylococcus aureus (enterotoxins)	Man	–	+	–	+	Ham, poultry and egg salads, cream-filled bakery products, ice cream, cheese,
Vibrio cholerae O1	Man, marine life	+	+	±	+	Salad, shellfish
Vibrio cholerae, non-O1	Man,marine life	+	+	±	+	Shellfish
Vibrio parahaemolyticus	Seawater, marine life	–	+	–	+	Raw fish, crabs and other shellfish
Vibrio vulnificus	Seawater, marine life	+	+	–	+	Shellfish
Yersinia enterocolitica	Water, wild animals, pigs, dogs, poultry	+	+	–	+	Milk, pork, poultry
VIRUSES						
Hepatitis A & E viruses	Man	+	+	+	–	Shellfish, raw fruit and vegetables
Calici viruses	Man	+	+	–	–	Shellfish, salad
Rotavirus	Man	+	+	+	–	No information
PROTOZOA						
Cryptosporidium parvum	Man, animals	+	+	+	–	Raw milk, raw sausage (non-fermented)
Cyclospora cayetanensis	Man	+	+	0(unlikely)	–	Raspberries
Entamoeba histolytica	Man	+	+	+	–	Vegetables, fruits
Giardia lamblia	Man, animals	+	±	+	–	Vegetables, fruit
Toxoplasma gondii	Cats, pigs	0	+	–	–	Undercooked meat, raw vegetables
HELMINTHS						
Ascaris lumbricoides	Man	+	+	–	–	Soil-contaminated food
Clonorchis sinensis	Freshwater fish	–	+	–	–	Undercooked/raw fish
Fasciola hepatica	Cattle, goats	±	+	–	–	Watercress
Opisthorchis viverrini/felineus	Freshwater fish	–	+	–	–	Undercooked/raw fish
Paragonimus spp	Freshwater crabs	–	+	–	–	Undercooked/raw crabs
Taenia saginata and *T. solium*	Cattle, swine	–	+	–	–	Undercooked meat
Trichinella spiralis	Swine, carnivores	–	+	–	–	Undercooked meat
Trichuris trichiura	Man	0	+	–	–	Soil-contaminated food
NATURAL TOXINS						
Mycotoxins						
—aflatoxins	Oilseeds, maize, figs	–	+	–	–	Bakery products, milk, peanuts
—ochratoxins	Plant products	–	+	–	–	Nuts, rice, coffee, beer
—trichothecenes	Grain	–	+	–	–	Bakery products
—ergot	Grain	–	+	–	–	Bakery products

alkaloids						
—fumonisins	Maize		+			Maize-based foods
Phycotoxins						
paralytic diarrheic shellfish poisoning amnesic —neurotoxic	Shellfish	–	+	–	–	Shellfish and shellfish-based foods
—ciguatoxin	Reef (fin) fish	–	+	–	–	Foods based on reef fish
Inherent plant toxins						
—glycoalkaloïds	Nightshade plants	–	+	–	–	Potato, tomato, egg plant, paprika
—cyanogens	Cassava, sorghum, almonds, legume seeds	–	+	–	–	Foods prepared from these plants
—amatoxins	Toxic mushrooms	–	+	–	–	Mushrooms

[a] Almost all acute enteric infections show increased transmission during the summer and/or wet months, except infections due to rotavirus and *Yersina enterocolitica*, which show increased transmission in cooler months.
[b] Under certain circumstances some multiplication as been observed. The epidemiological significance of this observation is not clear. + = yes – = no ± = rare 0 = no information

Table 1. Some important foodborne hazards and their salient epidemiological features (adapted from WHO Technical Report Series, No. 705, 1984, *The Role of Food Safety in Health and Development: Report of a Joint FAO/WHO Expert Committee on Food Safety*)

Not only has epidemiological surveillance during the last three decades shown an increase in the prevalence of foodborne illness, there have also been devastating outbreaks of diseases such as salmonellosis, cholera, enterohaemorrhagic *Escherichia coli* (EHEC) infections, and hepatitis A in both developed and developing countries. Furthermore, cholera and other diarrheal diseases, particularly infant diarrhea, traditionally considered to be spread by water or through person-to-person contact, were shown to be largely foodborne. In several industrialized countries, epidemiological studies showed an unexpectedly high annual prevalence of foodborne disease—10% to 15% of the population. In the late 1990s, more accurate data from the US suggested that this figure may be as high as 30%. While comparable data from developing countries are lacking, one can safely assume that this figure is higher and the health consequences even more severe.

It is certain that the problems of food safety will plague mankind in the twenty-first century, especially as several global trends continue to negatively influence the safety of food and drinking water. Such trends include population growth, uncontrolled urbanization, increase in international trade in food and animal feed, and other factors (see *Factors of Significance for Food Safety*).

In this contribution, an attempt is made to identify the major factors that will strongly influence food safety in the first few decades of the new century, and to suggest strategies to meet the situation. In this context, reference will be made to the need to have up-to-date food legislation, improved surveillance and monitoring programs, health education in food safety, and a number of other programs in place. Most important, however, there needs to be a paradigm shift: food should not only be

considered as an agricultural/trade commodity, but also as a public health issue. Therefore, food safety has to be seen by the public health community as an essential public health function, as acknowledged by the World Health Organization. Consequently, food safety has to be integrated along the entire food chain, from farm to table, with the three sectors (i.e. government, industry, and consumers) sharing responsibility. However, within governments, sharing responsibility between different government agencies (e.g., agriculture, health, trade, and so on) has not proven successful. It is, therefore, essential to consolidate the various governmental food safety responsibilities and to create a single food safety agency with responsibility for the entire food chain, from farm to table. The health sector should assume responsibility for this food agency, since the other governmental sectors often promote commercial interests, which may be in conflict with the protection of consumer health.

And finally, food safety has to form an essential component of a health-based nutrition policy and nutrition education, as nutritional requirements should influence the decisions regarding food choices. These, along with poor nutrition, may influence the frequency of falling ill with foodborne disease.

2. Biological Pathogens

2.4. Developing Countries

Biological contaminants, largely bacteria, viruses, and parasites, constitute the major cause of foodborne diseases. In developing countries such contaminants are responsible for a wide range of disease (e.g., cholera, campylobacteriosis, *Escherichia (E.) coli* gastroenteritis, salmonellosis, shigellosis, typhoid and paratyphoid fevers, brucellosis, amoebiasis, poliomyelitis, and so on). Taken together, diarrheal diseases, especially infant diarrhea, are the dominant problem and indeed one of massive proportions.

Annually, some 1.5 billion episodes of diarrhea occur in children under the age of five, resulting in some 1.8 million deaths. While traditionally it was thought that contaminated water supplies were the main source of pathogens causing infant diarrhea, it is now estimated that up to 70% of diarrheal episodes may be foodborne. Various pathogens have been identified as a cause of diarrhea. These include bacteria such as *E. coli*, *Shigella spp.*, *Salmonella spp.*, *Vibrio cholerae* O1, and *Campylobacter jejuni*; protozoa such as *Giardia lamblia*, *Entamoeba histolytica*, and *Cryptosporidium* spp.; and also enteric viruses such as rotavirus, hepatitis A, and E viruses and calici viruses. Infections due to pathogenic *E. coli* are the most common cause of infant diarrhea. Complementary food contaminated with pathogenic *E. coli* causes up to 25% of all diarrheal episodes in infants and children. Campylobacteriosis and shigellosis account for 5% to 15% and 10% to 15%, respectively, of diarrheal disease episodes in infants and children.

The seventh pandemic of *Vibrio cholerae* O1 biotype El Tor, which started in 1961 in Indonesia, spread in 1991 to South and Central America and Mexico. In 2005, 56 countries had officially notified WHO of cholera cases for a total of 131 943 cases and 2272 deaths. Food was frequently implicated in the transmission of cholera.

Infections due to helminths are also a worldwide public health problem, particularly affecting developing countries. Examples are *Trichinella spiralis*, *Taenia saginata*, and *Taenia solium*, which are acquired through consumption of undercooked or uncooked meat. Ascariasis is one of the most common parasitic infections and is estimated to affect some 1 000 million people. Trematodes such a *Clonorchis* spp., *Fasciola* spp., *0pisthorchis* spp., and *Paragonimus* spp. infect some 40 million people, particularly in Asia, Africa, and Latin America. More than 10% of the world's population is at risk of becoming infected by these parasites, which are transmitted through the consumption of raw or inadequately processed freshwater fish, shellfish, or aquatic plants.

2.5. Industrialized Countries

Although the situation regarding foodborne diseases is serious in developing countries, the problem is not limited to those countries. Industrialized countries have experienced a succession of major epidemics. It has been estimated that foodborne diseases in the US cause approximately 76 million illnesses, 325 000 hospitalizations, and 5 000 deaths annually. Surveys in several other countries suggest that 10% to 15% of the population may suffer from a foodborne disease annually.

With today's improvement in standards of personal hygiene, development of basic sanitation, safe water supplies, effective vaccination programs (especially for poliomyelitis), food control infrastructure, and the wide application of food-processing technologies, many foodborne diseases have been either eliminated or considerably reduced in industrialized countries (e.g., poliomyelitis, brucellosis, cholera, typhoid and paratyphoid fevers, milkborne salmonellosis). Nevertheless, most countries experienced an important increase in several other foodborne diseases. The situation in England and Wales illustrates this trend (Figure 1).

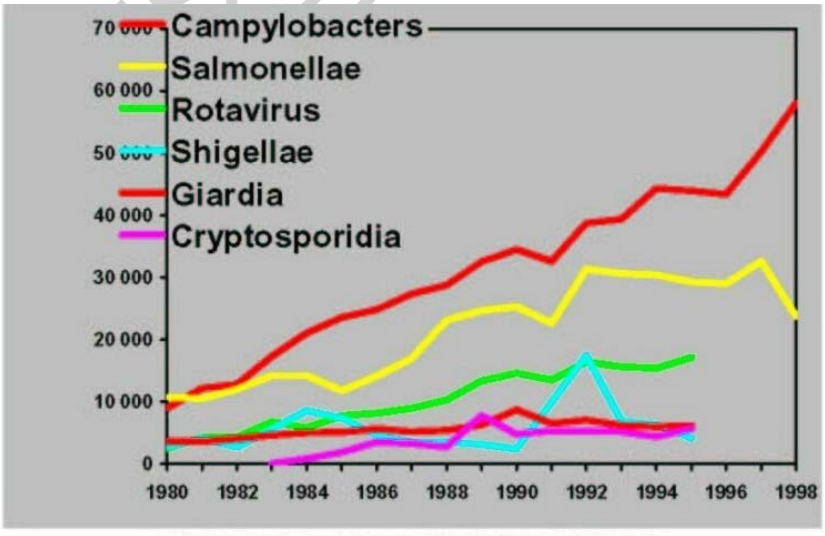

Figure 1. Foodborne diseases in England and Wales

Salmonellosis is of particular importance in many countries. Raw meats, poultry, eggs, milk and dairy products, fish, shrimp, frog legs, yeast, coconut, sauces and salad dressing, cake mixes, cream-filled desserts and toppings, dried gelatin, peanut butter,

cocoa, chocolate, and other foods have been identified as being contaminated with S*almonella spp*, and, subsequently, serving as vehicles for the transmission of this disease. As a result of industrialization and mass production, large outbreaks have been reported.

In 1985, a salmonellosis outbreak involving up to 197 000 people (16 000 confirmed cases) in six US states was caused by pasteurized but recontaminated milk from one Chicago dairy. Also in the US, another large salmonellosis outbreak associated with nationally distributed ice cream products occurred in 1994. While the exact number of ill people is not known, the number of persons exposed to contaminated products may have been substantial, as approximately 400 000 gallons of the implicated products were distributed throughout the US.

In addition, many industrialized countries are experiencing outbreaks of diseases due to relatively new types of foodborne pathogens such as *Campylobacter jejuni*, *Listeria monocytogenes*, and *E. coli* H 157:O7. Campylobacteriosis has increased to such an extent that it is now the leading foodborne disease in several industrialized countries, such as the UK (Figure 1). As in the case of *Salmonella*, the main vehicles for the transmission of *Campylobacter* are poultry meat and unpasteurized milk.

Listeria monocytogenes (L.m.) causes severe foodborne infections, with a high fatality rate in susceptible individuals. The fatality rate, especially in neonates and immuno-compromised adults, is in the range of 27% to 30%. Although diseases caused by L.m. are rare, this microorganism has been implicated in several important outbreaks involving different types of food such as milk, cheese, vegetables, and meat products. L.m. in hot dogs and other meat and poultry products resulted in several large product recalls in the US. At present there is no full understanding of its ecology, but it is known to be able to grow at refrigeration temperatures and at a wide range of pH; it is thus of major concern to food industries producing products that support the growth of L.m. and which have an extended shelf life at refrigeration temperatures.

Outbreaks of *E. coli* O157:H7 are causing concern in many countries, because the pathogen causes severe damage to health, even death, particularly in children. Outbreaks of this infection have been reported in Australia, Canada, Japan, the US, the UK, and many other European countries. In 1993, a major outbreak of *E. coli* O157:H7 infection affected some 500 people in the northwestern states of the US. Many children developed hemolytic uremic syndrome (HUS), and four died as a result. Another large outbreak caused by this pathogen occurred in Africa in 1992, affecting probably thousands of people, with an undocumented number of cases of HUS. Drinking water and cooked maize were the vehicles of transmission. In 1996, in an outbreak of *E. coli* O157:H7 in Japan, 6309 schoolchildren and 92 school staff members were affected. The outbreak resulted in two deaths. The epidemiological investigation identified fresh radish sprouts (kaiware-daikon) as the probable cause of the outbreak. This was the largest outbreak ever recorded from this pathogen. Another important outbreak of *E. coli* O157:H7 occurred in Scotland between November 1996 and January 1997. Some 400 people were affected, and about 20 elderly people died as a consequence. The outbreak was traced to cold cooked meat (loose or in sandwiches) bought from a local butcher.

Another emerging problem is diarrheal illness due to *Cyclospora caytenensis*. In the US and Canada, three large outbreaks occurred in 1996, 1997, and 1998. The outbreaks were attributed to the consumption of imported fresh raspberries, probably contaminated through water. The route of transmission of cyclospora needs to be further elucidated, but it is believed that the parasites may be transmitted indirectly via the fecal-oral route.

Hepatitis A is common all over the world: some 10 persons to 50 persons per 100 000 are affected annually. Shellfish grown in contaminated water have often been recognized as a source of this disease. An epidemic of shellfish-borne hepatitis A in China in 1988 affected some 292 000 persons (with 32 fatalities) and was related to the consumption of contaminated clams. Food contaminated by infected food handlers and not subsequently sufficiently heated may also transmit the disease. Therefore, many cases of hepatitis A are known to be restaurant associated.

2.6. Health Effects of Foodborne Diseases

Except for a few diseases, such as botulism, brucellosis, listeriosis, and typhoid fever, foodborne diseases are often viewed as mild and self-limiting. Although this may be true in a number of cases, in many other cases the health consequences can be serious, even life threatening. The false perception has, in part, contributed to the lack of attention paid to the problem. Foodborne diseases vary in their health consequences depending on the disease agent, the stage of treatment, and the duration of the illness, in addition to the age and susceptibility of the individual. Acute symptoms include diarrhea, vomiting, abdominal pain, cramps, fever, and jaundice. In the case of many foodborne diseases, healthy adults recover within a few days to a few weeks from acute health effects.

Some foodborne diseases can, however, cause serious and chronic sequelae on the cardiovascular, renal, articular, respiratory, or immune systems. In a survey of 32 448 cases of foodborne diseases in Russia, chronic health effects occurred in more than 11% of patients, with hypertension and cholelithiasis being most frequent. A number of patients also developed myocardial infarction.

Examples of health complications associated with foodborne illness are reactive arthritis and rheumatoid syndromes, meningitis, endocarditis, Reiter's syndrome, Guillain-Barre syndrome, and hemolytic uremic syndrome (HUS). For example, salmonellosis has been reported to cause reactive arthritis in some subjects. In the milkborne salmonellosis outbreak that occurred in Chicago in 1985 (see *Industrialized Countries*), some 2% of patients developed reactive arthritis as a result. It is estimated that up to 10% of patients with enterohemorrhagic *Escherichia coli* (including *E.coli* O 157) infection may develop HUS, with a case-fatality rate ranging from 3% to 5%. The manifestations of listeriosis may include septicemia, meningitis, encephalitis, osteomyelitis, and endocarditis. Infection caused by *V. vulnificus* may be present as fulminate septicemia, often complicated with necrotizing cutaneous lesions. According to some studies, the case-fatality rate for patients with preexisting liver disease is 63% and for those without liver disease 23%. Cysticercosis, an infection with the larval stage of *Taenia solium*, common particularly in South America, may lead to cerebral lesions.

The liver flukes *Opisthorchis viverini* and *Clonorchis sinensis* cause mechanical obstruction of the biliary tract and recurrent pyogenic cholangitis, and are carcinogenic to humans.

In certain groups (e.g., the elderly, infants, young children, pregnant women, the malnourished, and immuno-compromised individuals), these health effects may be even more serious. For example, in pregnant women listeriosis can lead to abortion, stillbirth, or malformation of the fetus; the overall fatality rate is about 30%. In an outbreak of listeriosis in pregnant women in Western Australia, the fatality rate of infected fetuses was as high as 50%.

Transplacental infections of *Toxoplasma gondii* may occur in some 45% of infected pregnant women. In 10% to 20% of nonfatal morbidity, the infants may suffer from damage to the central nervous system and retinochoroiditis, leading to blindness. It is believed that infected but asymptomatic infants may also develop some sequelae later in life, most commonly retinochoroiditis. It is estimated that, worldwide, in about 3 pregnancies out of every 1 000 pregnancies the fetus/infant is affected by toxoplasmosis. In the US, toxoplasmosis is considered the most expensive foodborne disease. Foodborne diseases are one of the most important underlying factors for malnutrition and, indirectly, for respiratory tract infections. Repeated episodes of food-bome diseases over a period of time can lead to malnutrition, with serious impact on the growth and immune system of infants and children. An infant whose resistance is suppressed becomes more vulnerable to other diseases (including respiratory tract infections) and is subsequently caught in a vicious cycle of malnutrition and infection. Many infants and children do not survive under these circumstances (Figure 2).

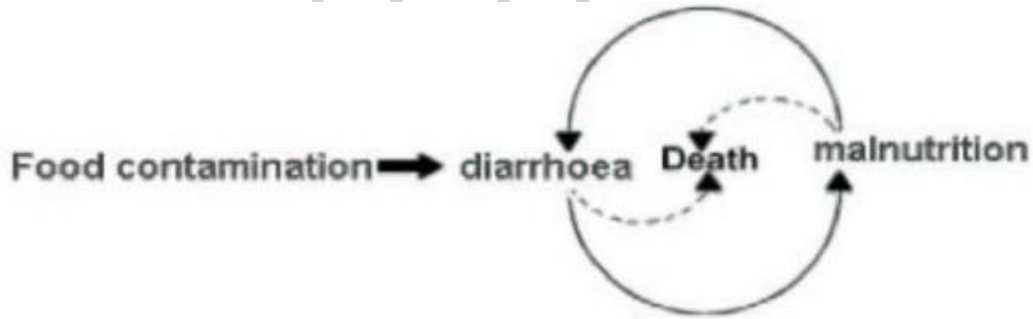

Figure 2. The vicious diarrhea-malnutrition cycle

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Biographical Sketches

Fritz K. Käferstein, after studying at veterinary schools in Giessen and Berlin, received his veterinary degree in 1962 from the University of Giessen. He obtained in 1964 his D.V.M. for a thesis on the identification and significance of the presence of antibiotic residues in meat. At that time he worked as research assistant at the Veterinary Faculty of the University of Giessen.

From 1968 to 1972, F.K. worked for the New Zealand Department of Agriculture as a Supervising Veterinarian in the meat industry. Upon his return to Germany, he joined the German Federal Health Office, first as Chief of the Food Safety Unit in the Robert-von-Ostertag-Institut and later as Director of the Center for Monitoring and Health Evaluation of Environmental Chemicals in Food. In this capacity he was also directing the WHO Collaborating Center for Food Contamination Monitoring and collaborated closely with various groups in WHO.

In 1977, F.K.was appointed by the President of Germany as Director and Professor.

In 1980, WHO offered him the managership of the just established Food Safety Program, which got its own administrative structure in 1985. During his time with WHO, F.K. developed food safety from a marginal to a core and priority public health program and initiated the concept of shared responsibility for food safety. F.K. retired from WHO in July 1998 as Director of the Program on Food Safety and Food Aid. During the 18 years with WHO, F.K. served also as WHO Joint Secretary of the Codex Alimentarius Commission.

Since November 1998, F.K. works as Distinguished Visiting Scientist for the Food and Drug Administration and the Food Safety and Inspection Service in the US. He also is an Adjunct Fellow at the Center for Food and Nutrition Policy at Georgetown University, Washington, DC, and lectures on food

safety at the School of Public Health, Yale University, New Haven, Connecticut.

In 1998, F.K. received the R.E. Engel Award for outstanding contribution and dedication to food irradiation. In 1999, F.K. was invited to deliver the Ivan Parkin lecture at the annual meeting of the International Association of Food Protection and received an award to honor his contributions and dedication to the field of food safety. F.K. is the winner of the Walter F. Snyder Award 2000 of the National Environmental Health Association. In 2000, F.K. was selected as an Honorary Diplomat of the American Veterinary Epidemiological Society. F.K. is a Founding Fellow of the International Academy of Food Science and Technology and a Member of the WHO Expert Advisory Panel on Food Safety.As of 2001, F.K. works independently as International Food Safety Consultant.

Dr. Yasmine Motarjemi has a Master's Degree in Food Science and Technology from the University of Languedoc, in Montpelier, France, and a Ph.D. degree in Food Engineering from the University of Lund in Sweden.

After ten years of research and academic work at Lund University on water activity and heat and mass transfer in foods, in 1990 she joined the Food Safety Programme of the World Health Organization (WHO). During the ten years of service at WHO, she served as the WHO representative to many Codex Alimentarius Committees.

In 2000, Dr. Motarjemi joined Nestel, in Vevey, Switzerland, as Food Safety Manager in the Quality Management Department.

Dr. Motarjemi is co-author of two WHO publications, and many book chapters and articles on topics from food technology to foodborne diseases and food safety.

Dr. Gerald Moy is a staff scientist with the Programme of Food Safety at WHO in Geneva. He serves as manager of the GEMS/Food Programme, which has established a global database for food contamination.

He received his Bachelor's Degree in Chemistry from the University of Wisconsin and his Doctorate from Oregon State University in physical organic chemistry in 1976. This was followed by a postdoctoral fellowship in biophysics at the University of New Mexico. In 1978 he joined the US Food and Drug Administration, where he served as Consumer Safety Officer for food additives and animal drugs, and as Desk Officer for Multilateral Programs. In 1987 he became the Food Safety Advisor for the WHO Western Pacific Region's Environmental Health Centre based in Kuala Lumpur, Malaysia. Since 1991, Dr. Moy has been at WHO headquarters in Geneva.

His numerous publications include a chapter in *Mycotoxins in Agriculture and Food Safety* (Marcel Dekker), and in *International Standards for Food Safety* (Aspen), and the article, "Healthy Marketplaces: An Approach for Ensuring Food Safety and Environmental Health," in the *Journal of Food Control*.