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Foodborne Disease and Vulnerable Groups

Introduction

Foodborne disease may be caused by pathogenic microorganisms or by toxic chemicals. For microbial hazards, susceptibility may be increased by many factors, particularly those that reduce immune system function. For example, neonates, infants, young children are more vulnerable to certain foodborne diseases because of immaturity of their immune and physiologic systems. For the elderly, progressive weaknesses of the immune system play a major role. Another group is pregnant women because of immune tolerance to the fetus. Also vulnerable are those having poor nutritional status, existing health problems, such as HIV infection and liver disease, and drug therapies which suppress the immune system, such as those for cancer and organ transplantation. Such persons are not only more likely to acquire foodborne infections, but also are prone to more severe disease outcomes, including higher mortality rates. The main pathogens involved include bacteria (*Salmonella*, *Escherichia coli*, *Campylobacter*, *Listeria monocytogenes*) and viruses (norovirus, rotavirus), as well as parasites (*Cryptosporidium*, *Giardia*, *Toxoplasma gondii*).

For chemical intoxications, windows of vulnerabilities may occur at different stages of life and can result in both acute and chronic health effects. Chemical exposures of the fetus can lead to spontaneous abortion, low birth weight, structural congenital abnormalities and carcinogenesis. The fetus and the young are also vulnerable to chemically-induced mental and physical developmental deficits, such as reduced intelligence caused by exposure to lead. Because children consume twice to three times the amount of food on a body weight basis compared to an average adult, children are generally more vulnerable because of their increased exposure to toxic chemicals. In the case of food allergies, vulnerability is due to an overly active immune system in contrast to biological hazards where the immune system is impaired. Allergies due to food proteins are not uncommon with the most predominant being allergies to milk, eggs, peanuts, tree nuts, fish, shellfish, soy, and wheat and where reactions can be mild to life-threatening. While the number of people allergic to a specific food may be low, the total number of people with food allergies is sizable. Another vulnerable group is those who are deficient in a key enzyme that inhibits their metabolism of certain food components, such as lactose.

Foods known to be contaminated with microbial or chemical hazards that may pose risks to vulnerable groups should be considered for intervention measures to reduce such risks. Processing of food has been effective in removing many of these biological and chemical hazards. In some cases, foods specifically designed for vulnerable groups have been developed and marketed. For pre-packaged food, labeling has been used to promote safe handling of food and warn of possible hazards. Education of vulnerable groups (and those who prepared food for them) has also been used to reduce risks for these populations.

Groups Vulnerable to Microbiological Hazards

Important factors in the acquisition and development of foodborne diseases include the virulence of the pathogenic agent (bacteria, virus and parasite), the exposure to the agent in a meal or over short time, and resistance of the person to infection, including immune competency. In particular, immune competency is negatively affected by the age (the young and the elderly), pregnancy, and other factors. For healthy adults, many infectious foodborne illnesses result in gastrointestinal symptoms, like vomiting and diarrhea, which are generally self-limiting or require only modest supportive care. Epidemiological evidence, however, has shown that groups who are at increased risk of infection, develop more severe outcomes and have higher mortality rates.

The most important factor in this vulnerability to foodborne disease is impaired immune response which can take many forms. For example, immunosuppression may be caused by inherent immunodeficiency (genetic), malnutrition, immunosuppressive drug treatment, certain diseases like HIV/AIDS, cancer, cirrhosis or other liver diseases and poor nutritional status, like iron deficiency anemia. Attempts have been made to better understand the relationship between immunosuppression and vulnerability to foodborne infections. An abundant international scientific and medical literature, including case reports, surveys and reviews, has been published on foodborne diseases in vulnerable populations which provides insight on this growing public health problem which affects both developed and underdeveloped countries.

Neonates, infants and children

Neonates and infants are more vulnerable to a range of pathogens because their immune systems are not fully mature. Developmental immaturity, reduced production of immunoglobulin, mucus and acid, and deficient gut motility necessary for appropriate local response to pathogens are major factors. Except for neonates and infants protected by exclusive breastfeeding to the age of 6 months, weaning food contaminated with pathogens sets in motion the diarrhea-malnutrition cycle that is one of the primary causes of infant and young child mortality in developing countries. The World Health Organization estimates that 760,000 deaths a year in children under the age of five are caused by diarrheal disease attributed mainly to contaminated food and water. This estimate would be larger if other causes of death due to other opportunistic infections and malnutrition itself were included.

Micronutrient deficiencies (vitamin A which maintains the integrity of the epithelium in the gastrointestinal tract as well as zinc, and copper) also adversely affect immune response. These deficiencies further increase the vicious cycle between diarrhea and malnutrition. However, interventions have focused on treatment rather than prevention. For example, data from sub-Saharan Africa and Southeast Asia has indicated a decline in child mortality due to diarrheal diseases largely due to the promotion of oral rehydration therapy, but morbidity rates remain high. With an estimated 1.7 billion cases a year, diarrheal diseases are the leading causes of malnutrition in children under the age of five.

In a number of countries, especially in Asia and Africa, weaning foods are often prepared under unhygienic conditions, and thus are frequently heavily contaminated with pathogens. Some studies indicate an increase in the incidence of diarrheal diseases starts soon after weaning is initiated. Among children, diarrheagenic *E. coli*, and more especially enteropathogenic *E. coli* and enterotoxigenic *E. coli* (ETEC), are major causes of infantile bacterial diarrhea in developing countries. Because of the diversity

of subtypes and consequently of antigens, children may be subject to repeated infections by pathogenic *E. coli* because of the lack of immune protection. Enterohemorrhagic *E. coli* (EHEC) infections can result in hemorrhagic colitis with a small percentage of cases developing hemolytic uremic syndrome (HUS), a life-threatening complication characterized by hemolytic anemia, thrombocytopenia, and renal insufficiency. Young children are at the highest risk of developing HUS.

Beside diarrheal diseases, several non-typhi serotypes of *Salmonella* Enterica (NTS) are an important cause of childhood bacteremia with a high associated case fatality of 20-25%, especially in Africa. While infection of healthy adults usually results in self-limiting gastroenteritis of short duration that does not require antibiotic therapy, the very young are at increased risk, with higher incidence of disease, more serious complications and higher case-fatality rates. In comparison to NTS, *S. typhi* is a highly adapted, invasive, human-restricted pathogen which has now the greatest impact in developing countries, especially school-age children from resource-poor settings with inadequate water and sanitation systems; they are disproportionately affected with an estimated total of 400,000 cases occurring annually in Africa. The emergence and spread of *S. typhi* strains having multiple resistance to nearly all commonly available antibiotics in most developing countries is a growing major public health problem.

Two pathogens deserve special mention regarding neonates and infants in spite of low disease incidence: *Cronobacter* spp. and *Clostridium botulinum*. While *Cronobacter* spp. causes invasive infections in all age groups, higher incidence is observed in neonates and infants. Outbreaks have been detected most commonly among newborns and very young infants in hospital nurseries and neonatal intensive care units and contaminated powdered infant formula has been epidemiologically linked with infections. Infants are also especially vulnerable to infection by spores of *C. botulinum*, which, after ingestion, can germinate and colonize the infant colon producing botulinum neurotoxin. Honey is a well-recognized vehicle for this disease.

Campylobacter (*C. jejuni* and *C. coli*) is one of the most common causes of bacterial acute gastroenteritis worldwide and an important cause of childhood morbidity. In developed countries, the disease is found mainly in children <5 years and in young adults. Bacteremia is detected in less than 1% of patients and is more often diagnosed among the very young or very old or in immunocompromised patients.

Shigella is the most important cause of bloody diarrhea worldwide. In a prospective population-based study in six Asian countries over the period 2000 - 2004, covering 600,000 persons of all ages, *Shigella* was isolated from 2,927 (5%) of 56,958 diarrhea episodes. The incidence for children <5 was 13 episodes per 1,000 residents/year while the overall incidence was 2/1,000/year.

Two viruses, rotavirus and norovirus, are responsible of a majority of gastroenteritis in children. The incidence of rotavirus diarrhea is high, affecting all children worldwide no matter the level of sanitation, quality of water and food type or behavior. A multicenter study in seven European countries indicated that diarrheal episodes in children <3 three years caused by rotavirus were more severe generating an increase in emergency consultations and hospitalizations. Norovirus is the well-known cause of foodborne outbreaks worldwide, which often occur in closed and crowded environments, such as those found in hospitals, nursing homes, day-care centers and cruise ships.

Intestinal parasitic infections contribute to the enteric disease burden experienced by children. Low birth weight, malnutrition, stunting and lack of breastfeeding have been identified as predisposing factors. The two most frequently identified parasites are *Giardia lamblia* and *Cryptosporidium* (*C.*

hominis and *C. parvum*). Although cryptosporidiosis and giardiasis affect persons in all age groups, the highest incidence is observed for children 1-9 years.

Pregnant women

Pregnant women are especially vulnerable to a number of foodborne infections that may be transmitted to their fetus. Because the fetus has genetic traits of the father, the maternal immunological system must be down-regulated during pregnancy to become tolerant of certain cellular antigens present in the fetus. Hormonal changes, such as an increase in progesterone, also increase a pregnant woman's vulnerability to the infection by certain pathogens, especially *Listeria monocytogenes* and *Toxoplasma gondii*. Because they are intra-cellular microorganisms, cell-mediated immunity plays a critical role in the control of the disease. While the *Listeria* infection of the mother may be asymptomatic or appear as a self-limiting non-specific flu-like illness during the third trimester, the transplacental transmission of the organism may have serious consequences for the fetus and newborn, including spontaneous abortion, fetal death, stillbirth, and severe neonatal septicemia. Many types of industrially processed ready-to-eat foods which support *L. monocytogenes* growth during extended refrigerated storage are well known food vehicles. This is the likely reason that listeriosis is mainly reported from developed countries. Data from the USA and from France clearly rank pregnant women among the highest risk groups for listeriosis.

Another important disease for this vulnerable group is toxoplasmosis. When a pregnant woman is newly infected by *Toxoplasma gondii*, the disease is often unrecognized because symptoms are mild. However, the consequences for the pregnancy can be significant, including miscarriage, stillbirth and preterm birth, or neurologic disorders in the infant (mental retardation and visual impairment). During the last decade, toxoplasmosis seroprevalence in women who were pregnant or of childbearing age was high in most of the world with a trend towards lower seroprevalence in Western Europe and the USA. Contaminated meat, especially horse, pork, lamb, and venison, is thought to be the source of infection in at least half of the cases with the remainder due to direct or indirect exposure to feces of the cat, which is the requisite host for the parasite.

Hepatitis E is transmitted by the fecal-oral route and contaminated water or food supplies have been implicated in major outbreaks. The ingestion of raw or uncooked shellfish has also been identified as the source of sporadic cases in endemic areas. Every year there are an estimated 20 million hepatitis E infections, over 3 million acute cases of hepatitis E, and 56 600 hepatitis E-related deaths. Hepatitis E is found worldwide, but the prevalence is highest in East and South Asia and sub-Saharan Africa. Hepatitis E is usually self-limiting but may develop into fulminant hepatitis (acute liver failure). Pregnant women are at greater risk of obstetrical complications and mortality from hepatitis E, which can induce a mortality rate of 25% among pregnant women in their third trimester. China has produced and licensed the first vaccine to prevent hepatitis E virus infection, although it is not yet available globally

In addition, transplacental infection of the fetus, preterm delivery or low birth weight were also reported for *S. typhi*, *C. jejuni*, *Brucella* species (generally *B. melitensis*), *Coxiella burnetii* (causing Q fever) and hepatitis A.

The elderly

In contrast to neonates, the immune system in the elderly is characterized by a general decline in cell function. Qualitative and quantitative changes in the efficiency of humoral and cell-mediated and innate immune responses contribute significantly to increased risk of severe illness and mortality. Low gastric acidity and reduction of peristalsis are contributing factors. In addition to these factors, underlying medical conditions such as diabetes, prolonged use of antibiotics, macro- and micronutrient deficiencies, chronic illness, physical disabilities, can also contribute to the morbidity and mortality of foodborne disease in the elderly. Lifestyles, such as handling food differently, traveling to exotic countries or living in long-term care facilities (LTCFs), can also increase risk.

In the USA, the highest morbidity rates were in older adults (>65 years) for all foodborne pathogens except *Shigella*. Overall, most deaths (58%) occurred in persons >65 years old. *Listeria monocytogenes* had the highest case fatality rate, followed by *Vibrio parahaemolyticus*, EHEC, *Salmonella*, *Campylobacter*, and *Shigella*. In Australia in 2007, 54% of the reported outbreaks of gastroenteritis occurred in LTCFs. *Salmonella*, *C. perfringens* and *S. aureus* were the most frequent bacterial pathogens incriminated. In recent years, noroviruses have emerged as a major cause of gastroenteritis outbreaks in LTCFs in a number of countries. In the Western countries, given their ageing population profiles, foodborne disease in the elderly will become a major public health problem, especially in LTCFs, unless better prevention and control measures are implemented.

The immunosuppressed

The emergence of HIV infection since the early 1980s, the increasing use of solid and hematologic transplantation, the increased number of patients with cancer treated with chemotherapy and immunotherapy and the use of immunosuppressive medication for some chronic diseases are four major factors explaining the increase of immunocompromised patients. In these patients, foodborne diseases are often characterized by atypical presentations caused by opportunistic pathogens, making the detection and management of infections in such patients more difficult.

HIV/AIDS patients

HIV infection, the most common immunodeficiency state worldwide, is characterized by an increased susceptibility to opportunistic and common pathogens, including a high proportion of foodborne diseases. The condition is aggravated by malnutrition. *Salmonella* and *Campylobacter* infections are frequently characterized by persistent infection, with more severe and prolonged diarrhea, multiple recurrences, increased risk of septicemia and metastatic infection and high case-fatality rates (20-25% in Africa). In addition, co-infection with HIV and malaria is very common in sub-Saharan Africa. Malnutrition, the immune system, malaria and diarrhea are interconnected, which increases the burden of diarrheal disease. The increasing prevalence of antibiotic resistance complicates the management of this disease.

Cerebral toxoplasmosis was one of the first opportunistic infections to be described in HIV-infected patients. After the acute infection stage, *T. gondii* continues to exist in human tissue. In people with immunodeficiencies, rupture of cysts results in disease reactivation, including encephalitis or disseminated toxoplasmosis. Toxoplasmosis remains one of the main causes of early death among HIV/AIDS patients in some countries. Cryptosporidiosis is also a common opportunistic enteric protozoal disease with higher prevalence among HIV-infected persons presenting with diarrhea and low CD4 lymphocyte count <200cells/ μ L. Chronic diarrheal cases were frequently found to have polyparasitic infection.

Cancer, organ transplant and certain other patients

Some cancers (hematologic cancers for example) induce a higher risk of several bacterial and viral foodborne infections. Similarly, pharmacologic agents that induce immunosuppression, used to prevent rejection of a transplanted organ or for cancer treatment (including radiation), are well known factors predisposing to foodborne disease. This has been demonstrated for nearly all bacteria, viral and parasitic food pathogens. For example, the case fatality rate of listeriosis according to patients' characteristics in France ranged from 20% to 40%, with the highest for cases with lung and pancreatic cancer; similarly, the same study demonstrated that organ transplantation patients had a >100-fold increased risk of listeriosis (>5 cases/100,000) compared with persons <65 years with no underlying conditions. Immunosuppression caused by some chronic diseases, such as chronic cold hemagglutinin disease, rheumatoid arthritis, systemic lupus erythematosus, and Crohn's disease, makes these patients more susceptible to foodborne infections. Patients being treated for gastroesophageal reflux disease, e.g. antacids or proton pump inhibitors, may also be at risk.

Groups Vulnerable to Chemical Hazards

Toxic chemicals may also adversely affect certain vulnerable groups, but by different mechanisms than biological hazards. The neonates, infants and young children, are vulnerable to certain chemicals which impact on their development, especially that of the nervous and endocrine systems. Another factor which makes children more vulnerable to toxic chemicals in general is that their exposure is usually two to three times that of an adult because of their higher consumption on a body weight basis. For most chemical hazards in food, young children are usually the greatest risk, unless the chemical is in a food that they do not like to eat, e.g. broccoli. Pregnant women, namely and their fetes, are similarly at risk of birth defects and developmental deficits as a result of *in utero* exposures. In the case of persons sensitive to food allergens, vulnerability is not caused by reduced immunity but rather an over response of the immune system. Vulnerable groups can also be genetically predisposed to the toxic effects of certain chemicals because of differences in their absorption, distribution, metabolism and excretion of food components.

Neonates, infants and children

While they are severely affected by microbiological hazards, neonates, infants and children are also highly vulnerable to chemical hazards in foods. They are also more highly exposed because on a body weight basis, they consume two to three times as much food as an average adult. Because their metabolic pathways are immature, their limited ability to metabolize, detoxify and excrete many toxicants makes them less able to deal with toxic chemicals, although this is protective against a few chemicals, e.g. paracetamol. However, the more critical aspect of their vulnerability is their rapid growth and development processes which are extremely sensitive, and often their inability to repair damage caused by even short-term exposures. If brain cells are destroyed by contaminants such as lead or methyl mercury, or if false hormonal signals are sent to developing reproductive organs, the adverse effects may be irreversible and result in developmental and behavioral problems many years or decades later.

Whether they are breast- or bottle-fed, neonates and infants during the first months of life are particularly at risk because they rely on a single source of food to provide all of their nutrient needs.

For example, the omission of a critical nutrient in infant formula can result in injury or death because no other food is consumed. An infant formula that failed to contain salt caused irreversible mental retardation in infants in the USA and resulted in the adoption of legislation that raised the level of Good Manufacturing Practices for infant formula similar to those used in the pharmaceutical industry. Even with heightened precautions, periodic incidents involving infant formula that contained a toxic chemical (melamine) or lacked an essential nutrient (methionine) have occurred. However, even breastmilk is not risk free. Although it is the best, and by some experts, the only food for infants, chemical contaminants coming through the mother's body may pose health concerns. For example, the presence of DDT and other organochlorine pesticides in breastmilk has been shown to arise from contaminated food consumed by the mother and to bioaccumulate in her adipose tissue. Such chemicals have caused endocrine disruption in animals. Today, the appearance of other endocrine disruptors in breastmilk, such as dioxins, polychlorinated biphenyls and bisphenol A, have raised safety and policy issues that science has struggled to answer. For example, assessing the long-term impact of complex mixtures of endocrine-disrupting chemicals is proving difficult. Few chemicals have been tested for their potential adverse effects on neonates and infants. The World Health Organization has stated that its Acceptable Daily Intakes established for food additives and pesticide and veterinary drug residues do not apply to neonates and infants under 12 weeks of age. As a precaution, several jurisdictions have established very conservative limits for such chemicals in infant formula and baby foods.

Pregnant women

Maternal health can be affected by toxic chemicals in food, particularly when acute poisonings occur. Low level exposures to chemicals at currently allowed limits are probably below the threshold which may cause adverse health effects. However, some studies suggest that exposure of pregnant women to agricultural pesticides and arsenic is linked to gestational diabetes and to later development of type 1 diabetes. The most important impact of chemicals is on the developing fetus that undergoes profound transformations which are driven by a complex dynamic of genetics and biochemical feedback. The placenta was once believed to shield the developing fetus from most chemicals, but it is now known that the fetus is exposed to hundreds of chemicals, many of which arise from the maternal diet. Only recently has research been undertaken to assess the health impact of such exposures. From environmental disasters, such as in Minamata Bay, it is known that the consumption of contaminated food may not have any obvious health effect on the mother, but can cause severe harm to the fetus. While many of these chemicals originate from mother's daily diet, some chemicals, such as dioxins and polychlorinated biphenyls, bioaccumulate in adipose tissue and are mobilized during pregnancy when maternal fat reserves are used. Special windows of vulnerability are associated with long-term, irreversible effects on reproductive and neurological systems. For example, women who were exposed *in utero* to the drug diethylstilbesterol taken by their mothers developed a rare vaginal cancer decades later. Another example is the drug thalidomide which was taken by pregnant women during a window of vulnerability and which caused birth defects in an estimated 10,000 infants in Europe and elsewhere.

In spite of the difficulty in doing such studies, recent research in the USA has identified and quantified the impact of fetal exposures to lead, organophosphate pesticides and methyl mercury. The neurotoxic effects of these chemicals on intelligence as measured by IQ was estimated to result in the loss of 27 million, 17 million and 0.3 million IQ points, respectively. For US children, the average loss was 1.6 points which is more than the IQ loss due to preterm birth or ADHD. While not perceptible on an individual basis, the potential shifting of the bell curve raises serious societal concerns. For example, a reduction in the average IQ of 5 points means that half as many children will be in the category of "intellectually gifted," while twice as many will be "intellectually impaired". The economic cost is

estimated to be many billions of dollars due to lost productivity, costs of diagnosis, treatment, special education, incarceration and other indirect costs. Other potential developmental neurotoxins that may be found in food include arsenic, PCBs, toluene, ethanol, manganese, fluoride, DDT, chlorpyrifos, tetrachloroethylene and polybrominated biphenyl ethers.

The allergen sensitive

In contrast to vulnerability to biological hazards, those who are vulnerable to allergic reactions from foods display a hyper reaction of their immune systems. A food allergy is manifested by an IgE-mediated process that first involves sensitization to a food protein and then at a later time, elicitation of the allergic reaction by re-exposure to the protein. In some documented cases, exposure to very small traces of the allergen have caused death. Allergic reactions are caused by the rapid release of histamine and tryptase. A cascade of physiological processes may also cause other adverse reactions. Common food allergens include peanuts, milk, eggs, tree nuts, fish, shellfish, soy, and wheat, which account for about 90% of all allergic reactions. In some countries, allergies to mustard, buckwheat and sesame are common. Although sulfites do not cause a true allergic reaction, sulfite-sensitive people may experience similar reactions as those with food allergies. Asthmatics, many of whom are children, are at greater risk of sulfite sensitivity.

While the number of persons sensitive to particular food may be small, 6 to 8% of children under the age of three and nearly 4% of adults are estimated to be vulnerable to allergens. The incidence of sulfite sensitivity in the general population is thought to be less than 2%, but is estimated to be between 5 and 13% for asthmatics. About 50% of children with allergies to milk, egg, soy, and wheat will outgrow their allergy by the age of 6. Peanut and tree nut allergies are less likely to be outgrown. For reasons that are not entirely understood, the diagnosis of food allergies has become more common in Western nations in recent times.

Gluten sensitivity is composed of a range of disorders associated with the consumption of wheat, rye and barley and their products that contain gluten and more specifically, its alcohol-soluble fraction, gliadin. The condition is characterized by a variety of immunological, morphological and symptomatic manifestations that may also be shared by celiac disease and irritable bowel syndrome. Only about 40-50% of gluten sensitive patients may have IgG or IgA anti-gliadin antibodies. Consequently, the condition is also referred to as a gluten intolerance.

The food intolerant

Nonimmune-mediated intolerances are those caused by metabolic deficiencies or toxicological reactions to food chemicals. The most common forms of metabolic intolerance are associated with enzyme deficiencies, including lactose intolerance, aldehyde dehydrogenase deficiency and favism. Lactose intolerance is a common metabolic deficiency caused by the lack of the enzyme lactase, which breaks down lactose into glucose and galactose. While this enzyme is present in infancy and early childhood in all humans, its production declines as most people mature. Up to 70% of adults worldwide have reduced lactase activity. When such individuals consume dairy foods, lactose remains undigested and passes into the large intestine where fermentation by microflora produces cramps, flatulence and diarrhea. Another enzyme deficiency involves aldehyde dehydrogenase which oxidizes acetaldehyde to acetic acid during the metabolism of alcohol. Primarily found in Asian populations, this intolerance to alcohol results in erythema, or flushing, when alcoholic beverages are consumed. This condition has been linked to a great risk of esophageal cancer, but on the positive side, to lower rates of alcoholism.

Favism is the result of a deficiency in glucose-6-phosphate dehydrogenase and is manifested by an abnormal breakdown and loss of red blood cells after consumption of fava beans (broad beans). Such beans contain the glycosides vicine and convicine, which are thought to be responsible for the effect. Another intolerance is a deficiency in phenylalanine hydroxylase that converts phenylalanine to tyrosine. The deficiency affects about 1 in 10,000 - 20,000 people, but adverse health effects can be minimized by observing strict dietary regimes that avoid phenylalanine.

Prevention of Foodborne Disease in Vulnerable Populations

While general food safety messages are also applicable to vulnerable populations, targeted advice according to their specific vulnerability should be considered to ensure an appropriate level of foodborne disease prevention. The national food safety / public health agencies of a number of countries have developed such recommendations for populations at increased risk. For example, the U.S. Department of Agriculture's (USDA) Food Safety and Inspection Service and the U.S. Department of Health and Human Services' Food and Drug Administration (FDA) have prepared « Guides for People at Risk of Foodborne Illness » to provide practical guidance on how to reduce risk of foodborne illness to people with cancer, HIV/AIDS and diabetes, transplant recipients, pregnant women, and older adults. Several organizations— for example, WHO (World Health Organization), USDA, the Food Standards Agency of the United Kingdom—have issued guidelines to ensure product safety, including information on safe infant formula preparation, storage and handling.

To aid persons with food allergies and intolerances, some countries have responded by instituting labeling laws that require food products to clearly inform consumers if their products may cause allergies or intolerances. For example, processed food that contains the artificial sweetener aspartame that contains phenylalanine must be labeled with a specific warning for phenylketonurics. Some countries also require companies to warn customers when a food has been prepared with the same equipment that was previously used for those containing food allergens, i.e. carry-over.

Conclusions

Several groups have been identified as being vulnerable to foodborne diseases caused by various microbiological and chemical agents in food. Because of their higher disease incidence, more serious complications and/or greater mortality, these groups bear the brunt of the burden of foodborne diseases. Consequently, specific prevention measures should be undertaken by governments, the food industry and individuals to reduce such foodborne risks to the extent possible. For biological hazards, infants in developing countries suffer the greatest health consequences from foodborne diarrheal disease which is a major obstacle in the realization of Millennium Development Goal no. 4 ("Reduce child mortality"). With safer weaning food, the incidence of diarrheal disease can be reduced and with it, child mortality. For chemical hazards, prevention of exposure, particularly of the fetus, infants and young children, will require further improvements in the hazard characterization and exposure assessment of chemicals in the food supply. The management of such risks, however, needs to take into account the health and economic implications for society and that has often proved to be controversial.

In regard to vulnerable groups, the food science and technology community might contribute to the development of new foods and formulations to accommodate specific needs of vulnerable groups, such as safer weaning food. On the other hand, when developing a new food or formulation, consideration should be given to assessing the safety of the new products for vulnerable groups. Even changes in the

source of raw materials and other inputs as well as changes in the manufacturing process might have a potential impact on a vulnerable group. Labeling is also critical to many vulnerable groups and efforts should be made to educate vulnerable groups about the content and handling of particular foods as well as specific messages which can be either positive (assurances), negative (warnings) or provide important storage and usage instructions. Catering services and suppliers of food provided to schools, and day-care centers for young children, hospitals, long-term care facilities and vulnerable people in their homes should take extra precautions to ensure food safety. The food science and technology community is in the best position to serve as advocates for greater food safety for vulnerable groups and to contribute to cost-effective solutions.

Websites

The Institute of Food Science and Technology has authorized an Advisory Information Statement on microbiological food safety for children and vulnerable groups prepared by its Professional Food Microbiology Group, originally issued June 1997, updated October 1998 and reviewed and updated September 2001. <http://www.ifst.org/document.aspx?id=213>

The U.S. Department of Agriculture's Food Safety and Inspection Service (FSIS) and the Department of Health and Human Services' Food and Drug Administration (FDA) have partnered to create six booklets with food safety advice for populations that are most susceptible to foodborne illness. The booklets in this "at-risk series" are tailored to help older adults, transplant recipients, pregnant women, and people with cancer, diabetes or HIV/AIDS reduce their risk for foodborne illness.

<http://www.foodsafety.gov/poisoning/risk/>

The Federal Institute for Risk Assessment has prepared guidance for caterers to hospitals, rehabilitation centers, long-term care facilities, child care centers, schools and recreational centers to better ensure that food provided to these vulnerable groups is safe. <http://www.bfr.bund.de/cm/364/safe-food-especially-vulnerable-groups-in-community-institutions.pdf>

To ensure the safe preparation of infant and follow-on formula, guidance materials have been developed by several national and international organizations.

http://www.nal.usda.gov/wicworks/WIC_Learning_Online/support/job_aids/formula.pdf

<http://www.food.gov.uk/multimedia/pdfs/formulaguidance.pdf>

<http://www.who.int/foodsafety/publications/powdered-infant-formula/en/>

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ABOUT IUFOST

The International Union of Food Science and Technology (IUFOST) is the global scientific organisation representing more than 300,000 food scientists and technologists from over 75 countries. IUFOST is a full scientific member of ICSU (International Council for Science) and it represents food science and technology to international organizations such as WHO, FAO, UNDP and others. IUFOST organises world food congresses, among many other activities, to stimulate the ongoing exchange of knowledge and to develop strategies in those scientific disciplines and technologies relating to the expansion, improvement, distribution and conservation of the world's food supply. IUFOST Contact: General Secretariat, IUFOST, 112 Bronte Road, Oakville, Ontario, Canada, L6L 3C1 Telephone: + 1 905 815 1926, e-mail: secretariat@iufost.org, www.iufost.org