

## Review Article

# Prevention and control of food safety risks: the role of governments, food producers, marketers, and academia

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**Background:** Food systems are rapidly changing as world population grows, increasing urbanization occurs, consumer tastes and preferences change and differ in various countries and cultures, large scale food production increases, and food imports and exports grow in volume and value. Consumers in all countries have become more insistent that foods available in the marketplace are of good quality and safe, and do not pose risks to them and their families. Publicity about food risk problems and related risks, including chemical and microbiological contamination of foods, mad-cow disease, avian flu, industrial chemical contamination all have made consumers and policy makers more aware of the need of the control of food safety risk factors in all countries.

**Objective:** To discuss changes in food systems, and in consumer expectations, that have placed additional stress on the need for better control of food safety risks.

**Outcomes:** Food producers, processors, and marketers have additional food law and regulations to meet; government agencies must increase monitoring and enforcement of adequate food quality and safety legislation and coordinate efforts between agriculture, health, trade, justice and customs agencies; and academia must take action to strengthen the education of competent food legislation administrators, inspectorate, and laboratory personnel for work in government and industry, including related food and food safety research.

**Conclusions:** Both Government and the food industry must assure that adequate control programs are in place to control the quality and safety of all foods, raw or processed, throughout the food chain from production to final consumption. This includes appropriate laboratory facilities to perform necessary analysis of foods for risk and quality factors, and to carry out a wide range of food science, toxicological and related research.

**Key Words:** risk analysis, risk assessment, risk management, risk communication, chemical and microbiological contamination of foods

## Introduction

Over the past 25-30 years rapid changes in the food supply industry have taken place in many parts of the world. World population has grown rapidly, reaching 6 billion in the year 2000, and is projected to grow to 8-10 billion by the year 2050. At the same time many people in all countries have moved from rural settings to the cities, and urban populations are still rapidly growing. Cities of more than 1,000,000 inhabitants are common in all parts of the world.<sup>1,2</sup>

Overall population growth and urban growth have led to many new challenges to food systems. The distance from food production points to places of food consumption has grown enormously, and foods are now often shipped over thousands of kilometers to reach final consumers. Within countries the growth of cities has required the strengthening of food distribution mechanisms as food move from farms or fishing waters to consumers in cities or rural towns and villages. While some farming families still grow most of the food they consume, these people represent a very small percentage of all people in a country that have to meet their nutritional needs on a daily basis. However, the total number of people involved in food production, processing, trade and food service, and work related to these fields represents

the largest number of employed people in virtually every country.

In order to meet new population configurations and needs, food production, processing and distribution/marketing systems have undergone dramatic changes. Older systems of cultivation of fruits, vegetables, cereals, animals and animal products, and capture fishing have changed to more efficient, more sustainable, and more productive systems. These new systems require improved seeds, proper fertilizers, large volumes of processed animal feeds, improved food storage, distribution and processing and the manufacture, use and maintenance of a wide range of tractors and other farming and food handling equipment.<sup>3</sup>

More efficient use of water and other inputs such as fertilizer have enabled significant improvements in yields per hectare for cereal grains and vegetables. Fish farming, or aquaculture, has enabled large increases in the amount of

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fish available in many countries, as harvests of ocean or fresh water fish have dropped dramatically due to over-fishing and destruction of native fish stocks. Mixed farming systems where vegetables, fruits, farm animals and fish are all grown in integrated systems have been very useful to small farmers in increasing the efficiency of land and water use, particularly in developing countries. Production of "organic foods" has also created a niche market for small farmers in many countries.

Use of new recombinant DNA techniques to produce new varieties of crops, cereals, vegetables, oil seeds, cotton, and fish have enabled production of crops without extensive tilling of the soil, helping to slow down or stop erosion, with a great reduction in the use of pesticides, or with more rapid growth and better feed efficiency in certain species of fish. Some genetic modifications have also allowed increases in nutrients such as vitamin A in rice, and many more developments are expected in this area.<sup>4</sup>

With the growth in cities and other population centers, new systems of distribution of foods have been needed. Also, when food is grown or harvested, there is usually a surplus that cannot be consumed immediately by those growing or harvesting the foods. Most foods are perishable and have to be either consumed soon after harvest, or stored in special facilities to slow down or prevent deterioration, or processed in some way to preserve the basic quality and nutritive value, making the food product available to consumers throughout the year.<sup>5</sup>

Many other food products that are prepared using many different ingredients are sold to consumers in food markets for consumption in the home, or in food service establishments such as restaurants, cafes, fast food or street food situations. The range of these products covers dry cereals, breads, and other products such as canned foods that do not need special thermal conditions, or products that need special heat, chilled or cold environments to stay in good condition. Each of these special environments can carry with them food safety concerns such as basic decomposition or rot, formation of mold and mycotoxins, food losses due to insects, rodent or other pest attacks, and growth of micro-organisms, especially pathogens.

With the growth of world population and the shift of people from rural settings to cities, new food production and processing systems have been developed. While these new systems can be very efficient to produce the increased amounts of foods needed to feed the world population, they can also bring about new food risk problems. For example, in recent years use of inappropriate animal feeding materials in the European Community and elsewhere led to large-scale problems with bovine spongiform encephalitis ("mad cow disease"), with some cases occurring in humans, called new-variant Jakob-Creutzfeldt Disease. Contamination of animal feed with oil containing high levels of dioxins and poly-chlorinated biphenyls (PCB's) in Belgium led to large scale recalls of contaminated chicken flesh and eggs, pork and other animal products. Microbiological contamination of milk and ground beef with listeria or hemorrhagic E.coli has caused a number of deaths in the USA. Current concerns about avian flu and the possibility of wide spread human influenza with a mutated virus from infected birds is causing

concern. In most of these food risk areas, introduction of new and larger scale production systems without adequate quality and safety controls have been associated with the food risk problems.<sup>6,7,8,9,10</sup>

Over the past 50 years both developed and developing countries have experienced a growth in gross national product, and more available income to many or most people. While problems on under-nutrition are still acute in many countries, these and most other countries have a growing middle-class that can afford to change their food habits from mainly cereal-based diets to diets with more elaborate food and more animal based food products. These changing food habits are in large part the driving force for the wider range of food products discussed above, including frozen foods. In most cultures higher cost foods were previously associated with feasting on special occasions such as weddings, birthdays, anniversaries, etc, but these feasts have always created a taste for more of the special foods associated with such events. With higher levels in income, and with newer systems of information such as radio and television, and, including advertising, demand for higher cost foods, including animal products has grown in many countries and population groups. In addition to possible nutrition problems, this new demand for special products can also create food safety concerns.

The new demands on food systems due to population growth and changes in demand have clearly demonstrated that agriculture and food production is a major motor or growth in most developing countries. In addition to basic food products, agriculture and fish production are important factors in creating employment directly in food production, and in other areas. Agriculture also produces non-food items such as wool, cotton and other fibers, hides and skins for leather, and creates employment opportunities for the production and maintenance of farm equipment, and in producing and making available all of the inputs needed for agriculture, including seeds and animal feeds. Agriculture also enables countries to improve their domestic trade, and expand export possibilities for raw, semi-processed, or processed foods.<sup>11</sup>

No country is self-sufficient in all of the foods it needs to meet consumer demands, so import and export of food products and essential food products for food and animal feed is necessary. Consumers demand protection from food quality and safety risks in domestic foods and food imports, so food exports must also be controlled. Many exported foods do not meet import requirements of other countries, leading to rejection, destruction or costly reconditioning of shipments, reduction of prices for further shipments, import bans for some classes of products from various countries, and severe damage to the reputation of food producers in countries with consistent food export problems.

As an example of food import rejections, in one month the US Food and Drug Administration normally finds food quality and safety problems in about 1,000 shipments of foods from other countries. For example, during the period January to June 1997 there were 4,795 food shipments detained by the US Food and Drug Administration (FDA). Poor food handling that led to filth in foods accounted for 32% of these shipments, violations of FDA

low acid canned foods regulations for 12%, contamination with pathogenic microorganisms for 11%, labeling violations for 10%, decomposed fish products for 8%, pesticide residue violations for 7%, moldy foods for 6%, food additive violations for 6%, heavy metals contamination 6%, and others for 3%. The FDA finds problems of this type on a regular basis, and the value of the detained shipments is more than 1 billion US\$ (\$1,000,000,000) each year.<sup>12</sup>

### Food safety risks

In order to assess food safety risks, set limits for various products added to foods in production or processing, or contaminants in foods, a risk analysis process must be carried out. Risk analysis processes are usually controlled by governments through the application of food quality and safety legislation, with pre-market approval systems used for many possible food risks. Production of basic risk analysis information is the responsibility of both governments and industry, with academia playing a role in many research aspects. Every country must have a working system of risk analysis to prevent or control food risk factors. Countries with adequate systems have adequate legislation to require risk analysis as a part of food production and marketing. These Governments either employ needed toxicologists, chemists, microbiologists, geneticists and other experts to carry out risk analysis work, or have a series of outside expert committees to make risk analyses. Food producers and marketers must provide adequate information to the government under existing legislation to show the safety in use of limits for various risk factors. Research by academia or special testing laboratories often supplies the basic toxicological and related data used in food risk analysis.<sup>13</sup>

Risk analysis is performed for many different purposes. A large body of literature exists on basic procedures, and on different topics such as engineering, pharmaceuticals, etc, with some differences in definitions, which sometimes leads to confusion.

Food risk analysis consists of three basic steps, risk assessment, risk management, and risk communication. Once a compound for use in food or a contaminant has been identified as a potential food safety risk, risk assessment procedures are used to produce necessary data on the actual composition of the product under consideration with detailed specifications of the composition, and methods of analysis for the product as used in foods, and adequate levels of toxicological and related data to enable the setting of safe limits for the presence of the compound or contaminant in all foods, or in specific foods. Once limits have been set, risk management is the responsibility of government to monitor the food supply and use of approved compounds to assure that legal limits are being followed, and the responsibility of food producers to put in place and properly administer risk management quality and safety systems to control risk factors. Risk communication is the process where technical information about risks is shared between government, food producers, academia, legislators and the public so that all concerned have adequate and understandable information showing that food risk factors are being properly controlled.

Systems to analyze and control food risks vary from

country to country, depending on the size of the country, national legislation, budgets, etc. In smaller countries risk analysis may be limited to use of data from FAO and WHO expert committees on food additives, animal drug and pesticide residues, or chemical or microbiological contaminants. The same persons carrying out the risk assessment may also be the risk managers and communicators. In larger countries there may be a clear separation between people and offices carrying out the three risk analysis tasks, with occasional friction between the three groups as to which group should set the agenda and tasks for the other two groups. This friction is, of course, counterproductive and it is best when all concerned realize the importance of productive cooperation, rather than competition.

As discussed above, there are many food risk factors that must be controlled in each country to assure that adequate consumer protection exists. Food risks could be classified as those with:

- a) Acute Health Effects
- b) Chronic Health Effects
- c) Chemical Risks
- d) Microbiological Risks
- f) Economic Risks

In the area of acute health effects, a majority of these problems are associated with pathogenic microorganisms, bacteria, viruses, or mold byproducts (called mycotoxins). Bacteria such as Salmonella, Listeria, Campylobacter can cause serious food poisoning morbidity and mortality. Some bacteria, such as Staphylococci and Botulinum can form toxins as by-products of their growth in foods, and cause death or severe food poisoning morbidity when foods containing these toxins are eaten. Viruses in foods and in live animals or animal products can also cause food-based morbidity and mortality. Mycotoxins such as aflatoxin and Fusarium mold by-products have been found to be severely toxic to cattle and birds, and have been shown to be carcinogenic and mutagenic in humans. Mycotoxins occur in moldy foods, such as cereal grains, and in animal products such as milk when animals have been fed moldy feed.

Chronic health effects are usually related to chemicals added to food or contaminating foods. In the production and processing of foods many different products are used such as fertilizers, pesticides, herbicides, food additives, sanitizing agents, cleaning compounds, and in food packaging. Concern about the safety in use, and of residues of these chemicals in foods have led to pre-market clearance procedures for most chemicals that may be in or on foods. The first level of concern is whether these products can be carcinogenic or mutagenic. Additional concern exists about possible damage to the digestive system, muscles, nerves, the immune system and other body organs. Because of these concerns, food laws and regulations require pre-market testing data and formal clearance of chemicals used in the production and processing of foods, with limits set for use of food additives, pesticide residues, or other chemicals in food. Since exposure to such chemicals is projected over the entire lifetime, safety factors are built into the approval process for such chemicals to as-

sure safety in use. Monitoring have the actual use and levels in foods is also carried out systematically in many countries.<sup>14,15</sup>

Chronic health effects have also been related to heavy metal contaminants in foods such as lead, mercury and cadmium. Lead contamination of food and the environment has been linked to encephalopathy, neuritis, anemia and learning disabilities in children, and to other possible body system damage. Mercury in food has been linked to nerve damage. Cadmium in food, particularly cereals, has been associated with kidney damage. Heavy metal contamination can occur due to presence of such metals in soils and rock formations, or from industrial contamination, where industrial waste is not properly handled. Other industrial chemicals can also contaminate foods, with PCB's and dioxins as the most common contaminants found. PCB's have been widely used in large electrical transformers, and in other industrial uses, and usually also contain dioxins. Dioxins are highly carcinogenic, and PCB's also have some toxicity. Another area of risk consideration is related to new foods ("novel foods") that are new to the market in a particular country, or are produced through recombinant DNA techniques to introduce desirable traits in foods.<sup>16</sup>

Foods produced through biotechnology are relatively new in the marketplace, and have caused some concern. These foods have special characteristics such as resistance to insects, enabling reduced use of pesticides in the field, resistance to herbicides allowing more efficient growth of crops such as soybeans, higher levels of vitamins such as vitamin A in rice ("golden rice") or faster growth and better feed efficiency in certain fish species such as salmon. In the review and approval of such foods, food regulatory official have established the principle of "substantial equivalence" to enable judgment of the safety and appropriateness of new food products developed through use of biotechnology. While there has been widespread production and utilization of such crops in many countries, after adequate safety reviews, there is still strong resistance to such foods in other countries and regions. Ongoing research and science-based information to consumers is helping to reduce concern levels, but more is needed to completely resolve all areas of concern in many countries.

As mentioned above, a number of safety factors are included in the pre-market approval of chemical added to foods. In addition, in assessing other chemical or microbiological problems, food safety officials try to assure the maximum safety of foods. It is often necessary to allow some low level of contamination with heavy metals or mycotoxins when it is impossible to assure complete absence of such contamination. In such instances a wide range of toxicological testing is done to identify a "no-effect" level for humans with regard to such contamination, and this is needed to assure an adequate supply of the foods involved for humans or for animal feeding purposes. Again, strict monitoring of the levels present in susceptible foods is required to avoid chronic or acute health effects.<sup>17</sup>

Another area of food risk relates to economic risks. As shown above, many foods are susceptible to chemical and microbiological problems, and a number of other factors can also cause food problems. These include proper food

labeling, compliance with applicable food composition standards, control of food hygiene to avoid decomposition or contamination by insects, rodents or birds, as well as spoilage or pathogenic microorganisms. Each of these areas can present a large-scale economic risk to the food producer, processor, and to the national economy if the foods cannot be marketed due to failure to meet food regulatory requirements. Thus the economic risk factor associated with improper foods is equally as important as far as consumer well being and national economy is concerned as are food problems related to acute or chronic health risks.

### **Role of governments, food producers, marketers, and academia**

In order to have proper control of food risks, close cooperation and coordination is needed between government, food producers and marketers, academia, and with policy makers and consumers. Each group has a role to carry out, and if any fail, the entire food system can be as risk.

### **Governments**

Each country has an organization of national, provincial or state, and local government entities. Each level of government within a country has a role to play in assuring the quality and safety of food supplies. At the national level, government also has international responsibilities with regard to bi-lateral trade to and from other countries, and with the international FAO/WHO Codex Alimentarius Commission and the World Trade Organization.

Government policy makers and food control agencies must assure that adequate food control legislation (laws and regulations) are in place to enable control of all food risk factors, and for adequate consumer protection. Legislation should be adequate to meet current food risk needs, but should not be so detailed as to be incomprehensible, nor scattered among a welter of decrees, rules and other policy documents so that transparency and understanding of the rules are easily understood.

In addition to legislation, government at all levels has the responsibility to adequately fund government pre-market approval process and monitoring operations that are designed to assure that food legislative requirements are being met. Research needs at the government level should also be adequately funded. This means funding of a well-trained top administrative food control staff, an effective system of risk analysis, a properly trained inspectorate to monitor, inspect, sample and advise on all food risk matters, adequate food analysis laboratories equipped and supplied with necessary equipment and reagents to carry out needed analyses, effective liaison with all aspects of the food industry to provide advice on meeting food legislation needs, and effective liaison with government justice officials when legal action is needed to correct problems in the food system.<sup>18</sup>

At the international level governments should be aware of the destination of food exports and assure that they meet the requirements of importing countries, and should also assure that food imports are properly controlled. They should also participate actively in the work of the FAO/WHO Codex Alimentarius Commission that prepares international standards, recommendations and

guidelines for foods that are the benchmark for judging the acceptability of foods in international trade. This Codex work is specifically recognized in the World Trade Organization agreements, and should be closely followed for domestic food supplies and exports to assure consumer protection and avoid international food risk problems.<sup>19</sup>

### **Food producers**

This area includes a wide range of entities, such as small and large-scale farmers, capture or fish farming people, food storage, food processing and preservation, food marketing for wholesale or retail sales, including restaurants and other food service operations. With increasing world population and urbanization, food chains and food webs have become increasingly complex. Assuring food quality and safety today requires adequate knowledge and ability by all in the food business to meet or exceed the basic food legislation requirements. This in turn requires the creation and implementation of food quality systems that assure the basic composition, nutritive value and safety of foods. Systems devoted only to control of food safety will inevitably fail to prevent food problems since economic risks such as food losses, attacks by insects, or food composition and meeting standards will be ignored. Thus an adequate food quality system in the field or water, in harvesting, storage, processing and preservation, and marketing is an essential to controlling food risk problems.<sup>20</sup>

Preparing, testing, adjusting and implementing adequate control systems requires a good level of knowledge of the factors that are important in producing good quality and safe foods. Industry, government through extension and advisory services, and academia all have important roles to play in educating and assisting food producers in preparing and implementing adequate quality control systems. This includes the content of food legislation, good farm and fishery practices, and good manufacturing, storage and marketing practices. Preventing the deterioration of the quality and safety of foods prior to consumption, whether at farm level, or after shipments of foods over thousands of kilometers, requires knowledge, skill, and determination.

### **Marketers**

Food marketing, and wholesale and retail level requires close attention to proper food storage and, in food service operations, to food preparation. Many fresh, semi-processed or processed foods are temperature sensitive and must be held under special conditions. Frozen foods should not be allowed to thaw, and chilled foods such as dairy products, many juices, fresh and processed meats, cheeses, and fruits and vegetables need specific controlled temperature storage. Even relatively stable products like bread and cereal products must be sold on a "first-in/first out" basis to prevent insect problems, staleness, mold, and related problems. In food service operations, close attention to food hygiene is needed. Many people involved in food marketing and food service are relatively unskilled individuals, requiring owners to have detailed training manuals and training programs for all new employees.

### **Academia**

The educational community in all countries is extremely important to food quality and safety. At the university level there is a need for good curricula to train food chemists, microbiologists and others who can understand and apply the science needed to assure the quality and safety of foods throughout the food system. This especially includes food scientists, technologists and biologists who are critical to inspecting and assuring the quality and safety of traditional or new food products. In addition academia has a critical role to play in research into food quality and safety problems, and qualified researchers and research, applied and basic is needed in all countries to confront persistent and new food problems.

At the primary and secondary school levels approved curricula should include basic education on the value of foods, the importance of balanced diets in proper nutrition, and adequate science training for those who will go on to university to studies related to food quality and safety.

### **Conclusions**

Food safety risks present challenges to governments, food producers, marketers and academia. Assuring the quality and safety of foods requires adequate legislation, and properly funded and staffed government offices and laboratories equipped to meet the food risk challenges of today. Food producers must understand the regulatory requirements for food risk control, and take appropriate steps to assure efficient and effective quality control systems in the production, storage, processing and marketing of foods. Food Marketer must also have special quality control systems in place to assure good storage practices, and proper food handling in food service operations. Academia at all levels need to have appropriate curricula and research facilities to produce knowledgeable consumers, and properly trained people for food quality and safety work in government, food handling, and academia.

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