Contaminated food of animal origin: hazards and risk management*

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**Summary of conclusions**

Essential elements for effective food safety programs are:
- sound, transparent, science-based import/export regulations
- up-to-date active disease surveillance and information systems
- efficiently functioning veterinary services
- alert field veterinarians, public health officials able to detect food-borne illnesses
- fully participating and cooperating animal industries.

A food production chain using science-based and transparent pre-harvest and post-harvest food safety programs is much more likely to satisfy consumers food safety concerns than present meat inspection procedures and end-point sampling. Such overall food safety programs also will protect an exporting country against the unfair or unjustified use of food safety concerns as non-tariff trade barriers. Pre-harvest programs must be based on “good management practices” (GMP) and post-harvest programs must apply both GMP and Hazard Analysis and Critical Control Point (HACCP) principles. Surveillance and information systems, GMP and HACCP and import/export regulations all require a basic understanding of risk analysis elements: risk assessment, risk management and risk communication.

- It is recommended that training of veterinary and public health personnel in risk analysis methodologies and their practical application be considered by the World Bank for fostering global food safety.

**Beef, pork and poultry meat**

At the slaughter and processing plant, traditional organoleptic meat inspection procedures are inadequate to deal with the hazard of human pathogens in the gut of healthy animals. Risk management for these pathogens requires a process of pathogen reduction at the farm level, and during slaughter and processing. The meat industry is committed to producing high quality wholesome products to maintain consumer confidence. To meet the goal of prevention contamination of beef, pork or poultry products at the farm, GMPs must be applied, including residue assurance programs. During slaughter and processing

*Acknowledgement*

The review and editing of the document by Dr. Alwynelle Ahl, Director of the Office of Risk Assessment and Cost-Benefit Analysis, USDA, is highly appreciated.
HACCP systems are increasingly used to replace or supplement traditional meat inspection and end-point sampling. Livestock producers and veterinarians must be aware of these changing requirements for farm-animal food safety. The application of GMPs and/or HACCP at the farm or the slaughterhouse require a level of management sophistication that usually is not available in developing countries.

For developing countries that produce meat or animal products for export to developed countries, the establishment of GMP/HACCP programs is imperative, in order to maintain consumer confidence and market position. Risk analysis is the basis for import/export safety as well as GMP/HACCP. It is therefore essential:

- to introduce GPM at the farm level with emphasis on lowering the pathogen load of animal prior to slaughter,
- to use GMP/HACCP at export packing plants,
- to train veterinarians in risk analysis methods related to food safety and the import/export of animal products to provide the necessary know-how for the support of these programs.

Swine

In underdeveloped countries, in addition to the general problems mentioned above, swine cysticercosis results from a high percentage of infected pigs, particularly those not slaughtered through official channels.

- Sanitary measures must prevent the contamination of the environment with human feces in order to break the life cycle of the tapeworm.
- Consumers can prevent most pig-borne food safety hazards by cooking pork and pork products.

Poultry

Even if the actual numbers of pathogenic organisms on broiler carcasses leaving processing plants are low, those pathogens in prepared (and undercooked) poultry products are amplified if held at room temperature. The handling of raw carcasses can be a source of cross-contamination of other foods.

- Poultry products must be properly cooked, cooled and stored, to prevent foodborne illness, particularly in commercial or institutional food service settings where larger quantities of food are being prepared at one time.

Meat from small domestic ruminants

In most developing countries butchering of sheep and goats for local consumption often happens under poor hygienic conditions and the meat is sold or kept under conditions that favor external bacterial contamination and multiplication.

The larval stage of the dog tapeworm (*Echinococcus granulosus*) is found mainly in organs of sheep and goats. In humans, *E. granulosus* cause a severe disease with hydatid cysts in the liver and/or the lungs.
• Educational programs must aim at raising the level of awareness of producers, meat handlers and consumers with regards to the safe handling of small ruminant meat.
• In countries where sheep are raised for the export of mutton or lamb, risk reduction methods must be applied similar to those in beef packing plants to minimise contamination with micro-organisms or chemical residues.
• Dogs must be prevented from feeding on organs of small ruminants to prevent tapeworm infection.

**Dairy products**
Microbiological contamination of raw milk must be minimized. In general this means that:
• Milk producers must adopt standards of GMP.
• Dairy processing plants must adhere to HACCP principles and be required to examine unprocessed products (i.e., milk or cull cows) for potential human pathogens.
• Trace-back procedures must try to locate dairy farms producing milk containing harmful organisms.

In developing countries:
• Milk must be adequately cooled before pasteurization to prevent bacterial growth and development of heat-resistant microbial toxins.
• Pasteurization equipment must function properly and post-pasteurization contamination must be prevented.
• If milk is not pasteurized it should be adequately boiled before consumption. Sellers of such unpasteurized milk must be made aware of the importance and means to improve hygiene.

Difficulties in improving the sanitary quality of sheep and goat milk, include the low level of production per head, the milking system, the difficulty involved in machine milking, the conditions under which the herds or flocks are raised, adverse climatic conditions and the spread of production over a wide geographic area. Ewe and goat milk is used for cheese making that often lacks standardized technology, standard regulations or pasteurization. In order to maintain consumer confidence it is essential to:
• Raise sanitary standards for the production of milk of small ruminants.
• Pasteurize the milk prior to cheese manufacturing.

**Horse meat**
The two principal agents in horse meat for food-borne disease in humans are *Salmonella* and *Trichinella*. The main chemical hazard to human health from the consumption of horse meat is cadmium, particularly if the horse meat originated from heavily polluted industrial regions.

**Products from farmed deer, ostriches and crocodiles**
Products from farmed unconventional livestock species are subject to the same requirements as for conventional meat. Public health risks associated with the marketing of meat from farmed deer are no greater than those of other meats. Consumption of meat from farmed ostriches poses little public health risk. For meat from farmed crocodile, there is a distinct possibility of
contamination with human pathogens, depending on housing, feed, slaughter technique and hygienic practices under which crocodiles are reared. Quality of water in which crocodiles are raised is also important. However, slaughter and hygienic processing procedures, makes the consumption of meat originating from farmed crocodile a negligible public health risk.

- GMP should address consumer concerns for safety of these types of food.

*Game*

Wild game meat is not usually subject to veterinary inspection and meat can be contaminated by organisms associated with a lack of hygiene.

- Wild game meat should be well cooked prior to consumption.
- Some traditional processing methods, such as the preparation of ‘biltong’ (sun-dried meat) may not guarantee the complete destruction of all zoonotic agents.

*Seafood*

The current system for prevention and control of seafood-associated foodborne disease is inadequate. Seafood safety control programs must address the following:

- environmental safety
- mechanical spreading of infectious or toxic agents through human activity
- development of new culturing and fishing procedures.
- change in eating habits and traditional eating habits of ethnic groups
- awareness of public health personnel of rare diseases
- ability to detect toxins and disease agents by specific and sensitive analytical methods
- consumer education as the most realistic option to protect public health.

*Aquaculture*

Aquaculture offers a controlled form of aquatic food production. Safety can be compromised by environmental contaminants and mishandling during processing, marketing or preparation. Developing countries may lack data on trace chemical contaminants in aquacultural products and public health risks may be high in certain circumstances or where contaminated fish is a staple in diets. Potential public health risks can be avoided by:

- proper site selection,
- responsible production management (GMP)
- use of monitoring and controls (HACCP)
- surveillance programs, including sampling and testing of both imported and domestic products for potential residues
- education and training of farmers, particularly of small-scale fish farmers on the recommended treatments or materials which pose health concerns and on criteria for a suitable production site.
- properly equipped laboratories with adequately trained personnel to conduct accurate analytical detection work.
- development of rapid, reliable residue detection test kits
- proper cleaning, processing, storage, handling, marketing and cooking of highly perishable aquaculture products.
Non-biological contaminants
Consumers in developed countries are becoming very concerned about drug residues in products of animal origin. In order to prevent international trade barriers and consumer confidence the following must be implemented:
• standardization of testing methods used to detect drug residues
• standardization of methods for determining minimum residue levels
• establishment of active surveillance programs to monitor residues.

Introduction

The consumption of animal proteins is a luxury for most of the world population. Thus, discussions around food safety of products of animal origin mainly relate to concerns of people in developed countries that consume processed and packed foods, usually far removed from the original source. The urban consumer of a hamburger or a chicken nugget in industrialized parts of the world prefers not to associate those with cattle, poultry or manure. Unfortunately, for most other peoples in the world, most food of animal origin is too expensive. The amount of milk, beef, poultry or fish they consume per capita often is very small. If animal protein is included in the diet, except for canned meat, it is usually derived from local animals and consumed immediately by a relatively small group of people. Under those conditions the safety of animal products or of food-borne diseases become of much lesser importance compared to the safety of available water used for drinking or cleaning meat, poultry, pots and pans. Food safety in third world countries is important, but unless the water used by people in their daily life is clean and safe, it will be hard to tell if they are ill from contamination of their water, their food, their hands, ....or all of the above.

Until recently, the principal food safety issue in the mind of the public was chemical residue contamination and food additives. Foods from animals (principally meat, fish, milk and eggs) can potentially be contaminated with one or more of the thousands of man-made chemicals which are used in society. Relatively few of these occur with any regularity in foods from animals, but the most contentious residues are antibacterial drugs, hormonal growth promoters, pesticides, industrial chemicals and heavy metals. Also, industrial chemicals and heavy metals that are not used specifically for agricultural purposes can contaminate animal feeds or the animal environment and thereby gain access to milk, meat or eggs. Non-biological contaminants continue to be very important with respect to international trade and consumer confidence.

Traditionally, concerns for food safety have focused on zoonotic diseases (animal diseases that can be transmitted to man) and on residues from environmental chemicals, drugs and other toxic agents which can accumulate in animal tissue. Until recently, scientists assumed that public health was affected only by micro-organisms which make animals sick. These zoonotic agents were prevented by ensuring that only healthy animals entered the food supply. Environmental chemicals, drugs and other toxic agents were avoided by residue testing programs.
During the past fifteen years it has been recognized that human illness can be caused by microbial pathogens that have little or no influence on animal health. Most of these human infections are very acute serious diseases, but some may have chronic consequences which can last a lifetime. The human pathogens are normal inhabitants of the animal intestinal tract which during slaughter or processing and are deposited on meat products to reach the plates of consumers. These problems are being recognized more frequently around the world as the international trade of animal products increases. Moreover, the microbial agents often show resistance to physical or chemical treatments or to antibiotics, and there is growing suspicion that the use of antibiotics in animal production is stimulating the creation of such antibiotic-resistant micro-organisms.

Game species and wild species raised in farm-like conditions are increasingly important as food sources within countries and in international trade. Food preferences have changed so that consumption of meat of wild animals, either farm bred or naturally harvested, is becoming more common. Fish, whether caught in the wild or farmed, is also increasing in popularity with consumers world-wide. These changed conditions create new opportunities for the spread of human pathogens through the global movement and trade in these products. Safety of food for the human consumer has thus risen to prominence, as food from a contaminated source may be shipped across countries and continents.

The Scientific and Technical Review Volume 16(2) of the Office International des Epizooties explores food-safety hazards related to products of animal origin with the aim to present international perspectives on food safety. The safety of food of animal origin for human consumption has become an essential part of the public health debate. With the increases in international trade, the principles of equivalence, harmonization and transparency of food safety systems become more significant. Risk assessment methods evaluating food safety, based on these principles, become more important as well.

Food safety related to the consumption of animal-derived protein encompasses a wide variety of foods and of production and processing procedures. Since the same disease agent may have quite different risks or risk mitigation and prevention measures for different products, the Scientific and Technical Review Volume 16(2) presents the food safety issue through a wide spectrum of commodities. In the present paper the hazards of contaminating agents and the risk they pose for public health will be reviewed and summarized for each of these commodities. A “hazard” is a biological, chemical, or physical agent in food with the potential to cause an adverse public health effect. In contrast, “risk” is a function of the probability of an adverse health effect and the severity of that effect in a particular consumer population, consequential to the presence of a hazard in food.

Hazard analysis and critical control point (HACCP) systems are enabling food production establishments, such as meat packing plants, to identify and evaluate the food safety hazards which may affect product safety. HACCP provides a quality control tool designed to replace or
supplement traditional meat inspection and end-point sampling, particularly in the case where such inspections or sampling are inefficient.

Simply stated, food producers are asked to think about what could go wrong, to plan to avoid it, to document adherence to their plan, and to verify that production problems were avoided. Good management practice (GMP) and risk assessment are essential elements in this process.

The HACCP system is a seven-step process designed to manage risk, as follows:

- hazard analysis
- critical control point identification
- establishment of critical limits
- monitoring procedures
- corrective actions
- record-keeping
- verification procedures.

It requires an analysis of hazards concerned and the selection of control points, e.g. in the slaughter or processing line, that must be systematically monitored. It helps with the management and implementation of controls necessary to prevent – or to keep within acceptable limits – those hazards, to monitor the performance of controls, and to maintain routine records. Any deviation from the norm established for each control point must trigger corrective action. The application of GMP and HACCP principles during handling and processing of food should contribute significantly to improving food safety.

The provisions of the World Trade Organization (WTO) Agreement on the Application of Sanitary and Phytosanitary Measures are designed to liberalize trade while protecting human, animal or plant life or health. The Codex Alimentarius Commission of the Food and Agriculture Organizatio (FAO) and World Health Organization (WHO) is responsible for developing standards, guidelines and recommendations for food safety and quality while the OIE develops those for animal health and zoonoses. Standards and recommendations of these two organizations are benchmarks to evaluate national sanitary regulations affecting international trade.

**Beef**

The problem of microbial safety of beef is contamination during slaughter. The muscles of a healthy animal are sterile: that is, no bacteria of fecal origin are present in the muscle tissue. Many of the microbial pathogens of current concern survive in the environment, in water, on pastures and in food, unless precautions are taken to ensure pathogen control. Contamination of fresh beef and beef products with human pathogens is a consequence of a wide array of pre-harvest, harvest and post-harvest factors. Transportation may favor contamination as animals are placed in close proximity to other animals and stress may further enhance cross-contamination with these pathogens. Slaughter and processing procedures can also enhance cross-contamination from the hide, gastrointestinal tract and other surfaces of the animal during slaughter and dressing.
Hazards
Bacterial infections of public health concern are: *Salmonella*, *Shigella* sp., *Campylobacter*, *Escherichia coli* O157:H7, *Listeria monocytogenes*, *Clostridium perfringens*, and *Mycobacterium bovis*.

With the exception of *M. bovis* (the microorganism of bovine tuberculosis), transmission of the bacterial hazards occurs through consumption of beef contaminated with the contents of the bovine gastrointestinal tract during slaughter, dressing and further processing. *Campylobacter jejuni* and *E. coli* are common causes of foodborne illness in many countries. *L. monocytogenes* is implicated in sporadic cases of foodborne illness on a world-wide basis but there is little evidence to implicate beef as a significant source. Contamination of beef carcasses with *C. perfringens* is likely to originate predominantly from the processing environment. A significant amount of beef is obtained from dairy cows, but dairy cows do not seem to harbor foodborne pathogens at a greater prevalence than either feedlot cattle or cattle grown on open pastures most of the year. However, mastitis of dairy cull cows caused by *Staphylococcus aureus* is a particular hazard. There is no evidence on a world-wide basis that *M. bovis* (the causitive agent of bovine tuberculosis) is a meat-borne hazard.

Parasitic diseases hazards are *Toxoplasma gondii* and *Taenia saginata* (beef tapeworm). *T. gondii* is an obligate intracellular protozoan parasite which infects a broad spectrum of vertebrates, amongst others by the ingestion of undercooked meat contaminated by oocysts or tissue cysts, or by the ingestion of sporulated oocysts from soil contaminated by cat faces. *T. saginata* infection of cattle is an important foodborne zoonosis in many countries.

BSE is causing concern among consumers of beef because of the discovery of a new variant form of Creutzfeldt-Jacob disease in humans which may be linked to BSE in cattle. BSE has had major consequences for the international trade in beef and meat products. The epidemic in the United Kingdom is thought to be caused by the feeding of cattle with meat-and-bone meal contaminated with the agent. The use of this product is now prohibited in the UK and several other countries.

Drug residues in beef have been reported internationally. These include antimicrobials, anti-inflammatory, growth promoters, parasiticides and insecticides. Public health concerns include toxic and anaphylactic reactions, and development of drug-resistant strains of bacteria. The use of antibiotics in animal feeds may lead to the potential development of resistant bacterial pathogens in food-producing animals exposed to the antibiotics.

Risk management
Reducing all pathways for fecal contamination of products to the maximum extent practicable will be the most important factor in achieving desired food safety objectives for fresh beef. General attention to livestock management, environmental hygiene and transport are well-established methods of limiting the numbers of cattle shedding of human pathogens but specific interventions to significantly reduce or eliminate infection with human have yet to be identified.
There are currently no scientifically defined critical management points or critical control points
to manage foodborne pathogens at the pre-harvest level. Thus, contamination rates will not be
significantly altered by presently-available pre-harvest control strategies.

A number of specific risk reduction measures can lower the pathogen load of farm animals:
• Proper pen maintenance to lower pathogen levels of pens. Feedlot cattle are kept in dirt
   pens, and the space allocated to each animal is relatively small compared to that of pastured
cattle. GMP consists of keeping the pens well drained, scraping the pens frequently to
remove excessive organic matter and controlling mud.
• Withholding feed from cattle for 24 hours prior to transportation to the slaughterhouse
   increases human loads in cattle, however, only a small percentage of cattle are at risk, since
most are slaughtered within 12 to 24 hours after leaving the feedlot.
• Stress of cattle must be avoided at any time. Stress increases the number of cattle shedding
human pathogens.

Risk reduction measures for T. gondii are unknown. The oocysts are not detectable at post-
mortem inspection and there is a lack of knowledge on undercooked beef as a potential
pathway for human infection. The effect of attempts to limit feline fecal contamination of the
animal husbandry environment with T. gondii is unknown.

Risk reduction during the pre-harvest control of T. saginata can be very successful. Strategies
to prevent completion of the life-cycle of the parasite can have a dramatic effect on carcass
infection rates.

Monitoring of the quality of cattle feed from all sources is essential. Feed additives and feed
medication must be stored in areas in such a way that contamination with other chemicals,
rodents and insects is avoided. Prevention of BSE is thought to include the avoidance of meat-
and-bone meal in ruminant feeds.

Any medication which must be used other than as directed on the label must be administered in
accordance with the instructions of the attending veterinarian. Withdrawal times for animal health
products used in an extra-label manner must be extended significantly. Vaccines, deworming
preparations, pesticides, antibiotics, etc. should only be used in accordance with approved label
instructions. Records must be kept for each group of cattle, showing the date used, product
used, serial or lot numbers of the products, dosage, route of administration and site of
administration of all injections.

A complete record of pesticide use must be kept, including product identification, serial or lot
number, the date the product is used, the amount used, the person who administered the
pesticide, the animal or animals treated with the pesticide, and the pre-slaughter withdrawal
time. All employees who work with pesticides must be trained in the safe usage of the products.

Conclusions
The prevention of contamination of beef at the farm level is a viable hazard reduction strategy on well-run farms and can be obtained by voluntary good management practices, including residue assurance programs. This requires active involvement of livestock producers and veterinarians. Livestock producers and food-animal veterinarians must be aware of changing requirements for farm-animal food safety as hazard analysis and other risk-reduction activities become increasingly more common.

To prevent international trade barriers associated with drug residues in beef, the following conditions must be implemented:

- standardisation of testing methods used to detect drug residues
- standardisation of methods for determining minimum residue levels
- establishment of active surveillance programmes to monitor residues.

At the slaughter and processing plant, traditional official meat inspection procedures are inadequate to deal with the hazard of human pathogens in the gut of healthy animals. To minimize public health hazards from these pathogens it is necessary to involve industry in a process of pathogen reduction. In the developed countries the meat industry is committed to producing high quality wholesome products to maintain consumer confidence and HACCP systems are increasingly applied to replace or supplement traditional meat inspection and end-point sampling.

Application of GMP and/or HACCP at the farm or the slaughterhouse require a level of management sophistication that may or may not be available in developing countries. The establishments of GMP programs is imperative for packing plants in developing countries producing meat for export, in order to maintain their market position.

BSE is not likely to become a problem in developing countries since imported or locally produced meat-and-bone meal is usually not added to bovine rations.

**Sheep and goat meat.**
Sheep and goat meat is an important source of animal protein in many parts of the developing world.

**Hazards:**
Bacterial contaminants are similar to those of beef. Toxoplasmosis in mutton and goat meat is a particular hazard for immuno-compromised people and pregnant women. It is one of the main causes of abortion in ewes and goats.

Other pathogens which may be associated with the consumption of meat from small ruminants include: *Clostridium perfringens*, *Cryptosporidium parvum* and *Campylobacter jejuni*. As with other ruminant species, *Escherichia coli* O157:H7 can be considered an important emerging pathogen.

The larval stage of *Echinococcus granulosus* is a parasite found mainly in sheep and goats, but that can also occur in cattle, pigs, horses and humans. The final host for *E. granulosus* is the
dog. In humans, *E. granulosus* cause a severe disease with hydatid cysts in the liver and/or the lungs.

The occurrence of scrapie is of some concern in some countries because it is aspongiform encephalopathy and may be possibly linked to BSE, through the practice of feeding meat-and-bone meal contaminated with the scrapie agent.

The transportation method of meat from abattoir or butcher shop to retail sales outlets contribute to public health risks. In developing countries sheep and goat meat often is transported in a car trunk or cart, without refrigeration or physical protection, which increases the risk of contamination. Fresh meat frequently is sold at open-air or covered markets, which often do not have refrigeration facilities. Butcher shops or market stalls often attract many flies and with a high ambient temperature the potential is high for bacterial contamination and subsequent multiplication of micro-organisms in meat. Meat may also be contaminated by dust if openly displayed in such environments.

**Risk management:**
Contamination of sheep and goat meat must be prevented through hygienic handling during preparation procedures. Fortunately, it is a common practice to overcook or pressure-cook sheep and goat meat, thereby reducing public health risks. However, cross-contamination may occur during food preparation in the kitchen.

The following measures will help to reduce the risks caused by contamination of sheep and goat meat:

- Prohibit slaughter of animals in non-hygienic facilities. National or municipal health authorities must regularly inspect and approve these facilities.
- Provide potable water, liquid and solid waste disposal systems, as well as basic hygiene of personnel, equipment and slaughter methods.
- Transport meat and/or products of animal origin in containers or vehicles equipped for this purpose.
- Implement public education and information programmes to encourage consumers to purchase only high-quality meat products.
- Prevent feeding of dogs with organs of small ruminants that contain the larval stage of *E. granulosus*.

**Conclusions**
Meat from small ruminants is an important source of animal protein in several of the developing countries. However, butchering of sheep and goats often happens under poor hygienic conditions and the meat is sold or kept under conditions that favour external bacterial contamination and multiplication.

In countries where sheep are raised for the export of mutton or lamb, similar risk reduction methods are being applied as in beef packing plants to minimize contamination with micro-organisms or chemical residues.

**Dairy products**
The origin of contamination by pathogenic bacteria varies with the type of product and the mode of production and processing. Contamination of milk and dairy products by pathogenic microorganisms can be of endogenous origin, following excretion from the udder of an infected animal. Contamination may also be of exogenous origin, through direct contact with infected herds or through the environment (e.g. water, personnel). Treatment and processing of milk inhibits or encourages the multiplication of micro-organisms. When a milk-borne disease outbreak occurs, the cause is usually either post-pasteurization contamination or improper processing.

Production of ewe and goat milk is an important source of animal protein for the population of third world countries.

**Hazards**

Milk-borne pathogens are mycobacteria (tubercle bacteria), *M. paratuberculosis*, *Brucella* sp., *Listeria monocytogenes*, *Campylobacter jejuni*, *Staphylococcus aureus*, *Salmonella* species, *Escherichia coli* O157:H7, *Yersinia enterocolitica*, *Cryptosporidium* and *Bacillus cereus*. Serious infections in humans caused by *Salmonella* Typhimurium and *S. Dublin* have been linked to the consumption of dairy products. Also *S. aureus* and the production of enterotoxin by this organism are associated with serious illness in humans.

Several agents have been isolated from sheep and goat milk. Unlike cow milk, the production and distribution of goat milk and sheep milk, hygienic, quality and microbiological standards are not well defined. Infectious agents in goat milk are particularly threatening for certain population groups, namely: those with impaired immunosystems, babies, the aged and the sick, who coincidentally are the target consumer groups for goat milk. Goat milk is commonly used for on-farm manufactured cheese, with or without thermal treatment. Ewe milk is not consumed fresh, but instead is an important raw material for cheese. Goats are susceptible to *Brucella melitensis* infection which is more virulent for humans than *B. abortus* which may be found in cow milk.

Browsing habits of sheep and goats result in greater chance that these animals consume poisonous plants, with the potential for natural plant toxins to be excreted in the milk. The consumption of milk contaminated by drug residues may lead to allergic reactions in sensitive people and can induce resistance to antibiotics in opportunistic micro-organisms. Although accidental human health hazard is unlikely, there should be concern for consumers of goat milk (neonates) with immature detoxification pathways. Analytical tests typically used for the detection of antibiotic contamination of cow milk may be inaccurate when applied to ewe or goat milk.

**Risk management**

Pasteurization may not destroy all pathogenic micro-organisms present in milk but it reduces the number of harmful micro-organisms to a level at which they do not constitute a significant health hazard. "Pasteurized", labels a dairy product that has been heated at some time/temperature relationship to ensure microbial destruction.
Originally, pasteurization was defined as a heating process of not less than 142°F (61.1°C) for 30 minutes. The high-temperature short-time (HTST) process applies a standard of 161°F (71.7°C) for 15 seconds. ‘Ultra-pasteurized’ (UHT) is used for a dairy product that has been thermally processed at or above 280°F (137.8°C) for at least 2 seconds, either before or after packaging.

Milk pasteurized under UHT pasteurization conditions has an extended shelf-life when kept refrigerated. UHT sterilization processing destroys not only pathogenic bacteria but also heat-resistant bacterial spores. As a result, milk products sterilized in this manner and packaged under aseptic conditions may be stored at ambient temperatures for 6 months or more.

Milk-borne disease outbreaks are usually associated with drinking raw milk. Disease outbreaks associated with cheese made from unpasteurized milk indicate that the 60 days of ripening required before distribution may not be sufficient to completely eliminate pathogens such as mycobacteria, *Salmonella*, *Listeria* and *E. coli* O157:H7. Pasteurized milk is usually considered pathogen-free with the exception of the spores of *Bacillus cereus*.

Alkaline phosphatase is a native enzyme of cow milk and ewe milk and has a thermal resistance greater than that of the most heat-resistant of the non-spore-forming pathogens commonly found in milk. This property provides the basis for the routine alkaline phosphatase test to indicate proper pasteurization of skimmed or whole milk. No similar analytical method exists to measure the efficiency of pasteurization of goat milk. Raw goat milk has a low native alkaline phosphatase activity, and as a result, the test using alkaline phosphatase activity as an indicator of the completeness of pasteurization is unsatisfactory for goat milk.

**Conclusions**

Farmers must try to minimize microbiological contamination of raw milk. Ideally, this means that milk producers, with the help of their veterinarians, must adopt standards of ‘good dairy practices’. Dairy processing plants must adhere to HACCP principles and be required to examine unprocessed products (i.e., milk or cull cows) for potential human pathogens. If any of these harmful organisms are detected, trace-back procedures must be done trying to locate the dairy farm of origin.

In developing countries, it is advisable that milk at least be adequately cooled, boiled or preferably be pasteurized to prevent bacterial growth and development of heat-resistant microbial toxins. Pasteurization equipment must function properly and post-pasteurization contamination must be prevented. Difficulties in improving the sanitary quality of sheep and goat milk, include the low level of production per head, the milking system, the difficulty involved in machine milking, the conditions under which the herds or flocks are raised, adverse climatic conditions and the spread of production over a wide geographic area.

An important part of ewe/goat milk is used to make cheese. Most of these cheeses are of ‘artisan-type’ and recipes and manufacturing methods are passed on from generation to generation without a standardized technology, standard regulations or pasteurization. The market for these specialized cheeses is expanding, and the image of ‘healthy food’ attached to
goat and ewe milk and milk products has increased their economic importance beyond traditional geographical borders. It is in the producers best interest to raise sanitary standards in order to maintain consumers confidence.

Pork and pork products
Pork is the most popular meat consumed in the world today (44% of world meat protein consumption is derived from pork and pork products). It is produced under a wide variety of production systems ranging from simple backyard pigs or the pigs living on garbage belts to family operated farms or large scale integrated pig industries with sophisticated bio security measures. This whole range is present in developing countries. For instance in the Southern States of Brazil the integrated swine industry is very well developed, while in other parts of that country backyard pig raising is common practice. Public health hazards of pork are commensurate with this situation.

The safety and quality of pork and pork products are of increasing concern to consumers, especially in industrialized countries. Consumer demands and a steady increase of national and international food safety and public health standards are introducing substantial changes in the pork industry. Those changes require the development of quality assurance systems to be operated throughout the production chain. The role of the pork producer is changing from solely raising pigs to being an indispensable part of the pork production chain aimed at the supply of a wholesome, safe and high-quality food product.

Hazards
Salmonella spp., Yersinia enterocolitica, Campylobacter are bacterial infections of pigs that often are present without overt signs of illness and with no apparent macroscopic lesions and thus are not observed at routine meat inspection.

Three parasites pose a public health risk from the ingestion of raw or undercooked pork, namely: Trichinella spiralis, a nematode or roundworm, Taenia solium, a tapeworm, and Toxoplasma gondii, a protozoan or single-celled organism. All three parasites have a worldwide distribution.

T. spiralis: Transmission of trichinellosis in the sylvatic cycle relies on predation and carrion feeding. The lowest prevalence rates in domestic swine are found in countries where meat inspection programs have been in place for many years.

T. solium: The cycle of infection is perpetuated by sanitary conditions allowing pigs exposure to human waste, along with inadequate methods for preparing and cooking pork.

T. gondii: Transmission of toxoplasmosis to pigs on the farm occurs by various means. Risk factors for exposure to T. gondii tissue cysts and trichinae are virtually identical. These include exposure to live or dead rodents and other wildlife, as well as deliberate or inadvertent feeding of raw or undercooked meat scraps containing infective stages. Unlike trichinae, toxoplasmosis can also be acquired from the environmentally resistant oocyst stage shed by cats.
**Risk management**

The probability of foodborne, pork-related risks to public health through pork produced from pigs on farms using a pre-harvest food safety approach is lower than that of traditional farming without food safety awareness. Pre-harvest food safety programs to decrease the incidence of pork-borne health risks and to improve consumer confidence in pork products include:

- Implementation of food-safety specific GMP and HACCP programs at the farm level aiming at reducing risks of contaminated pork products to public health.
- Implementation of monitoring and surveillance programs at slaughter
- Implementation of a certification procedure involving independent agencies and people, such as accredited veterinarians and quality consultants.

Feedmill products are a major source of *Salmonella* for pigs, unless the finished feedstuffs have been heat-treated. Normal biosecurity measures applied on most well run pig farms are sufficient to prevent the introduction of bacterial infections from the herd surroundings.

Classical meat inspection procedure consisting of ante-mortem inspection of slaughter animals and visual inspection and palpation of carcasses to detect pathological changes do not reveal the presence of zoonotic agents such as *Salmonella* spp., *Y. enterocolitica*, *Campylobacter* or *T. gondii*. Inspection procedures are effective, however, in eliminating the majority of risks from *T. spiralis* and *T. solium*. No suitable methods for the post-slaughter detection of *T. gondii* are available. All three parasites are inactivated by various methods of cooking, freezing and curing, and some information is also available on inactivation by irradiation. Good production practices, including a high level of sanitation, rodent and cat control on farms, can prevent opportunities for exposure of pigs to these parasites. In addition, proper commercial processing, and adherence to guidelines for in-home preparation of meat are effective methods for reduction of risks for human exposure.

At slaughter, loosening of the rectum often spreads feces over the carcass. In some industrial countries the problem is avoided by using a plastic bag to seal off the rectum. Also removal of the ‘pluck set’ (tongue, larynx, trachea, lungs, heart and liver) contributes significantly to contamination of the pig carcass with *Salmonella* spp. and *Y. enterocolitica*.

Most consumers are aware that proper handling and thoroughly cooking of pork product reduces the risks due to pathogens.

**Conclusions**

A pork production chain using a science-based, transparent pre-harvest food safety program is required to satisfy consumers food safety concerns. Also such programs are extremely useful in protecting an exporting country against the unfair or unjustified use of food safety concerns as non-tariff trade barriers.

Pre-harvest risk-reduction programs can either prevent the contamination of the carcass (*Trichinella* and *Toxoplasma*) or contribute significantly to minimizing the pathogen-associated risks (*Salmonella, Campylobacter, Yersinia, Listeria*).
Particularly in underdeveloped countries sanitary measures must be taken to prevent contamination of the environment with human feces in order to break the life cycle of tapeworms. In these countries under-reporting of swine cisticercosis results from a high percentage of pigs that are not slaughtered through official channels, particularly those prone to exposure to *Taenia*.

Fortunately, consumers prevent most pig-borne food safety hazards by cooking pork and pork products.

**Poultry and poultry products**

Poultry meat is produced in all corners of the globe from backyards chickens flocks to highly integrated industries. Consumers are particularly concerned about the public health risks of poultry products produced by intensive, large scale operations.

**Hazards**

The largest number of foodborne illness cases attributed to poultry and poultry products are caused by paratyphoid serotypes of *Salmonella* and by *Campylobacter jejuni*. *Salmonella* infection occurs by direct contact with clinically ill or symptomless birds, by the consumption of contaminated feed or water and through the environment. Contamination of the hatchery may be the most important source of *Salmonella* in broilers. *Salmonella* infected birds shed the organism, resulting in contamination of the environment and of other birds. Subsequent contamination of the transport vehicles at the time of harvest contributes to the contamination of the carcass or meat product during slaughter and processing. *Campylobacter* is not considered an animal husbandry problem for the broiler chicken industry in terms of animal health. No efforts are made to prevent colonization of broiler chickens by *C. jejuni* as part of a flock health maintenance plan. *C. jejuni* is not present in the droppings of newly hatched chicks, but colonization occurs within days after exposure. Once *C. jejuni* appears in a flock, it spreads rapidly to virtually all the chickens. The organism occurs in water, animals and food. For instance, *C. jejuni* is found among feral as well as domestic animals, and in birds, mammals and insects. House flies have been shown to be carriers of *C. jejuni*.

Poultry arrive at the slaughter processing plant with various amounts of fecal contamination on the skin and feathers. Evisceration contributes to the contamination of carcasses, although generally the viscera are removed in such a way that contact of intestinal contents with the carcass is minimized. Plant workers or equipment can cross-contaminated carcasses.

**Risk management**

Biosecurity is the main requirement to prevent colonization of flocks by *Salmonella*. It involves using all measures possible to control the spread of the organisms. This includes:

- An “all-in-all-out” program followed by a rigorous cleaning and disinfection program
- Rodent control, especially while the premises are empty, to prevent recontamination of the environment by *Salmonella*-infected rodents after cleaning and disinfection
- Restriction of movement of birds, people and equipment, combined with good sanitation
• Avoidance of contact between poultry and migratory water fowl and measures to ensure that small birds cannot again access to the poultry house.

‘Catching crews’, vehicles, cages and crates used for broiler movement potentially transmit diseases from farm to farm and can be an important source of *Salmonella* contamination.

Good egg and hatchery sanitation can reduce *Salmonella* infection in broiler chicks. In the hatchery, these include the following:

• Effective washing and sanitizing of hatching eggs at the breeder farm
• Disinfecting the air in hatching cabinets
• Administering a yeast-type preparation to the hatching chicks to prevent attachment of *Salmonella* to the gut wall
• Administering a competitive exclusion product such as lactobacillus which provides long-term protection against gut colonization by unwanted microorganisms
• Use of effective sanitizing chemicals.

The use of pelleted feed is recommended since the pelleting process generates heat which can kill *Salmonella*. Dedicated feed delivery vehicles and good sanitation practices (as well as biosecurity/rodent control) help prevent poultry feed from being contaminated. Periodic, routine testing of the water source for toxic chemical residues and bacteria is important. Chlorination of the water supply helps to prevent water-borne spread of *Salmonella* and *Campylobacter*.

Regular cleaning and disinfection of the slaughter/processing plant and equipment are essential for maintaining sanitary conditions. Feather removal begins with scalding, or submersion in hot water, followed by mechanical picking. External contaminants are removed during scalding, picking and rinsing, but these processes also serve to distribute bacteria. Proper carcass chilling effectively controls microbial growth on carcasses. Carcass chilling carries the risk of cross-contamination because of large numbers of carcasses present at any one time in the same tank of water.

Microbial reduction can be accomplished through the implementation of the following methods:

• Counter-flow scalding
• Post-scald hot water carcass sprays
• Addition of chlorine to the bird wash in the picking room, the water used on the transfer belt, final wash and chill tank.

Irradiation, used in conjunction with proper food processing and preparation techniques, could further reduce contamination of slaughtered poultry.

Food handling is very important in the reduction of foodborne illnesses caused by *Salmonella* and *Campylobacter* on poultry products. Foodborne diseases usually arise when the causative organism, initially present in low numbers, is allowed to multiply on the chicken carcass surface during production, distribution, preparation or storage of foods. Growth on carcasses can be prevented by prompt and efficient chilling. Proper cooking destroys micro-organisms present on the chicken carcass. Cross-contamination of foods such as salads, contribute to the problems arising from unsafe food handling.
**Conclusions**

The actual numbers of *Salmonella* organisms on broiler carcasses leaving the processing plant are usually very low and are not considered to be a serious health risk if prepared using ordinary cooling and cooking practices. However, even low doses of *Salmonella* and *Campylobacter* in prepared (and undercooked) poultry products are amplified if held at room temperature. The handling of raw carcasses or fluids may be a source of cross-contamination for other foods if these are not properly cooked, held, cooled and stored. The risk of illness may be further amplified in commercial or institutional food service settings where larger quantities of food are being prepared at one time.

**Horse meat**

The world production of horse meat is increasing. The most important producers are Italy, France, Poland, Romania, the former Yugoslavia, USA, Argentina and Canada. The trade is mainly in the form of live animals or chilled/frozen carcasses.

**Hazards**

Horse meat is consumed mostly as medium rare grilled meat or as rare minced meat. Its high glycogen content stimulates the development of bacterial contaminants and requires particular attention to the handling and preparation of the meat.

Horse meat does not seem to offer more microbiological risks such as those of *Salmonella* than meats from other species. Among the zoonotic agents that potentially could contaminate horse meat are *Pseudomonas mallei* and *P. pseudomallei*, causative agents of malleus and melioidoses, respectively. Larva of *Trichina spp.* can occur in horse meat. Even though the horse is a herbivore the forage may contain carcasses of infected animals like rats. Outbreaks of human cases of trichinosis have been observed particularly in Italy and France. Levels of cadmium were observed to be 50 times higher in horse meat than that of pork or beef from the same region. Particular high concentrations of this heavy metal were found in the liver and kidneys of horses.

**Risk management**

Sanitary measures for the production of horse meat do not differ from those of meat from other farm food animals. However, the high glycogen content of horse meat makes it a very favorable substrate for the growth of micro-organisms and requires special care with regard to handling and refrigeration. For instance in France, the use of horse meat for institutional food preparation is not allowed.

Control and prevention of *P. mallei* and *P. pseudomallei* consist of normal sanitary measures for imported horses.
Freezing and cooking of horse meat destroy the larva of *Trichina*. In countries where horse meat is consumed ‘well done’ no cases of trichinosis, caused by horse meat have been observed. Curing of horse meat with certain combinations of time and salt concentrations are also effective in killing the parasite.

The risk of cadmium contamination can be minimized by general measures of environmental protection and avoiding human consumption of liver and kidneys from horses originating from heavily polluted industrial areas.

**Conclusions**
The two principal agents in horse meat for food-borne disease in humans are *Salmonella* and *Trichinella*. The main chemical hazard to human health from the consumption of horse meat is cadmium, especially from heavily polluted industrial regions.

**Alternative livestock production**
Three very different types of commercial livestock farming are covered: deer farming, ostrich farming and crocodile farming. These operations illustrate the type of public health risks that might be expected when developing alternative livestock production systems.

**Deer**
In the early 1970s, the high prices paid for venison, coupled with falling prices for beef and lamb encouraged deer farming in Germany, Scotland and New Zealand. Techniques were developed for the production of venison from deer at stocking densities comparable in biomass with those used for conventional grazing livestock and using similar husbandry systems.

**Hazards**
Bovine tuberculosis (*Mycobacterium bovis*) is a potential public health hazard posed by this alternative livestock industry. Deer appear to be no more susceptible to this disease than cattle and the post-mortem controls are similar for both species. The low overall prevalence of the disease in deer and the limited potential of human exposure to infected meat or meat products, minimizes the threat to public health.

No cases of bovine spongiform encephalopathy (BSE) have been reported in deer, despite the use of infected meat-and-bone meal as feed for many deer on farms and zoos prior to the withdrawal of this product. Therefore, deer meat does not seem to pose a BSE hazard. However, a scrapie-like spongiform encephalopathy known as chronic wasting disease (CWD) of deer has been recognized in the USA.

**Risk management**
Venison must be harvested and handled according to regulations are similar to those which control the handling of other red meat from cattle and sheep. This requires ante-mortem inspection, handling of the carcasses in rigorously controlled premises, and meat inspection by qualified inspectors. Most retailers prefer to source venison from farms rather than the wild, because the farmed product is more consistent than the wild product, available for twelve
months of the year, and processed under hygienic conditions. Meat from lesser reliable sources may be falsely labeled as farmed deer meat. These products certainly represent higher health hazards. There is no control with regard to the age or sex of the animals from which the meat is derived, and the labelling of even the species is frequently inaccurate. Slaughter on very extensive farms or parks (which are not classified as farms), is carried out by rifle and the meat may then be treated as wild game with virtually no controls or meat inspection.

**Ostriches**
Ostrich meat is seen by many as a desirable, low fat, low cholesterol, red meat alternative to beef. Ostriches have no infectious or contagious species-specific diseases, but are susceptible to a number of infectious agents acquired from and common to other avian species. Some of these agents may pose a threat to public health as well.

**Hazards**
A worker contracted on a South African ostrich farm contracted Crimean-Congo haemorrhagic fever infection from handling tick-infested slaughtered ostriches and ostrich tissues. In another incident, workers at the ostrich abattoir contracted the infection, presumably from a single ostrich in the viraemic stage.

Intensively reared ostrich chicks which have failed to establish a normal intestinal flora are susceptible to infections with salmonellae and other enterobacteria. Older birds appear to be relatively resistant to these infections.

No parasitic agents transmissible to humans have been found in ostriches.

**Risk management**
Crimean-Congo haemorrhagic fever is not a disease of ostriches, but of humans. Viraemia in ostriches following infection remains clinically inapparent and persists only a few days. It is recommended that all ostriches were kept under tick-free conditions for at least 14 days prior to slaughter.

**Crocodile meat**
Crocodile meat is a by-product of skin production. Due to the high value of the skin and the fact that skin does not ‘peel’ off easily, crocodile skinning is very labor-intensive and provides opportunity for contamination of the meat.

**Hazards**
Crocodiles have crocodile-specific diseases varying from species to species. Crocodiles can carry and transmit certain non-specific pathogens. The main areas of concern to public health are salmonellosis and sparganosis. The possibility of contamination with *Salmonella*, depends on housing, feed, slaughter technique and hygiene practices under which the animal is reared. Numerous *Salmonella* spp. have been isolated from crocodiles, but most of these are believed to be harmless gut inhabitants. Results of samples from the flesh of farmed crocodiles during
slaughter at crocodile abattoirs suggest that the public health risk of consuming crocodile meat is minimal.

Sparganosis results from crocodiles becoming infected with the tapeworm *Spirometra erinacei* which produces an infective stage (spargana) in the muscle. People who consume infected meat may develop sparganosis resulting in inflammation of the skin, swellings or muscle pain.

**Risk management**

Most *Salmonella* infections are acquired from feed, thus a significant reduction in the infection rate can be expected from feeding compounded pellets, as is currently done on many crocodile farms. Another mitigating influence can be attributed to keeping the crocodiles in closed, temperature-controlled conditions, out of reach of salmonella-carriers such as flies, lizards and small rodents. Crocodiles are fasted for three days prior to slaughter to prevent contamination by leakage of gastrointestinal contents. The strict avoidance of pre-slaughter handling stress, e.g. by shooting the crocodiles in the pen, is another important factor reducing the rate of *Salmonella* contamination of the meat.

In Australia the entire outer surface of the killed crocs is washed with a chlorine solution spray prior to chilling of the carcass. This chlorine wash has been shown to be very effective. The carcasses are hung for several hours before being skinned and are rarely eviscerated (due to the cuts of flesh required by markets), which prevents contamination due to accidental leakage of gut contents. Prior to packaging, the flesh is dipped in acetic acid or chlorine to eliminate possible contamination which may have occurred.

The risk of infection with *S. erinacei* is considered negligible as most crocodiles raised on commercial farms are housed in concrete pens thus preventing exposure to the intermediate host (freshwater crustaceans). Spargana are readily destroyed by freezing the meat. The possibility of contracting sparganosis from eating cooked crocodile meat treated that way is considered extremely unlikely, particularly if the meat is frozen immediately after processing.

**Conclusions for alternative livestock farming**

Meat from farmed deer, is subject to the same requirements as conventional red meat. Public health risks associated with the marketing of venison from game farms are no greater – and in fact are probably less – than those associated with other red meats.

There is very little public health risk from the trade in and the consumption of ostrich meat. However, concerns about the risk of Crimean-Congo haemorrhagic appear to be legitimate. Contamination of ostrich meat with *Salmonellae, Chlamydia, Pasteurella, Mycobacteria* and *Erysipelas* might in principle be possible, but has never been reported. No parasites are known which could be transmitted through ostrich meat to human consumers. Residues from growth hormones, antibiotics and acaricides are potential public health hazards.

For crocodile meat, there is a distinct possibility of contamination with *Salmonella*, depending on housing, feed, slaughter technique and hygiene practices under which the animal is reared.
However, slaughter and hygienic processing procedures make the consumption of meat originating from farmed crocodile a seemingly negligible public health risk.

**Meat of wildlife**

Wild game meat is unique among the different categories of products of animal origin intended for human consumption. It is not ‘produced’ in the same way as livestock. Carcasses of wild animals are generally not subjected to a formal meat inspection. Ante-mortem examination for potentially hazardous biological and chemical agents is by definition impossible. The harvesting of wild animals is executed mainly by use of firearms from a distance and under primitive field conditions. This situation does not lend itself readily to any formal abattoir ‘line’ structure in which the carcasses, corresponding organs and head can be easily identified for inspection purposes.

The handling, storage and processing of wild game meat and meat products, especially in large quantities and on an ‘industrial’ scale, can lead to risks of cross-contamination, the dissemination of potentially unhealthy products and a danger of food poisoning.

**Hazards**

Most wild animal carcasses are never subjected to formal meat inspection as they are usually sourced from kills (by hunters) or informal population reduction culls. This may result in hazards to consumers, as macroscopically identifiable lesions (e.g., parasitic cysts, tubercles and abscesses) which would normally have been removed by trimming and partial or total condemnation of the carcass, enter the human food chain. Furthermore, potentially more dangerous, yet sporadic and rare infestations of wildlife are often macroscopically inapparent (e.g., Crimean-Congo haemorrhagic fever, Rift Valley fever, brucellosis, anthrax, *Salmonella* and others) and the presence of such pathogens may frequently not even be suspected.

As with domestic livestock, an important public health hazard is carcass contamination by enteropathogenic or toxigenic bacteria which may occur if the abdominal viscera are accidentally damaged by bullets or during evisceration. Bacterial zoonotic agents recognized among wildlife include anthrax, bovine brucellosis and bovine tuberculosis. This hazard of tuberculosis may be compounded by the human immunodeficiency virus (HIV) pandemic sweeping the African continent, causing an increased immuno-compromised human population.

Crimean-Congo haemorrhagic fever and Ebola virus infection are sporadic but important potential pathogens of humans. Risk results from handling of carcasses or consumption of animal in the viraemic phase of the disease.

Several parasitic diseases in wildlife are also reason for concern. Some of those are wildlife specific, others also occur in domestic livestock such as trichinae and tapeworms.

**Risk management**
Substantial risk reduction for zoonotic transfer of significant pathogens can be obtained by adhering to certain basic practices, such as refraining from utilizing any organ which appears abnormal, wearing disposable rubber gloves when dressing carcasses, trimming and washing potentially contaminated bullet-wound channels, and thorough cooking of meat and edible offal.

For Ebola virus infection a primate link appears to exist in Central and West equatorial Africa. Veterinarians, biologists and local villagers should be informed of the potential dangers of handling primate carcasses and raw primate-derived ‘bush meat’, especially when the animal has been found dead.

Conclusions
For wild game meat, the greatest public health risk inevitably stems from lack of veterinary inspection and contamination of the meat by organisms associated with a lack of hygiene. It should be well cooked prior to consumption. Some traditional processing methods, such as the preparation of ‘biltong’ may not guarantee the complete destruction of all zoonotic agents.

Seafood
Mollusks are implicated more than any other marine animal in seafood-borne illnesses. Mollusks generally inhabit shallow areas close to shore and pollution sources. They do not move out of those potentially contaminated areas, which increases the likelihood of bacterial and viral contamination. As filter feeders, mollusks collect high levels of microbial pathogens within the internal tissues. Consequently, the consumption of raw bivalves is one the most common causes of seafood-borne disease associated with contamination at the source.

Fish tend not to be restricted to small localized areas and therefore are not restricted to potentially contaminated areas. Human illnesses connected with fish vectors are caused by toxins, bacteria, viruses and parasites.

Hazards
Several illnesses are a result of toxic algal blooms, the growth of naturally occurring bacteria and diatoms causing paralytic shellfish poisoning, neurotoxic shellfish poisoning, diarrhoetic shellfish poisoning, amnesic shellfish poisoning and ciguatera. Paralytic shellfish poisoning usually involves recreational harvesters or their families, often as a result of ignoring notices regarding areas which had been closed to harvesting. New problems involving paralytic toxins are associated with the consumption of contaminated lobsters. Neurotoxic shellfish poisoning is caused by a concentration of the red tide dinoflagellate and its neurotoxin in shellfish.

Ciguatera is a clinical syndrome which causes several gastrointestinal and neurological disorders in humans. Herbivorous fish feeding on toxic algae are consumed by higher carnivores. In the food chain the toxin accumulates in fish tissues up to toxic levels. Humans are usually affected from the consumption of tropical reef fish or higher carnivores from tropical or subtropical regions.

Scombroid (histamine) poisoning is the most significant cause of illness associated with certain types of fish such as tuna, bluefish, mackerel etc. Poisoning is caused by the consumption of
fish with high histamine levels derived from naturally-occurring marine bacteria. Improperly stored fish aggravates the problem. Cooking has no impact on the toxic effect.

Bacterial pathogens associated with fecal contamination represent only a small portion of the shellfish-associated human disease outbreaks. Bacteria associated with fecal contamination of seafood include *Salmonella*, *Shigella*, *Campylobacter*, *Yersinia*, *Listeria*, *Clostridium*, *Staphylococcus* and *Escherichia coli*. Naturally-occurring bacteria have become the leading cause of shellfish-borne illness. Most of these indigenous bacteria belong to the genera *Vibrio*, *Aeromonas* and *Plesiomonas*. However, *V. cholerae* is not strictly a naturally-occurring bacterium. In some cholera pandemics, the main route of infection has been through the consumption of fecal-contaminated water. *V. cholera* survives well in warm waters of moderate to low salinity.

Non-cholera *Vibrio* spp. account for more cases of shellfish-related disease than any other known agent. Vibrios multiply quickly after harvesting if proper temperature conditions are not maintained and substantial multiplication may take place during post-harvest transport. Raw oyster consumption is the most common route for human infection with *Vibrio* spp.

Hepatitis and viral gastroenteritis have been linked to the consumption of contaminated shellfish. Enteroviruses have been commonly isolated from marine waters and shellfish. Norwalk virus and gastrointestinal viruses (small round structured viruses) are the most significant cause of viral shellfish-associated disease among several others.

The most important of the helminths acquired by humans from fish are nematodes, cestodes and trematodes, but only a few cause serious disease. Illness caused by these parasites are associated with social-cultural and behavioral patterns of certain ethnic groups, in particular the consumption of raw or undercooked seafood.

**Risk management**

Fecal indicator systems for shellfish-harvesting waters have been very effective in protecting consumers against general types of fecal contamination. Areas with counts higher than established baseline values must be closed to harvesting. Approved areas must be retested at least every three years. However, several pathogenic bacteria are not predicted by this system. This is expected for naturally-occurring bacteria, but appears also to be true for some fecal-related bacteria (*Salmonella* and *Campylobacter*).

Most illnesses due to paralytic shellfish poisoning arise from recreational harvesters who collect shellfish in areas which are officially closed. Education of the public must aim at preventing these incidents, as cooking does not always destroy the toxins.

Some specific risk management measures include:

- Closure of shellfish harvesting beds during red tide
- Alert the public through the local media and through warning notices posted on beaches of closed areas found to be toxic
- Moving of shellfish from contaminated harvesting waters to pristine waters for one to two weeks, but this may not provide full consumer protection
• Proper storage of fish to prevent Scombroid illness linked to post-harvest contamination and spoilage
• Freezing the fish prior to pickling or marinating to kill helmintic parasites.
• Heat inactivation of parasites which is the single, most effective method for eliminating the risk of parasitic infections and which can be achieved during processing or by the consumer.

Risk management measures for parasites include avoiding particular harvest areas, sizes of fish, or even particular species of fish. The method of capture, handling, and storage of the catch can directly affect the presence and numbers of parasites. Selective harvesting of younger fish will reduce the likelihood of large numbers of parasites. Certain fish stocks or geographic locations have excessive numbers of parasites, and must either be avoided by fishing vessels or the harvested fish must be adequately processed.

The extent of processing – including heading and gutting, candling and trimming – and the type of product derived (fresh, frozen, salted or pickled) can all contribute to the control of the risks posed by helminths. The most effective means of killing the parasites are either freezing or heat inactivation.

Seafood HACCP serves to identify sources and points of contamination (levels, transmission, fate and transport of micro-organisms including regrowth and inactivation potential), and exposure of the consumer to the contaminant. For the protection of public health, routine surveillance using new pathogen-specific techniques should be used. These must provide more rapid, specific and sensitive approaches for better detection of agents and toxins, including immunoassay, polymerase chain reaction amplification of target viral genomes and high performance liquid chromatography. These techniques, in combination with risk assessment methods and HACCP, must start to address the need for improvement in the safety of seafood.

Conclusions
The current system for prevention and control of seafood-associated foodborne disease has long been recognized as inadequate. Key factors which allow diseases to emerge are:
• environmental changes
• mechanical spreading of infectious or toxic agents through human activity
• development of new culturing and fishing procedures
• social change in eating habits and traditional eating habits by of certain ethnic groups

Any control program must address the above concerns in order to be successful in reducing the number of fish and shellfish-borne diseases. Greater awareness by public health personnel of rare diseases and better ability to detect agents by more specific and sensitive analytical methods are essential. Consumer education is the most realistic options to protect public health.

Aquaculture
With the diminishing supply of seafood from natural sources, aquaculture becomes increasingly important. It is a specialized form of agriculture practiced throughout the world under varying conditions, ranging from home-use subsistence to large-scale commercial systems. Production occurs in all types of environments and hundreds of species are cultured world-wide. The
responsibility for food safety lays with producers and processors to distributors, retailers and
food services, including home consumers. Proper sanitation, handling and preparation methods
must be observed by all those involved.

**Hazards**
The incidence of foodborne illnesses involving farm-raised species as vectors is relatively low
and are usually linked to the consumption of raw or undercooked products grown in sites
contaminated by surface waters or watershed runoff.

Public health hazards arise from shellfish production in waters with bioaccumulation of naturally-
occurring contaminants and trace environmental residue contaminants. Human illness as a result
of environmental chemicals is commonly associated with long-term exposure only. Herbicides
and pesticides are used in aquaculture to control aquatic weeds or other pests. Organic
contaminants and persistent organochlorine pesticides can pose safety risks for many years after
use. Residues in shellfish occur in areas near waste or industrial sites.
Toxins, bacterial, viral and parasitic public health risks in aquaculture are similar to those
mentioned under seafood. Foodborne diseases arise from unsanitary handling or preparation
and storage at incorrect temperatures or from the consumption of raw or undercooked
products.

**Risk management**
Unlike wild fisheries, inland aquaculture systems can minimize public health risks by proper site
evaluation and good aquacultural practices. Responsible use of pesticides and therapeutic drugs
prevents contamination of the product. Water quality certification programs and field
surveillance efforts including product sampling, testing and monitoring are critical safety issues.
Potential aquaculture production sites can be evaluated to minimize environmental chemical
contamination or to determine mitigation needs.
Pesticides used to control aquatic weeds or other pests should be suitable for aquaculture sites.
Pesticide products should be used only according to label directions, and containers should be
properly disposed of to prevent contamination of waters. In areas where agricultural crops are
grown in close proximity to aquacultural ponds, an adequate buffer zone should be established
to avoid potential drift from aerial spraying. Alternatively, the use of careful manual methods of
pesticide application are recommended. Marine sites should be situated far from industries
associated with environmental pollutants, such as paper and pulp mills.

Aquaculture, like other animal agriculture sectors, relies upon good management and proper use
of drugs and chemicals to combat infectious disease pathogens. Some countries have few or no
regulations on the use of drugs or chemicals in aquaculture and lack guidance to producers on
proper usage. Concern is mounting regarding the widespread use of drugs, particularly human
drugs, in aquaculture because of the potential for evolution of antimicrobial resistance in human
pathogens caused by such use. The lack of international harmonization or equivalencies in the
regulation of aquaculture drugs can impede international trade.
The aquaculture environment when managed properly can prevent many of the problems related to the harvesting and collection of seafood. Captive fish and shellfish farmed in open waters are exposed to the same algal bloom toxins as their wild stock counterparts, but potential risks can be reduced by understanding the natural phenomena of biotoxins, planning carefully for site selection and monitoring for known toxin-producing algae. Public awareness, coastal engineering and classification of waters also can help in protecting public health. Other public health hazards, associated with water and potentially poorly managed aquaculture environments, are linked to the transmission of human diseases by insect or snail vectors, such as schistosomiasis, malaria and filariasis.

Human feces are commonly used as a fertilizer in rural areas in the developing world. Farm workers and consumers of raw products sourced from ponds exposed to untreated human feces may experience high incidences of parasitic, bacterial and viral diseases. Treating human wastewater before application as a fertilizer can drastically reduce public health risks.

**Conclusions**

Aquaculture will be an increasingly important source of food. Potential public health risks can be avoided by proper site selection, responsible production management and the use of monitoring and control methods. Aquaculture offers a more controlled form of aquatic food production and is less prone to common seafood-borne illnesses, but safety can be compromised by environmental contaminants and mishandling during processing, marketing or preparation. Human health risk data and information associated with environmental contaminants or drug and chemical residues are lacking. Few countries have the ability to initiate and maintain a surveillance program for chemical residues which includes sampling and testing of both imported and domestic products. Rapid, reliable residue detection test kits are few or lacking. Laboratories are usually not be properly equipped or personnel may not be adequately trained to conduct accurate analytical detection work. Developing countries may lack data on trace chemical contaminants in aquacultural products and public health risks may be high in certain circumstances or where contaminated fish is a staple in diets. Potential abuse or carelessness associated with the misuse of illegal compounds to manage diseases or pests should be avoided through the education and training of farmers. Rural, small-scale fish farmers, in particular, may need information on the recommended treatments or materials which do not pose a public health concern and on criteria for a suitable production site.

Proper cleaning, processing, storage, handling, marketing and cooking of highly perishable aquaculture products will minimize potential safety hazards. Health problems may arise when abuse of regulations and carelessness occur.