Food-safety concerns in the poultry sector of developing countries

Jenni Kiilholma
Animal Production and Health Division, Food and Agriculture Organization of the United Nations, Viale delle Terme di Caracalla, 00153 Rome, Italy.

SUMMARY
Poultry production is one of the fastest growing livestock industries as a result of its advantages in terms of land use and improvements in the food conversion rate of genetically superior poultry breeds. Among the major concerns related to this development are health issues threatening not only animal production, but also the people using the products derived from these animals. Microbiological risks, such as salmonella-related food poisoning, pesticide residues from feed production, and resistance problems following the use of antibiotics in animal production have become the focus of attention.

In the industrial world, legislation and regulations have been implemented, involving both the public and the private sectors. However, in many developing countries such measures do not exist. Food-borne illnesses are, therefore, still major problems in developing countries. This paper discusses the measures that can and should be taken by developing countries to ensure safe products from the poultry sector. Examples are given from Bangladesh. As production conditions vary greatly as a result of socio-economic, political and environmental factors, regulations applied in one part of the world may not be suitable elsewhere. It is also questionable whether a developing country that does not aim to enter the export market for poultry, or livestock products in general, should apply the same standards as an exporting country. Many countries only produce for their national markets and therefore lack the incentive to follow international regulations; approximately 90 percent of global livestock products are sold in domestic markets. Nevertheless, the prevalence of food-borne diseases in developing countries is alarmingly high, and action is needed especially with regard to consumer awareness. To achieve this, there is a need for more information to be gathered about the conditions in individual countries, and for country-specific political action.

1 INTRODUCTION
The world is experiencing a growing population and rising incomes. This has led to increasing demand for food products, especially meat, milk and eggs. Together with innovations on the supply side, this has caused rapid growth of the livestock sector as a whole. The process has been referred to as a “livestock revolution” comparable to the “green revolution” of the 1960s.
The search for the most viable protein sources has resulted in particularly rapid growth of industrial poultry production. Poultry does not need pastureland, and the food conversion rate of genetically superior poultry breeds is very good compared to other livestock such as cattle. Technical advances in the feed industry have added to the progress. Pork production has followed a similar pattern to poultry. Intensification has brought food-safety concerns into sharper focus (Blancou et al., 2005), and these concerns have been increasingly acknowledged, at least in developed countries, as information technology and medical science have advanced (Nelson, in FAO, 2005).

Per capita demand for meat and fish products in developing countries has grown at a rate of 3.7 percent over the last 20 years (FAO, 2003). At the same time, the new intensive production systems of the developing world are facing more and more pressure to comply with the regulations that prevail in the global market.

The various factors that influence production conditions (e.g. environment, infrastructure and culture) give rise to differing demands for food-safety standards in different parts of the world. Food-borne diseases can also be related to demographic movements from rural areas to the cities, which cause overcrowding and, therefore, problems with hygiene, sanitation, housing conditions, etc., particularly in developing countries (Heath, 2006). Public health service systems are often unable to adapt to the rapid pace of urbanization. The urban lifestyle has also led to changes in consumption patterns, with more food products consumed outside the home, and to growing consumption of prepared foods (Stamoulis et al., 2004). Increased trade in food and feed across country borders, together with increased

<table>
<thead>
<tr>
<th>Food supply system</th>
<th>Health and demographics</th>
<th>Social situation/lifestyle</th>
<th>Health system and infrastructure</th>
<th>Environmental conditions</th>
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<tbody>
<tr>
<td>Mass production and distribution – larger outbreaks, etc.</td>
<td>Population growth</td>
<td>Increased consumption outside</td>
<td>Decrease of resources and increase of food businesses</td>
<td>Pollution</td>
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<tr>
<td>Intensive agriculture – increased use of drugs and pesticides, etc.</td>
<td>Increase in vulnerable groups, e.g. the elderly, immunosuppression, malnourishment</td>
<td>Increased travel</td>
<td>Lack of water supply, sanitation and fuel for cooking</td>
<td>Changes in ecosystems – lack of water and resources</td>
</tr>
<tr>
<td>International trade</td>
<td>Increase in the number of displaced people</td>
<td>Changes in food preparation habits</td>
<td>Inadequate training of health workers</td>
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<td>More food service establishments – lack of training</td>
<td>Rapid urbanisation – lack of sanitation and water</td>
<td>Poverty and lack of education</td>
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<td>Longer food chain</td>
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<td>Lack of time</td>
<td>Lack of access to technologies</td>
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<td></td>
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<td>Changed social and cultural behaviour</td>
<td>Lack of consumer awareness</td>
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Source: adapted from Motarjemi and Käferstein (1999).
leisure and business travel, is contributing to the global character of the food-safety problem (see Table 1).

Food safety can be defined as the system that keeps food and food products free from substances hazardous to human health. Food safety should be a part of governments’ strategies to ensure secure food for the consumers. In this context, a “hazard” refers to any biological, chemical or physical property that may cause unacceptable risk (FAO, 1998). The emergence and discovery of new food-borne pathogens and other food-related hazards has increased the need for food-safety measures. The intensification of food production has also changed food processing and handling systems and raised new challenges for food-safety institutions. Intensification has led to large amounts of potentially infectious material being concentrated at single sites, such as large industrial production establishments or processing plants, and has therefore contributed to the potential for large-scale outbreaks of infection. Changing consumption patterns – street vendors and home cooking of primary products are giving way to the purchase of processed food from supermarkets – make food-safety an issue of public concern rather that just a matter for individual consumers.

Developing countries face difficulties in achieving food-safety goals in animal production systems. These difficulties result from inter alia unstable administrative and political structures, lack of infrastructure, and lack of investment in food-safety measures and research, as well as from inadequate consumer information.

Responsibility for ensuring safe food for the consumer has traditionally been seen as the responsibility of public institutions. However, with the intensification and industrialization, responsibility has been shifted to a wider set of stakeholders including the private producer and the consumer.

2 BACKGROUND
2.1 Objectives
The objective of this paper is to describe the food-safety problems facing industrial poultry production systems in general, and then to examine the situation in developing countries – illustrated by a country example. The main risk factors affecting the whole vertical chain of industrial poultry production are described. The control measures, regulations and tools that are commonly applied in developed countries are also briefly described. Some common food-safety issues affecting developing countries are discussed. Utilizing the country example, the question of whether it is appropriate in developing countries to enforce control and regulation systems of the type commonly applied in the developed countries is addressed. Some of the constraints faced by developing countries, such as difficulties in risk management, and lack of administrative capacity, technical qualifications, information technology and so forth, are examined. The importance of cultural, environmental and political factors is highlighted.

The above-mentioned factors certainly differ across the developing world. Nonetheless, the objective is to use the country example to shed some light on the general situation in the developing world. Bangladesh, one of the poorest countries in the world but which has a relatively rapidly growing poultry sector, is used as the example.

The information presented here is drawn from the literature and from personal communication with experts working in the field or in research.
2.2 Defining the production systems

Seré and Steinfeld developed a framework for classifying livestock production systems (FAO, 1996). This classification first distinguishes “solely livestock” from “mixed farming” systems. The first category is then divided into “landless” and “grassland-based” systems. The landless system can also be referred as “industrial”. This group has two subgroups: monogastric and ruminant production. Finally, the monogastric system is divided into pork and poultry (meat and eggs) production. This paper will first focus on the “industrial” poultry production system, and will then consider whether the other production systems could be included under food-safety regulations of the type implemented in the industrial system.

FAO has formulated an additional classification of poultry production – Sectors 1 to 4 – based on the level of biosecurity. Sector 1 is defined as “an industrial integrated system with high level biosecurity and bird/products marketed commercially”. Sector 2 is described as a commercial system with moderate or high biosecurity and birds/products usually marketed commercially. Sector 3 is also described as a commercial system, but with low or minimal biosecurity and birds/products entering live-bird markets. Sector 4 produces chickens for local consumption only, and is described as having minimal levels of biosecurity. This sector is sometimes called the village or backyard sector. The definitions are constantly under discussion, and some doubts are expressed about categorizing sectors on the basis of biosecurity levels, due, for instance, to disputes about the definition of the term “biosecurity” itself. This paper focuses on the differences that these sectors face with regard to the global regulatory food-safety environment.

Parallel markets for poultry products can be identified in developing countries. On the one hand is industrial production or the formal sector, and on the other the informal market where official hygiene regulations and control measures are not followed (Enste and Schneider, 2000). It is also possible to categorize the poultry market into the export and domestic production sectors. Some vertical integration exists in developing countries – mostly involving Sector 1 and 2 farms. Such farms follow the regulations set by the industry. These are often private rules that have been set according to the needs of the target market and the local circumstances. There is quite an important difference between the two markets. However, there are many examples of interaction between the two, so the division is far from clear cut.

This paper concentrates mostly on broiler meat production, but some parallels to the production of chicken eggs are drawn.

3 THE POTENTIAL RISK FACTORS

Three types of food-borne risk factors for human health can be recognized (FAO, 1998). The first group of risk factors comprises microbiological factors such as Campylobacter spp. and Salmonella spp. The second group of risk factors comprises chemical factors such as residues from veterinary medications, pesticides, natural toxins or environmental pollution. Excessive use of medication during poultry production, or disinfectants used in the food-processing industry, can give rise to the problem of resistance. This adds to the problem of food hygiene. The third group of risk factors comprises physical hazards such as bone-pieces in meat; this group is not further considered here.
3.1 Microbiological risk factors

Microbiological risk factors include bacteria, viruses, protozoa, helminths, prions and mycotoxins. The most important group with respect to poultry are bacteria such as *Salmonella* spp., *Campylobacter* spp., *Listeria*, clostridia, enterococci and *E. coli*. As far as viruses are concerned, the significance of avian influenza should not be overlooked. Helminths, prions and protozoa are not considered to be major threats to food hygiene in industrial poultry production. Microbiological risk factors can be found in all poultry production systems. The most common microbiological pathogens connected with shell eggs are *Salmonella*, *Campylobacter*, *Listeria* and other enterobacteriaceae (Jones et al., 2006). The eggs can be infected vertically before laying or as a result of contamination from the environment. Cracks and other damage to the egg shell are obvious locations for pathogen multiplication.

**Bacteria**

One of the most studied food-borne pathogens is *Salmonella* spp. It is easily spread during the trade and processing of poultry products, specifically non-processed and non-heat handled products. This spread has been facilitated by industrialization and the growing international trade in animal feed, live animals and food. Food-borne *Salmonella* infection in humans is a very widespread problem in the industrialized world. In the European Union (EU), almost 200 000 people were infected during 2004 (EFSA, 2006); Mead et al. (1999) report an estimated annual figure of 1.4 million infections in the United States of America. The risk of infection with *Salmonella* has been worsened by the spread of pathogen strains with resistance to antimicrobials, a possible consequence of excessive use of antimicrobials in animal feed and as veterinary treatments (Antunes et al., 2006). The virulence of *Salmonella* is related to its ability to avoid host defence mechanisms and to invade non-phagocytic cells, its resistance to environmental factors and its production of enterotoxins (Plym Forshell and Wierup, 2006).

The increasing problem of *Salmonella* infection is not necessarily attributable entirely to the growth and intensification of poultry production; changing consumption patterns may also be a factor. Forsythe and Waldroup (1992) suggest that changes to consumer behaviour, such as eating out more, increased use of microwaves for heating and re-heating food, and increased use of salad bars outside the home, have contributed to the increase in human *Salmonella* infections in the United States of America. More or less similar patterns of consumer behaviour can be found in the other parts of the industrialized world. The above-mentioned study showed, however, that the incidence of human infections increased during the summer months, which implies that processing procedures may not be adequately adjusted to account for high temperatures.

*Salmonella* is also vertically transmittable, and some human infections can be traced to eggs. Infection with *Salmonella* can occur before laying (Humphrey, 1994), but the surface of the eggs gets contaminated quickly if there is infection in the environment. Chicks hatched uninfected can also be colonized very quickly. In the latter case, the infection can be detected two weeks after hatching, i.e. after the so-called lag phase.

Animal feed is a potential source of *Salmonella* infection. Crump et al. (2002) report several cases in which the *Salmonella* strains found in human food have been traced back to animal feed. In countries in the EU, there are specific requirements for the application of
feed-processing techniques to control the most common pathogens, including *Salmonella*. For example, in Denmark there are requirements for heat treatment of feed, and for feed producers to follow HACCP (hazard analysis and critical control points) regulations (Danish Veterinary and Food Administration, 2006).

Sander *et al.* (2002) investigated the additional problem of resistance arising as result of the use of disinfectants in the hatcheries; they identified the same strains of resistant *Salmonella* in the processing plants as in the related hatcheries.

_Campylobacter* is one of the pathogens most commonly causing food-related illnesses in humans. The bacteria can cause diarrhoea, gastro-intestinal pain and nausea in infected people. In rare cases it also causes Guillain-Barré syndrome, an immunological failure that causes damage to parts of the peripheral nervous system. The most common species of *Campylobacter* diagnosed in humans are *C. jejuni* and more rarely *C. coli* (Jacobs-Reitsma *et al.*, 1995); however, there are some small differences between geographical areas. Infections with multiple strains have been identified in most of the flocks of broiler chickens (Jacobs-Reitsma *et al.*, 1995). *Campylobacter* does not cause clinical signs in poultry (Wagenaar *et al.*, 2006). It remains unclear how flocks get infected with *Campylobacter* before harvesting, but there are several theories. Feed and water, vectors such as rodents and flies, horizontal transmission between birds, and contamination in the hatcheries are possible routes of entry (Hald *et al.*, 2004). The view has been that *Campylobacter* is not transmitted vertically, and that chicks are born infection free. The young birds are rapidly colonized only after hatching – infection can be detected after the so-called lag phase of one or two weeks. Vertical transmission has, however, been provoked in experimental conditions, and *Campylobacter* has been found in the oviduct of the chicken and in the semen of the rooster (Byrd *et al.*, 2007). This could imply that the bacterial contamination is traceable to the hatcheries and that layers might be infecting the eggs.

*Campylobacter* is particularly found on raw poultry meat. It is very vulnerable to drying out, but can survive for months in small pools of dirty water. Warm-blooded animals serve as reservoirs (Adams and Moss, 2004). Because of the vulnerability of the bacteria there have been many successful programmes of eradication in primary production. However, the end-result of these measures is questionable; the most probable site for recontamination is the carcass processing plant. Shell eggs are not a major source of *Campylobacter* infection in humans.

Other bacteria, such as *Clostridium perfringens*, *C. botulinum*, *Listeria monocytogenes* (Rørvik *et al.*, 2006) and *E. coli* O157:H7 can also be found in poultry products (WHO, 2007), but these organisms cause food-borne illnesses less frequently than do the two pathogens described above. Besides pathogens associated with the animals themselves, organisms associated with humans, such as members of the enterobacteriaceae and Staphylococcus, are major hygiene concerns in the handling of food products.

**Mycotoxins**

Mycotoxins secreted from certain strains of fungus can be found in various feed ingredients, including those used in poultry feed. Mycotoxins can infect the plants during their...
growth or during processing and storage; they can be distinguished into plant pathogens and storage mycotoxins (D’Mello, in FAO, 2004a). Types of feed differ from region to region, and therefore the range of mycotoxins also varies. In tropical areas, *Aspergillus* spp. are the most common organisms involved, while in more temperate areas, *Penicillium* spp. are more common. The third group of toxin-producing fungi is *Fusarium*, which produces fumosin toxin (ibid.). The main toxins of food-safety concern are the carcinogenic mycotoxins aflatoxin B1, aflatoxin M1 and ochratoxin A (FAO, 2000). Oyaejide et al. (1987) report that over half the poultry feedstuff examined in Nigeria was contaminated with aflatoxin B1. The Nigerian findings also indicated a higher prevalence of mycotoxins in feeds stored on the farm than in those stored by the feed producer (ibid.). This implies a lack of good management practices on the part of the poultry producer. These substances should be carefully monitored in poultry meat and eggs because of their carcinogenicity to humans. Industrial feed processing mills use various methods to control the risks associated with mycotoxin, including pelleting, heat treatment and irradiation.

### Other microbiological risk factors

Parasites of poultry that can cause human infection are very rare. Moreover, virus infections caused by orthomyxoviridae (avian influenza viruses) can be described as a risk factor for the actors involved in food production, but not directly as a hazard for the consumer of the processed poultry product. Prions are mostly considered to be a hazard associated with cattle and sheep meat products rather than poultry products (van de Venter, 2000).

Another important issue, related to both microbiological and chemical risk factors, is the problem of resistant strains of pathogenic bacteria that can affect humans. The spread of resistant strains may be related to the widespread use of antibiotics to treat animals and as growth promoters especially in broiler feed.

### 3.2 Chemical risk factors

Some chemical substances can be traced all the way into poultry end-products. There are, nowadays, strict restrictions in many countries, but elsewhere residues of antimicrobial medicines can still be found in the end-products.

During the production of feed, there is a need to control the residues of organic and inorganic environmental pollutants such as dioxins, chlorinated biphenyls, furans and heavy metals (Saegerman *et al.*, 2006). The control of feed quality and safety is increasing in importance as a result of the expanding international trade in animal feed products. Other risk factors that should be considered are pesticide residues from feed production, and genetically modified organisms (GMOs). A discussion of the latter issue is, however, beyond the scope of this paper.

### Antibiotic residues

Antibiotic residues in food products can be the result of excessive use of antimicrobials in veterinary practice or as a supplement in ready-produced animal feed. Policies regulating the use of antibiotics vary greatly between countries; in the developing world, the control is probably generally insufficient.

There are two ways in which the antibiotics in feed can affect human health: the direct
effect of the residues in poultry meat and eggs, and the indirect effect resulting from the selection of antibiotic resistant strains of pathogenic bacteria. The issue of the use of antibiotics as feed additives and the restriction of this use is somewhat controversial. Some suggestive studies imply that the benefits of reducing the amount of resistant bacteria by controlling the use of antibiotics as feed additives might be overshadowed by an increase in the number of cases of human food-borne illnesses (Singer et al., 2007). The latter authors describe a model that illustrates the relationship between food-borne illness and the health status of the flocks that supply the food products. The model, which used Campylobacter infection as an example, suggests that a small decrease in the levels of illness in the animal flocks will significantly decrease the rate of human infections (ibid.). Moreover, the correlation between the use of antibiotics as growth promoters and the prevalence of pathogen strains has not been definitely proven. The ban in the EU (European Council Directive (EC) 2821/98) was partly a result of pressure from certain member countries; it was accepted as a preventive action in accordance with the precautionary principle (Williams, 2001). Developing countries might not have the motivation or the capacity to enforce such regulations. However, the desire to continue or commence exports to European markets might be a driving force favouring a ban.

The continuous development of techniques for detection also contributes to the problems that developing countries face in terms of conforming to international standards. Technological differences can lead to confusion and unpredicted economic losses associated with the disqualification of export products (Phongvivat, in FAO/WHO, 2004). The acceptable levels for most antibiotics are described under the minimum residue level system (MRL) (ibid.).

Antibiotics are still used as growth promoters in many developed countries, including the United States of America. However, the four main additives, virginiamycin, bacitracin, spiramycin and tylosin, were banned in the EU in 1998 (European Council Directive (EC) 2821/98). Four others, bambermycin, avilamycin, salinomycin and monensin, were banned in 2006 (Hong et al., 2005). The antibiotics are used in order to enhance the production qualities of poultry and other livestock. Some studies have shown that production systems using antibiotics as feed additives achieve growth rates up to 10 percent higher than those not doing so (Hughes and Heritage, in FAO, 2004b). There have been other beneficial effects on the product quality, such as decreased fat and increased protein in the meat, as well as indirect benefits such as a reduction in the amount of feed needed, and therefore a reduction in the amount of waste. The practice evidently also decreases the occurrence of gastro-intestinal infections – adding an animal-welfare component to the considerations.

**Pesticides**

Intensive use of pesticides in many developing countries also affects the safety of food via animal feed with a high level of residues. In order to control plant pests and vectors of disease, the use of versatile pesticides has been widespread in many parts of the developing world. This practice has not been without consequences for the environment, production animals, feed, food crops and public health. There have been studies of immune system-related illnesses, such as immunosuppression and hypersensitivity (Street, 1981), as well as many other illnesses that could be related to the excessive use of pesticides and the result-
ing residues in food products. These illnesses, but also both acute and chronic toxicities, have been reported both in human and animals (Lu and Kacew, 2002). Pesticide use is highly regulated in the EU and in the United States of America; residue levels are therefore under strict control. However, in a developing country the situation may be quite different. This is illustrated by a study from India (Singh, 2001), which examined various food products for pesticide residues. All the Indian states were included in the study and several pesticides were examined – HCH (hexachlorocyclohexan, also called hexachlororebenzen HCB), DDT, monocrotophos, cypermephrin, quinolphos, aldrin and endosulfan. Of the 12 eggs examined, 83 percent were found to contain residues. Ninety-two percent of the livestock tissues examined were found to contain traces of pesticides. HCH, DDT and aldrin were found at toxic levels in poultry products. In addition, HCH residues were found at toxic levels in livestock feed. HCH, DDT and aldrin are still widely used as insecticides in many countries, although they have been banned in most developed countries. In addition to acute toxicity, HCH can cause hormonal disorders and liver and kidney failure in humans and other animals. Aldrin belongs to a group of organochlorides most of which are banned from use in the developed world. Aldrin, however, is still used in the United States of America as a termite pesticide.

**Other chemical risk factors**

Disinfective agents used in production establishments and processing plants are also risk factors. Chlorinated water used in rinsing the carcasses has also raised concerns among consumers. In the EU the use of chlorinated water is banned, but in the United States of America it is a common practice. The use of disinfectants to clean the equipment in production and processing establishments might, as mentioned above, also give rise to a problem of resistance.

### 4 THE VERTICAL CHAIN

The different steps of the food production system need specific regulations. However, food-safety interventions should optimally be considered as a whole, i.e. should be coordinated through the whole vertical system (see Figure 1). The chain from “farm to fork” starts with feed production, and continues through the hatcheries to the slaughterhouses, processing plants, wholesalers, retailers and the end consumer. Between these steps there is transport and storage, during which maintaining the cold-chain is crucial. The hygienic behaviour of the end consumer, such as washing hands and kitchen utilities after handling raw poultry meat or eggs, is the final factor in avoiding the food-borne illnesses related to poultry products.

WHO formulated a three-step approach to mitigating the risk posed by *Salmonella* spp. (WHO, 1980); the terms used are also relevant for other microbiological hazards. The first step is pre-harvest control, which focuses on the feed and poultry producers. The second step is harvesting control, which covers hygiene measures at the time of slaughter; these are described in the Codex HACCP model (see Table 2 for an example). The third step is post-harvest control, which covers the product from the processing establishment all the way to the end-consumer. Each of these three stages has to be taken into consideration in order to prevent risk factors entering the chain.
It is suggested that the first step, pre-harvest control, is the most important means to prevent infection with pathogens such as *Salmonella*, as traditional control systems are unable to control for these pathogens later in the chain. Singer *et al.* (2007) describe three reasons why it is important to process only healthy animals – thus emphasising the importance of pre-harvest measures. First, a sick animal will shed pathogens into the surroundings and onto other animals; second, processing a sick animal may require additional handling in order to separate the infected parts from the carcass, which may add to the risk of cross-contamination; and third, certain illnesses lead to pathological changes in the carcass which may cause increased fragility of specific organs. *E. coli*-originated airsacculitis, which causes adhesions of the inner organs and therefore increased risk of ruptures during mechanical processing and increased risk of cross-contamination, is mentioned as an example of the latter problem (ibid.).

Poultry producers have an important role in preventing risk factors from entering the food chain. In the developed world this role has become more or less clear to the farmers as a result of official regulations and increased hygiene demands originating from consumers and retailers. The enforcement of these regulations is done through control visits by governmental authorities to production establishments, and by continuous control on the part
### TABLE 2
Generic HACCP model for raw chicken: process flow diagram for slaughterhouse

<table>
<thead>
<tr>
<th>INPUTS</th>
<th>PROCESS STEPS</th>
<th>EDIBLE OUTPUTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Live birds</td>
<td>1. Receipt of live birds</td>
<td>Head</td>
</tr>
<tr>
<td></td>
<td>2. Hanging</td>
<td>Feet</td>
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<tr>
<td></td>
<td>3. Stunning</td>
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<td></td>
<td>4. Killing</td>
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<td></td>
<td>5. Bleeding</td>
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<tr>
<td></td>
<td>6. Scalding</td>
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<tr>
<td></td>
<td>7. Defeathering</td>
<td></td>
</tr>
<tr>
<td>Water (possibly with bactericidal agent)</td>
<td>8. Washing</td>
<td>Edible offal (liver, gizzard, heart)</td>
</tr>
<tr>
<td></td>
<td>9. Head pulling</td>
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<td></td>
<td>10. Hock cutting</td>
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<td></td>
<td>11. Venting</td>
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<tr>
<td></td>
<td>12. Evisceration</td>
<td></td>
</tr>
<tr>
<td>Water (possibly with bactericidal agent)</td>
<td>13. Washing</td>
<td></td>
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<tr>
<td></td>
<td>14. Crop removal</td>
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<td></td>
<td>15. Neck cracking/cutting of neck flap</td>
<td>Necks</td>
</tr>
<tr>
<td>Water (possibly with bactericidal agent)</td>
<td>16. Washing (inside/outside)</td>
<td></td>
</tr>
<tr>
<td>Water with ice (possibly also with bactericidal agent)</td>
<td>17. Chilling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18. Re-hanging</td>
<td></td>
</tr>
<tr>
<td></td>
<td>19. Conveying to secondary processing area</td>
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<tr>
<td></td>
<td>20. Portioning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21 a. Storage</td>
<td></td>
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<tr>
<td></td>
<td>22 b. Deboning</td>
<td></td>
</tr>
<tr>
<td>Packaging materials</td>
<td>22. Packaging</td>
<td>Packed whole chicken or chicken portions</td>
</tr>
<tr>
<td></td>
<td>23. Chilling/freezing</td>
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<td></td>
<td>24. Storage</td>
<td></td>
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<td></td>
<td>25. Dispatch</td>
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</tbody>
</table>

**Source:** MAF (2000).

of the establishments themselves. An efficient traceability system linking the food product to the farm has enabled efficient and rapid intervention measures in the event of an outbreak of a food-borne disease. It has been shown that improvements made to the health of production animals have positive effects on the safety of animal-derived food products for humans. Singer *et al.* (2007) showed that there is a strong correlation between the health
of production animals and level of food-related human illnesses. Veterinary services are also important. The non-regulated use of antibiotics as veterinary treatment might be a link to the appearance of resistant strains of pathogens posing a threat also to human health. The antibiotics used for veterinary treatment can in some cases overlap with crucial ones used to treat human illnesses.

Slaughterhouses and food-processing establishments are the next links in the chain of food safety. The post-slaughter poultry carcass is a suitable growing medium for many pathogens, including human pathogens. Hygiene procedures when handling the carcass are, therefore, crucial and should be carefully planned and monitored to avoid contamination and cross-contamination of the food products. Packaging, transport, shelf-life and storage, as well as the maintenance of the cold-chain are important considerations. The cleaning and disinfecting of the premises and transport vehicles involved in these processes should be controlled. Resistance issues should be considered in the choice of the products used. Food products are then transported to wholesalers, retailers and finally to the consumers. Many cases of food-borne illnesses could be avoided by applying good hygiene practices in the home or in restaurants. Consumer information and education is, therefore, crucial, especially in developing countries where hygiene standards are poor.

4.1 Responsibility for control

Three major stakeholders can be identified in an industrial poultry production chain– the producer, the consumer, and the government. In industrialized countries, there are strong consumer-protection organizations which directly, or indirectly through governmental institutions, put pressure on the producer to supply safe products. A shift of legal responsibility from the government to the producer has been the common trend in developed countries (FAO, 2007). According to this mindset, the optimal role of the government is as a guarantor of the system through administrative and regulatory methods – the producer being the one managing the systems. A major factor in the prevention of food-borne illnesses is to ensure that stakeholders from all sides understand their responsibilities and voluntarily introduce good hygiene practices.

5 Food-Safety Regulations and Risk Analysis

5.1 Risk-analysis tools

In order to set up food-safety strategies for countries or regions, some basic frameworks have been designed by international regulators. The modern approach is to use risk analysis tools. Briefly, such tools include the following steps (Adams and Moss 2000):

- identification of the hazards (i.e. the risk factors described above);
- exposure assessment – estimating the likely intake of the agents;
- hazard characterization – quantitative and qualitative analysis of the risk factors; and
- risk characterization – estimating the probability and severity of the possible food-borne illness.

This approach has to a large extent been successfully implemented in the developed-country food production sector. However, the proper implementation of risk-analysis tools requires certain basic components. These include efficient public health institutions, sufficient laboratory facilities, properly trained human resources and functional infrastructure.
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(FAO, 2007). Obviously, many countries are weak with respect to one or more of these components. A careful analysis of the country or region should, therefore, be implemented before considering the application of such tools.

5.2 The international regulatory environment

Large parts of developed-world markets follow international sets of rules. The major players in the international rule-setting forum are the FAO/WHO Codex Alimentarius Commission with its Hazard Analysis and Critical Control Point (HACCP) guidelines; the World Organisation for Animal Health (OIE) with its Terrestrial Animal Health Code, and the World Trade Organization (WTO) which sets the sanitary and phytosanitary (SPS) framework for international trade. The Codex Alimentarius Commission has also set out guidelines for good agricultural practices (GAPs), good manufacturing practices (GMPs) and good hygiene practices (GHPs). These sets of rules and practices are widely accepted in developed countries and international markets.

In addition to the main rule setters mentioned above, there are several other international and regional bodies. Internationally, there is for example, the International Atomic Energy Agency (IAEA) which sets regulations concerning irradiation of food and feed, etc. Regionally, there are organizations such as the European Food Safety Authority (EFSA) and the African Regional Standardization Organization (ARSO). Regulations set by private industry should also be taken into consideration. These regulations are sometimes more stringent than those described above. Moreover, they often include regulations related to quality aspects not considered to influence human health.

The international rules are set to protect the consumer, but have been criticized for setting trade barriers that prevent developing countries from entering international markets because of the high costs associated with implementation. In particular, the private standards imposed by some parts of the industry are the target of such criticisms. Another consideration is that the international rules may be of little relevance to poor developing countries that are not involved in the international livestock trade. According to Randolph et al. (2007) 90 percent of the world's livestock trade is within domestic markets.

In the developed world, food products are mostly sold in large marketing systems, such as supermarkets. However, in the developing world there is a vast informal sector involving live-markets and street vendors of food. The production and slaughter systems in the developing world also differ greatly from the industrial model described above. This poses complications for the implementation and enforcement of food-safety regulations: how can the informal and the formal sectors be linked, and how can homogenous food-safety policies be implemented throughout the market?

6 FOOD-SAFETY CONCERNS IN DEVELOPING COUNTRIES

Food-borne diseases are major health problems throughout the world. According to statistics from WHO, 1.8 million people died of diarrhoeal diseases in 2005 (WHO, 2007). Motarjemi et al. (1999) estimate that up to 70 percent of such cases are associated with contaminated food (though not restricted to livestock products). In addition, the WHO report states that in industrialized countries up to 30 percent of the population is reported to be affected by a food-borne disease each year, implying that the proportion in developing countries might be much higher.
In developed countries, the control of food-borne illnesses has been relatively successful with the help of measures described above. Public-sector measures, such as vaccination of animals, vector control, medication, slaughter inspection, risk analysis and consumer education, have been used to advance food safety in these countries (Blancou, 2005). However, in many developing countries, attempts to use such measures have been less successful.

The public sector in developing countries faces various constraints, including poor financial resources, infrastructure and information. Mills et al. (2004) point out that some public health projects have failed, despite proper funding and the help from international community, as a result of a weak public sector and poor infrastructure.

Many countries, including many developing countries, have officially introduced food-safety regulations in order to meet the demands of international markets and global agreements. However, such efforts have often remained theoretical or have only been implemented in large industrial establishment that have international customers. Small producers have often not been integrated within the regulatory framework, and hence are left to operate in the informal market sector. Azevedo and Bankuti (2002) describe the situation in Brazil, where the implementation of stricter regulations has led to a growth of the informal market, resulting in more “unsafe” food being sold to the consumers. This effect is a result of the increased costs associated with producers having to upgrade to the new safety regulations (ibid.). The poor populations of developing countries are described as having a high price-sensitivity, and consequently they will readily switch to buying products from the informal market if the prices of food products in the formal, regulated, market rise.

Azevedo and Bankuti (2002), however, also describe positive experiences from Brazil: in addition to the federal regulations implemented in the export sector, other, more lenient, regulations have been introduced at state and municipality level. Establishments that follow these regulations are allowed to supply state and municipal markets, respectively. This has inevitably resulted in food produced according to different hygiene standards being sold in the national market, but it has decreased the share of the informal market as a whole. A significant number of informal slaughterhouses have moved into the formal market as a result of the introduction of the less strict state-level and municipal-level measures (ibid.).

The other major problem in developing countries is a lack of information among consumers. There are many consumer interest groups working in the developed countries, but these groups are absent, less visible or weaker in developing countries (see discussion of Bangladesh in the following section).

The implementation of international food-safety standards, such as the FAO/WHO Codex standards described above, may not seem relevant to non-exporting developing countries. However, as Randolph et al. (2007) point out, alarm over a zoonotic disease can quickly affect the domestic market for livestock products. For example, in Bangladesh the mere news of highly pathogenic avian influenza outbreaks elsewhere caused a temporary drop of 70 percent in the consumption of poultry products (ibid).

Even if these international regulations were to be implemented in the industrial production plants, the average developing country consumer might not benefit. Ayieko et al. (2005) reported that even in the more developed cities in Africa, such as Nairobi, only 8 percent of meat products were bought from supermarkets. This implies that live markets
and home-slaughtering remain widespread. Another study (Omore et al., 2005) shows that lack of proper controlling institutions leads to a high prevalence of food-safety hazards, even in products sold in supermarkets.

Large regional differences exist with respect to the consumption of different livestock products, as a result of differences in culture and eating habits. This can affect the focus of food safety-related measures. For example, in Bangladesh, where fish is the most important animal product, this particular sector has been the focus of food-safety policies, while development in other sectors, such as poultry, has been slower.

7 LESSONS FROM BANGLADESH

Production of poultry meat and eggs in Bangladesh has been growing quite rapidly over the last 15 years. Poultry meat production increased from 66 000 tonnes in 1990 to 102 000 tonnes in 2005, and egg production increased from 85 000 tonnes to 160 000 tonnes over the same period (FAOSTAT). Quasem and Islam (2004) estimated the growth rate of chicken production in Bangladesh to be 5.3 percent per annum, and predicted that consumption of broiler meat and eggs would grow by 95 percent and 78 percent, respectively, in the period to 2020. This growth is being driven by the growth in market demand – the same pattern that is seen globally.

As poultry is not an internationally marketed commercial product in Bangladesh, few organized vertical production systems have been established. One exception is the Aftab Poultry Ltd., which produces processed poultry for the few supermarkets that exist in Dhaka and Chittagong. Most poultry is sold in live bird markets, and about 90 percent of the rural families keep small numbers of chickens (Das et al., 2008). This means that, apart from the Aftab farms, there are no processing plants or organized slaughtering. Aftab operates a system of contract farms – a total of 560 in 2005 (Begum, 2005).

In 1999, there were only two laws related to slaughter and meat – the Animal Slaughter and Meat Act (1957) and the Municipal Corporation Ordinance (1983). These two laws define animal categories allowed for slaughtering, provisions for meatless days, etc. However, they do not set out minimum procedures for slaughter (Svendsen, 1999). Moreover, they do not cover guidelines for pre-slaughter and post-slaughter inspection (ibid). In 2005, the Animal Disease Act and the Animal and Animal Products Quarantine Act were approved by the country's parliament. However, it remains to be seen how successful the implementation of these laws will be.

One factor contributing to the slow implementation of international regulatory tools such as HACCP in the poultry sector in Bangladesh is extremely high start-up costs. For example, the cost of implementing HACCP in the shrimp industry to meet EU standards was equivalent to more than 9 percent of annual sales, which represents quite an overwhelming figure for the small producer (Cato et al., 1998).

A study in 1997 recorded a 10 percent prevalence of Salmonella in commercial poultry farms in Bangladesh (from 1 200 farms tested) (Hoque et al., 1997). Salmonella is in fact endemic throughout the country. Official records for the prevalence of Campylobacter are lacking (personal communications with P. Biswas, University of Chittagong, Bangladesh).

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The prevalence of other major microbiological risk factors such as clostridia, *Listeria, E. coli,* and *Staphylococcus aureus* is also largely undocumented.

With regard to chemical risk factors, the use of antibiotics is widespread throughout the poultry sector. Antibiotics are used for therapeutic purposes and as growth promoters in feed. The antibiotics used include oxytetracycline, amoxycillin, co-trimoxazole, gentamicin and ciprofloxacin (personal communication with P. Biswas, University of Chittagong, Bangladesh).

Despite the efforts made by the government, there are major deficiencies with respect to food safety in poultry production of Bangladesh. Consumer awareness of food-borne illnesses is quite elementary. Consumer organizations of the type that in industrialized countries exert pressure on producers to apply food-safety measures are weak or non-existent in Bangladesh (personal communication with Dr. Giassudin, University of Chittagong, Bangladesh). This may contribute to a lack of implementation of existing policies. A recent critical overview (Amjad, 2007) assessed the consumer protection legislation in Bangladesh and concluded that the main public-health problems were similar to those found in other developing countries. One of the main issues is a lack of awareness among consumers. Illiteracy is a factor. There is also a lack of awareness of consumer rights and food-safety risks. Another problem is evidently financial. Even if awareness were greater, financial limitations would still affect consumers’ choices and promote the consumption of poorer quality products. Despite efforts to establish consumer-protection legislation, enforcement remains poor (ibid.). Moreover, according to some reports (e.g. Harboe, 1998), the vertical links from the government to the villages are quite weak; a given village may lack the information or the incentives necessary to apply the food-safety regulations passed by parliament.

8 DISCUSSION AND CONCLUSIONS

It is quite difficult to define a best model for food-safety practices applicable to the developing world as a whole. More country-specific data on risk factors throughout the vertical chain are needed. The political environment, the state of infrastructure and so forth should also be carefully assessed before policies are formulated.

Surveillance and data collection systems are often lacking or not functional, meaning that reliable data about risk factors are unavailable. Restructuring or establishing food-safety services may require substantial education of veterinary and the health inspectors at all levels.

A market-driven approach could be a way to achieve success in food safety, but this would need interest and large investments from the industry. There would definitely be difficulties in implementing a thorough control system, because of the existence of the vast informal sector in which animals are not slaughtered in the abattoirs but in homes or at the markets. The Brazilian model, mentioned above, might offer a way forward for some countries. The evidence presented from Bangladesh, suggests that efforts to improve food safety in poultry production should start at the local union or village level with simple regulations directed towards addressing the most prominent deficiencies in the food-safety system. Clearly, this would, again, require identification of the major risks and their entry points into the food chain. Village-level education campaigns, directed at community work-
ers such as teachers, and thus reaching the consumers, as well as at restaurants, would be essential. The main message is clear. Investment in basic education, and thus increasing consumer awareness, should be seen as a key element of food-safety strategies in developing countries.

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