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Title: An Approach to a Microbiological Risk Assessment in the Poultry Sector in Trinidad

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AN APPROACH TO A MICROBIOLOGICAL RISK ASSESSMENT IN THE POULTRY SECTOR IN TRINIDAD

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ABSTRACT

International studies and epidemiological data have revealed a strong association between salmonellosis and chicken meat. This association provides serious challenges for food safety and international trade. Microbiological Risk Assessment is a food safety tool that is used to determine the incidence of food borne illnesses. The procedure identifies a microbiological hazard in the entire food continuum (from farm to fork), and estimates the adverse effects to human health, of ingesting the microbial hazard. The Assessment integrates four steps, hazard identification, hazard characterisation, exposure assessment and risk characterisation, to produce a practical estimate of risk. In each step, knowledge of the prevalence and concentration of the pathogen, and the probability and magnitude of health effects, are combined to represent a cause and effect chain. An approach to a quantitative risk assessment of Salmonella in broiler chicken in Trinidad is examined. In this approach, Salmonella and chicken meat are linked to human illness from consultation with food safety experts and the evaluation of epidemiological data and information. Historical epidemiological data from the Caribbean Epidemiology Centre and the National Surveillance Unit (Trinidad and Tobago), supplemented with international epidemiological data, are best suited to develop a dose-response model. In the exposure assessment, data on the levels of Salmonella at the risk- determining stages are analysed. Sampling and analysis of chicken meat and the farm environment are instituted to estimate the source and frequency of Salmonella. Where sampling of broiler chicken meat is not practical, survey data provide values for the factors that influence growth and death of Salmonella. Predictive models are then used to estimate the changes in the concentration of pathogens in the food, prior to consumption. Finally, in the risk characterization module the information derived from hazard characterization and exposure assessment, are integrated using Monte Carlo modelling, @Risk computer software, to produce a numerical estimate of the probability of salmonellosis from the consumption of chicken meat.

Keywords: Broiler chickens, Salmonellosis, Microbiological risk

Introduction

Microbiological Risk Analysis is a new and emerging discipline in the area of food safety (Brown 2002). According to the Codex Alimentarius Commission (CAC) (1999), this analysis consists of three steps (i) microbiological risk assessment (MRA), (ii) risk communication and (iii) risk management. The development of this procedure is rapidly increasing because of the major adverse, health, economic and social implications that are experienced by a country or business from foodborne pathogen-related outbreaks. It is estimated that one-third of the population in developed countries is affected by foodborne diseases each year, and a higher number in developing countries (Food and Agriculture Organisation/World Health Organisation (FAO/WHO) 2002). Nevertheless, the true extent of the problem is not known, as most cases of foodborne illnesses are not reported (WHO 2001).

For over 100 years *Salmonella* has been reported as causing illness, and it is now the leading foodborne pathogen worldwide (FAO/WHO 2002). The estimated incidence rate for salmonellosis per 100,000 population recorded for the year 1997 was U.S.A., 14;

Australia, 38; Japan, 73; Netherlands, 16; and Germany, 120 (Centres for Disease Control (CDC) 2001). Franco et al. (2003) noted that *Salmonella* caused 36.8% of the reported cases of foodborne illnesses of known aetiology in Latin America, more than any other pathogen. Salmonellosis accounted for 55.1 % of the reported foodborne disease cases in Korea from 1993 to 1996, and 77.1 % of the outbreaks in the European Union (Franco et al. 2003).

The Caribbean Epidemiology Centre (CAREC) (2001) noted that the major cause of foodborne illnesses of known aetiology in the English-speaking Caribbean region is *Salmonella*. During the period 1995 to 1999, the annual average number of cases of foodborne illnesses and salmonellosis reported in the sub-region was 1929 and 424 respectively. Salmonellosis is therefore associated with 22% of the foodborne illnesses reported in the region (CAREC 2001).

In the Republic of Trinidad and Tobago, the annual average number of cases of foodborne illnesses reported during the period 1995 to 2003 was 569 (National Surveillance Unit (NSU) 2004). During the same period, the annual average number of salmonellosis cases reported was 85, approximately 15% of the total number of cases reported annually (National Surveillance Unit 2004). Additionally, during the period 1998 to 2003, *Salmonella* was associated with 40% of the major outbreaks of foodborne illnesses (NSU 2004).

According to Bell and Kyriakides (2002) poultry, especially broiler chickens, is a major reservoir for *Salmonella.* Contamination may approach 100% in intensively-reared flocks due to poor sanitation practices. Unhygienic practices during slaughter and subsequent handling increase the contamination of carcasses and the percentage of contaminated carcasses (Varnam and Evans 1996). Consumption of raw or undercooked chicken or the consumption of re-contaminated cooked chicken is the prime cause of salmonellosis from poultry. Consumption of cross contaminated foods that do not undergo heat treatment by cooking, from poultry, during preparation, also plays a role in outbreaks (Varnam and Evans 1996).

The high level of broiler meat consumption in the Republic of Trinidad and Tobago makes this product very important, regarding the safety of the nation's population. However, food safety laws that regulate the industry are inadequate and non-specific and not stringent enough to minimise the risk of poultry-related salmonellosis. Additionally, the laws that regulate the industry are incorporated into various pieces of legislation, thus, the enforcement is shared by various governmental agencies and this poses a challenge for proper enactment. Whereas the large processing plants introduced the Hazard Analysis Critical Control Points (HACCP) method of quality control as a voluntary approach to improve the microbiological quality of processed chicken (Caribbean Poultry Association (CPA) 2001), the general sanitation practices amongst the smaller enterprises, including pluck-shops, are considered to be low (CPA 2003). Additionally, Caribbean Community (CARICOM) countries are unable provide assurance to member countries and other states that wish to import poultry and poultry products that these products are safe (Webb, 2003).

The policy initiative of the government of the Republic of Trinidad and Tobago (GORTT) is to reduce importation taxes for chicken and turkey parts from 86% to 40% (Lord 2004a) and to remove surcharge on imported chicken (Lord 2004b). This initiative, however, increases the risk of dumping inferior chicken on the local market, thereby increasing the risk of cross-border transmission of pathogens. It also limits the growth and expansion of the domestic industry.

Significance of Microbial Risk Assessment

The aim of MRA is to provide risk managers and decision makers with science-based data, information or recommendations that may enable them to make appropriate decisions to control foodborne microbial hazards (van Schothorst 2002). The procedure determines the factors in the food continuum, from production to consumption, that magnify the risk of the food to consumers. The areas of deficient data are identified and recommendations are established to guide food safety strategies (Lammerding and Todd 2006). The significance of the method is compounded by the continued globalisation of the food supply (Forsythe 2002), resulting in an increased risk of cross-border transmission of infectious agents. Food production, manufacturing and marketing are international in nature and can transfer microbiological hazards from its processing point, to locations throughout the world (FAO/WHO 1999). As a result, food safety requires enhanced levels of international cooperation in setting standards and regulations.

However, the progression of the procedure is embedded in international trade, rather than consumer health protection, to eliminate the use of unwarranted consumer health protectionist measures, as barriers to international trade in food. Foods safety measures are not uniform around the world, and such differences can lead to trade disagreements among countries. This is particularly true if microbiological requirements are not justified scientifically. Therefore, it is necessary to assess the risk that infectious agents pose to human health in an international context, and to identify possible interventions to reduce or eliminate these risks (FAO/WHO 1999).

Microbiological Risk Assessment Framework

MRA is a scientific procedure that provides an estimate of the likelihood of infection, illness or death to humans, from exposure to foodborne microbiological hazards (FAO/WHO) 1995). Over the last 10 years, risk assessment procedures have proven to be an acceptable, science-based approach to developing strategies for the management of microbiological safety of food (Lammerding 1997). The process integrates four steps, hazard identification, hazard characterisation, exposure assessment and risk characterisation, to produce a practical estimate of risk (CAC 1999). In each step, the knowledge of the prevalence and concentration of the pathogen, and the probability and magnitude of health effects, are combined to represent a cause and effect chain (Lammerding and Paoli 1992).

In the 1990's, landmark decisions taken in international trade, propelled the risk assessment framework. In 1993, during the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) it was agreed that technical barriers to trade in food, including measures designed to protect public health, must be science-based (Stanton 2000). In 1995, the World Trade Organisation (WTO) succeeded . Hazard characterization forges a relationship between dose (exposure level) and response of the human host. The infection may be asymptomatic or may lead to acute illness, typically gastroenteritis. Recovery is imminent, but some patients develop chronic sequelae and some may die (Havelaar et al. 2005). Data from human trials, small animal studies, or epidemiological investigations are used to generate mathematical models that represent a dose-response relationship (Food and Drug Administration/ Centre for Food Safety and GATT and concluded the Sanitary and Phytosanitary agreement (SPS) (Stanton 2000). The SPS seeks to form a robust relationship between consumer health and trade. In so doing, the agreement recognizes the right of member countries to protect its citizens from any infection, illnesses and death associated with the consumption of food, but forbids nations to use this right to create health protectionist barriers to trade (Forsythe 2002). The agreement specifies that a sanitary barrier to trade must be employed, only if it is necessary to protect human, animal or plant health (CAC 1999). Therefore, such measures should be based on scientific principles, and maintained only if there is sufficient scientific evidence for support. The agreement noted that scientific evidence constitutes international standards, guidelines or recommendations or risk analysis. (Stanton 2000).

Hazard Identification

Hazard identification seeks to establish an association between the pathogen, its presence in foods, and the severity of adverse health effects to the human population (Barraj and Petersen 2004). This stage differs from the other stages in the risk assessment, as it merely describes the possibility of an adverse effect in qualitative terms, rather than quantitatively (Lammerding and Todd 2006). The scale and severity of hazards vary from individuals to global epidemics and from mild discomfort to death. This initial stage of the risk assessment covers likely sources of contamination from salmonellae that are introduced into the food continuum (Cahill and Jouve 2004).

Hazard Characterisation

Hazard characterization describes the adverse effects due to exposure to the pathogen, taking into consideration the basic characteristics of the organism, human host factors, and composition factors of the food matrix (Havelaar et al. 2005) Applied Nutrition, United States Department of Agriculture/Food Safety and Inspection Service, Centres for Disease Control and Prevention (FDA/USDA/CDC) 2003). The factors comprising this disease triangle are highly variable in practice. For example, pathogen factors vary in the amount and types of organisms. The host factors vary in age, sex and health of the consumer, and food consumed may vary in type and degree of cooking. In addition, the lack of knowledge relating to the

complex degree of interaction leads to a high degree of uncertainty (FDA/USDA/CDC 2003).

Exposure Assessment
Exposure assessment is a representation of the level of contamination in a food, and the quantity of the food that must be ingested, to induce microbiological foodborne illness (Barraj and Petersen 2004). Mathematical models are generated to evaluate the effect of the various factors from farm to table, including processing and human behaviour on the final microbial load reaching the consumer (Voysey and Brown 2002). The models provide an estimate of the level of contamination at the point of consumption, and the quantity of food consumed (Mc Nab 1998; Brown 2002).

Risk Characterisation
In the risk characterisation module, information from the previous stages of hazard identification, hazard characterisation and exposure assessment, are combined to derive the likelihood and severity of known or potential adverse effects in a given population, taking into consideration the attendant uncertainties (FAO/WHO 1995; Codex 1999). It is the final stage of the risk assessment, and describes the hazard qualitatively, such as high, medium, low, or quantitatively such as the number of human infections, illness or deaths per year per 100 000 population (Forsythe 2002).

Van Gerwen et al. (2000) noted that quantitative risk assessments are derived from mathematical analysis, and computer simulations are preferred because they give the best estimate of risk. However, there are many limitations that may prohibit a full-scale quantitative risk assessment, including the availability of sufficient data, time and financial constraints (van Gerwen et al. 2000). The output statement at each stage, and the final output of risk, are the major differences between qualitative and quantitative risk assessments. Although a numerical expression of risk is more valuable to managers, the constraints of data, time, and financial resources, may dictate a semi-quantitative or qualitative assessment (Brown 2002). A qualitative risk assessment serves as a good preliminary evaluation of a food safety issue (Jouve 2002).

Modelling
In quantitative risk assessment, mathematical models are generated from the given data, to provide a numerical expression of risk. Monte Carlo modelling is the most popular method of producing a stochastic model. Monte Carlo simulation uses many deterministic calculations, known as iterations, to generate a frequency distribution, which produces a single calculated risk. The resulting distribution produced represents the distribution of randomly generated inputs. Several computer programs including @Risk, Palisade Corporation, Crystal Ball, Decisioneering Inc. and Analytica, Lumina Decision Systems, are suited for Monte Carlo Modelling (Lammerding 2006).

Quantitative Risk Assessment of *Salmonella* in Chicken Meat Produced In Trinidad

This risk assessment methodology provides a structured and scientific approach for evaluating the probability of salmonellosis from the consumption of a single serving of cooked or under-cooked chicken prepared at home, from chilled whole broilers. These carcasses are processed at large-scale processing plants and retailed as chilled chickens at supermarkets in Trinidad. The approach is based on the four steps of a risk assessment: hazard identification, hazard characterization (dose response), exposure assessment and risk characterization.

Hazard Identification of Salmonella in Chicken Meat
Consultation with food safety experts provided a qualitative description of the problem and a rationale for the assessment. A review of epidemiological data from international sources, such as the FAO (FAO 2002), have linked the consumption of chicken and *Salmonella*, to human salmonellosis. The problem is experienced globally as reported by the FAO (FAO 2002). Regional and national surveillance databases, in Trinidad, were reviewed to determine the significance and severity of the problem in Trinidad. Data from CAREC and the National Surveillance Unit are best suited for this purpose.

Hazard Characterization of Salmonella in Chicken Meat
Epidemiological data, obtained from outbreak investigations, are best suited to establish a dose-response relationship between a hazard and a human response. Epidemiological data can be obtained from various agencies including CAREC, National Surveillance Unit, and the Public Health Laboratory. The attack rate (the number of persons exposed versus the number

of persons ill) provides an estimate of the response of the population. Additionally, outbreak investigations require analysis of samples of suspected foods, to determine the source and concentration of the etiologic agent. However, in Trinidad, there is a zero tolerance for *Salmonella* in cooked foods; therefore, laboratory analysis is based on methods of detection/ isolation rather than enumeration. National and regional data are inadequate to estimate a dose-response relationship, therefore, they are supplemented with expert judgement and international data.

The concentration of pathogen that is required to initiate infection is uncertain. Two pathways have been described (i) the threshold model, which describes the minimum infectious dose or level of the pathogen that a person can tolerate before becoming infected and (ii) the single cell model, which assumes that a single microbial cell is capable of causing illness (Forsythe 2002). The single cell model is preferred for this approach, since; it is consistent with reports of a large number of foodborne outbreaks. In these cases the number of infectious bacteria was very low and, the lower limit of infectivity is nearly impossible to prove. Threshold models are better suited for toxigenic microorganisms, as the response is based on the level of toxins produced, and not the number of microorganisms (Forsythe 2002).

Exposure Assessment of Salmonella in Chicken Meat

The prevalence of contaminated bird carcasses or products, and the probable numbers of organisms per contaminated unit, is estimated throughout the food continuum. The stages of the food continuum considered are (1) Production (2) Transport (3) Processing (4) Retail and storage (5) Preparation and (6) Consumption. In each module, the increase or decrease in the number of organisms is considered and the factors that contribute to the prevalence and number of organisms in each stage are examined. These factors include, but is not limited, to (1) cross contamination (ii) processing effect (iii) temperature abuse and (iv) the physiological ability of the organism to survive during each stage. The outputs from each module are used as inputs for the subsequent module (FAO 2002).

Prevalence And Concentration Of Salmonella In Broiler Chickens During Production

The prevalence of S*almonella* in live broiler chicken leaving the farm for processing and the number of *Salmonella* in each bird is estimated. The bird level prevalence is generated from the flock prevalence and the within flock prevalence. The flock prevalence and the within flock prevalence are estimated from sampling data. Representative sampling is used to obtain an estimate of the number of salmonellae in each bird.

Prevalence And Concentration Of Salmonella In Broiler Chickens After Transportation

Live birds are caught manually and placed in plastic crates. During transportation the birds are kept in open crates placed on top of each other. This can lead to cross-contamination as faeces from the birds in the upper crates can contaminate birds in the lower crates. This coupled with an increase in faecal excretion due to the associated stress factors of transportation such as temperature, vehicle conditions, road conditions and length of journey, can increase the number of *Salmonella*-positive birds. Inadequate cleaning and disinfection of the crates between trips can also contribute to an increase in the number of *Salmonella*-positive birds. As a result, live birds are sampled after transportation, prior to processing to obtain an estimate of the number of *Salmonella*-positive birds after transportation.

Prevalence and Concentration of Salmonella in Broiler Carcasses after Processing

Cross-contamination may lead to changes in the prevalence and numbers of salmonellae during the various stages of processing. In addition, scalding requires immersion of the carcasses in hot (not boiling) water. Increasing the temperature of the carcasses and subsequent contact surfaces promote the growth and proliferation of microorganisms. Representative sampling of the processed carcasses are conducted to estimate the proportion of *Salmonella*-positive carcasses and the number of salmonellae in each carcass.

Prevalence and Concentration of Salmonella in Broiler Carcasses during Retail, Distribution and Storage.

After processing, the carcasses are stored at the processing plant and then distributed to the retail outlets, for sale. The storage temperature and handling at the processing plant, retail outlets and the home, as well as the distribution process, can influence the final *Salmonella* load

on a carcass before preparation. The prevalence and numbers of *Salmonella* on unpackaged products can influence the level of cross-contamination to products that are *Salmonella* negative, and those that are contaminated with low levels of *Salmonella*. The proportion of *Salmonella* positive carcasses and the number of salmonellae in each carcass are estimated during retail storage using representative sampling procedures. The effect of time-temperature abuse during storage and distribution on the overall salmonellae loading is estimated using growth models. The Gompertz equation is best suited for this purpose.

Prevalence and Concentration of Salmonella in Broiler Meat during Meat Preparation

During preparation, the broiler meat is kept at ambient temperatures for long periods, which can facilitate the growth of *Salmonella*. Additionally, cross-contamination of the hands and the food preparation environment can transfer *Salmonella* to meat and other foods that are not contaminated. Survey data is best suited to provide reliable estimates of time/temperature abuse and cross contamination occurring during retail storage, distribution, transportation to home and preparation at home. These factors are used in growth models to estimate the proportion of *Salmonella*-positive carcases and the number of salmonellae in each carcass.

Effect of Cooking On Prevalence and Concentration of Salmonella in Broiler Meat

Thermal death due to cooking occurs in a logarithmic way, known as first-order inactivation kinetics. The Arrhenius equation that was developed for first –order chemical reaction kinetics can be used to describe the death of *Salmonella*. Alternatively, D values and z values can be used to show inactivation of *Salmonella*. Survey data can provide the values for the factors that influence thermal death due to cooking, such as temperature and cooking time. Thermal death models are generated to estimate the proportion of *Salmonella*-positive meat and the number of salmonellae present in the cooked meat.

Prevalence and Concentration of Salmonella in Broiler Meat during Cooling and Serving

After cooking, it is a common practice to cool meat at ambient temperature and then serve. Cooling at ambient temperature allows bacteria present in the food (from inadequate cooking or cross contamination) to multiply to dangerous levels. Subsequent consumption of food may lead to infection and illness. Additionally, there is a potential for cross-contamination of the product, from *Salmonella* present on hands, utensils and surfaces during serving. Time/temperature profiles, obtained from survey data, are input into growth models to predict the numbers of salmonellae present after these processes.

Amount of Broiler Meat Consumed In a Single Serving

The previous stages of an exposure assessment provide a quantitative prediction of the number of salmonellae on ready-to-eat broiler meat. A sample survey is then conducted to obtain data on the amount of meat in a single serving from whole broiler chicken prepared in the home, and the frequency of consumption. The predicted number of salmonellae actually entering an individual is used as an input in the next stage.

Scenario Tree

A scenario tree is developed for the risk of *Salmonella* consumption from a single serving of chicken prepared at home. The scenario tree shows the sequence of specific events in the food continuum pathway, from production to consumption. The likelihood of infection at each event in the tree determines exposure to the hazard.

Risk Characterisation

The final risk associated with the consumption of chicken is determined by combining the dose of *Salmonella* required to cause illness (hazard characterisation) and the likelihood of consumption of this specific dose in a single serving of chicken prepared at home (exposure assessment). Monte Carlo modelling using @ Risk software is used to generate a numerical expression of risk.

CONCLUSION

The solution to *Salmonella* infections is not forthcoming due to the constant changing epidemiology of the pathogen (Potter et. al. 2002). Therefore, the incidence of salmonellosis must be reduced through management of the factors that contributes to the incidence of this pathogen. A quantitative risk assessment of *Salmonella* in chicken meat provides an understanding of the proliferation of the pathogen from farm to table, and the adverse effects of the final quantity of *Salmonella* consumed. The assessment provides

recommendations to institute control measures, thereby reducing the incidence of *Salmonella* infections. This risk assessment study would provide the scientific basis for local food safety regulations and international trade policies.

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