The Application a Risk Management Framework in Support of Policy Development for Meat Safety in Rural Remote BC

Confidential Draft for Discussion

November 24, 2009

Background

Meat, eggs and dairy products are an important part of most people's diets. More and more BC consumers want these to be locally produced. Livestock farming is a key contributor to local food production. Farming and food processing go hand in hand - to be sustainable and contribute maximum value to rural economies local meat production needs local slaughterhouses.

In BC, the Meat Inspection Regulation requires slaughterhouse operators to be licensed if they offer slaughter services for livestock owners or produce meat for sale for human consumption. In most parts of the province this licensing requirement is relatively new. Livestock producers, meat processors and their customers are still adapting to the changes. Slaughterhouses must also comply with regulations relating to environmental protection, waste disposal, animal health and welfare, labour, workplace safety, the Agricultural Land Commission and Marketing Boards, as well as municipal zoning and other bylaws.

Meat production is particularly challenging for remote communities in BC with small and isolated populations. The Ministry of Healthy Living and Sport, in partnership with the Ministry of Agriculture, the BC Centre for Disease Control and the BC Food Processors Association is engaged in a project to consult with remote communities to identify viable solutions that support safe local meat production. A pilot project approach has been proposed to explore innovative options for small scale local meat production in isolated communities. This risk assessment project supports the development of a strategy for these pilots and provides an evidence-based framework for any required policy development.

Introduction – The Risk Analysis Process

Risk analysis

The risk analysis process (12) is made up of three elements: risk assessment, risk management and risk communication. During the course of the risk analysis these elements are highly integrated with risk assessors and risk managers constantly interacting. Risk managers are responsible for determining the objectives and scope of the risk analysis. They also integrate results of risk assessment with other related factors (e.g. social, economical, and cultural) to come up with risk management options or recommendations. Risk assessors are responsible for carrying out the risk assessment which is the scientific component of the risk analysis. Communication occurs throughout the risk analysis between risk managers and risk assessors and other related stakeholders. The processes and results of a risk analysis should be as transparent as possible. Public communication is a key component of risk management.

Risk assessment
Risk assessment is made up of three elements: hazard identification, hazard characterization, exposure assessment and risk characterization. Hazards can be biological (e.g. parasites and bacteria), chemical (e.g. antibiotic residues in meat) or physical (e.g. metal fragments in meat). Risk refers to the probability of an adverse health outcome caused by exposure to a hazard (e.g. infection, illness, hospitalization, mortality). It is very important to be able to differentiate between a hazard and a risk. A hazard that causes very serious or fatal illnesses in human beings can actually have a low risk of exposure (e.g. Ebola virus). Similarly there may be a high risk of exposure to a low impact hazard (e.g. rhinovirus responsible for the common cold).

Hazard identification: Hazard/s that will be considered in the risk assessment are identified during this step. This may be through review of jurisdiction-specific surveillance data or evidence from published literature.

Hazard characterization: The identified hazards are then characterised in terms of the severity and type of human illness they cause. In some instances the relationship between the amount of hazard (e.g. number of bacteria) and probability of illness is represented by a dose response curve. Also, certain segments of the population (e.g. seniors and babies) may be more susceptible to the hazard. Hazard characterization thus necessarily draws on the sciences of toxicology, pathophysiology and population health analysis.

Exposure assessment: This is one of the most important and time consuming step in a risk assessment. This process determines points in the process where products become exposed to the hazard. Probability of exposure as well as magnitude of the hazard is determined at each subsequent stage of the process until product is consumed by human beings. This requires detailed understanding of the specific local circumstances.

Risk characterization**:** This is the final step of a risk assessment that combines exposure assessment and hazard characterisation to give an estimate of the potential for adverse health effect in human beings. The outcome measure can be quantified as a probability of illness/death, number of illnesses or deaths per year or a risk score depending on the type of risk assessment that is conducted.

Risk assessment methods
A risk assessment could be quantitative, semi-quantitative or qualitative. Quantitative risk assessments are generally more preferred because they are more objective. Outcomes take the form of probabilities or number of illnesses caused by the hazard. Data requirements and computational demands of quantitative risk assessments render them more challenging to do. Qualitative

risk assessments are less demanding in terms of data requirements. Outcomes are normally in the form of categories (e.g. low, medium and high risk.

Risk Management Framework

The Codex Alimentarius Commission was formed in 1963 as joint collaboration between the Food and Agriculture Organization (FAO) and World Health Organization (WHO) to develop food standards. One of the methods they have developed is the Risk Management Framework (see Figure 2). This is a very practical and flexible method of conducting a risk analysis and one that we have adopted for this project . The main activities in the risk management framework are;

- a risk profile to confirm the need for further analysis
- risk assessment
- Identification of management options.
- choice and Implementation of a risk management strategy
- evaluation

Figure 2: Schematic presentation of a risk management framework.

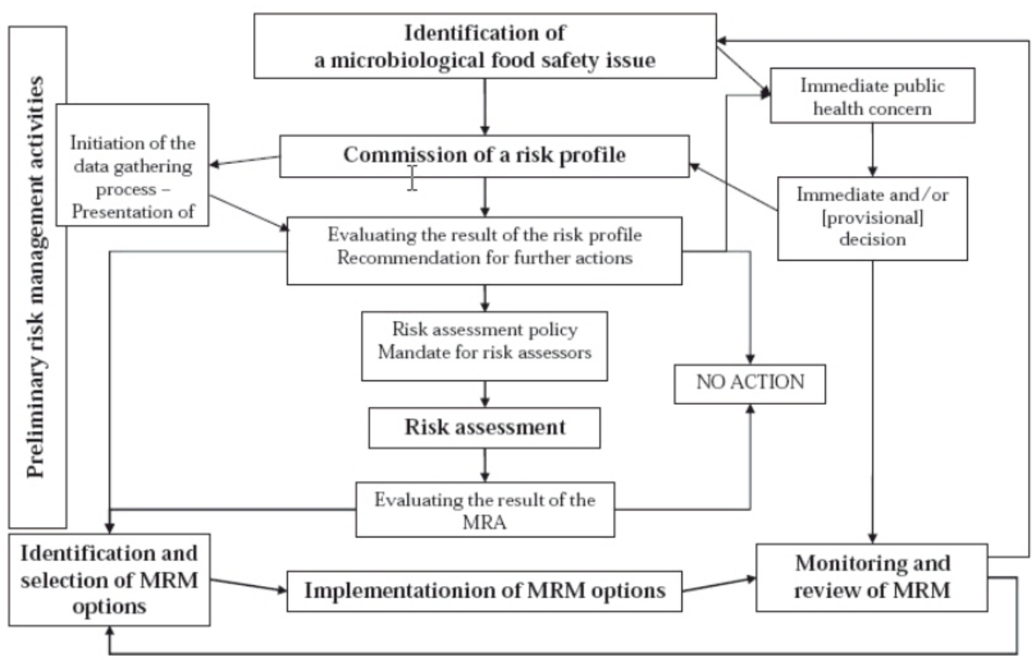


Figure 1: Diagrammatic overview of the microbiological risk management framework
(from the Draft Codex Principles and Guidelines for the Conduct of Microbiological Risk Management).

Applying a Risk Management Framework in support of policy development for meat safety in rural and remote BC

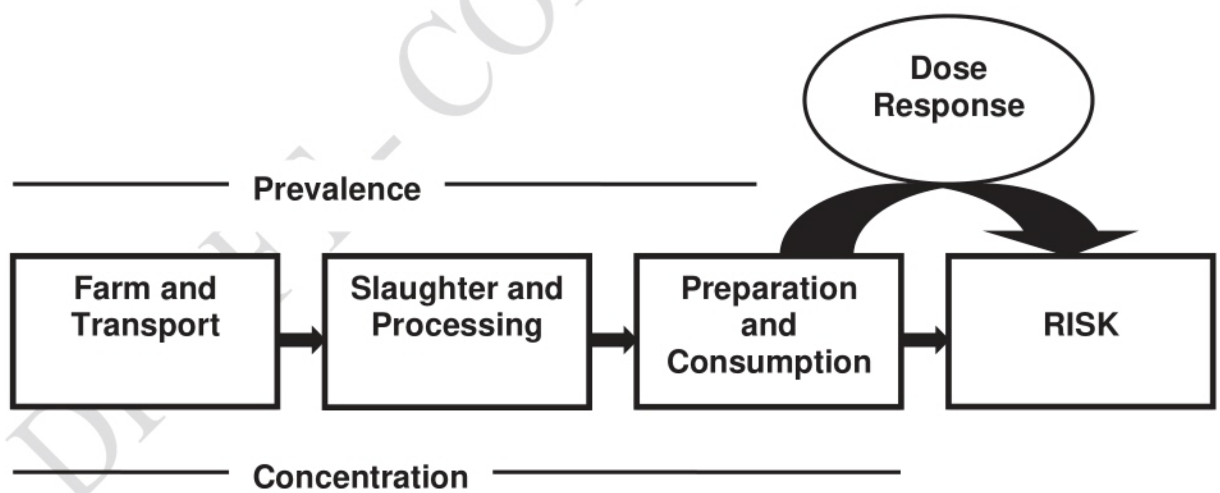
Goal and objectives

The over-arching goal of this risk assessment is to support an evidence-based approach to the regulation of small scale meat processing in the remote areas of BC.

Scope

The scope of this risk assessment is small scale and on-farm beef, pork and poultry slaughter scenarios as would occur in the identified three remote and isolated communities of BC. In the food production chain we are focusing on the period between farm production and consumption of meat (see Figure 2). Since the concept of risk begins during animal rearing, we will be taking relevant aspects of animal rearing into consideration in the risk assessment. From a food safety perspective, the focus is on preventing carcass contamination by pathogens (mainly bacteria) that are resident in the animal gut. Most investments in a slaughter plant are aimed at maintaining hygiene during processing as well as within the plant. Therefore, the focus of this risk assessment is on microbial hazards. Other potential human health risks associated with meat consumption including prion diseases and antibiotic exposure are not included in this risk assessment as they are neither increased nor mitigated by processing.]

Figure 1: Schematic presentation of a risk assessment on meat safety.



Hazard Identification and Characterization

There is a whole range of biological hazards of public health importance. For the purpose this risk assessment we will group them into those that are present in the live animal tissue before slaughter and those that can potentially contaminate the carcass during meat processing. Those that may be in live animal tissue include mainly parasitic infections (e.g. cysticercosis, trichinellosis). With improvement in hygienic and sanitation standards human to animal transmission of these parasites has drastically reduced and prevalence of cysts in animal tissue is very low with some countries managing to eradicate them. Processes like freezing and cooling meat as well as proper cooking have been effective in destroying these cysts. On the other hand food-borne disease outbreaks have continued with microbial hazards being mostly implicated. Most of these pathogens are bacteria that may be present in the animal's gut. They include Salmonella, E. Coli, Campylobacter, Yersinia, etc. The current risk assessment was based on Salmonella, E. coli and Campylobacter because they are the most common causes of food-borne illnesses in Canada and abroad (23).

Salmonella species

Human syndrome: Most infections are sub-clinical and are not specifically diagnosed. Usual clinical signs include diarrhoea, vomiting and low-grade fever. Sometimes progression to dehydration and death results, The very young or very old are at a higher risk for these serious outcomes. 1 – 2% of documented cases result in death.
Animal syndrome: Chicken, pigs, cattle, sheep and other wildlife are potential carriers.
Transmission: Through ingestion of contaminated food (fecal contamination). Arthropods (eg flies) are occasional mechanical vectors. The agent is fairly resistant to drying but is susceptible to heat, sunlight and most disinfectants. It resists freezing and can survive for months in inanimate environments under proper conditions.

E. Coli

Human syndrome: diarrhoea which may be complicated by other syndromes associated with specific serotypes. Enteroinvasive strains cause fever and dystentry while enterotoxic strains cause dehydration and shock. Enterohaemorrhagic strains (O157:H7) cause haemolytic uremic syndrome (HUS), hemorrhagic colitis or thrombotic thrombocytopenic purpura. Mortality is higher in infected neonates and those with impaired immunity, otherwise it is generally low (unless if there is underlying disease or HUS with brain damage).
Animal syndrome: Animals (cattle, pigs, poultry, sheep etc) are mainly carriers.
Transmission: Ingestion of fecal contaminated raw or undercooked food or poor hand washing after petting farm animals. It is a normal inhabitant of the intestinal tract of vertebrates. Not all strains are pathogenic and it is fairly resistant to environmental stress.

Campylobacter
Multiple serotypes with C. jejuni most commonly reported.
Human syndrome: C. jejuni causes typically benign enteritis which may be associated with acute diarrhea (some with visible blood), fever, abdominal pain and vomiting. Meningitis is an unusual complication. C jejuni is very common and is the leading cause of human diarrheal illness in many areas.
Animal syndrome: C. jejuni causes diarrhoea in calves and abortion in sheep. Chicken are the most important carriers of Campylobacter. Cattle, sheep, pigs, domestic and wild birds are also carriers.
Transmission: Ingestion of contaminated food, raw milk or water.

Given that pathogen reduction strategies are similar for most bacterial pathogens, the following risk assessments will focus on: E. coli in raw beef, Salmonella in pork and Campylobacter in chicken.

Exposure Assessment and Risk Characterization

Exposure assessment
As much as there are similarities in slaughter methods, there are also differences, particularly in infrastructure and equipment used. The number of animals and poultry slaughtered per year in these remote and isolated regions is low. In most of these small scale on farm slaughterhouses, red meat slaughter and processing occurs during autumn and winter seasons when pest activity (flies) is generally low. Prevalence rates of most enteric infections in animals are also generally low.

Before skinning and evisceration, meat is not contaminated with enteric bacteria even though the hide can often be contaminated. The risk of carcass contamination is highest during and after skinning when the meat is exposed. Possible sources of contamination include hide, perforated guts, surfaces, knives, pests (e.g. flies), dirty hands and clothing, aerosols. Generally, skinning and evisceration (gut removal) are the most significant in terms of carcass contamination. During exposure assessment each processing stage is explored to determine the prevalence of contamination as well as the magnitude of the hazard. Magnitude is normally measured as number of bacterial colony forming units (CFU) per gram or square centimetre.

We developed feasible slaughter scenarios (Tables 2 – 4 and Figures 3 – 5) based on a structured survey of 12 key informants; (farmers and processors) (see Appendix A). A detailed literature review was conducted. Most literature that is published on risk assessments or microbial sampling is on commercial slaughterhouses that use HACCP. We were unable to find any published literature on small scale on farm slaughterhouses. Using peer reviewed literature, we identified those processes that either increased or decreased the prevalence and magnitude of a hazard under small scale on-farm settings. Generally, for calculation purposes a factor of 2 was applied for increases, while for decreases a factor of half was applied.

Amongst others, the following factors were considered in exposure assessment:

1) Slaughter scale – small scale and less automated operations tend to slaughter lower volumes of animals. This is likely to result in lower chances of cross contamination. Because of the small scale nature of the operations it is possible to go a long way in preventing carcass contamination. Time pressure is significantly less in small scale operations.
2) Animal husbandry systems – more traditional, pasture based systems are associated with a lower prevalence of E coli in slaughter cattle (7;8;17). Also, animal density tends to be lower in smaller scale operations with animals more likely to experience varying levels of outdoor exposure. High animal densities are a risk factor for disease transmission and stress.
3) Pre-slaughter stress – this is a very important risk factor from both a food safety and quality perspective. Transportation of animals to the slaughterhouse and their unloading into lairages/cages causes stress to animals, which is a significant risk factor for hide/skin contamination and subsequently carcass contamination (10;18;26). Slaughtering animals on-farm elimiminates pre-slaughter stress imposed by transportation.
4) Machinery/equipment – appropriate machinery and equipment should be used to prevent carcass contamination and bacterial growth e.g. hoists, cutting knives, refrigerators. This is normally a challenge for small scale operators who may find it expensive to buy stainless steel machinery and tools. However, cheaper alternatives exist and these could be supported by enhanced sanitation programs, such as increased clean-up per animal slaughtered.
5) Hygiene and sanitation – Environmental, process and personal hygiene are important risk factors for contamination. On farm red meat slaughter is mainly conducted during the cooler months of the year when environmental bacterial growth conditions are not optimal. Processing is to a larger extent manual compared to large scale automated slaughterhouses and therefore personal hygiene measures are very important.

The following assumptions were made in the exposure assessment:

1) Potable water.
2) Small scale slaughter in remote and isolated regions.
3) Some form of cooling system is available to cool the carcasses within a reasonable time frame, including seasonal temperatures.
4) Pest control is practised.
5) Cleaning and disinfection of tools and surroundings before and after slaughter.
6) Personal hygiene: Hands washed with soap or hand sanitizer (before and during slaughter) and clean clothes.

Risk characterization

Risk characterization involves using data from hazard characterization and exposure assessment (mainly) to come up with a measure reflecting the likelihood of an adverse health effect. For this risk assessment we used a tool called Risk Ranger. Risk Ranger is a semi-quantitative risk management tool that was developed by two Australian scientists, Drs Thomas Ross and John Sumner (25). The tool is in spreadsheet software format and embodies established principles of food safety risk assessment, i.e., the combination of likelihood of exposure to a food-borne hazard, the magnitude of hazard in food when present, and the probability and severity of outcomes that might arise from that level and frequency of exposure. Input data constitutes 11 questions (Table 1). All questions have a number of options for selection and in some there is an option (called other) to put the exact data if available. There are 3 output parameters: probability of illness, number of illness per annum and risk ranking. The risk ranking value is scaled logarithmically between 0 and 100, where 0 represents no risk and 100 represents the opposite extreme where every member of the population eats a meal that contains a lethal dose of the hazard everyday. An increase of six in the ranking corresponds approximately to a tenfold increase in risk.

Risk Ranger serves as an aid to structured problem solving and can help to identify and focus attention on those factors in food production, processing, distribution and meal preparation that most affect food safety risk and that may be the most appropriate targets for risk management strategies. The tool is also useful in ranking the risks of various product/pathogen combinations. Risk Ranger has been validated and found to be a reliable tool (25). It has also been used in a number of studies in peer reviewed literature (19;27). As with any such software, the outputs are only as reliable as data entered.

Exposure assessments for E. coli in beef, Salmonella in pork and Campylobacter in chicken are presented in Tables 3, 4 and 5 together with Ranger inputs to demonstrate the connection between exposure assessment and risk characterization. Tables 5, 6 and 7 show risk rankings under different slaughter scenarios, for each hazard.

Risk Ranger results

Risk ranger was used to calculate the risk based on 3 scenarios: using Literature values (based on research conducted in big scale slaughterhouses), small scale on-farm slaughterhouses, and inadequate cooking (unlikely situation where cooking does not eliminate the hazard). Risk rankings for the 3 scenarios for E. coli in beef, Salmonella in pork and Campylobacter in chicken are shown in Table 8. Risk rankings show that the risk of illness due to eating well cooked meat is generally low given the assumptions previously mentioned are followed. For our calculations we assumed a very small risk of cooking not eliminating the hazards (0.00001). Considering that this is meat and it is only the external surfaces that are potentially contaminated (unlike hamburger meat), it is logical to assume that the cooking process eliminates any bacteriological hazards introduced through processing. The inadequate cooking scenario assumes that cooking fails to eliminate the hazards, hence the higher risk rankings.

Table 8: Summary of Risk rankings obtained using Risk Ranger of risk assessments of E. coli in beef, Salmonella in pork and Campylobacter in chicken.

Risk Scenario	Risk Ranking		
	Literature*	Small scale**	Inadequate cooking
E. coli - beef	31	29	58
Salmonella - pork	6	0	33
Campylobacter - chicken	27	25	54

Aggregation of Risk Ranger ratings: Low (0 - 25), Medium (26 – 40) and High (41 – 100)
* based on large scale processing
** based on scenarios developed for small scale remote operations

Discussion

The risk assessment shows that the risk of illness is generally low if the meat is well cooked. Remote small scale producers slaughter very few animals per year. The impacts of transportation stress and the lairage environment on hide contamination and subsequently meat contamination are well documented. Also, given that these are remote locations where animals would otherwise have to be transported long distances for slaughter, it is worthwhile to take advantage of the existing factors (i.e. small scale nature and no transportation) that promote a reduction in carcass contamination. Investments made to support pathogen reduction strategies in large scale commercial slaughterhouses may be suited to those circumstances with animals coming from different farms. There is also more pressure in commercial slaughterhouses to meet demand, so appropriate investments and strategies are required to mitigate the potential negative impacts of these circumstances on food safety. Production pressure is much less under small scale operations, so this presents an opportunity to invest more time in preventing carcass contamination. Among small scale slaughterhouses, there currently are a wide range of slaughter practices, partly influenced by the degree of investments made into the building, machinery and tools. The aim is to devise more uniform and cost effective slaughter processes that also mitigate the risk of food borne illness.

Conclusion

The application of a risk analysis process provides a useful focus for the assessment of the key factors that require attention and control to mitigate the risk of food-borne illness associated with small scale slaughter processes. The specific quanitification of risk in this area is a currently a challenge as there are gaps in the published literature with regard to evidence for many of the existing practises.

Through the use of the data where it is available and the application of estimates based on conservative assumptions where it is not, we are able to ascertain that, with the incorporation of baseline expectations regarding sanitation, and the use of a defined slaughter process appropriate to small scale operations, we did not demonstrate an inherently increased risk associated with the meat produced through these methods of slaughter.

The establishment of pilot projects for remote communities affords:

- the opportunity to monitor small scale operations in a trial period,
- fill in gaps in existing information about potential risk through targeted surveillance,
- more clearly define required process steps
- engage, train, and learn from producers and processors and,
- further delineate the policy framework necessary to regulate this important food production in BC.

Table 1: Risk Ranger input definitions/calculations and data sources

Risk Ranger Input	Definition/Calculation	Potential data sources
1) Hazard severity	Based on prevalence (human infections), severity (hospitalization rate), mortality rate.	Literature sources
2) Population susceptibility	Are other populations segments more susceptible than others?	Census data, Literature
3) Frequency of consumption	Assuming a portion size of 100g, and a given annual per capita meat consumption (kg), calculate the per capita number of portions. Calculate number of days between a portion by dividing 360 by the number of 100g portions.	Statistics Canada surveys, census data
4) Proportion consuming (%)	1) Total product produced/sold per year divided by average yearly consumption per person (get this from Statistics Canada surveys or literature). Divide this by total population, or 2) Directly from census data as an approximation	Statistics Canada surveys, literature
5) Total population	Total BC population	Census data
6) Proportion of raw product contaminated	Carcass contamination rate at final step before chilling.	Literature sources
7) Effect of processing on hazard	% reduction/increase in the proportion of contaminated carcasses due to processing (chilling, freezing, grinding, marinating, smoking, cooking etc).	Literature sources
8) Post processing contamination rate	% contamination after processing (e.g. handling during packing at retail). Has been calculated as similar to difference between raw product contamination rate and contamination rate at retail (with assumptions).	Food inspection data at retail or literature sources.
9) Post-process control	Related to bacterial growth after packing, how effective is cooling? Bacterial growth between packaging and cooking.	Literature.
10) Increase required to cause infection/intoxication	Number of colony forming units (CFUs) required to cause illness divided by post-	Literature sources

	processing number of colony forming units (calculate using concentration (CFUs/gram) and average portion size (g)).	
11) Effect of meal preparation	Likelihood of cooking/heating eliminating the hazard.	Literature sources

Table 2: Exposure assessment (under small scale, on-farm slaughter conditions) of E. coli O157:H7 in raw beef processing and Risk Ranger input values.

Process step	Activity and Equipment used	Risk reduction process/Comments	Risk Ranger input (
Rearing		Studies have shown a positive correlation between E. coli prevalence in cattle on farms and hide and carcass contamination (30). Hide contamination of cattle in the slaughterhouse could be as high as 76% (3). Prevalence of E. coli in cattle fed grass is lower than that in grain fed cattle (7;8). Range (grass) feeding is mainly practised in small scale farms. Literature shows that within herd prevalence of E. coli in feedlot cattle ranges from 1.5-3.6% while herd prevalence is about 61% (21). In beef, herd prevalence is about 25% while within herd prevalence in adult cattle is less than 0.7% (21). It is likely that some small scale farms do not have E.coli or have a low prevalence. Prevalence of E. coli is also seasonal, increasing during summer and spring and decreasing during fall/winter. Most small scale producers slaughter their animals during fall winter. A study showed that within pen fecal prevalence of E. coli in Alberta feedlot cattle ranged from 0-80% (median of 20%) while hide	6.Raw product contamination (%):0.0006% (29)

		prevalence ranged from 0-30% (median of 0%) (24). The hide prevalence indicates that at least 50% of the cattle did not have E. coli on their hides. Again this shows a high likelihood that most cattle slaughtered under small scale settings will not be contaminated with E. coli on their hides. Beef cattle reared in a temperate climate (New Zealand) under pasture-based animal husbandry systems have a high pre-slaughter cleanliness which reduces the likelihood of carcass contamination (17).	
Transportation		Transportation stress is one of the most significant causes of hide contamination in terms of both prevalence and amount (10;20). Animals slaughtered on farm are not subjected to transport stress. Stress leads to increased shedding of E. coli in the feces of animals that are carriers. It is also associated with increased fecal production and soiling of hides which is a significant risk factor for carcass contamination. Correlation between the concentration of E. coli in the feces with probability of illness ranks the highest followed by host susceptibility, carcass contamination factor and cooking preference (9). Absence of transport induced stress in on-	

		farm slaughter enterprises is a huge risk mitigation factor. A study showed that the hide prevalence of E. coli increased from 50% on the farm to 94% after the animals were transported to the slaughter house. The magnitude (CFU/cm2) also increased (3).	
Lairage	It is advised to withhold food for 24 hours and keep animals rested to reduce chances of carcass contamination during evisceration.	Keeping animals in a familiar environment before slaughter reduces stress. Animals should be led to the slaughter place without undue stress.	
Stunning	Free bullet vs captive bolt (under discussion). Free bullets are allowed in the field or stun box.		
Bleeding/Skinning	This should be done in a clean area such as field, tarp, or concrete. Animal should be bled and hoisted for skinning to prevent carcass contamination by the hide and surfaces.	Disinfection of knives with hot water/cold chlorine water (5 – 10ppm). Rewash knives when dirty. Risk of carcass cross contamination is lower if there are few animals that are slaughtered, especially coming from a low prevalence or E. coli negative herd.	
Evisceration	Tie off the rectum before evisceration.		
Splitting/Trimming	Trim visible contamination from carcass. Remove spinal cord (SRM rules??). Keep saw clean.	Trimming and washing do not result in the removal of substantial numbers of bacteria (14). Focus should be directed towards prevention of contamination.	
Washing	Washing with warm water recommended.	See above	
Chilling	Hang carcass in a chiller immediately. Carcass temperature should reach 4 degrees celcius		7.Effect of process (%): no effect 8.Potential for recontamination (%):minor or less

	with 24 hours.		9.Post processing control: not relevant 10.Increase from level of processing to infection/toxic dose: (1.4 logs CFU/g * 100g)/700 CFU (28) = 3.5
Cutting packaging	Cutting surfaces: Arborite, hard wood (follow national food code and public health requirement for restaurants)		
Cooling/freezing	Below 4 degrees.	Temperatures below 4 degrees generally do not sustain bacterial growth.	
Cooking (at home exposure)	The messaging to consumers should be to keep their meat frozen (if long periods) or chilled below 4 degrees (short periods). Cook to appropriate temperatures (National Food Code) and prevent cross contamination.		1.Hazard severity: moderate (19) 2.Consumer susceptibility: general 3.Consumption frequency: 307 * 100g portions per year ~ daily 4.Population consuming (census data) (%): remote areas populations/BC population = remote areas populations/BC population = 14693/4113485 = 0.4 5.Total population:4113485 11. Effect of preparation before eating: 0.00001

Table 3: Exposure assessment (under small scale, on-farm slaughter conditions) of Salmonella in raw pork processing and Risk Ranger input values.

Process step	Activity and Equipment used	Risk reduction process/Comment	Risk Ranger input
Rearing		Pigs are generally fed commercial diets. Salmonella prevalence (on skin) of about 27% has been reported in literature (6).	6.Raw product contamination (%): 1.6% (19)
Transportation		Transportation stress results in a seven fold increase in Salmonella prevalence in pigs at the slaughterhouse versus on farm (18). The pre-slaughter prevalence of pigs slaughtered on farm should therefore be lower than that of pigs that are transported, hence a reduced risk of carcass contamination.	
Lairage	Pre-slaughter pigs (from different pens) should not be kept in a pen for more than 12 hours.	Keeping pigs in a lairage after transportation is a risk factor for salmonella infection (18). There is an opportunity in small scale on-farm operations to avoid subjecting pigs to overcrowding.	
Stunning	Bullet , electric tongs		
Bleeding	Animals should be bled on clean floors/ surfaces.	Stunning and bleeding can be associated with a two fold increase (6) in prevalence (relative to pre-slaughter). This is believed to be related to activities around stunning and bleeding that predispose to contamination e.g. rolling pigs carcasses onto dirty contaminated floors after stunning.	
Scalding	Pig is hoisted and placed into a	The processes of scalding, and	

	scalding tank at up to 60-62 degrees for up to 10 minutes.	singeing are associated with a reduction in both bacterial load and prevalence.	
Dehairing	Pig is removed from scalding tank and placed into mechanical dehairer. If manual, carcass should not touch the floor.	Dehairing has been shown to increase the risk of carcass contamination (16). Manual dehairing presents the opportunity to sanitize/disinfect tools between carcasses which may not be practical in mechanical dehairing.	
singeing	Gas flame can be used.	See scalding	
Scrubbing	Skin is scrubbed to remove singed skin and hair. It is recommended that tools should be disinfected after each carcass.	Scrubbing/polishing may increase the risk of contamination (16).	
Washing	Wash with warm water.		
evisceration	Rectum is tied before evisceration.		
splitting	Saw is used.		7.Effect of process (%):No effect 8.Potential for recontamination (%): 6.9% (19) 9.Post processing control: Not relevant 10.Increase from level of processing to infection/toxic dose: 10^6 *100/(1*100)=10^6 ()
Trimming/washing	Warm water wash or cold water with acid.	Efficacy of trimming and washing on bacterial contamination is modest.	
chilling	Carcass is wrapped in brown paper and enclosed in cheesecloth and put in chiller.	Clean material should be used.	
Cutting /packaging	Carcass is quartered on farm and transported to butcher for cutting	Cutting surface should be hard and smooth. Wood, stainless steel, arborite are acceptable. There is no conclusive evidence relating cutting surface and risk of infection (11;22)	
chilling/freezing	Hang carcass in a chiller immediately. Carcass temperature should reach 4 degrees celcius with 24 hours.	Salmonella prevalence in carcasses chilled for 2 days was shown to be lower (14%) than that for carcasses chilled for 1 day (19%) in very small slaughterhouses of Wisconsin (1).	
Cooking (at home exposure)	The messaging to consumers		1.Hazard severity: mild (19)

	should be to keep their meat frozen (if long periods) or chilled below 4 degrees (short periods). Cook to recommended temperatures and prevent cross contamination.		2.Consumer susceptibility: general 3.Consumption frequency: 289 * 100g portions per year ~ daily 4.Population consuming (%):remote areas populations/BC population = 0.4 5.Total population: 4113485 11. Effect of preparation before eating: 0.00001

Table 4: Exposure assessment (under small scale, on-farm slaughter conditions) of Campylobacter in raw chicken processing and Risk Ranger input values.

Process step	Activity and Equipment used	Risk reduction process/Comments	Risk Ranger input
Rearing		On farm prevalence is a significant risk factor for carcass contamination. On farm prevalence of Campylobacter can reach 100% (2). Increased flock size is one of the most significant risk factors for on-farm campylobacter prevalence (15).	6.Raw product contamination (%):75% (5)
Transportation		Chicken are not subjected to transport stress when slaughtered on-farm. Transportation and holding prior to processing significantly increases the risk of carcass contamination. Prior to transport 12.1% of the chickens (skin) harboured an average of 10^2.71 CFU per carcass but after transport 56% harboured on average 10^5.15 CFU (26).	
Lairage		On farm slaughter chicken are not kept for a long time in pre-slaughter cages. This should reduce stress.	
Stunning	Lobotomy sometimes. Seems more practical for small scale processors not to stun but proceed to rapid decapitation.		
Bleeding	Most times birds are placed into killing cones and bled without stunning.		
Scalding	Chicken are placed in		

	tank/container with hot water.		
Defeathering	Manual (mostly) vs mechanical.	The defeathering stage presents an opportunity for carcasses to be contaminated by fecal material on the feathers. There is a potential for manual defeathering to result in less contamination than mechanical. A study showed that the carcass prevalence of Campylobacter in low volume slaughterhouses was lower (64%) than in high volume slaughter houses (78%) (5).	
Placed in cold water	Chicken carcasses are placed in ice water before being transferred for manual evisceration. Another option is to run excess cold water.	It is important to keep the temperatures low to prevent bacterial growth.	
Evisceration	Done on a hard flat surface – wooden, stainless steel	This step presents the highest risk of carcass contamination especially in automated plants (13). Manual evisceration done properly (under small scale settings) can prevent perforation of guts compared to using machinery. It is more feasible to ensure sanitation in manual relative to automated evisceration.	7.Effect of process (%): 60% (19) (reduction due to freezing/chilling) 8.Potential for recontamination (%): no (whole carcass) 9.Post processing control: Not relevant 10.Increase from level of processing to infection/toxic dose: moderate (19)
Placed in cold water	This is important for reducing bacterial growth. This could be a route for cross contamination of carcasses especially if the water temperature is high. Depending on how long the chickens stay, it may be advisable to use ice water.		
chilling	sometimes		
Cutting /packaging	Most times whole carcasses are sold.		

chilling/freezing	Carcasses are frozen after chilling	Freezing has been shown to significantly reduce carcass campylobacter bacterial load (13).	
Cooking (at home exposure)	The messaging to consumers should be to keep their meat frozen (if long periods) or chilled below 4 degrees. Cook to recommended internal temperature and prevent cross contamination		1.Hazard severity: minor (19) 2.Consumer susceptibility: general 3.Consumption frequency: daily 4.Population consuming (%):remote areas populations/BC population = 0.4% 5.Total population: 4113485 11. Effect of preparation before eating:

Table 5: Risk characterization of E. coli in raw beef using Risk Ranger.

Risk ranger questions	*Literature values	Small scale on-farm	Inadequate cooking
1)hazard severity	moderate	Moderate	Moderate
2)population susceptibility	general	General	General
3)consumption frequency	daily	Daily	Daily
4)% population consuming	0.4	0.4	0.4
5)population size	4113485	4113485	4113485
6)probability of contamination	0.0006	0.0006/2=0.0003	0.0006/2=0.0003
7)effect of processing on hazard	No effect	No effect	No effect
8)recontamination probability	minor	Minor	Minor
9)post processing effectiveness	Not relevant	Not relevant	Not relevant
10)increase needed to illness	700/10 (0.1*100)=70	700/5 (0.05*100)=140	700/5 (0.05*100)=140
11)meat preparation	0.00001	0.00001	No effect
Probability of illness	1.43*10^-9	7.14*10^-10	7.14*10^-5
Total predicted illnesses/year	0	0	5.36*10^3
Risk Ranking	**31**	**29**	**58**

Arbitrary aggregation of Risk Ranger ratings: Low (0 - 25), Medium (26 – 40) and High (41 – 100)

* For references to input values see Table 2

Table 6: Risk characterization of Salmonella in raw pork using Risk Ranger.

Risk ranger questions	*Literature values	Small scale on-farm	Inadequate cooking
1)hazard severity	mild	mild	mild
2)population susceptibility	general	general	general
3)consumption frequency	daily	daily	daily
4)% population consuming	0.4	0.4	0.4
5)population size	4113485	4113485	4113485
6)% contamination	1.6	1.6/2=0.77	1.6/2=0.77
7)effect of processing on hazard	No effect	No effect	No effect
8)recontamination probability	6.9	6.9	6.9
9)post processing effectiveness	Not relevant	Not relevant	Not relevant
10)increase needed to illness	10^6	2*10^6	2*10^9
11)meat preparation	0.00001	0.00001	No effect
Probability of illness	6.9*10^-13	3.45*10^-13	3.45*10^-8
Total illnesses/annum	0	0	2.59
Risk Ranking	**6**	**0**	**33**

Arbitrary aggregation of Risk Ranger ratings: Low (0 - 25), Medium (26 – 40) and High (41 – 100)

*For references to input values see Table 3

Table 7: Risk characterization of Campylobacter in raw chicken using Risk Ranger.

Risk ranger questions	*Literature values	Small scale on-farm	Inadequate cooking
1)hazard severity	minor	minor	minor
2)population susceptibility	general	general	general
3)consumption frequency	daily	daily	daily
4)% population consuming	0.4	0.4	0.4
5)population size	4113485	4113485	4113485
6)% contamination	75	40	40
7)effect of processing on hazard	60%	60%	60%
8)recontamination probability	no	no	no
9)post processing effectiveness	Not relevant	Not relevant	Not relevant
10)increase needed to illness	Moderate (100)	200	200
11)meat preparation	0.00001	0.00001	No effect
Probability of illness	3*10^-8	1.6*10^-8	1.6*10^-3
Total predicted illnesses	2.25	1.2	1.2*10^5
Risk Ranking	**27**	**25**	**54**

Arbitrary aggregation of Risk Ranger ratings: Low (0 - 25), Medium (26 – 40) and High (41 – 100)

* For references to input values see Table 4

Figure 3: Schematic presentation of the processing of beef from farm to fork.

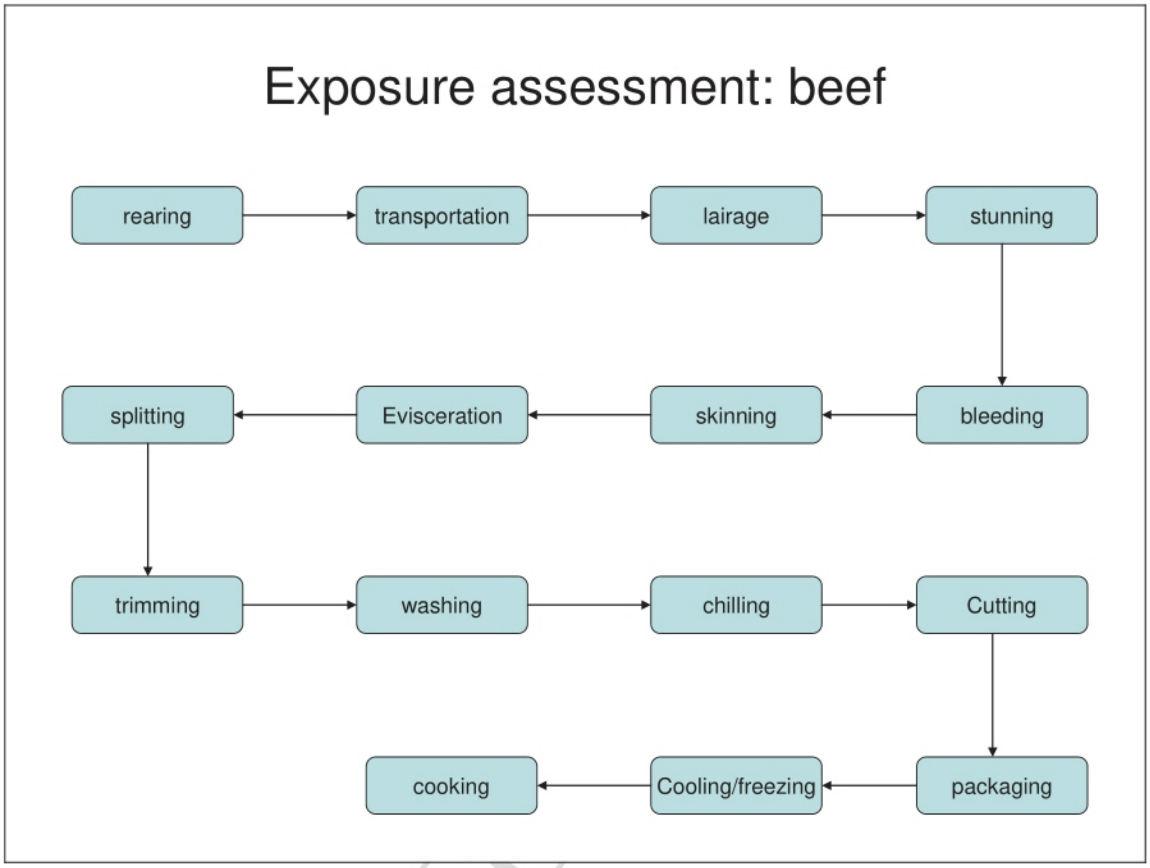


Figure 4: Schematic presentation of the processing of pork from farm to fork.

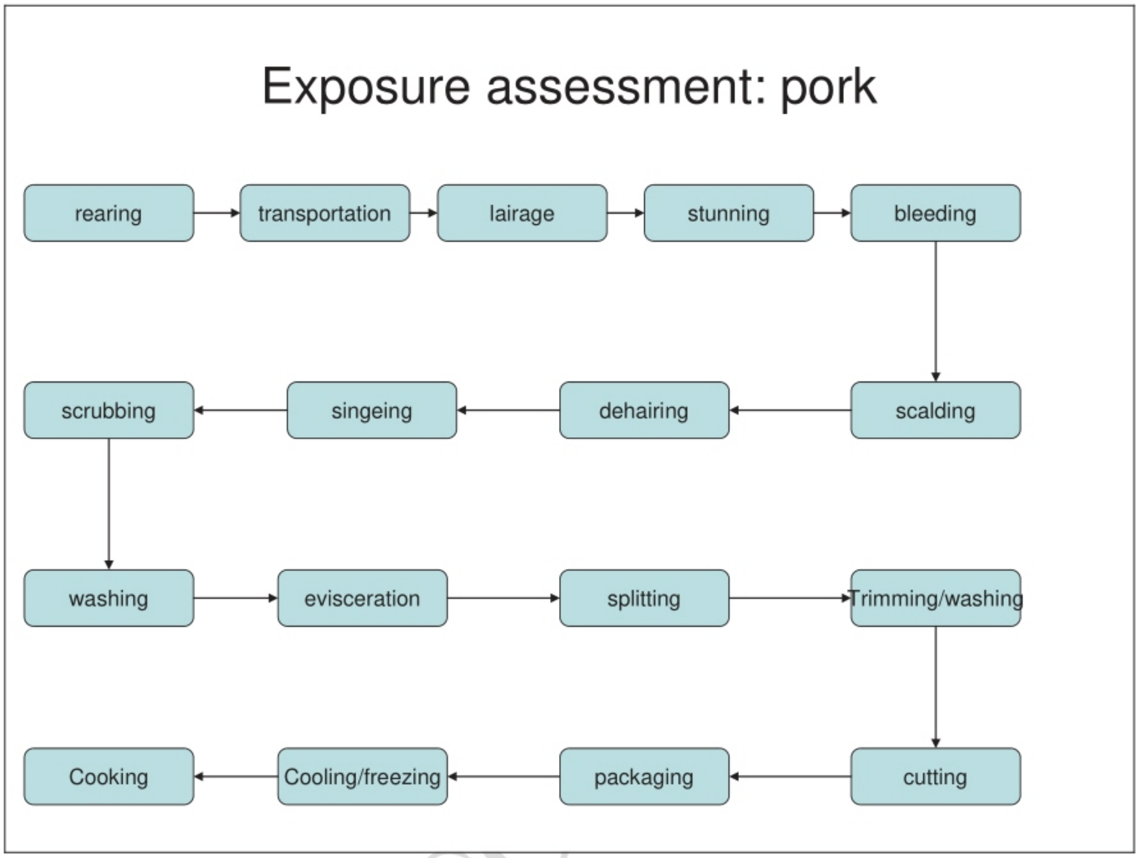
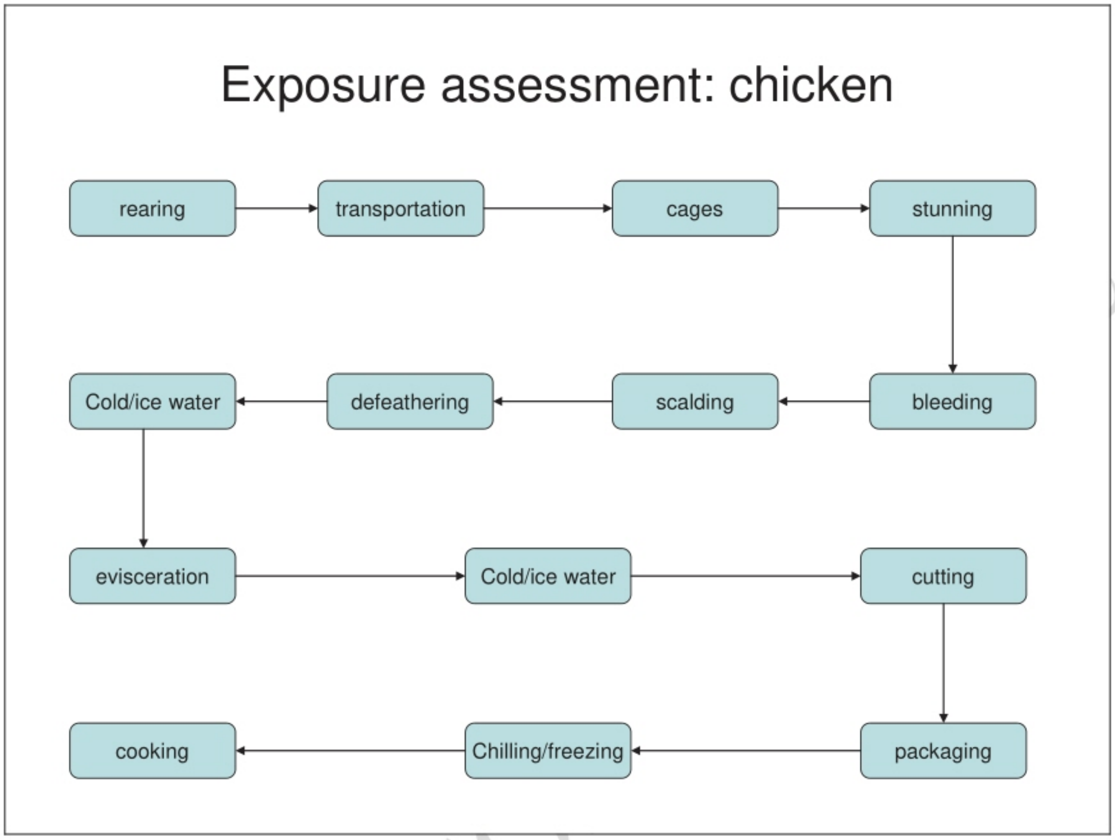


Figure 5: Schematic presentation of the processing of chicken from farm to fork.



References

1. Algino RJ, Badtram GA, Ingham BH, and Ingham SC. Factors associated with Salmonella prevalence on pork carcasses in very small abattoirs in Wisconsin. J Food Prot: 72(4); 2009.
2. Arsenault J, Letellier A, Quessy S, and Boulianne M. Prevalence and risk factors for Salmonella and Campylobacter spp. Carcass contamination in Broiler Chickens slaughtered in Quebec, Canada. J Food Prot: 70(8); 2007.
3. Arthur TM, Bosilevac JM, Brichta-Harhay DM, Guerini MN, Kalchayanand N, Shackelford SD, Wheeler TL, and Koomaraie M. Transportation and Lairage Environment effects on Prevalence, Numbers, and Diversity of Escherichia coli O157:H7 on Hides and Carcasses of Beef Cattle at Processing. J Food Protection: 70(2); 2007.
4. Arthur TM, Bosilevac JM, Nou X, Shackelford SD, Wheeler TL, Kent MP, Jaroni D, Pauling B, Allen DM, and Koohmaraie M. Escherichia coli O157 prevalence and enumeration of aerobic bacteria, Enterobacteriaceae, and Escherichia coli O157 at various steps in commercial beef processing plants. J Food Prot: 67(4); 2004.
5. Bohaychuk VM, Checkley SL, Gensler GE, and Barrios PR. Microbiological baseline study of poultry slaughtered in provincially inspected abattoirs in Alberta, Canada. Can Vet J: 50; 2009.
6. Bolton DJ, Pearce RA, Sheridan JJ, Blair IS, McDowell DA, and Harrington D. Washing and chilling as critical control points in pork slaughter hazard analysis and critical control point (HACCP) systems. J Appl Microbiol: 92(5); 2002.
7. Callaway TR, Anderson RC, Edrington TS, Genovese KJ, Bischoff KM, Poole TL, Jung YS, Harvey RB, and Nisbet DJ. What are we doing about Escherichia coli O157:H7 in cattle? J Anim Sci: 84; 2004.
8. Callaway TR, Elder RO, Keen JE, Anderson RC and Nisbet DJ. Forage Feeding to reduce preharvest Escherichia coli populations in catte, a Review. J Dairy Sci: 86; 2003.
9. Cassin MH, Lammerding AM, Todd ECD, Ross W, and McColl RS. Quantitative risk assessment for Escherichia coli O157:H7 in ground beef hamburgers. Int J Food Microbiol: 41; 1998.
10. Chase-Topping ME, McKendrick IJ, Pearce MC, MacDonald P, Matthews L, Halliday J, Allison L, Fenlon D, Low C, Gunn G, and Woolhouse MEJ. Risk Factors for the presence of high level shedders of Escherichia coli O157 on Scottish farms. J Clin Microb: 45(5); 2007.
11. Cliver DO. Cutting boards in Salmonella cross contamination. J AOAC Int: 89(2); 2006.
12. FAO and WHO. Food safety risk analysis: A guide for national food safety authorities (2006). Website: http://www.who.int/foodsafety/publications/micro/riskanalysis06.pdf

13. Figueroa G, Troncoso M, Lopez C, Rivas P, and Toro M. Occurrence and enumeration of Campylobacter spp. During the processing of Chilean burgers. BMC Microbiol: 9(94); 2009.
14. Gill CO. Visible contamination on animals and carcasses and the microbiological condition of meat. J Food Prot: 67(2); 2004.
15. Guerin MT, Martin W, Reiersen J, Berke O, McEwan SA, Bisaillon JR, and Lowman R. A farm level study of risk factors associated with the colonization of broiler flocks with Campylobacter spp. In Iceland, 2001 – 2004. Acta Vet Scand: 49(18); 2007.
16. Hald T, Wingstrand A, Swanenburg M, von Altrock A, and Thorberg BM. The occurrence and epidemiology of Salmonella in European pig slaughterhouses. Epidemiol Infect: 131(3); 2003.
17. Hathaway SC. Intensive (pasture) beef cattle operations: the perspective of New Zealand. Rev Sci Tech: 16(2); 1997.
18. Hurd HS, McKean JD, Griffith RW, Wesley IV, and Rostagno MH. Salmonella enterica infections in market swine with and without transport and holding. Appl Env Microbiol: 68(5); 2002.
19. Mataragas M, Skandamis PM, and Drosinos EH. Risk profiles of pork and poultry meat and risk ratings of various pathogen/product combinations. Int J Food Microb: 126; 2008.
20. Mather AE, Reid SWJ, McEwan SA, Ternant HE, Reid-Smith RJ, Boerlin P, Taylor DJ, Steele WB, Gunn GJ, and Mellor DJ. Factors associated with cross contamination of hides of Scottish cattle by Escherichia coli O157. Appl Environ Microbial: 74(20); 2008.
21. Meyer-Broseta S, Bastian SN, Arné PD, Cerf O, and Sanaa M. Review of epidemiological surveys on the prevalence of contamination of healthy cattle with Escherichia coli serogroup O157:H7. Int J Hyg Environ Health: 203(4); 2001.
22. Moore G, Blair IS, and McDowell DA. Recovery and transfer of Salmonella typhimurium from four different domestic food contact surfaces. J Food Prot: 70(10); 2007.
23. Public Health Agency of Canada. C-Enternet short report, 2007. Website: http://www.phac-aspc.gc.ca/c-enternet/pdf/sr2007-eng.pdf
24. Renter DG, Smith DR, King R, Stilborn R, Berg J, Berezowski J, and McFall M. Determinants and detection of Escherichia coli O157:H7 in Alberta Feedlot pens immediately prior to slaughter. Can J Vet Res: 72; 2008.
25. Ross T and Sumner J. A simple, spread-sheet based, food safety risk assessment tool. Int J Food Microb: 77; 2002.
26. Stern NJ, Clavero MR, Bailey JS, Cox NA, Robach MC. Campylobacter spp. In broilers on the farm and after transport. Poult Sci: 74(6); 1995.
27. Sumner, Ross T, Jensen I, and Pointon A. A risk microbiological profile of the Australian red meat industry: Risk ratings of hazard-product pairings. Int J Food Microb: 105; 2005.
28. Tuttle J, Gomez T, Doyle MP, Wells JG, Zhao T, Tauxe RV, and Griffin PM. Lessons from a large outbreak of Escherichia coli O157:H7 infections:

insights into the infectious dose and method of widespread contamination of hamburger patties. Epidemiol Infect: 122(2); 1999.
29. van Donkersgoed J, Bohaychuk V, Besser T, Song X-M, Wagner B, Hancock D, Renter D, and Dargatz D. Occurrence of food borne bacteria in Alberta feedlots. Can Vet J: 50; 2009.
30. Woerner DR, Ransom JR, Sofos JN, Dewell GA, Smith GC, Salman MD and Belk KE. Determining the prevalence of Escherichia coli O157 in Cattle and Beef from the Feedlot to the Cooler. J Food Protection: 69(12); 2006.

APPENDIX

Appendix A

Risk Profile Questions

1. What processes/steps are involved in the slaughter of different species of animals.
2. What kind of pathogen reduction methods are in place?
3. What are the most common variations of slaughter methods?
4. What type of infrastructure/tools are used in the slaughter chain?
5. What is the pre-slaughter protocol i.e. how are animals brought from the pens to the slaughter place? Are slaughter animals put in one pen or are they brought directly from their pens to the slaughter place?
6. How often are animals slaughtered and how many animals are slaughtered on a typical slaughter day?
7. How is the general animal health situation in these farms? Do farms have routine veterinary visits? Are they part of any quality assurance program?
8. To what extent do they use antibiotics or any veterinary drugs and do they observe the relevant withdrawal times before slaughter.
9. To what extent is organic farming practised?
10. What species are slaughtered on-farm?
11. How big are these farms (herd size)?
12. Where do they get their feed? Do they buy premixed feed or they mix on farm?
13. How is hygiene and sanitation? What chemicals are commonly used? How often do they clean? Do they wear clean clothing at each slaughter? Do they practise proper hand washing? How do they clean their instruments/machinery and how often do they do this?
14. Do they comply with animal welfare standards? What method is used for stunning? Are animals slaughtered in full view of other animals? Are animals moved from their pens in a humane way?
15. What type of meat products are sold?
16. Are appropriate storage facilities in place after slaughter?
17. How is the meat packaged for sale?
18. Is clean potable water available?
19. Any pest control activities?
20. What are farmers' and consumer perceptions of food safety? What level of importance is attached to food safety?
21. What changes are they prepared to make to ensure the production of a safe product?
22. What waste disposal strategies are in place?
23. Do they adhere to work safety standards?