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Highlights for Review

- Risk of developing salmonellosis through beef generally low in Zambia.
- Consumption patterns have an effect on risk of developing salmonellosis.
- Kitchen cross-contamination increases risk of developing *Salmonellosis.*
- Cooking alone not adequate response to exceptional events of beef contamination.

Quantitative Risk Assessment of Developing Salmonellosis through Consumption of Beef in Lusaka Province, Zambia

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Abstract

Based on the Codex Alimentarious framework, this study quantitatively assessed the risk of developing salmonellosis through consumption of beef in Lusaka Province of Zambia. Data used to achieve this objective were obtained from reviews of scientific literature, Government reports, and survey results from a questionnaire that was administered to consumers to address information gaps from secondary data. The Swift Quantitative Microbiological Risk Assessment (sQMRA) model was used to analyse the data. The study was driven by a lack of empircally-based risk estimation despite a number of reported cases of salmonellosis in humans.

A typology of consumers including all age groups was developed based on their beef consumption habits, distinguishing between those with low home consumption, those with medium levels of home consumption, and those with high levels through restaurant consumption. This study shows that the risk of developing salmonellosis in this population, from consuming beef, was generally low. At ID50 of 9.61×10^3 cfu/g and a retail contamination concentration of 12 cfu/g, the risk of developing salmonellosis through the consumption of beef prepared by consumers with low and medium levels of beef consumption was estimated at 0.06% and 0.08%, respectively, while the risk associated with restaurant consumption was estimated at 0.16% per year.

The study concludes that the risk of developing salmonellosis among residents in Lusaka province, as a result of beef consumption, was generally low, mainly due to the methods used for food preparation. Further work is required to broaden the scope of the study and also undertake microbiological evaluation of ready-to-eat beef from both the household and restaurant risk exposure pathways.

Keywords: Beef consumption; Quantitative risk assessement; Salmonellosis; sQMRA; Zambia

1.0 Introduction

The expanding trade of food and livestock, and increased human travel and migration are a means of spreading infectious diseases, irrespective of national borders (Evans & Leighton, 2014). This makes the control of infectious diseases and maintenance of food safety important for all countries. This expansion of trade and human travel may lead to a transfer of diseases to areas where such were not a problem originally. This is because disease spread is usually accompanied with cultural changes including eating habits, mass catering, complex and lengthy food supply procedures, increased international movement, and poor hygiene practices in the native community.

One of the most widespread infectious foodborne disease of humans is salmonellosis (Carrasco, Morales-Rueda, & García-Gimeno, 2012; Kagambèga et al., 2013; Teunis et al., 2010). Salmonellosis is a disease of both humans and animals caused by two species of *Salmonella* (*S. enterica* and *S. bongori*) (Kemal, 2014; OIE, 2014). The pathogens can cause enteric fevers, gastroenteritis, and septicemia which are of both socio-economic and public health importance (Ulaya, 2013). The majority of infections are associated with the ingestion of contaminated foods such as beef and beef products, poultry, pork, eggs, milk, cheese, seafood, fruits, juices, and vegetables (Freitas Neto *et al.,* 2010; Jackson *et al.,* 2013); although most infections caused by multidrug-resistant *Salmonella* are acquired through contaminated foods of animal origin (Abouzeed *et al.,* 2000).

Although the domestic market for beef is small and under-developed in Zambia, demand for beef products has grown steadily in Lusaka province, the capital region, now home to almost 2.7 million people (CSO, 2015). Shifting consumption patterns are associated with an emerging middle class with increasing purchasing power. There is also an increase in domestic beef production in both commercial and traditional sectors, and a rising import of beef and beef products to cover the increased demand in the country (World Bank, 2011). The increase in production may have negative impacts in terms of food safety, especially in traditional production, as the country does not have enough slaughter facilities (Lubungu, Sitko, & Hichaambwa, 2015). Indeed, Zambia, like other low and middle income countries of Africa, has few formal abattoirs compared to a large number of informal slaughterhouses associated with poor hygienic practices (Haileselassie, Taddele, Adhana, & Kalayou, 2013). There is higher risk of fecal spillage on the meat because of slaughtering on the floor (slaughter slabs). Given this senario, the chances of producing contaminated carcases are high, since contamination of carcasses may occur throughout the value chain (from production through to consumption). This might lead to the introduction of *Salmonella* into the food chain if there was an early exposure of domestic animals to the organism that results in long-term persistent infections (Muma, 1998; Isogai *et al.,* 2005; Haileselassie *et al.,* 2013; Ndalama & Mdegela 2013).

Salmonella has been previously detected in human samples in Lusaka; out of the 200 clinical diarrhoea stool samples, 9 (4.5%) were found to be bacteriological culture positive for *Salmonella* (Hang'ombe, 1998). Mwansa *et al.* (2002) reported that of 124 adults and 105 children with persistent diarrhea in Zambia, 6 (5%) and 21 (20%) were infected with non-typhoidal *Salmonella* (NTS) species, respectively. In an earlier study at the University Teaching Hospital (UTH), Lusaka, 45 strains of various NTS species were isolated from stool samples, blood, and cerebral spinal fluid (CSF)(Hangombe, 1998). About 93% of the strains were isolated from infants less than two years old. *Salmonella Heidelberg* was the most common species isolated from stool and revealed a multi-drug resistant character. This shows that *Salmonella* is present and that there is a risk of getting salmonellosis once an individual consumes contaminated food, including beef, or gets otherwise exposed (e.g. direct contact with infected animals).

Previous studies have also indicated that among the microbiological hazards in the beef value chain, *Salmonella* has a great public health significance (Dhanoa & Fatt, 2009; Kemal, 2014; Plym L & Wierup, 2006). Muma *et al.* (1998) isolated *Salmonella* from beef carcases in a survey involving abattoirs in Lusaka and Copperbelt provinces, whose results demonstrated that there was a high level of contamination on carcasses due to poor hygiene status in abattoirs (Muma, 1998; Ntanga 2013). Further, diarrhoeal cases have been reported in Lusaka, some of which were due to *Salmonella* infections (Mwansa *et al.,* 2002; Hang'ombe *et al.,* 2011).

Despite evidence of presence of *Salmonella* species in beef from previous research, very little is known about the risk of salmonellosis through consumption of beef in Lusaka Province and Zambia in general. It is therefore important to assess whether the increase in beef consumption increases public health burdens due to exposure to foodborne hazards.

To address this information gap, this study used a Swift Quantitative Microbiological Risk Assessement (sQMRA) model to quantify these risks (Evers & Chardon, 2010).

There is a paucity of published literature that demonstrates a quantitative risk of developing salmonellosis through the consumption of beef using sQMRA food safety risk analysis tool. This paper illustrates scenarios where both the household and restaurant risk pathways have been used to assess the risk of developing salmonellosis through the consumption of beef prepared in three different ways.

2.0 Methodology

2.1 Study area

This study was conducted in the Lusaka province of Zambia, an area with relatively high beef consumption due to high purchasing power (Sinkala et al., 2014).

2.2 Swift Quantitative Microbiological Risk Assessement *(sQMRA) model*

The sQMRA-model model was developed by Evers & Chardon, (2010). It is implemented in a Microsoft Excel spreadsheet. Deviating from a full-scale Quantitave Microbiological Risk Assessment (QMRA), where pathogen numbers are followed through the whole food chain, this model starts at retail and ends with the number of human cases of illness. The model is deterministic and includes cross-contamination and preparation (heating) in the kitchen and as well as dose–response relationship. The general setup of the sQMRA tool consists of consecutive questions for values of each of the 11 parameters, always followed by intermediate model output broken down into categories of contamination, cross-contamination and preparation, as show in Figure 2 under the results section. Model input and output are summarized and exposure as well as cases are attributed to the distinguished categories. As a relative risk measure, intermediate and final model outputs are always compared with results from a full-scale QMRA of Campylobacter on chicken fillet as shown in Figure 3, 4 and 5 under the results section. The model allows results of the research to be quickly interpreted in terms of public health risk, given that pathogen concentration is determined from the model. It is also more accessible and understandable for scientists that are new to the QMRA research area or are not very mathematically inclined (Evers & Chardon, 2010)

2.3 Study design and Data sources

The study used a cross sectional design which depended on both secondary and primary data sources.

Secondary data: This was a risk analysis desktop study which mainly depended on review of scientific peer reviewed papers and grey literature (secondary data). The literature review was guided by research questions based on the sQMRA model as shown in Table 1. Literature search was conducted on major electronic databases including Web of Science and Pub Med (NLM) using The Norwegian University of Life sciences (NMBU) library database. Further, grey literature from conference proceedings and reports from government institutions and Non-Governmental Organisations were obtained online using "Google search engine" and "Google scholar". Search of key terms such as, "Beef consumption, Quantitative risk assessement, Salmonellosis, beef value chain, Zambia", were used. Guided by questions in table 1, literature which contained relevant data were included in the study and the rest were exluded. This was the main source of data (almost 98%).

Primary data: After an extensive literature review, it was discovered that there were information gaps on serving portions and consumption patterns of beef in Zambia. A survey was therefore undertaken to fill these information gaps. This only formed about 2% of the data.

A structured questionnaire was used to address the information gaps on serving portions and consumption patterns. The study had a convenient sample size of hundred (100) respondents. The sampling frame was composed of respondents from two areas with a different socio-economic status (40 low and 60 medium income communities), so as to obtain a representative estimate of average serving portions and consumption patterns. Residential areas were used as a proxy for socioeconomic status using the Central Statistical Office conditions of leaving survey (CSO, 2010; Mweemba & Webb, 2008). Respondents were conveniently identified and interviewed from the butcheries in low and medium/high cost residential areas where they were found buying beef and restaurants were they were found eating beef.

2.4 Ethical Approval

Ethical approval was sought and approved from the School of Veterinary Medicine Board of Graduate Studies Committee and the University Of Zambia, Directorate of Graduate Studies (DRGS).

Table 1: Literature review guide based on SQMRA model

Case definition 1. What is the pathogen of interest? 2. What is the food product of interest? 3. What is the population size? 4. What are the population characteristics? 5. What is the consumption period?	***Consumption data*** 1. How many portions are consumed in the population per consumption period? 2. What is the average size of one portion? 3. What percentage of the portions is contaminated at retail? 4. What is the average concentration of colony forming units (cfu) per gram in contaminated portions?
Kitchens cross contamination 1. Given contaminated portions, what percentage of the portion will contaminate the environment? E.g. hands and kitchen equipment? 2. Given contaminated portions, what percentage of the cfu's on a portion will contaminate the environment? E.g. hands and kitchen equipment? 3. Given cross contamination, what percentage of cfu's in the environment ends up being ingested?	***Kitchen preparation*** 1. What percentage of the portions is prepared; Done, Half done, Raw 2. What percentage of cfu's on a portion will survive during preparation? -Done, Half done and Raw ***Infection and illness*** 1. At which dose (number of cfu's) per portion will half of the exposed population get infected? 2. What percentage of infected people will get ill?
Cfu = colony forming units	

2.5 Data management and analysis

The data collected from the survey were coded and entered into STATA, SE/ 12 for Windows (StaaCorp, College Station, TX). Descriptive statistics on average serving portions, consumption patterns, and kitchen preparation methods of beef were calculated. Data from the literature review were entered in the Excel version of the sQMRA model developed by Evers and Chardon, (2010). This model was then run twelve times to come up with results for the exposure assessment following the household and restaurant risk exposure pathways as shown in figure 1.

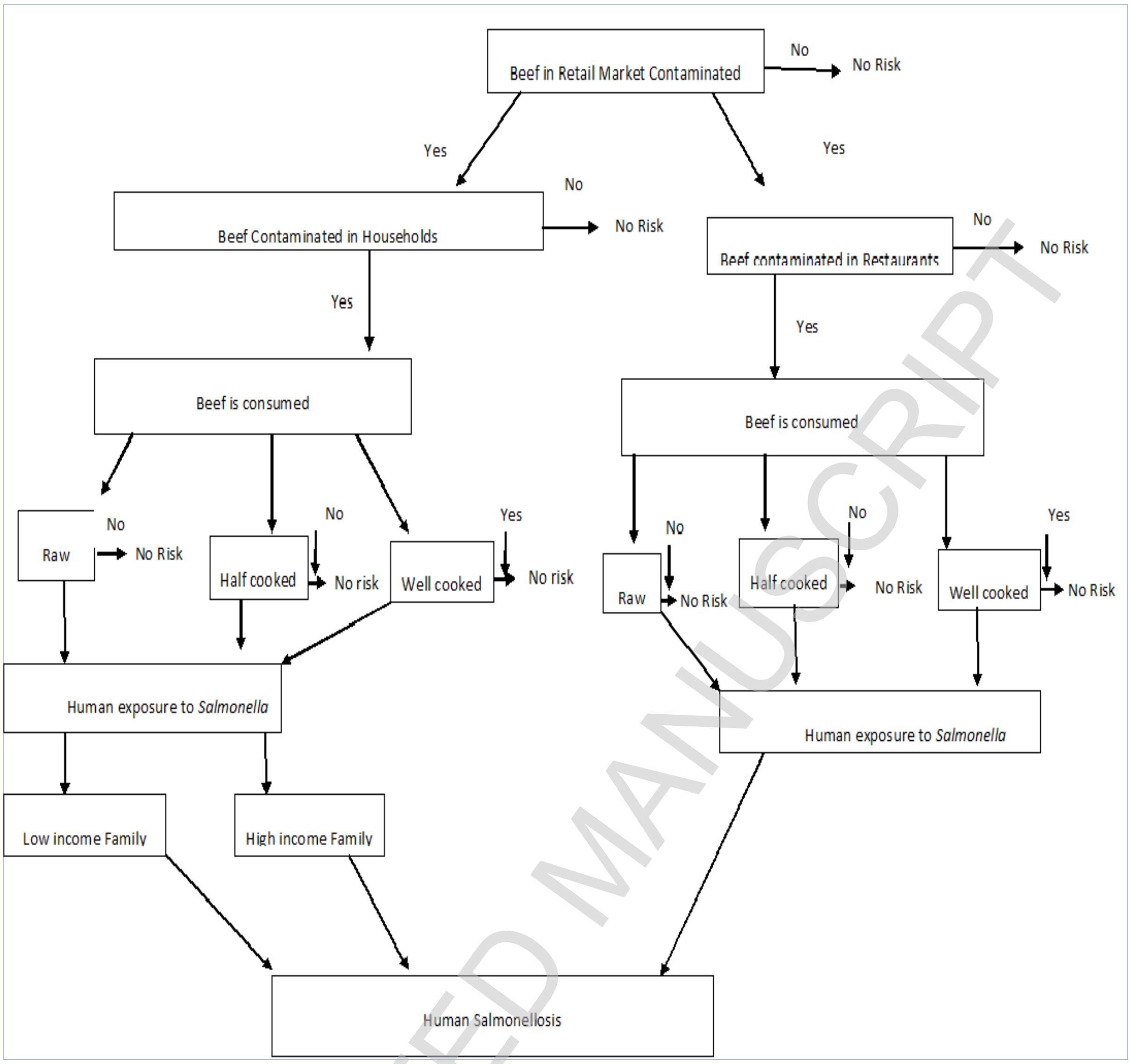


Figure 1: Conceptual framework of the household and restaurant risk exposure pathways

3.0 RESULTS

3.1 Exposure assessment

3.1.1 Case definition

The pathogen of interest was *Salmonella* species and the targeted product was beef. The population size of Lusaka province was taken to be 2,669,249 in this model according to Central Statistics Office of Zambia (CSO, 2015). A consumption period of one year was defined to assess the number of people who would get ill in this study (i.e., the number of people who would get ill per year).

3.1.2 Consumption data

In this study, a portion size was defined as the amount/ size of beef an individual consumes per meal. There was no available beef consumption data in Lusaka province. The study assumed that residents in Lusaka province who were employed consumed beef. According to Labour Force Survey of Zambia, 75% of the 2.67 million Lusaka residents were in formal or informal employment (CSO, 2015). Using the later information, the study therefore logically assummed that 75% of the residents in Lusaka province who were employed consumed beef because of their purchasing power (CSO, 2015; World Bank, 2011). The survey revealed that two portions of beef were served (Lunch and dinner). Hence the number of portions consumed by a population was calculated to be 2,001,937 per consumption period multiplied by 2 servings for lunch and dinner (4,003,874 portions).

3.1.3 Serving portions and consumption patterns

The results of the survey revealed that the average serving portion of beef per serving at a household level was 60g among low consumers and 83.1g among medium beef consumers, while that for restaurants (high beef consumers) was 192g. Most beef at the household level was prepared and consumed well done (91%); 9% was prepared half done; while no (0%) beef was consumed raw. The consumption patterns from the data showed that 60% of respondents consumed beef once every week, 16% consumed once in every fortnight, 15% consumed beef once a month and 9% consumed beef every day through various forms. At household level, beef was cooked once, but then served in two different periods (2 serving portions-lunch and dinner).

Contamination of raw beef at retail outlets: Literature review showed a wide range of raw beef contamination at retail outlets from 2.42% to 62% (Ahmad et al., 2013; Kumar, Rao, & Haribabu, 2014; Mrema, Mpuchane, & Gashe, 2006; Sallam, Mohammed, Hassan, & Tamura, 2014; Tafida et al., 2013; Van, Moutafis, Istivan, Tran, & Coloe, 2007; Yang et al., 2010). A similar study in Botswana revealed that retail contamination of beef stood at 20% (Mrema et al., 2006). This study therefore used the data from Botswana because it is a neighbouring country with similar experiences in retail beef handling practices like in many other low and middle income countries in Africa (Haileselassie et al., 2013; Mrema et al., 2006).

This study considered only minimum and high concentrations of *Salmonella* and hence the average concentration of colony forming units (cfu) per gram in a contaminated portion of beef was taken to have a minimum value of 3.36cfu/g and a maximum value of 12cfu/g (Ahmad et al., 2013; Ba'aba, 2014; USA -FSIS, 2011).

3.1.4 Kitchen cross-contamination

Due to a lack of literature on *Salmonella* in beef kitchen cross-contamination, *Salmonella* in chicken kitchen cross-contamination was used as a proxy. This is because cross-contamination does not differ regardless of the food product where preparation methods are similar (Evers & Chardon, 2010). The percentage of portions that would contaminate the environment such as the hands and kitchen was therefore set at 45% for restaurants and 40% under the household risk exposure pathways (Medeiros, Nascimento, & Robson, 2014). The percentage of cfu on a portion that would contaminate the environment such as hands and kitchen was 30% (Kusumaningrum *et al.,* 2003).

The percentage of beef portions that would cross-contaminate the environment such as the hands and household kitchen used in this model was assumed to range from 4 to 32% (12% of dishcloths, 24% of persons' hands, 4% refrigerator door handles, 20% oven door handles, 24% counter-tops and 32% draining boards) (Gorman *et al.,* 2002), while the percentage of cfu on a beef portion that would contaminate the environment such as the hands and kitchen in household was assumed to be 16.6% (Gorman *et al.,* 2002). In the household and restaurant risk pathways, it was assumed that 9% and 14% of cfu (value ranges from 0.02 to 75%) on a portion would end up being ingested as a result of beef that is prepared half done (Ravishankar *et al.,* 2010).

3.1.5 Kitchen preparation

From the questionnaire survey on beef preparation, the percentage of doneness on the portion of beef at household kitchen level was; 91% well done, 9% half done and 0% raw, while that at restaurant kitchen level was 84% well done, 16% half done (mostly roasted T-bone) and 0% raw. In the reviewed literature the percentage of beef prepared raw was high at 37% (Bogardet al., 2013) which was not realistic to African cultures like that of Zambia.

The percentages of microorganisms surviving on a contaminated portion of beef during preparation in both household and restaurant kitchen were 0%, 20% and 100% when beef was prepared well done, half done and raw respectively (Evers & Chardon, 2010). It was assumed to be zero when well done because of overboiling of meat which is normally practiced in Zambia; and 100% when raw due to poor hygiene practices along the beef value chain in developing countries (Haileselassie et al., 2013). Evers & Chardon, (2010) also used 0% in well done and 100% when prepared raw, in their sQMRA model.

3.1.6 Infection and illness

In this study, the dose (number of cfu's) per gram of portion that would cause half of the exposed population to get salmonella infection (ID50) was taken to be a minimum of 9.61×10^3 cfu (9,610) and maximum of 5.0×10^4 (Teunis et al., 2010; WHO/FAO, 2002). The study assumed that 100% of the exposed population would get ill when they ingested such doses of *Salmonella* (Blaser & Newman, 1982). The infectious dose of *Salmonella* was assumed to be a minimum of 9.61×10^3cfu/g and a maximum of 5×10^4cfu/g (Teunis et al., 2010). The average concentration of cfu's per gram in a contaminated portion of raw beef was a minimum of 3.36cfu/g and maximum 12cfu/g (Ahmad et al., 2013; Ba'aba, 2014; Teunis, 1997; USA -FSIS, 2011; WHO/FAO, 2002).

3.2 Risk characterisation

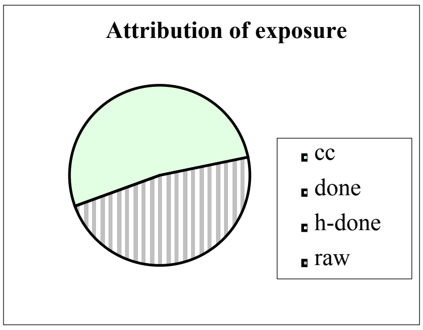
A total of 12 simulations which included eight from the household risk pathway (4 for the low beef consumers, 4 for medium beef consumers) and 4 for the restaurant (high beef consumers) risk exposure pathway, were run. Each run produced a summary of the input parameters (Figure 2) and the output model results for the highest risk of developing salmonellosis among the low beef consumers (Figure 3) and medium beef consumers

(Figure 4) in a household risk pathway and high beef consumers in a restaurant risk pathway (Figure 5).

INPUT PARAMETERS			
Pathogen:			Salmonella
Food product:			Meat
Population size:			2669249
Pop. Characteristics:			Population of Lusaka
Consumption period:			One year
Number	Para-meter	Question	Value
1	N	Portions consumed	4.0E+06
2	M	Portion size in grams	60
3	Sr/+	Prevalence in retail	20%
4	Cr/+	cfu per gram contaminated product	12.0
5	Scc/r	Portions causing cross. cont.	45%
6	Fcc	cfu's from portions to environment	30%
7	Fei	cfu's from environment to ingestion	9.0%
8	Sprd/cc	Portions prepared done	91%
8	Sprh/cc	Portions prepared half-done	9.0%
8	Sprr/cc	Portions prepared raw	0.000%
9	Fprd	cfu's surviving when prep. Done	0%
9	Fprh	cfu's surv. when prep. Half-done	20%
9	Fprr	cfu's surviving when prep. Raw	100%
10	ID50	ID50 (number of cfu's)	9.6E+03
11	Pill/inf	% people infected who get ill	100%
Time stamp:		04/07/2016 16:49	
sQMRA-tool			

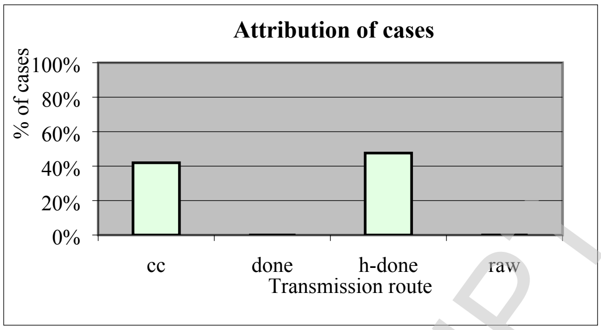
Figure 2: sQMRA input parameters for the low beef consumer under the household risk exposure pathway

EXPOSURE



Transmission route	Exposure
Cross contamination	44%
Prepared done	0%
Prepared half-done	56%
Prepared raw	0%

EFFECT



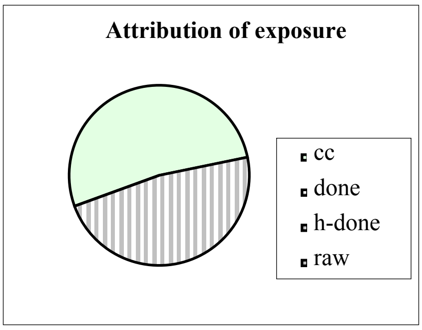
Transmission route	Calculation	Attribution of cases
Cross contamination	Scc/r = 0%	35%
Prepared done	Fprd = 0%	0%
Prepared half-done	Fprh = 0%	56%
Prepared raw	Fprr = 0%	0%

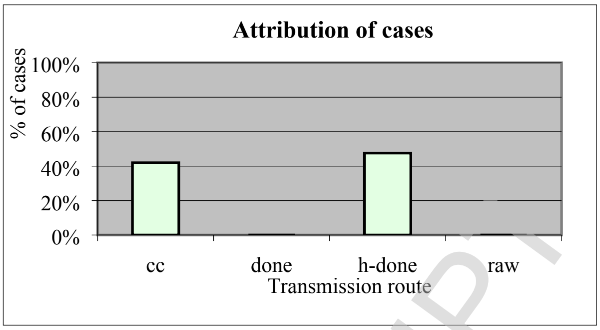
RELATIVE RISK — Compared with QMRA *campylobacter* in chicken fillet

Point of comparison	Model output	Reference data	Relative value
Portions consumed	4.0E+06	8.5E+07	4.71%
Contaminated portions (at retail) consumed	8.0E+05	3.3E+07	2.43%
Total number of cfu's before kitchen	5.8E+08	7.0E+10	0.82%
Total number of cfu's after kitchen	1.6E+07	6.1E+06	262%
Number of people ill	1.1E+03	1.2E+04	9.32%

Figure 3: Model output at 12cfu/g and ID50 at $9.61x10^3$ cfu (high probability for low beef consumers under the household risk exposure pathway)

EXPOSURE	EFFECT





Transmission route	Exposure
Cross contamination	44%
Prepared done	0%
Prepared half-done	56%
Prepared raw	0%

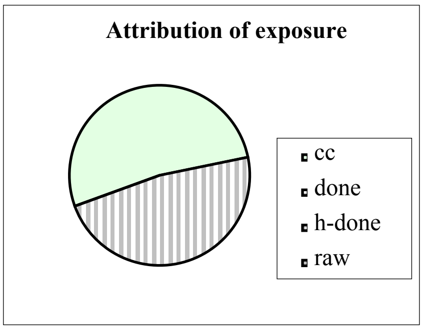
Transmission route	Calculation	Attribution of cases
Cross contamination	Scc/r =0%	35%
Prepared done	Fprd =0%	0%
Prepared half-done	Fprh =0%	56%
Prepared raw	Fprr =0%	0%

RELATIVE RISK compared with QMRA *campylobacter* in chicken fillet

Point of comparison	Model output	Reference data	Relative value
Portions consumed	4.0E+06	8.5E+07	4.71%
Contaminated portions (at retail) consumed	8.0E+05	3.3E+07	2.43%
Total number of cfu's before kitchen	8.0E+08	7.0E+10	1.14%
Total number of cfu's after kitchen	2.2E+07	6.1E+06	363%
Number of people ill	1.6E+03	1.2E+04	13%

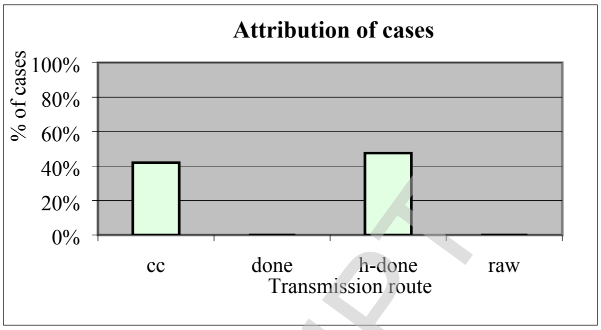
Figure 4: Model output at 12cfu/g and ID50 at 9.61×10^3 cfu (high probability for medium beef consumers under the household risk exposure pathway)

EXPOSURE	



Transmission route	Exposure
Cross contamination	52%
Prepared done	0%
Prepared half-done	48%
Prepared raw	0%

EFFECT		



Transmission route	Calculation	Attribution of cases
Cross contamination	Scc/r = 0%	42%
Prepared done	Fprd = 0%	0%
Prepared half-done	Fprh = 0%	47%
Prepared raw	Fprr = 0%	0%

RELATIVE RISK	Compared with QMRA *campylobacter* in chicken fillet

Point of comparison	Model output	Reference data	Relative value
Portions consumed	2.0E+06	8.5E+07	2.36%
Contaminated portions (at retail) consumed	4.0E+05	3.3E+07	1.21%
Total number of cfu's before kitchen	9.2E+08	7.0E+10	1.32%
Total number of cfu's after kitchen	4.4E+07	6.1E+06	728%
Number of people ill	3.2E+03	1.2E+04	26%

Figure 5: Model output at 12cfu/g and ID50 at $9.61x10^3$ cfu (high probability for the high beef consumers under the restaurant risk exposure pathway)

Table 2 (risk characterization) summarises the results of all the outputs of the 12 simulations. Of the 4 case scenarios for the low beef consumers (through the household risk pathway), scenario 3 recorded the highest risk with 1,100 out of a population of 2,001,937 people developing salmonellosis through the consumption of *Salmonella* contaminated beef, representing a probability of 0.04%.

Among the medium beef consumers through the household risk pathway, 1,600 out of a population of 2,001,937 people risked developing salmonellosis through consumption of salmonella contaminated beef, representing a probability of 0.05%.

Among the heavy consumers of beef (through the restaurant) risk pathway, 3,200 out of a population of 2,001,937 people risked developing salmonellosis through consumption of salmonella contaminated beef, representing a probability of 0.16%.

Table 2: Summary of the outputs of 12 simulations under household and restaurant risk exposure pathways

Low beef consumers under household risk pathway				
Scenario	Portion (g)	cfu/g	ID50	Model output (No. People ill per year)
1	60	3.36	9,610	320
2	60	3.36	50,000	62
3	60	12	9,610	1,100
4	60	12	50,000	220
Medium beef consumers under household risk pathway				
1	83.1	3.36	9,610	450
2	83.1	3.36	50,000	86
3	83.1	12	9,610	1,600
4	83.1	12	50,000	310
High beef consumers under restaurant risk pathway				
1	192	3.36	9,610	890
2	192	3.36	50,000	170
3	192	12	9,610	3,200
4	192	12	50,000	610

3.2.1 Uncertainity

Like many other risk analysis studies, there were substantial missing data as input parameters in the model. To cover up for these data gaps, a simple survey on the consumption patterns and serving portions of beef in the population was done to get the average serving portions, so as avoid too much reliance on logical assumptions and use of data from other countries. The pathogen numbers were followed through the food chain, which in this case starts at retail and ends with the number of human cases of illness. It would be more robust to follow the pathogen numbers along the entire value chain (farm to folk at a national level), but this would require more resources.

4.0 Discussion

This study was conducted with the aim of assessing the risk of developing salmonellosis through consumption of beef in Lusaka Province of Zambia. The key question was to find out whether beef sold in Lusaka province posed a risk of *Salmonella* infection through consumption of meals prepared at home and those consumed in restaurants. In this study, it was observed that the risk of developing salmonellosis as a result of beef consumption was generally low for both exposures from restaurants and in households. The low risk in the current study was attributed to low serving portions per meal, low consumption patterns and preparation methods of beef both in restaurants and in households.

The serving portion of beef has the potential to contribute to risk of *Salmonella* infection in humans. In this study, the average serving portion of beef was 60g and 83.1g per meal for low and middle income households and 192g/meal in restaurants. This contributed to low risks found in this study. The small serving portions could be attributed to the high price of beef on the market and hence most people opted for other livestock products rather than beef. This is in agreement with the previous findings on urban consumption patterns of livestock in Zambia where consumption patterns of livestock products was influenced by household affluence defined as the low, medium, and high expenditure terciles or income groups (Hichaambwa, 2012). In the same study Hichaambwa showed that within each city, the expenditure share of livestock products increased from the low to the high income group while it marginally decreased in the case of fish (Hichaambwa, 2012).

In terms of preparation methods, most of the beef consumed in Lusaka was prepared well done through boiling with only few (16%) in restaurants where T-bone was normally prepared half done. Consumption of T-bone contributed to doubling the risk of developing salmonellosis in the current study through the restaurant pathway. Consumption of raw beef was not a common practice in Zambia hence recording 0% and thus further reducing the risk.

Although consumption of well cooked beef does not pose a risk of developing salmonellosis, other ways of getting infection with *Salmonella* is cross-contamination in the kitchen which could occur when handling contaminated beef. Lordache and Tofan (2008) in a study on the cross-contamination of *Salmonella enteritidis* on sterile and non-sterile meat showed that cross-contamination of *Salmonella* could occur in the kitchen environment (Lordache and Tofan, 2008). In the current study, cross-contamination in the kitchen was one of the contributing factors for risk of developing salmonellosis. Results showed that much of the risk was contributed by cross contamination at restaurant level compared to other scenarios when concentration of *Salmonella* in retail beef was 12cfu/g of beef and infectious dose fifty of (ID50) $9.61x10^3$cfu/g. This was in agreement with the observation by Mughini-Gras et al., (2014) who showed that not using a chopping board for raw meat only (cross-contamination) and consuming raw/undercooked meat were risk factors for infection with *Salmonella* originating from cattle. In the current study, there were low numbers of predicted cases of salmonellosis at high contamination (12cfu/g) and high ID50 ($5x10^4$ cfu/g). This indicated that cooking alone cannot be considered an adequate response to exceptional events of extreme foodborne bacterial pathogen contamination; other factors like cross-contamination could lead to salmonellosis infection even when beef is well cooked (Teunis et al., 2010).

In general, the low risk of developing salmonellosis in the current study is in agreement with the observation by Abdunaser *et al.* (2009) who reported the risk of developing salmonellosis in human per 100g serving portion of ground beef to be low (ranging from 0 to $2.33x10^{-06}$), though it was based on ground beef contrary to the current study which considered beef without specifying whether ground or beef parts.

We acknowledge that this model is deterministic and does not allow the variability inherently linked to food-borne diseases to be modelled. However, our model could be a starting platform for further studies on the epidemiology of salmonellosis in Zambia. The model also represents a way of communicating results across regional and cultural/ economic borders.

Conclussion

The risk of developing salmonellosis from consumption of contaminated beef is generally very low among the beef consumers in Lusaka. This was attributed to low beef consumption and adequate cooking methods.

Declaration of interest

Authors declare no conflict of interest.

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