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Quantitative Risk ssessment of *E.coli* 57:H7 in Irish inced Beef

The National Food Centre

RESEARCH & TRAINING FOR THE FOOD INDUSTRY

RESEARCH REPORT NO 74

A QUANTITATIVE RISK ASSESSMENT OF *E. Coli* 0157:H7 IN IRISH MINCED BEEF

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SUMMARY

A national quantitative risk assessment was undertaken for minced beef in the Republic of Ireland. The objective was to estimate the probability of *E. coli* O157:H7 infection from consumption of Irish beef and to investigate the parts of the beef chain contributing most to the risk posed by this pathogen. The quantitative risk assessment was broken into 3 main modules: 1) production of boxed beef trimmings; 2) processing of trimmings and burger formation and 3) retail/domestic consumption phase. Key points in each module (beef hide, beef trimmings and beef products at retail) were validated using data derived from microbiology sampling at beef abattoirs, supermarkets and butchers' shops in Ireland.

The microbial data generated in the project indicated that this pathogen was present in the Irish beef chain at the following levels of contamination: bovine hide (prevalence 7.4%; concentration < $\log_{10}0.13$ – 2.97 cfu / 100 cm^2); beef trimmings (prevalence 1.7%, concentration <$\log_{10}0.13$ - $\log_{10}0.65$ cfu/g); minced beef products at retail (prevalence 2.8%, concentration <$\log_{10}0.52$ - 4.03 cfu /g). The strains isolated contained a range of virulence factors (*vt*1, *vt*2, *eae*A, and *hly*A) indicating the capacity of these strains to cause illness in humans.

Data for the retail/domestic part of the model was based on two main sources. Information on typical consumer handling practices in the domestic environment was derived from a questionnaire survey of consumers conducted by the Market Research Bureau of Ireland (MRBI). Data on storage temperatures at retail and in domestic refrigerators was gathered from snapshot studies in both environments. Consumption data figures for minced beef were derived from an Irish Food Consumption Survey carried out by the Irish Universities Nutrition Alliance (www.iuna.net).

A risk assessment model was developed for the beef chain based on the three main modules using @Risk software. Overall, the model predicted that the risk of illness from consumption of minced beef of beefburgers was low (1 illness per one million burgers/mince beef dishes consumed). Analysis of the data using the risk model indicated that initial prevalence and numbers of *E.*

coli O157:H7 on the bovine hide and the prevalence and numbers of *E. coli* O157:H7 on the beef trimmings have the greatest impact on overall risk from *E. coli* O157:H7 (level of pathogen to which the consumer is exposed) and on the probability of illness. The study indicates that *E. coli* O157:H7 is a problem in Irish beef and that further research on this pathogen and commodity is needed to reduce the risk posed.

INTRODUCTION

Risk analysis is a valuable tool in the management of microbial food safety issues and can provide a systematic approach for the regulatory authorities and the food industry to control the risk posed by a pathogen in a particular food commodity. Risk analysis consists of three elements: risk assessment, risk management and risk communication. Risk assessment is the scientific part of the process in which the hazards are identified and the risk posed by a particular hazard (*e.g.* pathogen) is calculated. Apart from an end-point calculation of risk, the risk model developed can be of value in determining the parts of the chain which contribute most to risk, in identifying the critical control points and setting quantitative critical limits as part of HACCP (Hazard Analysis Critical Control Point) systems.

The principals of risk assessment and the four stages involved (hazard identification, exposure assessment, hazard characterisation and risk characterisation) are outlined by the Codex Alimentarius Commission. Each of the stages is explained below.

Hazard identification

A hazard can be defined as an agent having an adverse effect on the public health of the human population and which may pose a short term, chronic, or fatal risk to a person. The identification of microbial hazard associated with a particular food is generally based on information generated from routine microbial analysis of the commodity or from an epidemiological linkage of a particular pathogen with a case of foodborne infection.

Exposure assessment

Exposure assessment is a quantitative assessment of the amount of a contaminant in a product to which a consumer is exposed at the time of consumption. The final estimation of the numbers and prevalence of pathogen in the food to be consumed is generally based on an accumulation of data on the pathogen throughout the food chain from the raw material through processing, retail distribution and domestic preparation. The overall exposure assessment relates the amount of contaminant in a designated amount of food with the amount of food typically consumed in a single serving. The information on the typical amount of food consumed is usually obtained from nutritional databases.

Hazard Characterisation

Hazard characterisation relates exposure to a hazard with a probable public health outcome (illness or death). A dose-response relationship can be used to estimate the amount (number) of the particular pathogens which may make a person ill or which may be fatal. The data used in generating dose-response models are derived from a variety of sources including human clinical trials, epidemiological studies based on food poisoning outbreaks, animal clinical trials, *in vitro* studies using cell lines, biomarkers or expert opinion. The logarithm number of micro-organisms ingested is plotted against the percentage of people that become affected to generate the dose response. Epidemiological data on clinical illness is also taken into account including the number of people normally affected in outbreaks, the profile of the population sickened (age, health status etc) and the severity of illness experienced (home recovery, hospitalisation, fatalities).

Risk Characterisation

In risk characterisation, the results of the exposure assessment and the hazard characterisation are combined, resulting in an estimate of the adverse health effect or risk to a population as a consequence of exposure to a particular

hazard. The risk characterisation is generally conducted using commercial software such as @Risk (Pallisade Corporation). The simulation calculation method is known as Monte Carlo. The error associated with overall risk prediction can be separated into uncertainty and variability.

The aim of this study was to conduct a national quantitative risk assessment on *E. coli* O157:H7 in minced beef and beefburgers in the Republic of Ireland. In the exposure assessment, a modular approach was employed with the chain broken in three main stages; 1) production of boxed beef trimmings, 2) processing of trimmings and burger formation and 3) retail/ domestic/ consumption phase. Key points in each module (beef hide, beef trimmings and beef products at retail) were microbiologically examined to determine the prevalence and concentration of the pathogen and used to validate the model. The exposure assessment was then linked to a hazard characterisation (dose-response) to generate the risk assessment model.

HAZARD IDENTIFICATION

Over the last 5 years (1999-2004), clinical cases of *E. coli* O157:H7 in Ireland have ranged from 1.7 to 2.1 cases per 100,000. The majority of these cases are sporadic and therefore difficult to relate to a source of infection. However, beef is considered to be one of the main vectors of the pathogen and so it is conceivable that this commodity is linked to some of the cases of *E. coli* O157:H7. For the purposes of this study, the hazard was identified as *E. coli* O157:H7 in Irish-produced beef.

EXPOSURE ASSESSMENT

The aim of the exposure assessment was to establish the prevalence and numbers of *E. coli* O157:H7 in a typical serving of Irish minced beef. The exposure assessment started with the animal presented for slaughter and followed through the chain to consumption. The chain was broken into three main modules; 1) the slaughter process, culminating in the production of

boxed beef trimmings, 2) beef processing and mince beef and burger formation and 3) the retail / domestic/ consumption phase. In order to validate the exposure assessment model, key points in each module (beef hide, beef trimmings and beef products at retail) were microbiologically examined to determine the prevalence and concentration of the pathogen.

The starting point for the exposure assessment and for microbiological sampling was the cattle hide which is considered to be one of the most important vectors of faecal contamination and, therefore, pathogens into the beef abattoir. Other sampling points in the abattoir included beef carcasses, head meat and beef trimmings (meat derived from boned-out carcasses). Following beef processing into mince or burgers, sampling efforts focused on the prevalence and numbers of the pathogen in beef at retail level. All samples were analysed using standard cultural protocols based on enrichment, immunomagnetic separation and plating onto Sorbitol McConkey agar with cefixime and tellurite (SMAC-CT agar) followed by the Polymerase Chain Reaction (PCR) and Pulse Field Gel Electrophoresis (PFGE) to genetically characterise the isolates. The results are summarised in Table 1 below.

Table 1. Prevalence and numbers of *E. coli* O157:H7 at various sample points along the beef chain in Ireland.

Sample type	Sample numbers	Number positive (%)	Numbers present
Bovine Hide	1500	109 (7.3)	Log_{10}0.13–4.24 cfu/100 cm^2
Beef Carcasses	132	4 (3.0)	Log_{10}0.70–1.41 cfu/g
Head Meat	100	3 (3.0)	Log_{10}0.70–1.00 cfu/g
Beef Trimmings	1351	32 (2.4)	Log_{10}0.70–1.61 cfu/g
Retail Minced Beef /burgers	1533	43 (2.8)	Log_{10}0.52–4.03 cfu/g

The virulence profiles varied between sample types. Among isolates from hide, 99/109 contained the attaching and effacing gene (*eae*A) and the haemolysin gene (*hly*A). 78/109 isolates had the flagellar H7 antigen encoding gene (*fli*C_{h7}). Only 6/109 isolates contained both verotoxin producing genes (*vt1*and *vt2*), 91/109 contained the *vt2* gene only while 1/109 contained the *vt1* gene only. The remaining 11/109 contained neither *vt1*nor *vt2*. All 4 beef carcass isolates contained the *eae*A, *hyl*A and *fli*C_{h7} genes. One isolate contained both the *vt1* and *vt2* genes, 2 contained the *vt1* gene only and 1 contained the *vt2* gene only. All 3 head meat isolates contained the *eae*A, *hyl*A, *fli*C_{h7} and *vt2* genes while none contained the *vt1* gene. On beef trimming, 31 of 32 isolates contained the *eae*A and *hyl*A genes, 30/32 contained the *fli*C_{h7} gene and 31/32 contained *vt1* or *vt2* or both *vt* genes. Of the 43 retail beef isolates, 41 possessed *vt*1 and *vt*2, *eae*A, *hly*A, *rfb* (pO157) and *fli*C_{h7}. The remaining 2/43 isolates contained only one of the *vt*1or *vt*2 genes together with all the other genes.

This generated data was used to validate the outcome for each of the three modules (production of boxed beef trimmings; processing of trimmings and burger formation; retail/ domestic/ consumption phase).

Consumer practices

One of the most difficult parts of the exposure assessment is the final phase of the chain, from the consumer purchase of beef at retail through its domestic storage and preparation. This part of the chain is obviously not regulated and it is difficult to conduct microbiological sampling or to predict the fate of the pathogen since exact storage and preparation methods are unknown and may be highly variable. In order to get an estimate of the fate of *E. coli* O157:H7 in this part of the beef chain in Ireland, a survey on consumer practices was conducted. The Market Research Bureau Ireland (MRBI) was commissioned to conduct a specially designed questionnaire (multiple-choice questions) which was administered by telephone survey to 500 people (covered gender, age and socio – economic diversity to beef consumers who were the main purchaser of beef in the household).

The following is a summary of the data generated on consumer habits regarding the purchase and preparation of beef mince. A high percentage of consumers (59%) purchased their beef early in their shopping trip and the majority of respondents (83%) did not use cooler bags for their chilled or frozen products. This practice may allow the temperature of the meat to rise sufficiently to allow any micro-organisms present to multiply. The majority of respondents (97%) returned home within two hours of shopping and refrigerated or froze the meat immediately. Approximately 44% of consumers stored their minced beef or burgers on a middle or high shelf in the fridge or uncovered, thus contributing to the risk of cross-contamination from meat drip to ready-to-eat foods on a lower shelf or from contact with adjacent food. The vast majority (96%) consumed fresh minced beef within two days of purchase and prior to the "best before date" thus limiting the period for growth of the pathogen in the meat.

With regard to the handling and preparation of food, the majority of respondents (58%) thawed their meat at room temperature and not in the refrigerator or microwave, thus potentially increasing the risk of pathogen growth on the outer surfaces of the meat which may reach room temperature quicker than its core.

The majority of consumers claimed to wash their hands (85%) and meat preparation surfaces and utensils (74%) after handling raw meat, which steps reduce the risk of cross-contamination onto other foods.

Practices used in handling or preparing minced beef differed significantly according to gender, age, education and socio-economic group. A significantly higher proportion of females (94%) cooked their burgers more thoroughly than males (67%). Younger people (18-34 years) were the least likely to check the 'use by' or 'best before' date on the packaging of beefburgers. Although differences were noted between food handling practices across gender and the different age groups, these differences were not statistically significant.

Consumption of beef in Ireland

Data on consumption of beef in Ireland was collated from the S.L.A.N. database (UCG) and the University Nutritional Alliance database (UCC). This database was established based on a nutritional survey conducted between 1997 and 1999 to provide up-to-date information on habitual food and drink consumption in Irish adults. The executive summary and the complete survey report are available at www.iuna.net.

The purpose of the analysis in this study was to estimate minced meat and beefburger intakes in the adult population as a whole, for men and women of different ages, taking into account seasonality and location of eating occasion. Emphasis was placed on describing the quantity of minced meat/burgers consumed on average per eating occasion and on intakes of minced meat and burgers in the food service sector, as this is relevant to the risk analysis.

The following is a summary of the data included in the Consumption data report.

Consumption of minced beef

Summary of consumption data for minced beef and burgers in 18-64 year old people in Ireland.

- 37% of the adult population consume minced beef in Ireland.
- With increasing age, there was a decrease in the proportion of mince consumers and a decrease in the average mince intake.
- A similar percentage of men (37.2%) and women (36.8%) were mince consumers.
- Among males, average mince intakes were lower in the over 50 age group than in younger men.
- The mean intake of mince per eating occasion was 88.5g.

- Younger adults reported more eating occasions that included mince than older adults.
- The mean intake of mince per eating occasion was highest in the 36-50 year age group (92.7g) and lowest among 50-64 year olds (81.8g).
- The mean intake of mince was higher in men (97.8g per meal) than in women (79.4g per meal) of all age groups.
- In men, 36-50 year olds had the highest consumption of mince per eating occasion although there were more mince consumers in the 18 to 30 year age group.
- Age had little effect on mince intakes in women. More women ate mince as part of a composite dish than men.
- There was very little difference in minced beef intake between winter (52%) and summer (48%) or in the mean intake of mince per meal between the two seasons (88.9g in winter and 88.0g in summer).
- The majority of mince-containing eating occasions were at home (86%) in all age groups.
- Mince intake was higher at home (93g per meal) than when eating out (55.7g per meal) and 18-35 year olds ate more mince-containing meals from the food service sector than the older adults.

Consumption of beefburgers

- Almost 28% percent of the adult population consumed beefburgers.
- With increasing age there was a marked decrease in the proportion of burger consumers.
- The average intake was 14.8g per day and intakes were similar across the age groups.

- 34% of men and 21.9% of women consume burgers with the highest rate of burger consumption reported among young men who also had the highest average intakes of burgers. Men consumed burgers about one and a half times more frequently than women.

- Mean intake of beefburgers was 70.8g per eating occasion and with increase in age, there was a sharp decrease in the number of eating occasions that included burgers.

- In men, with increasing age, there was an increase in the mean intake of burgers consumed in a dish per eating occasion, from 50g in 18-35 year olds to 64g in 50-64 year olds.

- There was no difference in the number of eating occasions that included beefburgers between winter and summer although the mean intake of burgers per eating occasion was higher in the summer (76g) than in the winter (65g) in all age groups.

- In winter, average burger intakes per eating occasion decreased with age while in summer they increased with age.

- Over 50% of all eating occasions that included burgers were consumed at home and the mean intake of burgers per eating occasion was highest when consumed at home (79g) compared with work (62g) and out (61g). In the food service sector, 65% of eating occasions that included burgers were at a takeaway. Almost a quarter (24%) of all eating occasions that included burgers were from takeaways. However, for takeaway burgers, the mean intake per eating occasion was higher in 51-64 year olds (69g).

HAZARD CHARACTERISATION

The number of cases of confirmed VTEC O157 and crude incidence rate in the Republic of Ireland between 1996 and 2002 (NDSC, 2003) is shown in Table 2.

Table 2 Number of cases of confirmed VTEC O157 and crude incidence rate in the Republic of Ireland, 1996-2003 (NDSC, 2003)

Year	Numbers of confirmed cases (number confirmed cases including non-residents)	Crude incidence rate per 100,000 population
1996	8	0.2
1997	31	0.8
1998	76	2.1
1999	51	1.4
2000	37(42)	0.9
2001	50 (52)	1.3
2002	68 (70)	1.7
2003	82 (86)	2.1

Most of these cases were sporadic, involving children between 1 and 4 years old. A number of suspect foods were reported by case but, as the majority of these were sporadic cases, it was not possible to epidemiologically link most of them to an infection source (NDSC, 2002).

The objective of this study was to estimate the probability of verocytotoxigenic *E. coli* infection resulting from a certain level of exposure. Human dose-response trials have not and may not be carried out with this highly pathogenic bacterium and so only estimates of the number of *E. coli* O157:H7 required to cause infection in humans are available. It was decided to use data available in the literature on infectious dose levels for humans infected with closely related bacteria - *Shigella dysenteriae* and Enteropathogenic *E. coli*. Enterpathogenic *E.coli* (EPEC) was chosen to represent the lower bound of an *E. coli* 0157:H7 dose-response function as has

been done in previous studies based on the assumption that *E. coli* 0157:H7 is unlikely to be less pathogenic than EPEC. *S. dysenteriae* was selected as an upper bound to the *E. coli* 0157:H7 dose-response function based on the assumption that *E. coli* 0157:H7 is unlikely to be more pathogenic than this invasive *Shigella*. Information on the number of illnesses attributed to beef in Ireland was deemed to be too small to derive any statistical significance. For this reason a model derived from USA data was used (Powell *et al.*, 2000).

The output of the dose-response model is an estimate of the number of people expected to fall ill for a given dose. The dose-response analysis was performed using a beta-poisson function. The dose-response model is given as:

$$p = 1 - (1 - D / \gamma_1)^{\gamma 2}$$

where p = probability of illness and D = dose of pathogen.

$$\gamma_1 = \frac{N_{50}}{(2^{\wedge}[1 - \gamma_2] - 1)}$$

N_{50} = dose necessary to cause illness to 50% of the exposed population.

The resulting dose-response model is given in Figure 1. The model predicts the average response for an administered dose given that organisms are randomly distributed in the medium. The function assumes that a single organism is capable of inciting illness in an individual. The output of the dose-response model is an estimate of the probability of human illness given a specific dose. The dose-response is combined with exposure predictions. Transposing the predicted exposure through the dose-response curve will result in an estimate of the number of people expected to become ill during a year as a result of a specific level of exposure.

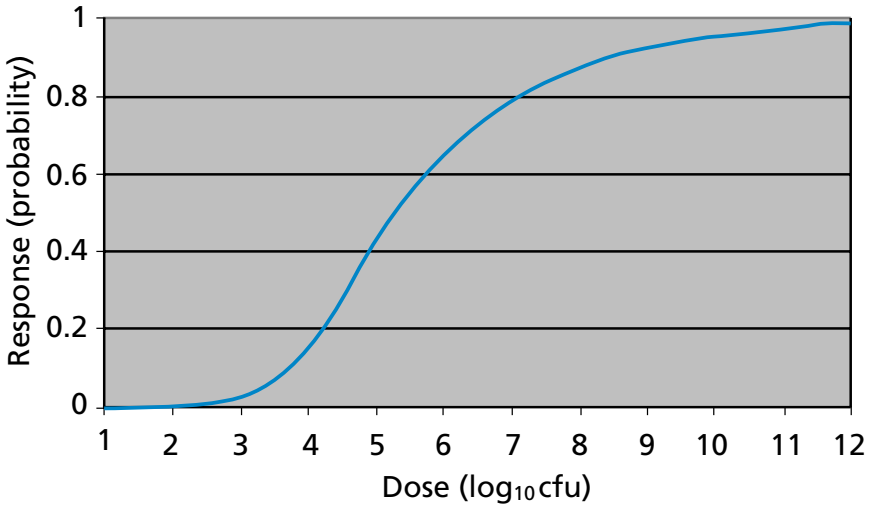

Figure 1: Dose-response model for *E. coli* O157:H7 (adopted from Powell *et al.*, 2000)

RISK CHARACTERISATION

A second order risk assessment model was completed for both the production of beef trimmings and the production of retail beefburgers. Bayesian analysis was used to reduce the uncertainty around the predicted risk estimate. This included incorporating the error associated with the microbiological methods (recovery rates are never 100% so the experimental count is an underestimation of the true number of micro-organisms present) used to generate the data for the model. The mean simulated prevalence of *E. coli* O157:H7 on beef trimmings was 2.51% (95th percentile range 0.95% - 5.1%). This is in good agreement with survey results as can be seen from Figure 2.

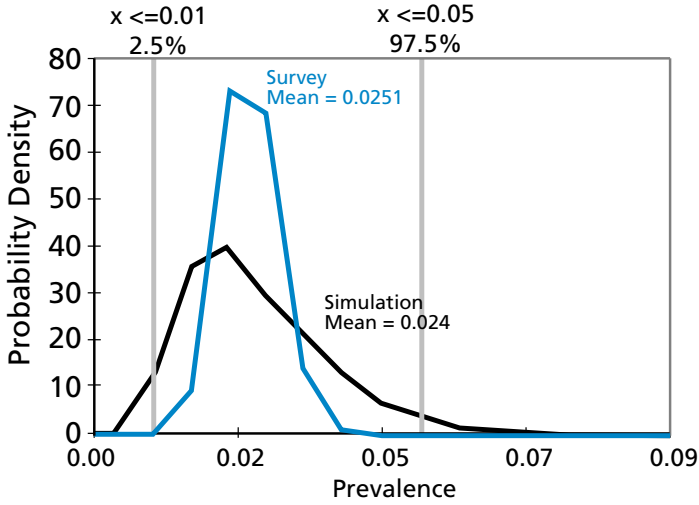

Figure 2: Model (simulation) results for the prevalence of *E. coli* O157:H7 in beef trimmings compared to microbiological survey results (including uncertainty analysis) for the prevalence of *E. coli* O157:H7 in beef trimmings

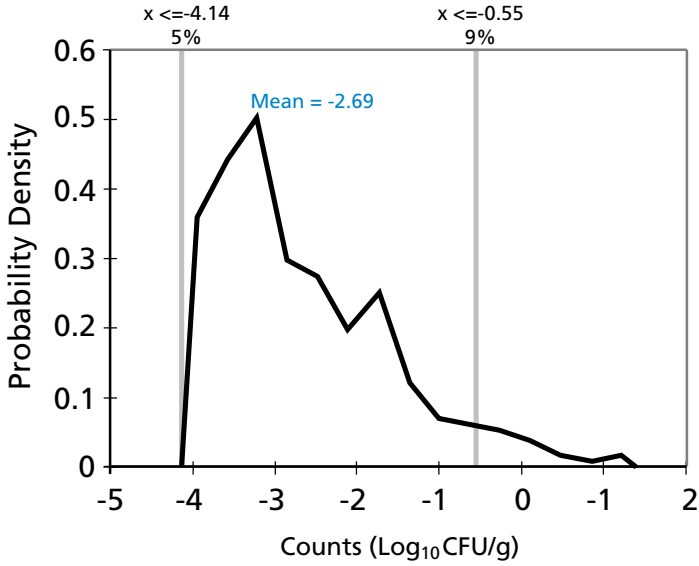

Figure 3: Predicted counts of *E. coli* O157:H7 in beef trimmings.

The simulated prevalence had a wider spread than the survey results indicating that uncertainties in the model remain. The simulated results indicate that many of the trimmings may have very low bacterial counts with 95th percentile -0.55 $\log_{10}$ cfu/g. This is supported by the fact that very few of the *E. coli* O157:H7 positive trim samples could be enumerated using direct plate techniques. Of the ones that were enumerated, the counts were between 0.05 - 0.65 $\log_{10}$ cfu/g, within the range indicated by the simulation model (Figure 3).

A sensitivity analysis revealed that parameters having a significant impact on model predictions included the hide-to-carcass transfer coefficient (0.199) and the initial hide prevalence (correlation coefficient 0.179).

Minced beef was modeled as coming from one or more 27.5 kg boxes of beef trimmings. Using data from a survey of *E. coli* O157:H7 levels on beef trimmings (Carney *et al.*, 2005), the probability of each trimming contributing to a batch of minced beef and the number of *E. coli* O157:H7 it contributes to the batch if contaminated was modeled.

From the time minced beef is produced until the time it is prepared and consumed, it is recommended that it be refrigerated or frozen. Experiments have shown that *E. coli* O157:H7 can grow at temperatures of 7.2°C or higher. Therefore, if temperature abuse of minced beef occurs during storage, *E. coli* O157:H7 growth can occur. A survey was conducted to determine mince storage practices in Ireland during retail sale, transport and home storage. The temperatures and times of mince storage were recorded.

The Gompertz growth equation was used to model the growth of *E. coli* O157:H7 in minced beef that suffered temperature abuse during retail sale, transport and home storage. The Gompertz equation predicts the amount of microbial growth that will occur for a given time at a specific temperature. The spreadsheet model combined the results of the survey of storage times and temperatures and the Gompertz growth equation in order to generate a distribution for the growth of *E. coli* O157:H7 likely to occur under typical handling conditions in Ireland.

The effect of freezing on *E. coli* O157:H7 numbers was modeled using a distribution that represented a decline in numbers of between 0 $\log_{10}$ cfu/g and 3 $\log_{10}$ cfu/g based on literature data. Using relevant distributions, the model was used to estimate the prevalence and counts of *E. coli* O157:H7 present in a 100 gram serving of fresh minced beef. The generated distribution for prevalence had a mean of 3.1% and a 90% confidence interval of 1.8% to 4.5%. This is in good agreement with a survey of fresh beef on retail sale that found 2.8% of samples were contaminated with *E. coli* O157:H7 (n=1533, 90% confidence interval of 2.2% to 3.5%; Cagney *et al.*, 2004). The spreadsheet model generated a distribution for the number of *E. coli* O157:H7 in a contaminated 100 gram serving that had a mean of 4.4 $\log_{10}$ cfu/serving with a 90% confidence interval of 0.78 to 7.54 $\log_{10}$ cfu/serving. This agrees well with the retail survey, which found *E. coli* O157:H7 numbers to be between 2.5 and 6.0 $\log_{10}$ cfu/serving (Cagney *et al.*, 2004).

Cooking practices in Irish homes were simulated by taking three cooking categories (well done, medium and rare as obtained from Task 3) and applying an inactivation model to simulate the effect of cooking on *E. coli* O157:H7 counts. An estimate of the prevalence and counts of *E. coli* O157:H7 post-cooking was obtained. These results were then transposed through the dose-response model to give an estimate of the probability of illness from a beefburger. The simulated mean probability of illness arising from consuming one burger was $10^{-5.94}$ *i.e.* approximately a one in one million chance of illness. The resulting distribution is given in Figure 4. It can be seen that the distribution is quite wide, highlighting the large uncertainty in the model. The results indicate the small risk of illness from consuming a beefburger.

While the structure of the simulation model has been completed, improvements of the input data are ongoing in an effort to reduce model uncertainty and reflect Irish producer and consumer practices as accurately as possible. This is an iterative process and will continue as new data becomes available.

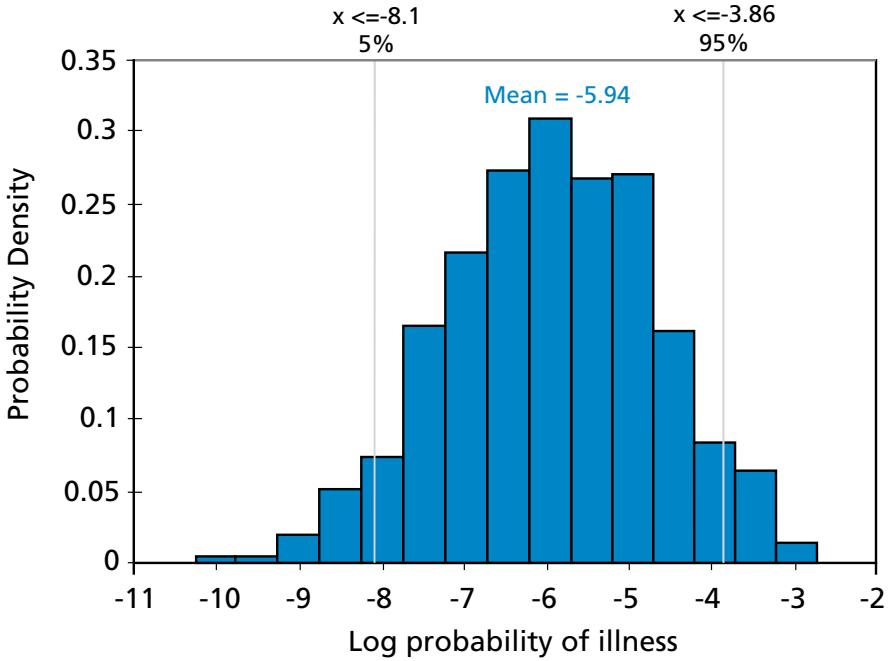

Figure 4: Probability of illness from a contaminated serving of fresh beefburger (mean = $10^{-5.94}$, approximately one in one million chance)

CONCLUSIONS AND RECOMMENDATIONS TO INDUSTRY

- The bovine hide is a significant source of contamination with *E. coli* O157:H7 and every effort must be made to reduce the level of visible faecal contamination on bovine hide and to limit cross contamination from hide to carcass during the slaughter process.

- While the prevalence of *E. coli* O157:H7 remains low throughout the beef chain (2.4 to 3%), the number of pathogens present on contaminated samples is highly variable and sporadic samples with extremely high numbers pose a particular risk to the consumer. Further research is needed to ascertain whether these high numbers are related to

a contamination incident with very high numbers or relate to a breakdown in the chill chain during the processing or distribution.

- The *E. coli* O157:H7 isolates recovered from retail beef in Ireland all possessed an array of virulence factors which would make them potentially pathogenic to humans indicating that beef is a possible vector of *E. coli* O157 infection for humans either directly as a result of eating undercooked beef or, more likely, from cross-contamination on to ready-to-eat foods (*e.g.* cooked meats, salads) in the retail or domestic environment, or from hand to mouth contact after handling raw beef.

The application of quantitative risk assessment to microbial foodborne pathogens is still a new and very dynamic field of research and advances in the area continue at a fast pace. It is an approach to food safety management which has now been adopted by major national and international agencies. New and better modeling techniques are now emerging both in terms of the models employed in exposure assessment to predict microbial growth / survival / and the models used in exposure assessments and risk characterisations. In particular, methods to separate error related to variability and uncertainty are continually improving. In a broader perspective, quantitative risk assessment has now and will continue to have better linkages with other management systems including HACCP, Economic Cost Benefit Analysis, Appropriate Level of Public Health Protection (ALOP) and Food Safety Objectives. With this multi-disciplinary approach food safety will in the future be managed more strategically, leading to overall improvements in public health protection from microbial food contaminants.

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