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A risk microbiological profile of the Australian red meat industry: Risk ratings of hazard–product pairings

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Abstract

A risk profile of microbial hazards across the supply continuum for the beef, sheep and goat meat industries was developed using both a qualitative tool and a semi-quantitative, spreadsheet tool, Risk Ranger. The latter is useful for highlighting factors contributing to food safety risk and for ranking the risk of various product/pathogen combinations. In the present profile the qualitative tool was used as a preliminary screen for a wide range of hazard–product pairings while Risk Ranger was used to rank in order of population health risk pairings for which quantitative data were available and for assessing the effect of hypothetical scenarios. 'High' risk hazard–product pairings identified were meals contaminated with *Clostridium perfringens* provided by caterers which have not implemented HACCP; kebabs cross-contaminated by *Salmonella* present in drip trays or served undercooked; meals served in the home cross-contaminated with *Salmonella*. 'Medium' risk hazard–product pairings identified were ready-to-eat meats contaminated with *Listeria monocytogenes* and which have extended shelf life; Uncooked Comminuted Fermented Meat (UCFM)/Salami contaminated with Enterohaemorrhagic *E. coli* (EHEC) and *Salmonella*; undercooked hamburgers contaminated with EHEC; kebabs contaminated by *Salmonella* under normal production or following final "flash" heating. Identified 'low' risk hazard–product pairings included cooked, ready-to-eat sausages contaminated with *Salmonella*; UCFM/Salami contaminated with *L. monocytogenes*; well-cooked hamburgers contaminated with EHEC. The risk profile provides information of value to Australia's risk managers in the regulatory, processing and R&D sectors of the meat and meat processing industry for the purposes of identifying food safety risks in the industry and for prioritising risk management actions.

Keywords: Meat industry; Risk profile; Qualitative and semi-quantitative risk ratings; "What-if" scenarios

1. Introduction

A risk profile of the Australian meat and meat products was commissioned to provide industry with risk ratings of hazard–meat and meat product combi-

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nations. The measure of risk used was the relative annual risk to the Australian population from the consumption of the specific food type, including comparison of the effects of various hypothetical scenarios. The profile was intended as a prelude to progressing to further risk assessments of identified hazard–product combinations and to advise on research and development priorities for the industry. Details of the risk profile approach and results of the hazard identification have been provided by Pointon et al. (in press) and Sumner et al. (2005), respectively.

Results of the hazard identification and data collation on the levels of contamination across the production sectors indicated there was sufficient evidence to support the risk rating of a range of microbiological hazard–product combinations which included:

- Meals provided by caterers (in association with *Clostridium perfringens*)
- Well-cooked and undercooked hamburgers (Enterohaemorrhagic *E. coli*—EHEC)
- Uncooked Comminuted Fermented Meats (EHEC and *Salmonella*)
- Ready-to-eat meats with extended shelf life, Uncooked Comminuted Fermented Meat (UCFM) and terrines (*Listeria monocytogenes*)
- Cross-contaminated meals served in home and cooked sausages (*Salmonella*)
- Kebabs contaminated with *Salmonella*

This report provides results of risk ratings obtained by qualitative and semi-quantitative approaches for the above hazard–product pairings and includes the effect of certain risk mitigation strategies.

2. Methodology

The risk profiling exercise was undertaken in two stages:

2.1. Qualitative Risk Ratings

A qualitative approach for the rating of risk developed by the International Commission on Microbiological Specifications of Foods (ICMSF, 2002) and M. Cole (personal communication and FSA, 2000) was used for a preliminary screen for meat and meat product categories using information on identified hazards. Risks associated with hazard–product combinations were rated according to this approach, including those where there were insufficient data to use a semi-quantitative approach. A risk rating of low, medium or high was assigned according to the criteria listed below.

Severity: The severity of the identified hazards was classified according to the International Commission of the Microbiological Specifications of Food (ICMSF, 2002) with level of severity defined as follows:

IA. Severe hazard for general population, life threatening or substantial chronic sequelae or long duration.
IB. Severe hazard for restricted populations, life threatening or substantial chronic sequelae or long duration.
II. High hazard; incapacitating but not life threatening; sequelae rare; moderate duration.
III. Moderate, not usually life threatening; no sequelae; normally short duration; symptoms are self-limiting; can be severe discomfort.

Occurrence risk: Occurrence risk is classified as low, medium or high for the recognised hazards. The occurrence risk rating was taken from the public health record though the paucity of adequate epidemiological information attributing outbreaks to specific food sources is acknowledged. There is also an apparent under-reporting of outbreaks that are caused by less virulent foodborne hazards.

Growth: An indication of whether growth of the pathogen in the product is required to cause disease is given. In general, microbiological hazards need to grow in the product or be present at high numbers before there is a significant risk of disease. However, for some hazards such as enterohaemorrhagic *E. coli* (EHEC), infection has followed exposure to less than 50 cells (Tilden et al., 1996).

Production, processing or handling of food: The production, processing or handling of the food may increase, decrease or not affect the hazard. For example, most processed meats undergo a thermal process which reduces levels of *L. monocytogenes* but the organism may subsequently grow during storage.

Consumer terminal step: Is a consumer terminal step, such as cooking, applied to the product? Cooking by the consumer will, for most biological hazards, reduce the subsequent risk of disease.

Epidemiology: Is the hazard–product combination recorded as a cause of food poisoning?

Comments: Are there any other contributing factors that may affect the risk rating of the hazard–product combination, e.g. undercooking of hamburger meat, cross-contamination, temperature abuse, etc.

Derivation of Qualitative Risk Ratings: Expert opinion was used to consider the severity and factors determining exposure.

2.2. Semi-quantitative risk ratings and mitigations

Where data were available, a semi-quantitative, spreadsheet software format, Risk Ranger (Version 2), was used to generate risk ratings and also to evaluate the consequences of a number of risk mitigations. Version 1 of the software has been published (Ross and Sumner, 2002) and the logic behind the system, as well as its limitations, explained. The software embodies established principles of food safety risk assessment, i.e. the combination of probability of exposure to a foodborne hazard, the magnitude of hazard in a food when present, and the probability and severity of outcomes that might arise from that level and frequency of exposure. The tool requires the user to select from qualitative statements and/or to provide quantitative data concerning factors that will affect the food safety risk for a specific population, from a specific food product and specific hazard, during the steps from harvest to consumption. The spreadsheet converts the qualitative inputs into numerical values and combines them with the quantitative inputs in a series of mathematical and logical steps using standard spreadsheet functions. Risk ratings were prepared for hazard–product pairings on a scale of 0–100 where zero represents no risk and 100 represents every member of the population eating a meal which contains a lethal dose of the hazard every day. The scale is logarithmic and is such that an increment of six in the ranking corresponds approximately to a 10-fold increase in risk.

Version 2 of Risk Ranger is modified from the original described in the above publication by reducing the "weight" given to "Moderate", "Mild" and "Minor" hazard severity classifications (Question 1) by a factor of 10. This preserves the risk rank scaling (0–100) and its original interpretation but better reflects the severity of fatal disease compared with non-life threatening hazards. Question 3 is also slightly modified to enable better discrimination of serving frequency. Risk Ranger V. 2 can be downloaded from http://www.foodsafetycentre.com.au/riskranger.htm.

The software is useful for teaching the principles of risk assessment in relation to food safety, in highlighting factors contributing to food safety risk and in ranking the risk of various product/pathogen combinations. As with any such software, however, the outputs are only as reliable as the data entered and users should remain aware of the intended uses and limitations of the software.

3. Results

3.1. Risk ratings

Information on prevalence of pathogens in raw meats was available from national baseline surveys of beef (Vanderlinde et al., 1998; Phillips et al., 2001a) and sheep meat (Vanderlinde et al., 1999; Phillips et al., 2001b). Consumption data were available from national surveys (ABS, 1999) and data on prevalence of *L. monocytogenes* in processed meats were gathered as part of a quantitative risk assessment on *L. monocytogenes* in smallgoods (Ross et al., 2004). Using the qualitative risk rating tool, a wide range of hazard–product pairings were screened and, for a number of pairings, semi-quantitative risk ratings (0–100) were also obtained (Table 1).

For entire red meat cuts (steaks, chops, roasts), because the site of microbiological concern is external, a terminal cooking step is sufficient to eliminate pathogens with a resulting 'Low' rating. For comminuted raw meat products which are consumed after cooking, e.g. hamburgers in which Enterohaemorrhagic *E. coli* (EHEC) was the hazard, the risk rating was zero, based on the Australian custom not to undercook hamburgers. By contrast, when *L. monocytogenes* was the hazard in fresh sausages, the risk rating was 11 ('Low') based on the possibility that some cells could survive at the centre if the sausage was undercooked. For *Salmonella* in kebabs undercooking was also considered possible, with a risk rating of 40 ('Medium' risk).

Risk rating for processed meats when *L. monocytogenes* was the hazard are presented in Table 2. Ratings

Table 1
Microbiological hazard risk rating for meat and meat products in Australia

Product[a]	Identified hazard	Risk rating	
		Qualitative	Risk Ranger[a]
Red meat entire cuts (steaks, chops, etc.)	*L. monocytogenes*	Low	Not done
	S. aureus	Low	Not done
	Aeromonas	Low	Not done
	M. paratuberculosis	Low	Not done
	Bacillus	Low	Not done
	Yersinia enterolytica	Low	Not done
	EHEC	Low	Not done
Processed meats			
Cured, cooked sausages, not requiring further cooking	*L. monocytogenes*	Low	25 (Low)
	S. aureus	Low	Not done
Uncooked fermented meats	*L. monocytogenes*	Low	12 (Low)
	Salmonella	Medium	33 (Medium)
	EHEC	Medium	33 (Medium)
Sous-vide	*C. botulinum*	Low	Not done
	L. monocytogenes	Low	Not done
Beef jerky	*Aflatoxin*	Low	Not done
Deli meats	*L. monocytogenes*	Medium	36 (Medium)
Terrines	*L. monocytogenes*	Medium	32 (Medium)
Meat products eaten cooked			
Fresh sausages	*L. monocytogenes*	Low	11 (Low)
Hamburgers	EHEC	Low	0
Kebabs	*Salmonella*	Medium	40 (Medium)

[a] Arbitrary aggregation of Risk Ranger ratings are: "Low" (25 or less), "Medium" (26–40), "High" (>40). Note that a change in risk rating of "6" is equivalent to an order of magnitude change in relative risk as defined in Ross and Sumner (2002).

were 'Low' for all hazard–product pairings except for deli meats and pates/terrines. Risk ratings for *L. monocytogenes* in cured, cooked sliced/shaved meats such as ham was 36 and for pate and terrines, 32. In both cases the 'Medium' risk rating stemmed from the likelihood of post-process contamination at production of 1% (Ross et al., 2004) coupled with a long shelf-life (up to 8 weeks) in the distribution/retail/consumer chain. The risk rating for *L. monocytogenes* in cured cooked sausages intended for consumption without further cooking (e.g. Strasburg) was 25 ('Low') reflecting the mandatory 5-D process required for *L. monocytogenes* under the Australia New Zealand Food Standards Code (FSANZ, 2004). For uncooked comminuted fermented meat (UCFM) the risk rating was 12.

No hazard–product pairings were rated 'High' using either the qualitative framework or the semi-quantitative Risk Ranger. It should be noted that estimates were based on an ID_{50} of $\sim 10^{12}$ CFU for the non-susceptible population, consistent with estimates recently presented by WHO/FAO (2004).

3.2. Risk ratings of "what-if" scenarios

Risk management stakeholders requested the development of scenarios to assess the effect of process or regulatory interventions current in Australia, posing the question: "where risk rating is low, is this because the product is inherently safe, or because of controls in the process/regulation?"

Table 2
Risk ranking summary for *L. monocytogenes* in processed meat products in Australia

	Cooked sausages	Salami	Deli meats	Pate/terrines	Fresh sausage
1. Hazard severity	Moderate	Moderate	Moderate	Moderate	Moderate
2. Population susceptibility	General	General	General	General	General
3. Frequency of consumption	Weekly	Weekly	Weekly	Monthly	Weekly
4. Proportion consuming (%)	75	25	100	25	75
5. Total population	19.7 million	19.7 million	19.7 million	19.7 million	19.7 million
6. Proportion of raw product contaminated (%)	10%	10%	10%	10%	10%
7. Effect of processing on hazard	100% reduction	99% reduction	100% reduction	100% reduction	No effect
8. Post processing contamination rate (%)	15	12	9	10.5	5
9. Post processing control	1000× increase	No increase	1000× increase	1000× increase	3× increase
10. Increase required to cause infection/intoxication	5×10^{10}	5×10^{10}	5×10^{10}	5×10^{10}	5×10^{10}
11. Effects of preparation before eating on hazard	99% reduction	No effect	No effect	No effect	99% reduction
Predicted cases per annum	0.04	0.0003	5	0.7	0.0001
Risk Ranking	25	12	36	32	11

3.2.1. Scenario 1: The effect of food safety plans on C. perfringens in the food service home sectors

Traditionally, this organism is believed to be the major cause of food poisoning in this food industry sector, albeit that the symptoms are mild for the general community. Illness usually follows slow cooling of cooked foods such as stews, gravies, and prepared meals through the "Danger Zone" (5–60 °C) and especially time in the range 43–47 °C when generation times can be <10 min (ICMSF, 1996). In Australia, cooling regimes are specified both in the Australian Standard for the Hygienic Production and transportation of Meat and Meat Products for Human Consumption (AS 4696:2002) and in Standard 3.2.2 of the Australian New Zealand Food Standards Code. In the former a 3-stage cooling regime for non-cured meats stipulates 50 °C within 2.5 h of completion of cooking, 50–12 °C within a further 6 h and 12–5 °C within a further 1.5 h. In the Food Standards Code, a 2-stage regime stipulates 60–21 °C within 2 h of completion of cooking followed by 21–5 °C within a further 4 h.

However, in the food service sector, not all jurisdictions in Australia have mandated the installation of a food safety plan which is necessary for safe cooling regimes. Accordingly, three scenarios were followed:

- Home chilling, where refrigeration capacity was in equilibrium with quantities requiring cooling
- Chilling in the food service sector without a food safety plan
- Institutional catering for the aged, a sector in which food safety plans have been either mandated or strongly recommended.

For each scenario, the risk rating and estimated annual illnesses in the population under consideration is presented in Table 3. In the home it was assumed, firstly, that relatively small volumes of food could be cooled effectively using the home refrigerator and, secondly, that food would be served promptly, negating the effect of abuse in a hot holding phase. For this scenario the risk rating was 46 and 2300 annual illnesses were predicted. In the food service sector it was assumed that food safety plans have not yet been implemented and that temperature abuse could occur either during cooling or during hot holding. In this scenario the risk rating was 54 and 59,000 annual illnesses are predicted. In institutional catering for the aged the risk rating was 40 and 250 annual cases were predicted, based on the assumption that effective food safety plans have been introduced to this sector.

3.2.2. Scenario 2: Enterohaemorrhagic E. coli in hamburgers

It is estimated that around 600 million hamburgers (100 g serving size) are consumed each year in Australia, equivalent to Most (75%) Australians consuming on a Weekly basis. In USA, around 300,000 t of Australian beef trim is consumed in hamburgers each year (3 billion servings of 100 g), which may be

Table 3
Risk ranking summary *C. perfringens* contamination of ready-to-eat meals in Australia

	General population	Caterers without HACCP	Aged, HACCP catering
1. Hazard severity	Mild	Mild	Mild
2. Population susceptibility	General	General	Slightly susceptible
3. Frequency of consumption	Weekly	Few times a year	Weekly
4. Proportion consuming (%)	Most	All	25
5. Total population	19.7 million	19.7 million	2 million within Australian population
6. Proportion of raw product contaminated (%)	10% (1/g, 100/serve)	10% (1/g, 100/serve)	10% (1/g, 100/serve)
7. Effect of processing on hazard	No effect on spores	No effect on spores	No effect on spores
8. Post processing contamination rate (%)	Nil	Nil	Nil
9. Post processing control	10× increase	1000× increase	No increase
10. Increase required to cause infection/intoxication	100,000×	100,000×	100,000×
11. Effects of preparation before eating on hazard	No effect	No effect	No effect
Predicted cases per annum	2300	59,000	250
Risk Ranking	46	54	40

equated with Everyone eating the product Monthly. In fact, Australian frozen beef trim is routinely blended with USA chilled trim and it is unlikely that "Australian" hamburgers per se are eaten in the USA. Nonetheless, for the purposes of the present exercise, the relative risk was estimated as if hamburgers comprising exclusively Australian beef were eaten.

It is believed that while all hamburgers produced commercially in Australia are fully cooked, some cooked at home may be undercooked. A scenario was developed where 20% of hamburgers were consumed undercooked, with a 90% reduction of the hazard. In Australia, the quantum of undercooked hamburgers would be 120 million (20% of 600 million), equating with every Australian consuming an undercooked hamburger a few times per year. In the USA, if 20% of hamburgers were undercooked, the quantum consumed would be 600 million, equivalent to 'Most' (75%) eating a 'Few times a year'.

Based on Australian studies on beef and sheep meats (Vanderlinde et al., 1998, 1999; Phillips et al., 2001a,b) the prevalence of EHEC in raw meats was assumed to be 0.1%. More recently, information on prevalence on beef carcases and trim over the period 1998–2002 was gathered as part of a submission to the United States Department of Agriculture (USDA), Food Safety Inspection Service (FSIS). EHEC was detected in 32/185,000 (0.01%) samples.

In Australia, as elsewhere, there are no data available on concentration of EHEC in raw materials used in UCFM manufacture. Thus, throughout this study assumptions were made based on material accumulated during the FAO/WHO risk assessment on *L. monocytogenes* in ready-to-eat foods (WHO/FAO, 2004). While some risk assessments (Bemrah et al., 1999; CFSAN/FSIS, 2003) have noted that pathogens are probably heterogeneously distributed in some foods, all to date have assumed that pathogens present in foods are distributed homogenously. This is clearly a simplification. A consequence of the assumption of homogeneity is that prevalence and concentration of pathogens in foods are often considered to be related properties particularly at very low concentrations. The observed prevalence will depend on the sample size and the extent of contamination of the batch. If the batch is contaminated at a level of >1 cfu/g, there is high probability that, in each 25 g sample, the pathogen of concern would be detected. If, however, the sample size were only 1 g, some samples would not contain cells of the pathogen. If the contamination level were 1/100 g, we would expect only one in four 25 g samples to "test positive", and it is then more usual to describe this concentration as "25% prevalence". In fact, the distribution of bacteria in a sample is likely to follow a Poisson distribution. In that case, if the mean concentration is X per gram, and there are Y grams per sample the count per sample is Poisson distributed with mean $X*Y$. More importantly, the probability of a positive result for a sample of Y grams is then: $1-\exp(-X*Y)$. Thus, for large amounts of product, prevalence and concentration are related and the estimate of the prevalence depends on the level of contamination and the sample size.

Similarly, products that permit the growth of pathogens may exhibit a low prevalence of contamination at the point of production and an apparently higher prevalence at the point of consumption. This is not necessarily due to re-contamination but may arise because the product was initially contaminated at a very low level. Subsequent growth in the product increases the probability of detection of that contamination. Accordingly, in the present hazard–product profile, the concentration of EHEC was assumed to be 0.1/g (equivalent to 10/serve).

In Table 4 are presented risk ratings and estimated illnesses from EHEC in Australia and USA from consumption of undercooked hamburgers made from Australian beef. In Australia, undercooked hamburgers are most unlikely to be prepared in the commercial sector, though they are possible in home cooking. The risk rating was 36 ('Medium' risk) with six EHEC illnesses predicted per annum if undercooking led to elimination of 90% of the hazard; the analogous prediction for consumption in USA risk rating was 36 with 61 predicted illnesses per annum.

3.2.3. Scenario 3: Enterohaemorrhagic *E. coli* in salami

Globally, there have been at least three outbreaks of illness from EHEC in salamis. In the USA in 1994, salami was recalled because of *E. coli* O157:H7 contamination (Tilden et al., 1996). In Australia in 1995, *E. coli* O111 in Mettwurst was implicated; there were around 150 illnesses of which more than 20 progressed to Haemolytic Uraemic Syndrome (HUS)

Table 4
Risk Rating summary EHEC contamination in undercooked hamburgers in Australia and USA

	Australia	USA
1. Hazard severity	Moderate	Moderate
2. Population susceptibility	General	General
3. Frequency of consumption	Few times a year	Few times a year
4. Proportion consuming (%)	Everyone	Most (75%)
5. Total population	19.7 million	270 million
6. Proportion (%) of raw product contaminated (concentration)	0.01% (0.1/g, 10/serve)	0.01% (0.1/g, 10/serve)
7. Effect of processing on hazard	No effect	No effect
8. Post processing contamination rate (%)	Nil	Nil
9. Post processing control	No increase	No increase
10. Increase required to cause infection/ intoxication	100×	100×
11. Effects of preparation before eating on hazard	90% reduction	90% reduction
Predicted cases per annum	6	61
Risk Rating	36	36

and one child died (Cameron et al., 1995). In Canada, illness was associated with consumption of Genoa salami contaminated with *E. coli* O157:H7 (Wiliams et al., 2000).

In the present scenario, based on the work of Ross and Shadbolt (2001) on inactivation of *E. coli* during fermentation and maturation of salami, a reduction in EHEC during the process by 2 log (99%) was assumed. Two concentrations of EHEC were modelled, 0.1/g and 10/g (equivalent to 10 and 1000/serve, respectively) as examples of “possible” concentration (0.1/g) and a “slug” of raw meat with higher concentration (10/g), respectively. If a 2-log reduction during manufacture occurs EHEC is reduced to 0.001/g (0.1/serve) and 0.1/g (10/serve). Since the very young and very old appear most susceptible to EHEC, its effect on very susceptible populations was also estimated.

As indicated in Table 5, Risk Ranger predicted one illness per annum (Risk rating = 33) both in the general population and in the very susceptible segment from consumption of salami provided that the prevalence and concentration of EHEC in the raw material were low. If product containing 10 EHEC/serve is consumed by very susceptible individuals the annual risk rating rises to 44 and 114 annual illnesses are predicted. For the present rating process, an infectious dose of 1000 was chosen for healthy individuals which approximates with that of 2000 used by Cassin et al. (1998).

3.2.4. Scenario 4: Salmonellosis from cross-contamination in the home

Meat prepared and eaten in the home is thought to pose little risk of salmonellosis because the site of microbiological concern is at the surface, which is thoroughly cooked. However, there is the possibility of cross-contamination to other, ready-to-eat items. In the present profile, the effect of cross-contamination from raw to cooked meats was modelled by

Table 5
Risk rating summary EHEC in salami consumed by the general and very susceptible populations in Australia

	General	Very susceptible	Very susceptible
1. Hazard severity	Moderate	Moderate	Moderate
2. Population susceptibility	General	Very susceptible	Very susceptible
3. Frequency of consumption	Weekly	Weekly	Weekly
4. Proportion consuming (%)	Some (25%)	Some (25%)	Some (25%)
5. Total population	19.7 million	19.7 million	19.7 million
6. Proportion (%) of raw product contaminated (concentration)	0.01% (0.1/g, 10/serve)	0.01% (0.1/g, 10/serve)	0.01% (10/g, 1000/serve)
7. Effect of processing on hazard	99% reduction	99% reduction	99% reduction
8. Post processing contamination rate (%)	Nil	Nil	Nil
9. Post processing control	Not relevant	Not relevant	Not relevant
10. Increase required to cause infection/intoxication	100	100	None
11. Effects of preparation before eating on hazard	50% reduction	50% reduction	50% reduction
Predicted cases per annum	1	1	114
Risk Rating	33	33	44

assuming various levels of undercooking at Question 11 in Risk Ranger. The present study used an ID_{50} for salmonellosis of 10,000 consistent with FAO/WHO (2001).

In Table 6, three levels of cross-contamination are simulated using undercooking rates of 1%, 10% and 50%, for which the Risk rating was 48, 54 and 58, respectively, with predicted annual salmonelloses of 5300, 53,000 and 267,000, respectively. Modelling cross-contamination in the home is extremely difficult; the present model is highly speculative and is undertaken merely to gain some idea of the possible scale of the consequences of that scenario.

3.2.5. Scenario 5: Salmonellosis from consumption of kebabs

Kebabs are a traditional Middle Eastern meat dish made by stacking layers of meat such as chicken, beef and lamb, which have been seasoned, marinated and sliced or minced, onto a vertical skewer to form a cone or cylinder shape. As the skewer rotates in front of a heat source, the outer layer of meat is cooked. The meat is then sliced and served in flat bread together with salads and dips.

Beneath the circulating kebab is a drip tray which catches fat, juices and slices of meat which fall inadvertently during carving. It has been suggested that juices in the tray have a temperature favourable for growth of *Salmonella* and that meat falling into the tray may receive a significant loading of the pathogen. It is also suspected that when demand is high, undercooked product may be served.

In Australia, there are anecdotal linkages between salmonellosis and kebab consumption and two scenarios were explored: firstly, the effect of cross-contamination when pieces of meat fall in the drip tray and, secondly, decontamination of contaminated pieces by rapid heating immediately prior to serving.

As can be seen from Table 7 “normal” production of kebabs has a risk rating of 40 (‘Medium’ risk) and is predicted to cause 250 salmonelloses per annum. However, if it is assumed that every serve of meat is cross-contaminated in the drip tray the risk rating rises to 58 (‘High’ risk) and 254,000 cases are predicted. Finishing pieces of meat by brief heating immediately before serving reverses the effect of contamination in the drip tray or serving undercooked product. Again, the inputs to this model are extremely speculative and are intended only to gain some insight into the possible effects of such contamination.

Based on the foregoing, the following product:hazard combinations were identified as:

‘High’ risk
- Meals contaminated with *C. perfringens* provided by institutional caterers who have not implemented an effective HACCP plan
- Kebabs cross-contaminated by *Salmonella* present in drip trays or served undercooked

Table 6
Risk rating summary *Salmonella* in meats prepared in the home by the general populations in Australia

	General	General	General
1. Hazard severity	Mild	Mild	Mild
2. Population susceptibility	General	General	General
3. Frequency of consumption	Daily	Daily	Daily
4. Proportion consuming (%)	Most (75%)	Most (75%)	Most (75%)
5. Total population	19.7 million	19.7 million	19.7 million
6. Proportion (%) of raw product contaminated (concentration)	1% (1/g, 100/serve)	1% (1/g, 100/serve)	1% (1/g, 100/serve)
7. Effect of processing on hazard	No effect	No effect	No effect
8. Post processing contamination rate (%)	Nil	Nil	Nil
9. Post processing control	No increase	No increase	No increase
10. Increase required to cause infection/intoxication	100	100	100
11. Effects of preparation before eating on hazard[a]	99% reduction	90% reduction	50% reduction
Predicted cases per annum	5300	53,000	267,000
Risk Rating	48	54	58

[a] The effect of cross-contamination from raw to cooked meats was modelled by assuming various levels of undercooking at Question 11 as a surrogate.

Table 7
Risk Rating summary *Salmonella* in kebabs consumed by the general populations in Australia

	"Normal" production	Contaminated in drip tray	"Finished" by flash heating
1. Hazard severity	Mild	Mild	Mild
2. Population susceptibility	General	General	General
3. Frequency of consumption	Weekly	Weekly	Weekly
4. Proportion consuming (%)	Some (25%)	Some (25%)	Some (25%)
5. Total population	19.7 million	19.7 million	19.7 million
6. Proportion (%) of raw product contaminated (concentration)	1% (1/g, 100/serve)	1% (1/g, 100/serve)	1% (1/g, 100/serve)
7. Effect of processing on hazard	99% reduction	99% reduction	99% reduction
8. Post processing contamination rate (%)	Nil	1%	1%
9. Post processing control	Not relevant	Not relevant	Not relevant
10. Increase required to cause infection/intoxication	100	10	10
11. Effects of preparation before eating on hazard	No effect	No effect	99% reduction
Predicted cases per annum	250	254,000	250
Risk Rating	40	58	40

- Meals served in the home cross-contaminated with *Salmonella*

'Medium' risk

- Ready-to-eat meats contaminated with *L. monocytogenes* and which have extended shelf life
- Terrines contaminated with *L. monocytogenes*
- Uncooked Comminuted Fermented Meat (UCFM)/ Salami contaminated with Enterohaemorrhagic *E. coli* (EHEC) or *Salmonella*
- Undercooked hamburgers contaminated with EHEC
- Kebabs contaminated by *Salmonella* under normal production or following final "flash" heating

'Low' risk

- Cooked sausages contaminated with *Salmonella*
- UCFM/Salami contaminated with *L. monocytogenes*
- Well-cooked hamburgers contaminated with EHEC

Thus, in answer to the question posed by risk managers: "where risk rating is low, is this because the product is inherently safe, or because of controls in the process/regulation?" it was concluded that none of the products considered is inherently safe and that regulatory and process controls are responsible for low risk ratings.

4. Discussion

While the risk rating by the qualitative method relies on a relatively subjective classification of 'Low', 'Medium' and 'High', there was general agreement with the risk ratings provided by Risk Ranger. Despite its limitations, Risk Ranger provides a more objective method for prioritising risks and is supplemented by the capacity to assess comparative risk where useful data are available.

In all risk rating exercises it is advisable to subject risk outputs to a "reality check" by comparing them with epidemiological data, where such data exist. In the case of *C. perfringens*, since no epidemiological data are available, no reality check can be made of Risk Ranger outputs, though predictions of almost 60,000 illnesses in the catering sector may be instructive, especially considering the high proportion of outbreaks involving this organism reported in the period 1991–2002 (Sumner et al., 2005).

Around 7000 salmonelloses are notified annually in Australia from all sources (food, water, contact with animals, etc.). The level of under reporting for *Salmonella* has been estimated by Mead et al. (1999) in United States of America as 38 and by Wheeler et al. (1999) as 3.2 in the United Kingdom, which on the basis of reported cases equates with around 250,000 and 22,000 Australian cases per annum, respectively. Risk Ranger predicts very few illnesses where meats are properly cooked and handled in the home. However, if cross-contamination is modelled (i.e. 50% of contamination on raw product causes illness) as a major cause of salmonellosis (as it is assumed to be for campylobacteriosis) there may be up to 267,000 cases/annum. When compared with the estimated Australian cases per annum this prediction indicates cross-contamination is likely to occur at a considerably lower rate (Table 6).

Kebabs have been implicated in outbreaks of salmonellosis and they may also be responsible for sporadic cases. When the practice of taking meat which may have been contaminated in the drip tray is modelled, 254,000 cases are predicted assuming that all kebab meat is handled in this same way.

In total, then, should cross-contamination be an important factor in the preparation of meats at home and in some food service sectors, there could be around 250,000 annual cases, equal to that of the estimated 250,000 salmonelloses. Since there are no data on cross-contamination of red meats this comparison with epidemiological data must be considered speculative. However, Mitakakis et al. (2004), in a survey of food handling in homes in Melbourne, Australia, found that significant proportions of respondents handled foods in a way which could place them at considerable risk of food-borne illness. For example, 47% of respondents did not wash hands correctly, while 41% mishandled raw foods, 70% did not clean contact surfaces correctly and 70% mishandled cooked foods.

OzFoodNet data for 1999–2002 (Anonymous, 2002, 2003) indicate there are around 40 annual cases of illness from EHEC from all sources. Hamburgers and UCFM have been associated with illnesses caused by EHEC. In Australia, undercooked hamburgers are most unlikely to be prepared in the commercial sector, though they are possible in home barbecuing where Risk Ranger predicted six illnesses per annum if undercooking led to elimination of only 90% of the hazard.

Since a 1995 EHEC outbreak in Australia involving Mettwurst (Cameron et al., 1995), the commercial fermentation processes in Australia have been improved and rationalised, with a narrower range of fermented products being manufactured, a significant proportion of which are cooked or heat-treated. Risk Ranger predicts one illness per annum from consumption of UCFM provided that the prevalence and concentration of EHEC in the raw material is low. Were this not to obtain, and salami were manufactured from meat which had a concentration of 10 EHEC/g, 114 illnesses are predicted.

Each year, around 50 listerioses are reported in Australia with the likelihood that the actual number is 100–120 assuming the underreporting factors estimated by Mead et al. (1999). An unknown quantum of febrile gastroenteritis also stems from consumption of food contaminated with *L. monocytogenes*. The likelihood of listeriosis from consumption of ready-to-eat meats increases with the degree of handling post-cooking, and length of shelf-life. Risk Ranger predicts a total of 10 illnesses from long shelf-life products such as vacuum-packed ham and deli meats. Thus, smallgoods may account for at least 20% of reported listerioses (Ross et al., 2004).

In undertaking the above comparisons with epidemiological data (where they exist) we do not mean to imply any great degree of precision between predicted cases of illness and those recorded in Australian statistics. It would be naïve to believe that Risk Ranger outputs could reliably emulate the richness of interpretation afforded by quantitative risk assessments, and the estimates should be regarded as an approximation. Ross and Sumner (2002) compared Risk Ranger illness predictions with independent data from a hepatitis A outbreak in Australia (Conaty et al., 2000) and from a Quantitative Risk Assessment of Cassin et al. (1998) which modelled illness from Enterohaemorrhagic *E. coli* in hamburgers. In each case Risk Ranger estimates were of the same order of magnitude as those reported by Conaty et al. (2000) and Cassin et al. (1998), a level of precision which is a useful output in exercises such as the present. Zwietering and van Gerwen (2000) considered that, even using fully quantitative risk assessment methods, simulation procedures do not yield absolute predictions but orders of magnitude.

While a simplification of the harvest to consumption pathway Ross and Sumner (2002) considered that the model underpinning the Risk Ranger offers a simple means of comparing foodborne risks from diverse products and of rating/prioritising risks. It can be used to screen foodborne risks and to identify those requiring more rigorous assessment. It also assists structured problem solving and focuses 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 use of the spreadsheet tool also provides opportunities to investigate “what if” mitigation strategies without the labour intensive, expensive and technically demanding quantitative risk assessments that may take many person-years to complete.

This work demonstrates that a tool such as Risk Ranger could be a useful adjunct to risk profiling. Risk profiling is one activity in preliminary risk management (CAC, 2003) involving the systematic collection of information needed to make a decision on risk management possibilities and where resources should be allocated to more detailed scientific assessment. Responding to the Risk Ranger questions addresses many aspects of risk profiling. Many risk assessments fail to deliver the desired precision for risk management decisions due to the lack of input data. The use of Risk Ranger provides an opportunity to assess the quality of the available data while deriving an estimate of the magnitude of the risk.

These results were circulated among risk managers such as Meat Standards Committee, the Australian Quarantine and Inspection Service (AQIS) and Food Standards Australia New Zealand (FSANZ). They have also been used by SAFEMEAT (a government–industry food safety partnership) to set food safety R&D priorities and provide the meat processing sector with a comprehensive resource for hazard analysis.

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