FOOD STANDARDS Australia New Zealand
Te Mana Kounga Kai – Ahitereiria me Aotearoa

Supporting document 2

ASSESSMENT OF MICROBIOLOGICAL HAZARDS ASSOCIATED WITH THE FOUR MAIN MEAT SPECIES

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Contents

Executive Summary

As part of Food Standards Australia New Zealand's proposal to assess whether a Primary Production and Processing Standard for Meat and Meat Products was required, FSANZ identified hazards that may be found in meat, where in the meat supply chain they may be introduced into the animal or the meat and where in the supply chain they may be controlled.

This report identifies hazards (both identified and potential) that may be associated with meat from the four main meat species (cattle, sheep, goats and pigs), and lists pathogenic microorganisms that, if unmanaged, present or may potentially present a risk to public health. The information has been derived from industry data, microbiological analyses and published scientific data. The document does not attempt to document the severity of illness presented by these hazards, nor does it determine the likelihood of their occurrence in the final meat product or characterise the risk they may present. The report does however review meat associated foodborne disease evidence in Australia.

A range of potential hazards have been identified along the production and primary processing chain. Limited, if any, prevalence and incidence data is available for these hazards in meat. Given the lack of epidemiological evidence also available, it would suggest that the likelihood of these hazards causing illness from consumption of meat is quite low.

The principal microbiological hazards associated with the four main animal species are:

Animal	Principal microbiological hazard
Cattle	Pathogenic *Escherichia coli*, *Salmonella* spp., *Campylobacter jejuni* and *C. coli*,
Sheep	Pathogenic *Escherichia coli* and *Salmonella* spp.
Goats	Pathogenic *Escherichia coli* and *Salmonella* spp.
Pigs	*Salmonella* spp., *Yersinia enterocolitica* and *Y. pseudotuberculosis*, *Toxoplasma gondii*, *Campylobacter jejuni* and *C. coli*.

During the animal production phase, there are a number of key inputs and activities which influence the manner in which hazards may be introduced or amplified. They are summarised below:

Input and/ or activity	Comment	Step in chain where control may be applied
Animal Health	Pathogens may exist in the animal with or without exhibiting clinical signs	Animals with clinical signs of disease or illness are identified and managed at: • Dispatch from farm/saleyard • Arrival at abattoir • Ante-mortem inspection Without clinical signs, potential hazards may be identified and managed at: • Slaughter to minimise contamination from external surfaces or internal spillage • Post-mortem inspection
Stress	Animals may be more susceptible to infection and/or have increased faecal	Minimise exposure of animals to stress during: • Transport • Lairage

Input and/ or activity	Comment	Step in chain where control may be applied
	shedding. Pathogens colonise the gut	
Feed	Feed has the potential to introduce pathogens into the gut or environment	Management of input of manure and fertiliser onto pasture Control supplements Oversight of ensilage operations
Water	Contributes to internal and external contamination	Access of animals to suitable drinking water
Environment and management of biosecurity	Pathogens may contaminate external surfaces of animal, or can lead to ingestion or infection of the animal	Pasture management Vermin and pest control Good agricultural practices Sound animal husbandry

During the primary processing stage there are two main sources of contamination to the meat carcass:

- External contamination: from the animal (hide, skin, fleece, hooves, faeces, etc) and the environment (including personnel), and
- Internal contamination: during evisceration and dressing operations and where the spillage of gastrointestinal tract contents occurs.

The burden of illness that may be attributed to meat and meat products was assessed by evaluating OzFoodNet outbreak data. Sixty-six outbreaks of foodborne illness associated with meat products in Australia were reported to OzFoodNet between January 2003 and June 2008. More recent data drawn from published OzFoodNet reports[1] indicate 42 meat-associated outbreaks were reported between June 2008 and December 2011. While the data demonstrates the occurrence of outbreaks involving meat, they are usually due to dishes containing a meat product. Attribution to a specific meat source is either limited or difficult to establish with any confidence. Where meat products have been implicated in foodborne illness, generally these were further processed products and the most common causative microorganisms were *Salmonella* serotypes, *Clostridium perfringens* and *Staphylococcus aureus*. The undercooking of meat and temperature abuse after cooking were the major causes of meat-associated outbreaks.

The findings of this assessment are consistent with the significant body of evidence that exists for the Australian domestic meat industry indicating that domestically-reared red meat (cattle, sheep, goats) and pigs, processed under existing standards, present a low risk to public health. Also evidenced is that industry personnel are mature in their knowledge and management of food safety risks.

Considerable data are available to support the safety of meat and meat products produced from beef, sheep and pork in Australia. The evidence suggests that Australian meat from these species has a low microbial load and generally low prevalence of pathogens. Many of the pathogens listed in this assessment occur infrequently or not at all on Australian meat.

[1] OzFoodNet Annual (2008, 2009, 2010) and Quarterly (2011) reports available at: http://www.ozfoodnet.gov.au/internet/ozfoodnet/publishing.nsf/Content/reports-1

Background

Food Standards Australia New Zealand (FSANZ) has responsibility for protecting the health and safety of consumers through the development of food standards. The FSANZ Act requires FSANZ, when developing or varying standards, to have regard to *"the need for standards to be based on risk analysis using the best available scientific evidence".*

The development and application of a Primary Production and Processing Standard for Meat and Meat Products will be dependent on an analysis of the public health and safety risks, economic and social factors and current regulatory an industry practices. The analysis of the public health and safety risks will be based on a comprehensive scientific assessment of public health hazards associated with the consumption of meat.

FSANZ uses a number of methodologies to assess hazards, including risk profiling, quantitative and qualitative assessments and scientific evaluations. The methodology utilised depends on the purpose of the assessment and on the availability, quality and quantity of data.

The assessment will consider all stages in the meat supply chain, from the growing environment through to primary processing. In undertaking the assessment, FSANZ will utilise available information including current microbiological and chemical surveillance data, epidemiological data, consumption data and existing published and unpublished risk assessments from a variety of sources.

Introduction

Purpose

The purpose of this assessment document is to provide a review of the inputs and key stages of the meat supply chain for cattle, sheep, goats and pigs.

In the process of undertaking this work, the following questions are being addressed:

- What are the factors (including inputs, practices and activities and environmental factors, etc) which influence hazards at each step of the meat supply chain?
- What are the food safety hazards associated with each factor of the meat supply chain?

The hazards associated with each step in the supply chain are described and listed in a series of tables. The outputs of this evaluation will also facilitate the identification of any significant gaps in knowledge, and assist in identifying the requirement for any further risk assessment work.

Scope

The assessment considers all stages of the meat supply chain, from the animal production environment up to the end of primary processing (*ie*: post-abattoir carcass or boning room) for the four main meat species; cattle, sheep, goats and pigs.

This assessment will identify both recognised and potential hazards but not food safety-related market access hazards as defined below:

- Recognised hazards are those where epidemiological data exists to support illness occurring as a result of consuming meat or meat products.
- Potential hazards are those hazards which may present a food safety risk from consumption of meat and meat products, but where no epidemiological evidence exists.
- Market access related hazards are those potential hazards related to food safety which are technical requirements to trade, *ie:* generic *E. coli* and Total Viable Counts.

Existing assessments

A number of comprehensive scientific assessments have been undertaken in Australia on the microbiological hazards that may be found in the major meat species and the risk posed to consumers from consumption of meat and meat products. These include scientific assessments and risk-profiles generated by Meat and Livestock Australia and Australian Pork Limited.

In 2008, FSANZ commissioned a review of the domestic meat supply chain[1] which indicated that some sectors of the meat industry, such as domestically reared red meat (cattle, sheep and goats) and pigs are fairly mature in their knowledge and management of food safety risks.

[1] Unpublished report, "Information, collation and review of risk assessments on meat and meat products", South Australian Research and Development Institute

Key findings of the report included:

- Considerable evidence exists supporting the microbiological and chemical safety of meat and meat products from commonly consumed species (beef, sheep and pork).
- In large part, meat associated outbreaks are a consequence of post cooking contamination or post cooking temperature abuse.
- The review of quantitative risk assessments indicates that control strategies employed closer to the consumer are more likely to have a direct and major effect on foodborne hazards.

The review notes that a large body of Australian, peer-reviewed work on red meat processing has been published over a number of decades, culminating in three national baseline studies on beef and sheep meat. These include analysis of indicator organisms such as Total Count, *Enterobacteriaceae*, Coliforms/*E. coli, Staphylococcus aureus* and the pathogens: *Campylobacter, Listeria*, *Salmonella* and Enterohaemorrhagic *E. coli* (EHEC). State based surveys have also been undertaken focused exclusively on domestic abattoirs and Very Small Plants.

The *E. coli* and *Salmonella* Monitoring (ESAM) program provides a database of over 300,000 test results for beef, sheep and pig carcasses processed at export establishments. ESAM data suggests that Australian meat from these species has a low microbial load and generally low prevalence of pathogens.

These Australian peer-reviewed and ESAM data indicate that standards of hygiene during slaughter and processing of beef, sheep and pigs in Australia are at least equal to those of major trading partners and competitors.

Epidemiological Evidence

The public health burden presented by meat and meat products in Australia was determined by examination of the epidemiological evidence assembled by OzFoodNet (Appendix 1).

The OzFoodNet Outbreak Register shows that between January 2003 and June 2008 there were 66 outbreaks associated with meat in Australia. More recent data drawn from published OzFoodNet reports[2] indicate 42 meat-associated outbreaks were reported between June 2008 and December 2011. The majority of outbreaks were due to dishes containing a meat product. Unfortunately attribution to a specific meat source is complex as outbreaks are usually reported as being a result of consuming a "mixed dish". Where meat products have been implicated in foodborne illness, these were generally further processed product with the causative microorganisms being *Salmonella* serotypes, *Clostridium perfringens* and *Staphylococcus aureus*. Undercooking of meat and temperature abuse after cooking are major factors in outbreaks.

[2] OzFoodNet Annual (2008, 2009, 2010) and Quarterly (2011) reports available at: http://www.ozfoodnet.gov.au/internet/ozfoodnet/publishing.nsf/Content/reports-1

Sources of foodborne illness are determined through epidemiological and/or microbiological analysis during outbreak investigations. Critical for the generation of good data is the ability to quickly identify an outbreak and initiate an investigation in order to attribute illness to a particular food. Difficulties exist because of:

- Time delays in recognition or notification of an outbreak;
- Food recall biases when attempting to gather food consumption histories;
- Long exposure windows for specific pathogens (e.g. *Listeria monocytogenes*);
- Reluctance of individuals to participate in investigations;
- Inability to trace food products to their source;
- Inability to obtain representative food samples for microbiological analysis; and
- A lack of precision in methods for sample analysis and pathogen identification.

It is important to recognise that outbreak data only represents a small proportion of actual cases of foodborne illness, as many outbreaks go unrecognised and/or unreported to health authorities. People do not always seek medical attention for mild forms of gastroenteritis, medical practitioners do not always collect specimens for analysis, and not all foodborne illnesses require notification to health authorities. Furthermore, most gastrointestinal illness occurs as sporadic cases with no obvious association with each other, and it can be very difficult to identify a source of infection from an investigation of a single case.

1. Cattle Production in Australia

Introduction

Traditionally, cattle production in Australia has been based upon extensive farming systems, which range from the harsh, dry climates of the north to the cooler, wetter, green pastures of southern Australia. Significant differences exist between climatic and geographical conditions, and on the species of animal grown and the production practices employed. Furthermore, beef production systems are evolving from extensive to semi-intensive and intensive units across the Australian landscape.

The Australian herd is over 28 million head of cattle, which produce around 3 million tonnes of beef and veal per annum (ABARE 2011 figures)[3].

Cattle Production

The organization of beef cattle production in Australia continues to advance, reflecting improved knowledge and changing market demands. Producers are switching to cow-calf operations, producing young cattle for feedlots or the live export trade and reducing production of grass fed animals.

Within the milder climatic conditions of Southern Australia, breeds such as *Bos Taurus* are grown predominately on pasture in the mountains and plains. While in the north, native pastures such as tropical grasses, scrub land and legumes prevail and these are more suited to breeds such as *Bos indicus*. Under these conditions cattle graze on extensive open-range holdings. Extensively reared cattle entering the marketplace are generally between 15-24 months of age with average slaughter weight (dressed carcass) in excess of 260kg (ABARE, 2011). The major inputs during production are feed and water, with supplementary feeding at certain times of the year or during drought.

Importantly, there has been an increasing trend in recent years towards finishing cattle on feedlots. In 2001, approximately 26 percent of beef was finished in feedlots in south-east Queensland and New South Wales. Feedlots provide some advantages over traditional extensive cattle production, including enhanced control over quality and attributes of the carcass. Over 700 accredited cattle feedlots existed in 2009.

Until receipt at the feedlot yards, cattle finished on feedlots are initially subjected to the same production methods and inputs as extensively reared cattle. Once in the feedlot environment, cattle are more contained, restricted in their movements, are at higher stocking rates and exposed to greater environmental influences (*i.e.* environmental conditions including heat). This can cause the animal to experience an increased level of stress which may increase pathogen carriage and load, potentially increasing contamination on carcasses from any ingesta spilled during processing.

Lower slaughter ages are adopted for specialized beef systems. For example calves range from 'bobby' calves slaughtered within a few days of birth, to specially fed heavier veal calves. Bobby calves present special needs, as they are quickly separated from the cow and artificially fed, then transported on the fifth day to the slaughterhouse. Cull cow and live animals rejected from export disposition are other sub-sections of the beef industry in Australia.

The key steps in the production and processing of cattle are summarised in Figure 1.

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[3] Available from http://www.daff.gov.au/abares/publications_remote_content/publication_series/australian_commodity_statistics?sq_content_src=%2BdXJsPWh0dHAlM0ElMkYlMkYxNDMuMTg4LjE3LjIwJTJGYW5yZGwlMkZEQUZGU2VydmljZSUyRmRpc3BsYXkucGhwJTNGZmlkJTNEcGJfYWdjc3RkOWFiY2MwMDIyMDEyXzEyYS54bWwmYWxsPTE%3D

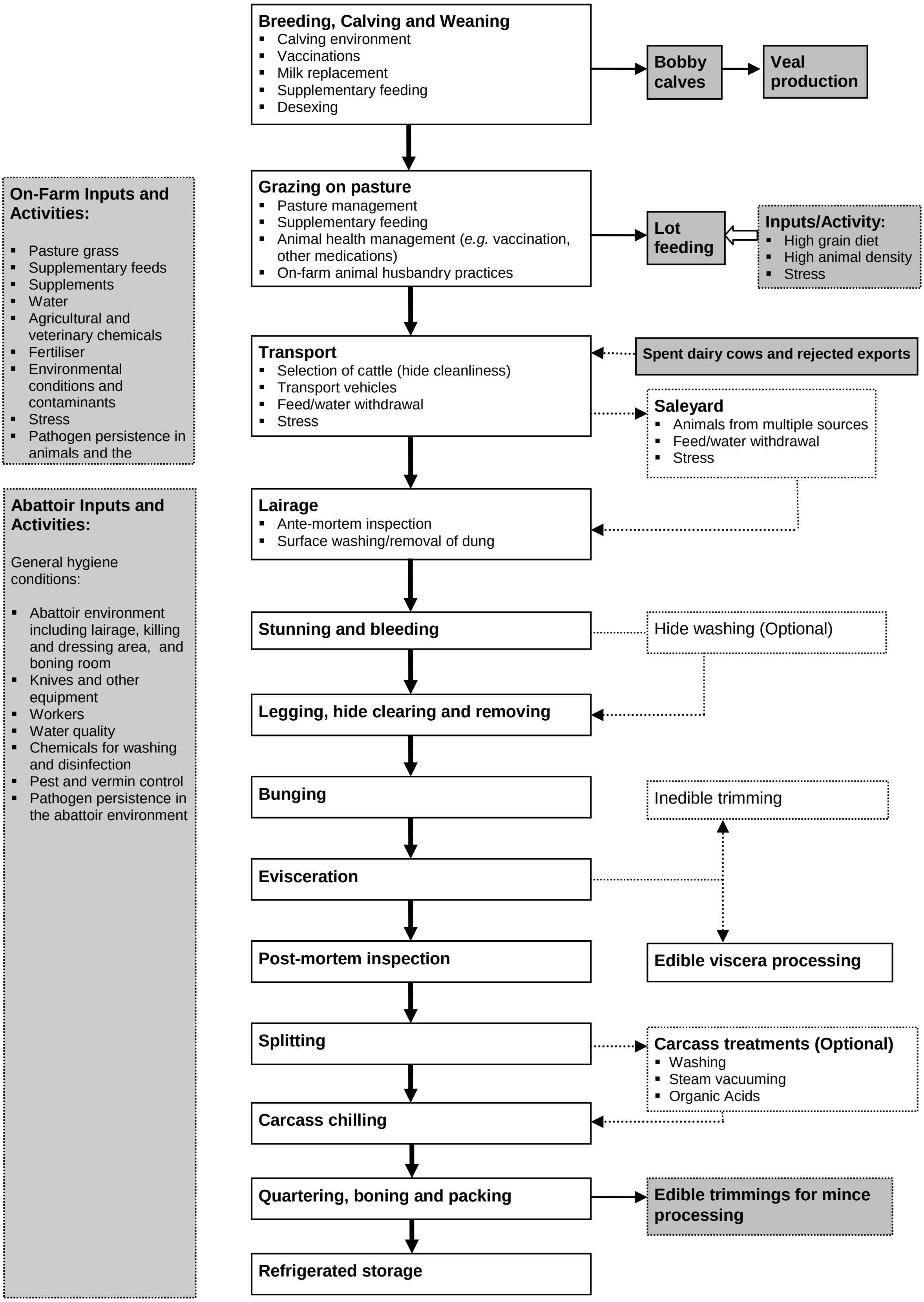

Figure 1: Major steps in cattle production and processing

Abattoir Operations

Regardless of the production method utilised, once the animal is received at the abattoir gate and enters lairage, slaughtering operations are undertaken using very similar processing steps.

Minor differences may exist depending on the plant's capabilities and design but the main steps remain the same. Others factors which may influence abattoir operations include: single species or multiple species plant; age of plant; chain speed; export or domestic; and different slaughtering practices.

Hazard Identification

The following tables outline the microbiological hazards that may be encountered along the cattle production and processing chain. Separate tables address the extensive and feedlot primary production methods, bobby calf production and the transport and slaughter operations.

(a) Extensive Cattle Production

Input/Activity	Comment
1. Animal Production (including calving, health status, zoonoses)	
1.1 Growing the cattle to market condition **(Animal health status of the cattle)**	Cattle may carry pathogens with or without exhibiting any clinical signs. **Notes**: The following hazards may be found in the gastrointestinal tract and exterior surfaces of cattle: *Foodborne pathogens more commonly associated with cattle include;* *Campylobacter* spp. *Clostridium* spp. Pathogenic *E. coli* *Listeria monocytogenes* *Salmonella* spp. *Yersinia enterocolitica* *Mycobacterium bovis* *Brucella abortus* *Other potential foodborne pathogens associated with cattle include:* *Yersinia pseudotuberculosis* *Mycobacterium avium* subsp. *paratuberculosis* *Cryptosporidium parvum and C. muris* *Giardia lamblia* *Sarcocystis hominis* *Toxoplasma gondi* *Taenia saginata* TSE agent
	Note: Carrier status includes the following states: ▪ Diseased animals due to infection with a pathogen ▪ Super-shedder (*i.e.* high levels of pathogens are present in the animal's gut and are shed in high levels in their faeces) ▪ Shedder (*i.e.* pathogens are present in the animal's gut contents and are therefore shed in faeces) ▪ Carrier (*i.e.* pathogens are present in organs but not gut contents therefore not shedding the bacteria into the environment)
	Cattle may carry pathogens normally associated with handling, which could potentially be transmitted via meat consumption. **Notes**: Examples include: ▪ Anthrax (*Bacillus anthracis*) ▪ Melioidosis (*Burkholderia pseudomallei*) ▪ Q Fever (*Coxiella burnetii*)
2. Animal Feed (includes pasture, grains, concentrates and silage)	
2.1 Pasture	A range of pathogens may be present in soil which can contaminate cattle.

Input/Activity	**Comment**
(Water/Soil/Faeces)	**Note:** Pathogens include: *Bacillus, Clostridium, L. monocytogenes, Salmonella* and pathogenic *E. coli*
	A range of pathogens may be present in irrigation water which can contaminate pasture. Irrigation water includes water from natural waterways or recycled water. **Notes:** Pathogens include; *Pathogenic E. coli, Campylobacter, Salmonella, Cryptosporidium, Giardia.*
	Pasture may be directly contaminated with pathogens excreted in cattle faecal matter, which may persist. Pathogens from contaminated pasture may be transferred to the external surfaces of cattle (hide) or the gut through consumption of contaminated pasture. **Notes**: Routes of pasture contamination include: Directly deposited from animals or through overland water runoff.
2.2 Pasture **(Effluents)**	Pasture may be contaminated with pathogens in effluents that are applied as soil fertilisers (ie manure and slurry). **Notes:** Effluents may be contaminated with pathogens that originate from cattle's gastrointestinal tracts and excreted in their faeces. Some pathogens may be able to survive during manure and slurry manufacturing processes and may be persistent for extended periods in the manure and slurry.
2.3 Feeds **(Including roughages, grains, concentrates, supplements)**	Animal feed including roughage (e.g. hay and silage), grain, concentrates and supplements may be contaminated with pathogens, which may result in a route of pathogen transmission to animals. **Notes:** Pathogens detected include: *Salmonella* spp. in protein meal, haylage and vegetable based feeds *E. coli* O157:H7 in forages and alfalfa *Cl. perfringens* in mixed animal feeds *Cl. botulinum* in haylage, silage, pasture, brewer's grains and mixed feed Parasites
	Pathogens may remain in silage as a result of inappropriate ensiling processes and be transmitted to cattle when silage is consumed. **Notes**: Under the optimal ensiling process, harvested forage is stored under moist anaerobic conditions, the lactobacilli flourish, which causes a decrease in pH, and other bacterial populations including pathogens will decrease. However, inappropriately prepared, stored or used silage will allow pathogens to survive and possibly multiply. If forage's moisture content is too high, appropriate fermentation by lactobacilli may not be occur, consequently the secondary fermentation by *Clostridium spp*. may take place. Pathogens such as *Listeria monocytogenes, Bacillus* spp., pathogenic *E. coli* and *Clostridia* spp. are reportedly detected in silage.
2.4 Meat and bone meal (MBM) **Concentrates and supplements**	Feeding ruminant by-products or materials which may contain TSE agents may contaminate cattle. **Notes**: A ruminant feed ban is currently in place in Australia. Australia continues to be free of the transmissible spongiform encephalopathies (TSEs).
3. Drinking Water (including town, reticulated, ground, surface and run-off water)	
3.1 Consumption of town/reticulated water	Water may be a source of microbiological contamination for stock. **Notes**: Low likelihood of pathogens being present, but cross-contamination may result in drinking water contaminating stock *e.g.* pathogenic *E. coli, Salmonella* spp., *Campylobacter* spp.
3.2 Consumption of groundwater	Unprotected groundwater is prone to faecal contamination from livestock, wild animals, domestic pets and humans which may contain a wide range of pathogens and may contaminate cattle. **Notes:** Pathogens may include pathogenic *E. coli, Salmonella* spp., *Campylobacter* spp.
3.3 Consumption of surface water and run-off water	Natural waterways in pasture (*e.g.* creeks, rivers and dams) may be contaminated with pathogens which could then be a source of microbial contamination of cattle. **Notes:** Natural waterways in pasture may be contaminated with pathogens, originating from agriculture, industrial or municipal wastewater discharged to the upper course of waterways.

Input/Activity	Comment
	Cattle may directly contaminate waterways, with depositing their faeces into waterways. Natural waterways may also be contaminated via surface water runoff caused by heavy rainfall.
3.5 Consumption of recycled water	A range of pathogens may remain in untreated or treated recycled water. The waste water treatment may not be sufficient to inactivate some pathogens. **Note**: The following pathogens are commonly found in insufficiently treated waste water: Viruses including Hepatitis A and Norovirus *Salmonella* spp. *Shigella* spp. *Vibrio* spp. *Clostridium spp. Legionella* spp., pathogenic *E. Coli*. Protozoan parasites including *Giardia* spp. and *Cryptosporidium* spp. Helminths including *Taenia saginata*
4. Animal Husbandry Practices (including veterinary chemicals, handling practices)	
4.1 Animal husbandry practices	Stress may impact on the animal's natural defence mechanisms resulting in an increased susceptibility to pathogens. Stress also causes increased pathogen shedding in the faeces. **Notes**: Pathogen growth and shedding by animals may be encouraged by a range of on-farm husbandry practices stressors. These include: drenching, restraining for veterinary check-ups including vaccination, restraining for transport preparation, de-sexing, dehorning, ear-marking, mustering, housing, competition for feed and water, extreme climate changes.
4.2 Medication of cattle	Therapeutic and other use of antimicrobials on cattle may lead to the emergence of resistant microorganisms. **Notes**: The use of antimicrobials in cattle may result in developing antimicrobial resistant strains of zoonotic pathogenic bacteria, existing in the animal's gastrointestinal tract.
5. Environment (including premises, building and equipment, personnel)	
5.1 Environmental contamination of the farming environment	Stock may become directly contaminated by pathogens derived from environmental sources. **Note**: Some foodborne pathogens are ubiquitous in the farming environment, while others may be introduced into the farming environment by poor biosecurity practices via visitors, vehicles, rodents, wild animals, carrions, houseflies and other insects such as cockroaches.

(b) Intensive (Feedlot) Production

Input/Activity	Comment
1. Animal Production (including calving, health status, zoonoses)	
1.1 Receipt of cattle	Disease transmission between animals due to mixing animals of different origins or higher animal density in the feedlot pen. **Notes:** Mixing of animals from different origins and social groups at markets contributes to the risk of contaminating animals with foodborne pathogens. Due to higher animal density, the lot feeding animals are more susceptible to a range of respiratory diseases, which may not be zoonoses but may reduce animals' natural immune system. As a result, the animals may become more susceptible to other pathogens, such as food-borne pathogens.

Input/Activity	Comment
1.2 Growing the cattle to market condition **(Animal health and carrier status of the cattle)**	Cattle may carry pathogens with or without exhibiting any clinical signs. *Refer Extensive Cattle Table* Stress may impact on the animal's natural defence mechanisms resulting in an increased susceptibility to pathogens. Stress also causes increased pathogen shedding in the faeces. Feedlot cattle may be susceptible to higher stress levels. **Notes:** Stressors in feedlot cattle may include: ▪ High animal stocking rates ▪ Grouping unfamiliar animals together ▪ Handling practices particular to the feedlot – transport from farm to feedlot, moving between pens and associated injuries ▪ Unclean environment including dirty and dusty floor, drinking water and pens ▪ Mixing sick animals with healthy ones ▪ Extreme climate conditions specific to the feedlot (eg there may be no shade available for animals) ▪ Competition of feed and water ▪ Feed and water changes when introduced to the feedlot
2. Animal Feed (includes pasture, grains, concentrates and silage)	
2.1 Pasture **(Water/Soil/Faeces)**	*Not applicable once animal is in feedlot environment*
2.2 Pasture **(Effluents)**	*Not applicable once animal is in feedlot environment*
2.3 Feeds (including roughages, grains, concentrates, supplements)	Animal feed including roughage (e.g. hay and silage), grain, concentrates and supplements may be contaminated with pathogens, which may result in a route of pathogen transmission to animals. *Refer Extensive Cattle Table*
2.4 Silage	Pathogens may remaining in silage as a result of inappropriate ensiling processes and be transmitted to cattle when silage is consumed. *Refer to Extensive Cattle Table*
2.5 Meat and bone meal (MBM) **Concentrates and supplements**	Ruminant by-products or materials being fed to cattle *Refer to Extensive Cattle Table*
3. Drinking Water (including town, reticulated, ground, surface and run-off water)	
3.1 Consumption of town/reticulated water	Water may be a source of microbiological contamination for stock. *Refer to Extensive Cattle Table*
3.2 Consumption of groundwater	*Refer to Extensive Cattle Table*
3.3 Consumption of surface water and run-off water	*Refer to Extensive Cattle Table*
3.5 Consumption of recycled water	A range of pathogens may remain in untreated or treated recycled water. The waste water treatment may not be sufficient to inactivate some pathogens. *Refer Extensive Cattle Table*
4. Animal Husbandry Practices (including veterinary chemicals, handling practices)	
4.1 Animal husbandry practices	Stress may impact on the animal's natural defence mechanisms resulting in an increased susceptibility to pathogens. Stress also causes increased pathogen shedding in the faeces. *Refer Extensive Cattle Table*
4.2 Medication of cattle	Therapeutic and other use of antimicrobials on cattle may lead to the emergence of resistant microorganisms. *Refer Extensive Cattle Table*
5. Environment (including premises, building and equipment, personnel)	
5.1 Environmental contamination of the environment	Stock may become directly contaminated by pathogens derived from environmental sources. *Refer Extensive Cattle Table*

Input/Activity	Comment
	Microbiological contamination of exterior surfaces of cattle from the environment of the feedlot production system. **Notes:** Animal's hides, hooves and feed may be visibly and microbiologically contaminated by soil and build-up of animal faeces on the feedlot floor. Water may be highly contaminated by the exterior surface of cattle as a large number of animals access a limited number of water troughs in a feedlot pen.

(c) Bobby Calf Production

Input/Activity	Comment
1. Animal Production (including calving, health status, zoonoses)	
1.1 Calving	Calving may result in microbial contamination of the newborn calf and the calving environment. There may be vertical transmission of foodborne pathogens from sick mother. **Notes**: The following pathogens may be transmitted vertically, found in contaminated artificial formula/milk for calf, and/or found in pregnant cow and new born calves (with or without clinical signs) with higher prevalence than in mature cattle: *Brucella abortus* EHEC (O157:H7) *Campylobacter spp.* *Listeria monocytogenes* *Clostridium spp.* *Corynebacterium ulcerans* *Salmonella spp.*
1.2 Growing the cattle to market condition	Cattle may carry pathogens with or without exhibiting any clinical signs. *Refer Extensive Cattle Table*
(Animal health and carrier status of the cattle)	Newborn animals are more susceptible to particular pathogens.
2. Animal Feed (includes pasture, grains, concentrates and silage)	
2.1 Pasture (Water/Soil/Faeces)	*Not applicable to bobby calves*
2.2 Pasture (Effluents)	*Not applicable to bobby calves*
2.3 Feeds (including roughages, grains, concentrates, supplements)	Contamination of artificial formula/milk for calf. **Notes**: Pathogens may be found in contaminated artificial formula/milk for calves either from the formula itself or via cross contamination from preparation utensils.
2.4 Silage	*Not directly applicable to bobby calves. Cross contamination from preparation utensils may occur*
2.5 MBM Concentrates and supplements	*Not directly applicable to bobby calves. Cross contamination from preparation utensils may occur.*
3. Drinking Water (including town, reticulated, ground, surface and run-off water)	
3.1 Consumption of town/reticulated water	Water may be a source of microbiological contamination for stock. *Refer Extensive Cattle Table*
3.2 Consumption of groundwater	Unprotected groundwater is prone to faecal contamination from livestock, wild animals, domestic pets and humans which may contain a wide range of pathogens and may contaminate cattle. *Refer Extensive Cattle Table*
3.3 Consumption of surface water and run-off water	Natural waterways in pasture (*e.g.* creeks, rivers and dams) may be contaminated with pathogens which could then be a source of microbial contamination of cattle. *Refer Extensive Cattle Table*
3.5 Consumption of recycled water	A range of pathogens may remain in untreated or treated recycled water. The waste water treatment may not be sufficient to inactivate some pathogens. *Refer Extensive Cattle Table*

Input/Activity	**Comment**
4. Animal husbandry practices (including veterinary chemicals, handling practices)	
4.1 Animal husbandry practices	Stress may impact on the animal's natural defence mechanisms resulting in an increased susceptibility to pathogens. Stress also causes increased pathogen shedding in the faeces. *Refer to Extensive Cattle Table*
4.2 Medication of cattle	*Refer to Extensive Cattle Table.*
5. Environment (including premises, building and equipment, personnel)	
5.1 Environmental contamination of the farming environment	Stock may become directly contaminated by pathogens derived from environmental sources. *Refer to Extensive Cattle Table*

(d) Transport, Saleyards, Lairage, Slaughter and Carcass Dressing Operations

Activity	**Comment**
All or most activities – transport and saleyards	Contamination, injury or other matters that could impact on the health or suitability of cattle for meat production occur because personnel lack skills and knowledge to implement practices that avoid injury to cattle, assess suitability for slaughter or other matters that could impact on the safety or suitability of cattle for meat production or the meat.
All or most activities- lairage, slaughter and carcass dressing operations.	Contamination, injury or other matters that could impact on the health or suitability of cattle for meat processing occur because personnel lack skills and knowledge to implement practices that avoid injury to cattle, assess suitability for slaughter or other matters that could impact on the safety or suitability of cattle for meat processing..
	Contamination from personnel involved in slaughter and meat processing
	Contamination from premises and equipment
	Contamination from premises and equipment and personnel
1. Preparation and Transport to Market/Abattoir	
1.1 Selection of cattle and handling operations **(according to the dirtiness)-**	Dirty cattle may increase the likelihood of pathogen contamination onto carcass from hides during the slaughtering and dressing process. **Notes**: Surface bacterial counts can rise, as the hide becomes dirtier. A range of foodborne pathogens may exist in the animal's exterior surfaces such as the hooves, hide and skin, fair or fleece. The hide dirtiness is influenced by a number of factors, such as: extensively or intensively produced (including whether housed), age, coat length, clipping, journey time, feeding regime.
1.2 Transport	Pathogens may contaminate cattle via cross-contamination from the transport vehicle. **Notes:** Foodborne pathogens can be detected in the transport vehicle prior to loading cattle. Pathogen prevalence on hides may be affected by: type of vehicle (ie single or double deck), floor type (ie metal or wooden), bedding (non or straw bedding), cleanliness of the truck, cleanliness of animals and the distance travelled.
	Stress in livestock occurs more frequently during the period between leaving the farm and slaughter (ie transportation). Such stresses may increase human pathogen shedding by livestock, and also increase pathogen loads within the animal or herd. **Notes:** The prevalence of pathogens in a herd may increase due to the host's weakened immune system. Pathogen loads being shed by the individual animal may increase. Stress may be caused prior to and during transport by: feed and water deprivation, mixing with unfamiliar animals, confined space (ie trucks), distance travelled, climatic change, changes in feed.
	Persistent pathogens in animals and the transport vehicle may be transmitted to other animals when comingled. **Notes:** Some foodborne pathogens can survive lengthy periods of time in animals and the environment during transport. Pathogens include: *Salmonella spp.*, EHEC, *Listeria monocytogenes*.

<table>
<tr><th>Activity</th><th>Comment</th></tr>
<tr><td>1.3 Feed Curfew</td><td>Pathogen loads in the animal may increase when they are deprived of feed and water prior to and during transportation. Extended time in lairage off feed may also increase pathogen load in the animal.

Notes: Feed deprivation (both reduced and interrupted) may: trigger the growth of pathogens in the rumen of livestock; change microflora in the rumen and lower digestive tract (e.g. colon) due to a changed pH level; decrease the animal's ability to eliminate the pathogen from the rumen.</td></tr>
<tr><td colspan="2">2. Saleyards</td></tr>
<tr><td rowspan="3">2.1 Holding and processing</td><td>Transfer of pathogens between animals in saleyard pens due to the common livestock marketing system mixing animals from multiple sources.</td></tr>
<tr><td>Increased chance of infection in younger animals.

Note: Younger animals are more susceptible to infectious agents, may be infected with higher loads of pathogens compared to mature animals and are more likely to attend the marketing activities.</td></tr>
<tr><td>Issue: Increased pathogen shedding due to stresses associated with marketing activities.

Note: Stressors include: excessive transportation; deprivation of feed and water; over crowding; unfamiliar feed; mixed with unfamiliar animals.</td></tr>
<tr><td colspan="2">3. Lairage</td></tr>
<tr><td>3.1 Lairage environment</td><td>Microbiological contamination of lairage environment by animals and subsequent transfer to other cattle in the pen.

Notes: The following bacterial pathogens have been detected in lairage environment and include:
E. coli O157
Salmonella
Campylobacter</td></tr>
<tr><td>3.2 Water</td><td>Use of untreated water for cleaning of the lairage environment may introduce pathogenic microorganisms.</td></tr>
<tr><td>3.3 Ante-mortem</td><td>Diseased, downer and dying animals may get through to slaughter.

Notes: Identification of animals that may not be displaying symptoms of disease or conditions which would make them unfit for human consumption, and/or may compromise the integrity of the slaughterhouse.</td></tr>
<tr><td></td><td>Microbiological contamination of lairage environment by animals and subsequent transfer to other cattle in the pen.

Notes: The following bacterial pathogens have been detected in lairage environment and include:
E. coli O157 detected: in all steps in lairage, pen side rails, Salmonella detected: in knocking box, on hide, in environment Campylobacter detected: on hide post-transit</td></tr>
<tr><td colspan="2">4. Slaughtering Operations</td></tr>
<tr><td>4.1 Cattle washing</td><td>Excessive levels of soil, dust and faeces on animal hide represent a source of contamination.

Notes: Bacterial pathogens have been detected after pre-slaughter wash on hide sites (inside hind leg, bung, flap and brisket) and residue of faecally contaminated hide after washing prior to slaughter.</td></tr>
<tr><td rowspan="2">4.2 Stunning and bleeding</td><td>Contamination of the slaughtering and processing environment.

Notes: Stunning method (including immobilisation) should ensure adverse effects such as blood-splash and fractures are avoided.

The following bacterial pathogens have been detected on cattle post-stunning & bleeding:
pathogenic E. coli (including O157, non-O157 and STEC)
Salmonella,
Staphylococcus (coagulase positive)</td></tr>
<tr><td>Captive bolt may be a source of contamination either from transfer of external contaminants to internal organs, or through re-use of captive bolt between animals.</td></tr>
</table>

Activity	Comment
4.3 Carcass hide washing **(also occurs post trimming)**	High microbial levels on carcasses. **Notes**: *E. coli* O157 detected pre & post carcass washing *Salmonella* detected pre & post carcass washing
4.4 Legging, hide clearing and hide removal	Opportunity for cross contamination between hide and carcass. **Notes**: Pathogenic bacteria detected on animals prior to hide removal. Isolates include: ▪ Pathogenic *E. coli* ▪ *Enterobacteriaceae* ▪ *Salmonella* **Notes**: Pathogenic bacteria detected on carcasses post hide removal. Isolates include: ▪ Pathogenic *E. coli* ▪ *Salmonella* ▪ *L. monocytogenes* ▪ Coagulase-positive *Staphylococcus* **Notes**: Contamination of carcass via microorganisms in air
4.5 Bunging	Opportunity for faecal leakage onto carcass and into processing environment. **Notes**: Pathogenic bacteria associated with bunging cattle include; ▪ Pathogenic *E. coli O157:H7* ▪ *Salmonella* ▪ *Enterobacteriaceae*. **Notes**: Washing pre-evisceration carcasses pre or post bunging can affect the carcass contamination from the rectum. Pooling in the rectal area from wash solution can influence carcass contamination
4.6 Evisceration	Opportunity for faecal contamination of utensils and slaughtering environment if carried out incorrectly. **Notes**: Pathogenic bacteria detected on carcass pre-evisceration include: ▪ Pathogenic *E. coli* ▪ *Enterobacteriaceae* ▪ *Salmonella* spp. ▪ *Mycobacterium avium* subsp. *paratuberculosis* **Notes**: Pathogenic bacteria detected on carcass post-evisceration include: ▪ *Campylobacter* spp. ▪ Coagulase-positive *Staphylococcus* ▪ Pathogenic *E. coli O157:H7* **Notes**: Pathogenic bacteria detected on utensils & within the slaughtering environment include: ▪ Coagulase-positive *Staphylococcus* ▪ Pathogenic *E. coli* ▪ *L. monocytogenes*
	Potential for pathogens in faeces or gastrointestinal tract to contaminate carcass. **Notes:** Pathogenic bacteria detected in faeces of slaughtered cattle post-evisceration include: ▪ Pathogenic *E.coli O157 [H7 & H-* (predominant)] ▪ *Salmonella* spp. ▪ *Campylobacter* spp. ▪ *L. monocytogenes* **Notes:** Pathogenic bacteria detected in faeces of slaughtered cattle post-evisceration include: ▪ Pathogenic *E. coli O157:H7* ▪ *Salmonella* spp.
4.7 Post mortem	Macroscopic evidence of disease or faecal contamination of the carcass. Potential for growth of any contaminating pathogens.
	Pathogenic organisms may be present in offal. **Notes**: *Campylobacter* spp. in liver.

Activity	Comment
4.8 Trimming	Carcass contamination. **Notes**: Pathogenic bacteria detected on carcass post-trimming include: ▪ *E. coli O157* ▪ *Salmonella* ▪ *Campylobacter* ▪ *Listeria* **Notes**: Pathogenic bacteria detected on carcass post-splitting include: ▪ *E. coli O157:H7*
4.9 Carcass washing (optional)	Excess microbial levels on carcasses. May also provide a moist environment for pathogens to survive. **Notes**: Pathogenic bacteria reported on carcasses post-washing include: ▪ *Mycobacterium avium* subsp. *paratuberculosis* ▪ Coagulase-positive *Staphylococcus* ▪ pathogenic *E. coli* (including *E. coli O157*)
	Washing may introduce contaminants that may be subsequently passed to the carcass. **Notes***: Cryptosporidium parvum*
4.10 Storage	Opportunity for outgrowth of pathogens. **Notes**: Pathogenic bacteria detected on chilled carcasses include: ▪ pathogenic *E. coli* ▪ *Salmonella* spp: ▪ *Listeria monocytogenes*
	Opportunity for cross-contamination between carcasses.
4.11 Quartering, boning and packing	Opportunity for cross-contamination. **Notes**: Pathogenic bacteria detected on meat in boning room include: ▪ *Staphylococcus* ▪ *B. cereus* ▪ *E. coli O157:H7* ▪ *Salmonella* spp. ▪ *L. monocytogenes*
	Beef Trimmings used to make ground beef may contain pathogenic bacteria. **Notes:** Isolates detected include: ▪ pathogenic *E. coli* ▪ *Salmonella* spp. ▪ *S. aureus* ▪ *Salmonella* spp ▪ *Campylobacter* spp. *(C.jejuni; C.coli)* ▪ *L. monocytogenes;* **Notes**: Pathogenic bacteria detected on equipment used in the boning process.
4.12 Storage of packed meat	Opportunity for outgrowth of pathogens

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2. Sheep Production in Australia

Introduction

The prime lamb industry is concentrated in New South Wales, Western Australia and Victoria with the main outputs being lamb meat and mutton. In addition, there are live sheep exports into the Middle East market. While large volumes of industry outputs are exported, Australians continue to consume large volumes of lamb meat.

Lamb and Mutton Production

Primary production of lambs and sheep are predominantly based on extensive production systems. The most efficient way to produce lambs is on quality pasture with at least 30% legume content ideal. The major inputs during primary production are feed and water, with some supplement feeding undertaken to achieve target growth rates. Cereal grains tend to be the most cost-effective form of feed supplementation.

Importantly, there is also an increasing trend towards finishing lambs in feedlot environments. Prior to receipt at the feedlot yards, lambs finished on feedlots are initially subjected to the same production methods and inputs as extensively reared animals. Once in the feedlot environment, lambs are more contained, restricted in their movements, are at higher stocking rates and exposed to greater environmental influences (*i.e.* environmental conditions including heat).

The Australian sheep industry has developed integrity systems to verify and assure the food safety status, to improve meat quality and to ensure the traceability of livestock. This is through all sectors of the sheepmeat industry, from the farm through to feedlots, transport, saleyards, and processing plants.

The key steps in the production and processing of sheep are summarised in Figure 2.

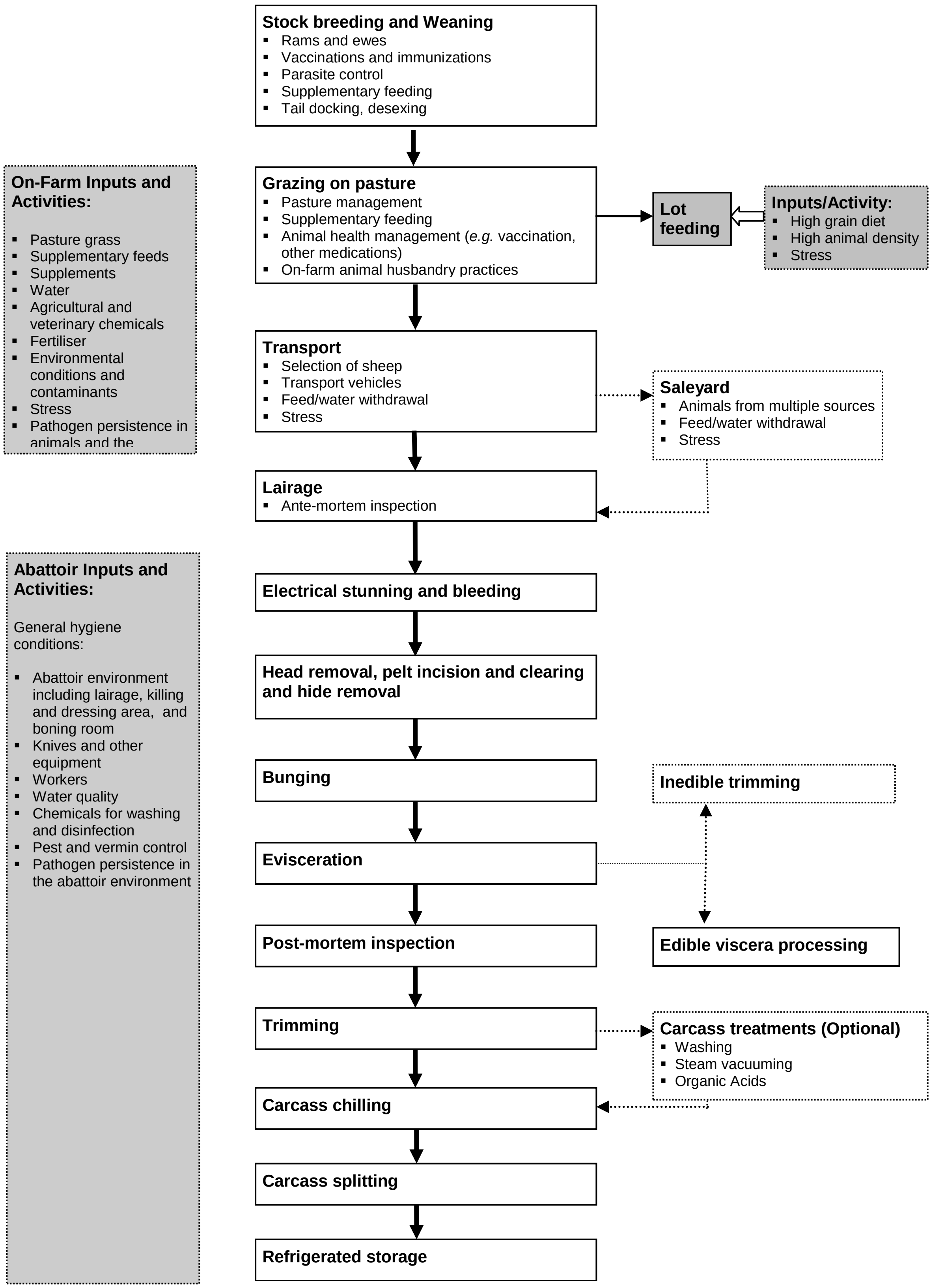

Figure 2: Major steps in sheep production and processing

Abattoir Operations

Production and slaughtering operations are undertaken using very similar processing steps.

Minor differences may exist depending on the plant's capabilities and design but the main steps remain the same. Others factors which may influence abattoir operations include: single species or multiple species plant; age of plant; chain speed; export or domestic; and different slaughtering practices.

Hazard Identification

The following tables outline the microbiological hazards that may be encountered along the entire sheep production and processing chain.

(a) Extensive Sheep Production

Input/Activity	**Comment**
1. Animal Production (including sourcing animals, birthing, health status, zoonoses etc)	
1.1 Growing the sheep to market condition **(Animal health and carrier status of the sheep)**	Increased pathogen load in lambs finished in a feedlot environment **Notes**: Feedlot lambs may be subject to increased stress and environmental conditions which may increase pathogen load in the animal.
	Sheep may carry pathogens with or without exhibiting any clinical signs. **Notes**: The following hazards may be found in the gastrointestinal tract and exterior surfaces of sheep: *Foodborne pathogens which have been more commonly associated with sheep include;* *Salmonella* spp. Pathogenic *E. coli* (EHEC) *Other possible foodborne pathogens associated with sheep meat include:* *Campylobacter jejuni* *Yersinia enterocolitica* *Yersinia pseudotuberculosis* *Cryptosporidium parvum* *Toxoplasma gondii* *Cryptosporidium parvum*
	Sheep may carry pathogens normally associated with handling, which could potentially be transmitted via meat consumption. **Notes**: Examples include: *Burkholderia pseudomallei(Melioidosis)* *Coxiella burnetii (Q Fever)* *Bacillus anthracis (Anthrax)*
2. Animal Feed (includes pasture, grains, concentrates and silage)	
2.1 Pasture **(Water/Soil/Faeces)**	A range of pathogens may be present in soil which can contaminate sheep. *Refer to Extensive Cattle Table*
2.2 Pasture **(Effluents)**	Pasture may be contaminated with pathogens in effluents that are applied as soil fertilisers (*i.e.* manure and slurry). *Refer to Extensive Cattle Table*
2.3 Feeds (Including roughages, grains, concentrates, supplements)	Animal feed including roughage (e.g. hay and silage), grain, concentrates and supplements may be contaminated with pathogens, which may result in a route of pathogen transmission to animals. *Refer to Extensive Cattle Table*
2.4 Silage	Pathogens may remaing in silage as a result of inappropriate ensiling processes and be transmitted to cattle when silage is consumed. *Refer to Extensive Cattle Table*

Input/Activity	Comment
2.5 Meat and bone meal (MBM) **Concentrates and supplements**	Feeding ruminant by-products or materials which may contain TSE agents may contaminate sheep. **Notes**: A ruminant feed ban is currently in place in Australia. Australia continues to be free of the transmissible spongiform encephalopathies (TSEs).
3. Drinking Water (including town, reticulated, ground, surface and run-off water)	
3.1 Consumption of town/reticulated water	Water may be a source of microbiological contamination for stock. *Refer to Extensive Cattle Table*
3.2 Consumption of groundwater	Unprotected groundwater may be contaminated by faecal matter from livestock, wild animals, domestic pets and humans which may contain a wide range of pathogens and may contaminate sheep. *Refer to Extensive Cattle Table*
3.3 Consumption of surface water and run-off water	Natural waterways in pasture (*e.g.* creeks, rivers and dams) may be contaminated with pathogens which could then be a source of microbial contamination of sheep. *Refer to Extensive Cattle Table*
3.4 Consumption of recycled water	A range of pathogens may remain in untreated or treated recycled water. The waste water treatment may not be sufficient to inactivate some pathogens. *Refer to Extensive Cattle Table*
4. Animal husbandry practices (including veterinary chemicals, handling practices)	
4.1 Animal husbandry practices	Stress may impact on the animal's natural defence mechanisms resulting in an increased susceptibility to pathogens. Stress also causes increased pathogen shedding in the faeces. *Refer to Extensive Cattle Table*
4.2 Medication of sheep	Therapeutic and other use of antimicrobials on sheep may lead to the emergence of resistant microorganisms. *Refer to Extensive Cattle Table*
5. Environment (including premises, building and equipment, personnel)	
5.1 Environmental contamination of the farming environment	Stock may become directly contaminated by pathogens derived from environmental sources. *Refer to Extensive Cattle Table*

(b) Transport, Saleyards, Lairage, Slaughter and Carcass Dressing Operations

Activity	Comment
All or most activities – transport and saleyards	*Refer to Cattle Transport Table*
All or most activities- lairage, slaughter and carcass dressing operations.	*Refer to Cattle Transport Table*
1. Preparation and Transport to Market/Abattoir	
1.1 Selection of sheep and handling operations (according to the dirtiness)-	*Refer to Cattle Transport Table*
1.2 Transport	*Refer to Cattle Transport Table*
1.3 Feed Curfew	*Refer to Cattle Transport Table*
2. Saleyards	
2.1 Holding and processing	*Refer to Cattle Transport Table*
3. Lairage	
3.1 Ante-mortem	*Refer to Cattle Transport Table*
	Microbiological contamination of lairage environment by animals and subsequent transfer to other sheep in the pen.

Activity	Comment
	Notes: The following pathogens have been reported to be detected in the lairage environment (international and domestic:literature) ▪ *Yersinia pseudotuberculosis* ▪ *Yersinia enterocolitica* ▪ *Campylobacter* spp. ▪ Pathogenic *E. coli* ▪ *Cryptosporidium parvum*
4. Slaughtering Operations	
4.1 Sheep washing	Excessive levels of soil, dust and faeces on animal fleece represent a source of contamination. **Notes**: Washing increased aerobic plate count levels on clean shorn, dirty shorn, clean woolly and dirty woolly
4.2 Stunning and bleeding	*Refer to Cattle Transport Table*
	Notes: Cutting of the oesophagus may contaminate the neck, head and blood with ruminal contents. **Notes:** Experimental simulation in sheep demonstrates the potential transfer of marker organisms detected in blood, liver, spleen, lung, kidney, lymph nodes, deep muscle and on carcass surface.
	Contamination to the surrounding environment. **Notes:** Experimental simulation in sheep demonstrates the potential transfer of marker organisms to the air, and slaughter man hands and apron after stunning
4.3 Pelt incision & cleaning	Opportunity for cross contamination between pelt and carcass. **Notes**: Pelt removal by mechanical means may allow dirt, dust and hairs to contaminate the carcass
	Notes: Conventional dressing systems may increase carcass contamination as sheep is hung by hind legs and cuts are made on hindquarters, hence the pelt is pulled from the hind/anus region over the carcass. With inverted dressing the sheep is hung by the forelegs and pelt is puller from the forequarter down to the anus.
4.4 Bunging	Opportunity for faecal leakage onto carcass and into processing environment. **Notes**: Washing pre-evisceration carcasses pre or post bunging can affect the carcass contamination from the rectum. Pooling in the rectal area from wash solution can influence carcass contamination.
4.5 Evisceration	Opportunity for faecal contamination of utensils and slaughtering environment if carried out incorrectly.
	Potential for pathogens in faeces or gastrointestinal tract to contaminate carcass. **Notes:** Pathogens detected post evisceration include: ▪ Pathogenic *E. coli* ▪ *Campylobacter jejuni/coli* ▪ *Campylobacter jejuni/coli* ▪ *Campylobacter spp.* ▪ *Salmonella* spp.
4.6 Post mortem	*Refer to Cattle Transport Table*
	Pathogenic organisms may be present in edible offal. **Notes**: Potentially pathogenic bacteria has been detected on sheep offal and includes: ▪ *Salmonella* spp. in liver; diaphragmatic muscle and abdominal muscle ▪ Lamb livers found to contain initial surface flora which included: *Bacillus, Staphylococcus.*
4.7 Trimming	Carcass contamination. **Notes**: Pathogenic bacteria detected on carcass post-trimming include: ▪ Pathogenic *E. coli* ▪ *Salmonella* spp. ▪ *Listeria* spp.
4.8 Carcass washing (optional)	Excess microbial levels on carcasses.

Activity	Comment
	Notes: May provide a moist environment for pathogens to survive. Pathogenic bacteria detected on carcass post-washing include: ▪ Pathogenic *E. coli* ▪ *Y. enterocolitica* ▪ *Salmonella* spp.
4.9 Storage	*Refer to Cattle Transport Table*
4.10 Quartering, boning and packing	Opportunity for cross-contamination. **Notes:** Pathogenic bacteria detected on meat in boning room.
4.11 Storage of packed meat	Opportunity for outgrowth of pathogens if stored above minimum temperatures for growth

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3. Goat Production in Australia

Introduction

Goat meat production in Australia involves a combination of strategies: the harvesting of rangeland goats; the breeding and production from rangeland goats; and the processing of farmed goats. The majority of goat meat is derived from rangeland goat populations, and these animals provide landholders with a source of goats suitable for cross-breeding with the main meat species such as Boer goats.

The term ‘rangeland’ describes goats that roam and are raised on natural grasslands, shrub lands, deserts and alpine areas. Supply chain development over recent years has helped improve the quality and consistently of rangeland goats, with animals drafted according to market specifications before being consigned for slaughter. Saleyards are rarely used and this ensures that goats are consigned direct from property of origin to slaughter, thus minimising transport and stress.

This utilisation of rangeland populations has allowed expansion of the domestic goat herd and supported demand for a more consistent supply of goat meat.

There are an estimated 2.6 million rangeland goats, distributed across all Australian states and territories. Rangeland goats are a complex management problem, because they are both a major environmental pest and a commercial resource, providing a source of income to farmers who muster them for sale.

Goat Production

The majority of goats slaughtered in Australia are derived from harvesting operations. Feral goats are present over much of Australia, with the largest numbers found in the semi-arid pastoral areas of Western Australia, western New South Wales, southern South Australia, and central and south-western Queensland.

Rangeland goats are harvested by mustering by motorcycle or horse with the aid of dogs or with light aircraft, taking advantage of the tendency for these goats to aggregate into larger herds. Goats may also be trapped at water, with traps consisting of a goat-proof fence surrounding a water point that is entered through one-way gates or ramps.

Pre-slaughter management can have a significant impact on the marketability of goat meat. It involves management practices at the point of capture or on-farm, through to slaughter. Mustering, drafting, loading, trucking, handling, noise, strange surroundings and mixing with other stock are all associated with the marketing process, and poor management of these pre-slaughter operations can reduce liveweights and carcass weights; impact on meat yields, meat quality and safety; and increase mortalities, injuries and condemnations.

Australia commenced exporting goat meat in 1952 and is the world’s largest supplier of chilled and frozen goat meat. The principal export markets are the United States, Taiwan, Malaysia, Korea, Singapore, and Canada.

The key steps in the production and processing of goats are summarised in Figure 3.

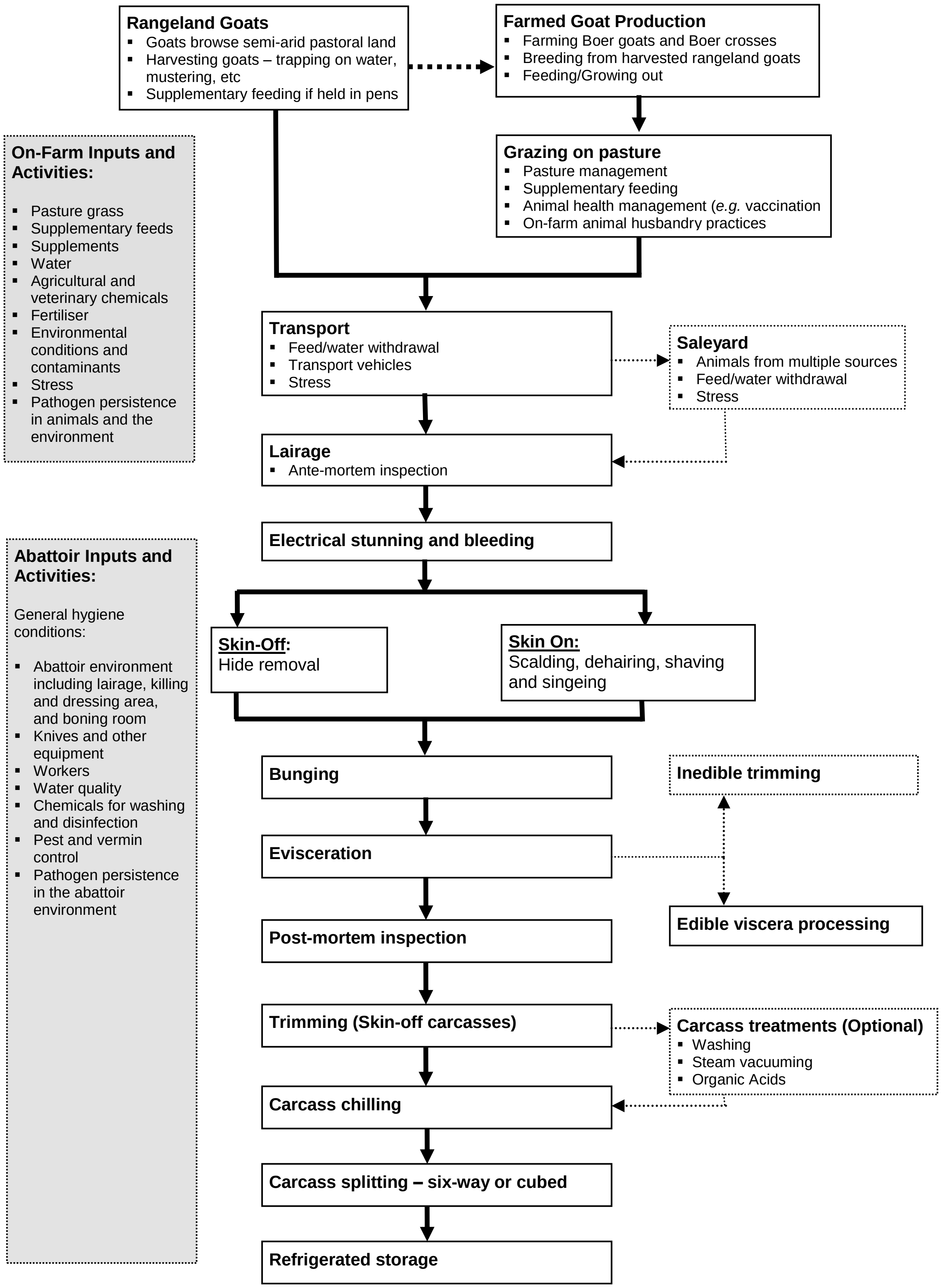

Figure 3: Major steps in goat harvesting, production and processing

Abattoir Operations

Production and slaughtering operations are undertaken using very similar processing steps.

Minor differences may exist depending on the plant's capabilities and design but the main steps remain the same. Others factors which may influence abattoir operations include: single species or multiple species plant; age of plant; chain speed; export or domestic; and different slaughtering practices.

Hazard Identification

The following tables outline the microbiological hazards that may be encountered along the entire goat production and processing chain.

(a) Goat Production (Rangeland and farmed production)

Input/Activity	Comment
1. Animal Production (including sourcing animals, birthing, health status, zoonoses etc)	
1.1 Trapping Rangeland Goats	Increased pathogen load in the animal **Notes:** Goats are trapped on water and held for up to 3 days. Fed hay. Once sufficient numbers are obtained, and then they're transported to slaughter. Feed curfew applies prior to loading. Exempt NLIS tagging requirement.
1.2 Growing the goat to market condition **(Animal health and carrier status of the goat)**	Higher pathogen load (*Salmonella* spp.) reported in rangeland goats
	Goats may carry pathogens with or without exhibiting any clinical signs. **Notes**: The following hazards may be found in the gastrointestinal tract and exterior surfaces of goats: *Foodborne pathogens more commonly associated with goat meat include;* *Salmonella* spp. Pathogenic *E. coli* (including O157) *Other possible foodborne pathogens associated with goat meat include:* *Campylobacter jejuni* *Yersinia enterocolitica* *Yersinia pseudotuberculosis* *Cryptosporidium parvum* *Toxoplasma gondii*
	Goat may carry pathogens normally associated with handling, which could potentially be transmitted via meat consumption. **Notes**: Examples include: *Burkholderia pseudomallei* (Melioidosis) *Leptospira spp. (*Leptospirosis) *Coxiella burnetii* (Q Fever)
	Age of the animal influences susceptibility of the animal to pathogens. **Notes:** Young kids (Capretto) have a carcase weight between 6 -12 kg (Hot Standard Carcass Weight) and may be more susceptible to pathogens, as may Chevon (no more than two-tooth and with no male secondary sexual characteristics)
2. Animal Feed (includes pasture, grains, concentrates and silage)	
2.1 Pasture (Water/Soil/Faeces)	A range of pathogens may be present in soil which can contaminate goats. *Refer to Extensive Cattle Table*
2.2 Pasture **(Effluents)**	Pasture may be contaminated with pathogens in effluents that are applied as soil fertilisers (*i.e.* manure and slurry). *Refer to Extensive Cattle Table*

Input/Activity	Comment
2.3 Feeds **(Including roughages, grains, concentrates, supplements)**	Animal feed including roughage (e.g. hay and silage), grain, concentrates and supplements may be contaminated with pathogens, which may result in a route of pathogen transmission to animals. *Refer to Extensive Cattle Table*
2.4 Silage	Pathogens may remaining in silage as a result of inappropriate ensiling processes and be transmitted to cattle when silage is consumed. *Refer to Extensive Cattle Table*
2.5 Meat and bone meal (MBM) **Concentrates and supplements**	*Refer to Extensive Cattle Table* **Notes**: A ruminant feed ban is currently in place in Australia. Australia continues to be free of the transmissible spongiform encephalopathies (TSEs).
3. Drinking Water (including town, reticulated, ground, surface and run-off water)	
3.1 Consumption of town/ reticulated water	Water may be a source of microbiological contamination for stock. *Refer to Extensive Cattle Table*
3.2 Consumption of groundwater	Unprotected groundwater is prone to faecal contamination from livestock, wild animals, domestic pets and humans which may contain a wide range of pathogens and may contaminate goats. *Refer to Extensive Cattle Table*
3.3 Consumption of surface water and run-off water	Natural waterways in pasture (*e.g.* creeks, rivers and dams) may be contaminated with pathogens which could then be a source of microbial contamination of goats. *Refer to Extensive Cattle Table*
3.4 Consumption of recycled water	A range of pathogens may remain in untreated or treated recycled water. The waste water treatment may not be sufficient to inactivate some pathogens. *Refer to Extensive Cattle Table*
4. Animal husbandry practices (including veterinary chemicals, handling practices)	
4.1 Animal husbandry practices	Stress may impact on the animal's natural defence mechanisms resulting in an increased susceptibility to pathogens. Stress also causes increased pathogen shedding in the faeces. **Notes**: Goats and in particular rangeland goats, appear to be particularly susceptible to stress conditions. Pathogen growth and shedding by animals may be encouraged by a range of on-farm husbandry practices stressors. These include: mustering, drenching, restraining for veterinary check-ups including vaccination, restraining for transport preparation, desexing, dehorning, ear-marking, housing, competition for feed and water, extreme climate changes.
4.2 Medication of goats	Therapeutic and other use of antimicrobials on goats may lead to the emergence of resistant microorganisms. *Refer to Extensive Cattle Table*
5. Environment (including premises, building and equipment, personnel)	
5.1 Environmental contamination of the farming environment	Stock may become directly contaminated by pathogens derived from environmental sources. *Refer to Extensive Cattle Table*

(b) Transport, Saleyards, Lairage, Slaughter and Carcass Dressing Operations

Activity	Comment
All or most activities – transport and saleyards	*Refer to Cattle Transport Table*
All or most activities- lairage, slaughter and carcass dressing operations.	*Refer to Cattle Transport Table*
1. Preparation and Transport to Market/Abattoir	
1.1 Selection of goat and handling operations (according to the dirtiness)-	Dirty goats may increase the likelihood of pathogen contamination onto carcass from hides during the slaughtering and dressing process. **Notes**: Rangeland goats sent directly to slaughter after being collected may have increased hide dirtiness. Surface bacterial counts can rise, as the hide becomes dirtier. A range of foodborne pathogens may exist in the animal's exterior surfaces such as the hooves, hide and skin, hair or fleece. The hide dirtiness is influenced by a number of factors, such as: extensively or intensively produced (including whether housed), age, coat length, clipping, journey time, feeding regime.
1.2 Transport	*Refer to Cattle Transport Table*
	Stress in livestock occurs more frequently during the period between leaving the farm and slaughter (*i.e.* transportation). Such stresses may increase human pathogen shedding by livestock, and also increase pathogen loads within the animal or herd. **Notes:** Goats are particularly susceptible to stress. The prevalence of pathogens in a herd may increase due to the host's weakened immune system. Pathogen loads being shed by the individual animal may increase. Stress may be caused prior to and during transport by: feed and water deprivation, mixing with unfamiliar animals, confined space (i.e. trucks), distance travelled, climatic change, changes in feed.
1.3 Feed Curfew	*Refer to Cattle Transport Table*
2. Saleyards	
2.1 Holding and processing	*Refer to Cattle Transport Table*
3. Lairage	
3.1 Ante-mortem	*Refer to Cattle Transport Table*
	Microbiological contamination of lairage environment by animals and subsequent transfer to other goats in the pen. **Notes**: The following bacterial pathogens have been detected in the lairage environment: ▪ Pathogenic *E. coli* ▪ *Salmonella* spp. ▪ *Campylobacter jejuni* ▪ *Cryptosporidium parvum*
4. Slaughtering Operations	
4.1 Goat washing	*Refer to Cattle Transport Table*
4.2 Stunning and bleeding	*Refer to Cattle Transport Table*
	Opportunity for cross contamination from ingesta spilled during bleedout.
4.3 Carcass hide washing (also occurs post trimming)	*Refer to Cattle Transport Table*
<u>Skin-On</u> **4.4a Scalding, dehairing, shaving and singeing**	Contamination of the carcass from scald tank. **Notes:** Scald tank water may redistribute pathogen contamination from hair and blood (if head has been removed) onto external surfaces of the goat or into neck wound.
	Contamination of carcass from residual hair. **Notes:** *Salmonella* is ubiquitous on goat hair.
	Temperature of scald tank water and/or transition time in tank may be insufficient to significantly reduce pathogen load on carcass.

Activity	Comment
<u>**Skin-off**</u> **4.4b Legging, hide clearing and hide removal**	*Refer to Cattle Transport Table* Contamination of the carcass. **Notes:** Contamination of the carcass can occur via cross-contamination from hide and/or equipment
4.5 Bunging	Opportunity for faecal leakage onto carcass and into processing environment **Notes**: Washing pre-evisceration carcasses pre or post bunging can affect the carcass contamination from the rectum. Pooling in the rectal area from wash solution can influence carcass contamination
4.6 Evisceration	*Refer to Cattle Transport Table*
	Potential for pathogens in faeces or gastrointestinal tract to contaminate carcass
4.7 Post mortem	*Refer to Cattle Transport Table* Pathogenic organisms may be present in edible offal.
4.8 Trimming	*Refer to Cattle Transport Table*
4.9 Carcass washing (Optional)	*Refer to Cattle Transport Table*
4.10 Storage	*Refer to Cattle Transport Table*
4.11 Quartering, boning and packing	Opportunity for cross-contamination **Notes**: Cross-contamination can occur from food handlers and/or equipment
4.12 Storage of packed meat	*Refer to Cattle Transport Table*

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4. Pig Production in Australia

Introduction

Pork production occurs predominantly in the grain belts of Australia reflecting the reliance on grain as the major source of pig feed. Hence the quantity of pork produced in each state is linked to the size of the major grain growing regions, but is also influenced by proximity to major population centres.

In contrast to most other meat products, a significant proportion of pig meat consumed in Australia is imported. In 2012-13, imports accounted for around 47 percent of total pig meat consumption, and at least 70 percent of the bacon, ham and smallgoods consumed in Australia.

Australian pork is also exported to markets in Singapore, Hong Kong, Japan and New Zealand.

Pig Production

The Australian pig industry comprises approximately 1500 pig producers producing around 4.7 million pigs annually (*personal communication, APL*). Pig production systems range from extensive outdoor farms to intensive operations.

The vast majority of pigs are intensively reared, using all-in all-out production strategies. This enhances disease management and enables producers to better meet market specifications. These all-in all-out systems generally use weekly batch farrowing methods, where sows are placed into groups to allow matings and farrowings to occur at distinct weekly intervals, making grouped movement and marketing of pigs more easily managed. Such systems make extensive use of artificial insemination.

In recent times there has been increasing use of off-site grow-out facilities, rather than single site farrow-to-finish operations. This minimises the transfer of infectious diseases from breeders to market pigs and also reduces stress. Under these production arrangements, there has been greater use of lower-cost ‘shelter’ facilities that group-house pigs on bedding (straw or rice hulls) rather than traditional sheds.

The use of outdoor production is increasing, practiced with sows and litters in southern Australia, with grower pigs usually brought into sheds or shelters after weaning.

Once grown to market size, pigs are taken to abattoirs for processing.

Average slaughter weights for Australian pigs are increasing as a result of genetic improvement, changing processor requirements, and industry efforts to achieve greater production efficiencies at farm and processing levels.

The key steps in the production and processing of pigs are summarised in Figure 4.

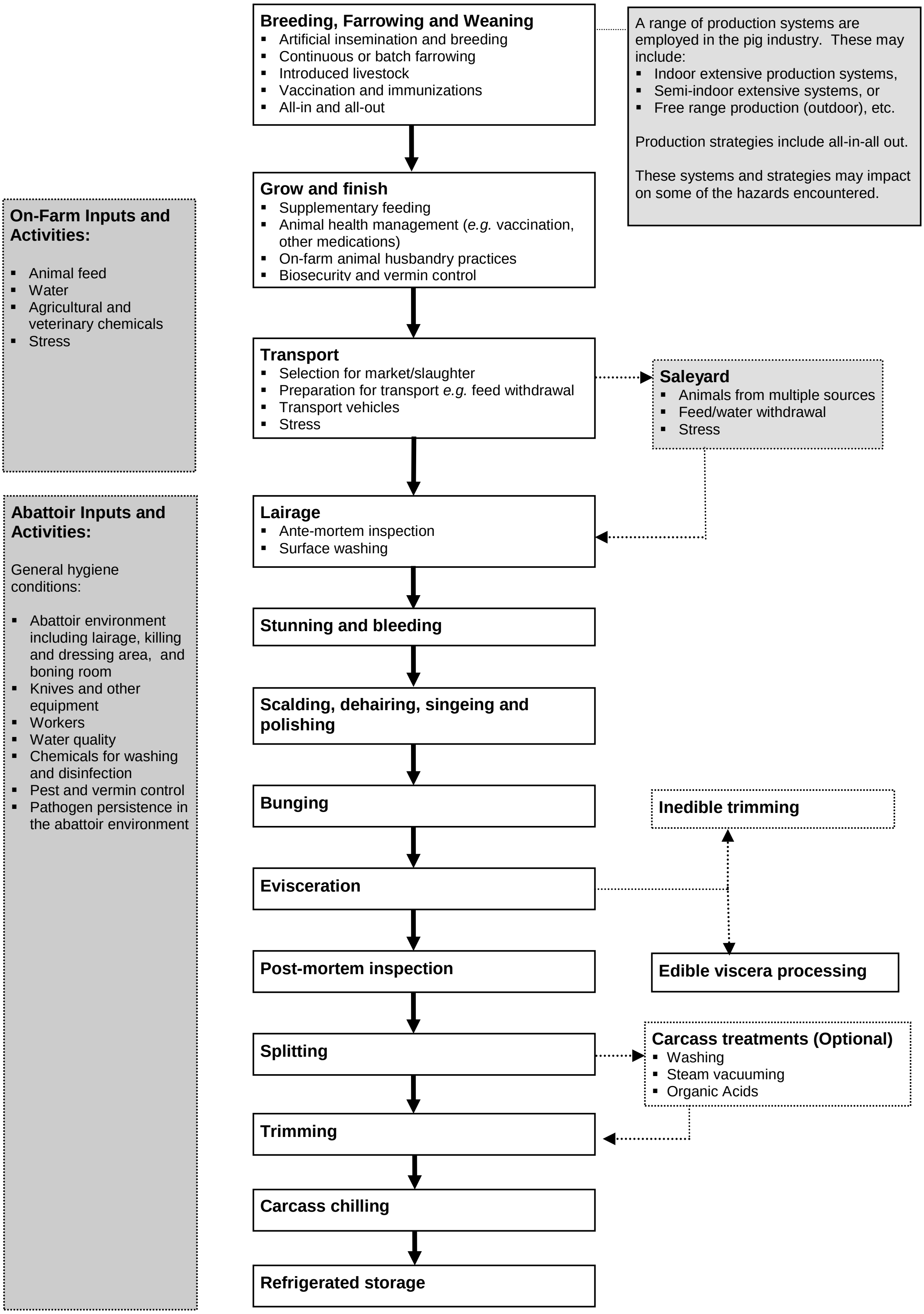

Figure 4: Major steps in pig production and processing

Abattoir Operations

Most pigs in Australia are slaughtered in dedicated pig processing facilities.

Minor differences may exist depending on the plant's capabilities and design but the principal processing steps remain the same. Factors which may influence abattoir operations include: age of plant; chain speed; and whether the plant is an export registered facility.

Hazard Identification

The following tables outline the microbiological hazards that may be encountered along the entire pig production and processing chain.

(a) Pig Production

Input/ Activity	Comment
1. Animal Production (including birthing, health status, zoonoses)	
1.1 Growing the pigs to market condition **(Animal health status of the pig)**	Pigs may carry pathogens with or without exhibiting any clinical signs. **Notes**: The following hazards may be found in the gastrointestinal tract and exterior surfaces of pigs: Foodborne pathogens which have been more commonly associated with pigs include: *Salmonella* spp. *Yersinia enterocolitica* *Toxoplasma gondii* *Campylobacter* spp. *(C. jejuni, C. coli)* *Listeria monocytogenes* Other possible foodborne pathogens associated with pigs include: *Y. pseudotuberculosis* *Clostridium perfringens* *Clostridium botulinum and Cl. difficile* *Cryptosporidium parvum* and *C. suis* Pathogenic *E. coli* *Giardia lamblia* *Sarcocystis suihominis* *Staphylococcus aureus* *Streptococcus suis* *Taenia solium* and *T. asiatica*
	Notes: Carrier status includes the following states: ▪ Animals showing clinical signs of disease due to infection with a pathogen ▪ Super-shedder (i.e. high levels of pathogens are present in the animal's gut and are shed in high levels in their faeces) ▪ Shedder (i.e. pathogens are present in the animal's gut contents and are therefore shed in faeces) ▪ Carrier (i.e. pathogens are present in organs but not gut content, therefore are not shed in faeces)
	Notes: Different herd types and different production systems may have an impact on the microbiological status of the animals. **Notes:** The prevalence of pathogens in the existing herd may increase when new stock is introduced.
2. Animal Feed (includes pasture, grains, concentrates, meal etc)	
2.1 Pasture **(Water/Soil/Faeces)**	A range of pathogens may be present in soil which can contaminate pigs. *Refer Extensive Cattle Table* *(outdoor production only)*
	Notes: For outdoor production systems, contamination may arise as a result of access to wild animals, birds and carrion. Pigs are known to readily eat both dead and living rodents and other wildlife including insects. Rodents, wildlife, flies and cockroaches can act as both

Input/ Activity	Comment
	vectors and reservoirs for pathogens in the farming environment. Carrion can be a reservoir of anaerobic bacterial pathogens. Important to note that pigs will have supplements beyond just pasture
2.2 Pasture **(Effluents)**	*Refer Extensive Cattle Table* *(outdoor production only)* Pasture may be contaminated with pathogens in effluents that are applied as soil fertilisers (ie manure and slurry.
2.3 Feeds **(Including grains, meal, pellets, supplements)**	Feeds including grain, meal, pellets and supplements may be contaminated with pathogens, which may result in a pathogen transmission to animals. **Notes**: Pigs are omnivores and therefore consume a wide range of feeds. Some studies indicate an association between pathogen infection and the feeding of particular ingredients, such as animal origin ingredients and by-product meal. **Notes:** The form in which the feed is presented may play a significant role in the pathogen prevalence in pigs. ▪ *Salmonella* has been reported in stockfeed. Serovars and prevalence reported differ depending on type of feed. ▪ A higher *Salmonella* sero-prevalence has been associated with feeding pelleted rations to finishers and feeding whey. . **Notes:** Feed may become contaminated with pathogens during transport, storage or within the farm feeding system.
2.4 Silage	*Not applicable to pigs.*
2.5 Meat and bone meal (MBM) **Concentrates and supplements**	Feeding of meat and bone meal may be a source of TSE agents which may contaminate pigs. **Notes**: Meat and bone meal is permitted in pig rations.
3. Drinking Water (including town, reticulated, ground, surface and run-off water)	
3.1 Consumption of town/reticulated water	Water may be a source of microbiological contamination for stock *Refer to Extensive Cattle Table*
3.2 Consumption of groundwater	Unprotected groundwater is prone to faecal contamination from livestock, wild animals, domestic pets and humans which may contain a wide range of pathogens and may contaminate pigs *Refer to Extensive Cattle Table*
3.3 Consumption of surface water and run-off water	Natural waterways (*e.g.* creeks, rivers and dams) may be contaminated with pathogens which could be a source of microbial contamination of pigs. *Refer to Extensive Cattle Table* *(outdoor production only)*
3.4 Consumption of recycled water	*Refer to Extensive Cattle Table*
4. Animal Husbandry Practices (including veterinary chemicals, handling practices)	
4.1 Stress caused by animal husbandry practices	Stress may impact on the animal's natural defence mechanisms resulting in an increased susceptibility to pathogens. Stress also causes increased pathogen shedding in the faeces. *Refer Extensive Cattle Table* **Notes**: Stressors include grouping unfamiliar animals together, changes in climate conditions, changes in feed types and watering, handling and transport of pigs, introduction of new animals into existing herds, weaning, unfamiliar noise and smells, high stocking densities, restraining, husbandry practices.
4.2 Medication of pigs	Incorrect use of therapeutics and other antimicrobials may lead to the emergence of resistant microorganisms. *Refer Extensive Cattle Table*

Input/ Activity	Comment
	Notes: *Salmonella Typhimurium* DT 104 with multi-resistance to ampicillin, streptomycin, tetracyclines, chloramphenicol and spectinomycin is endemic in overseas pork industry. No reports of DT 104 within the Australian domestic pork industry.
5. Environment (including housing systems, premises, buildings and equipment, personnel)	
5.1 Housing types	Types of housing may influence the types of pathogens that pigs may carry or be contaminated with. **Notes** : Factors influencing pathogen status include type of separation between units, type of pens, possibility of snout contact between pens, type of floor including whether dry or straw-bedded floor, partitions close-fitted to floor, quarantine facility, hygienic-lock facilities.
5.2 Environmental contamination of the farming environment	Pigs may become directly contaminated by pathogens derived from environmental sources. **Note**: Some foodborne pathogens are ubiquitous in the farming environment, while others may be introduced into the farming environment by poor biosecurity practices via visitors, vehicles, rodents, wild animals, pet animals, carrions, houseflies and other insects such as cockroaches.

(b) Transport, Saleyards, Lairage, Slaughter and Carcass Dressing Operations

Input/Activity	Comment
All or most activities - transport and saleyards	Contamination, injury or other matters that could impact on the health or suitability of pigs for meat production occur because personnel lack skills and knowledge to implement practices that avoid injury to pigs, assess suitability for slaughter or other matters that could impact on the safety or suitability of pigs for meat production or the meat.
All or most activities- lairage, slaughter and carcass dressing operations.	Contamination, injury or other matters that could impact on the health or suitability of pigs for meat production occur because personnel lack skills and knowledge to implement practices that avoid injury to pigs, assess suitability for slaughter or other matters that could impact on the safety or suitability of pigs for meat production or the meat.
	Contamination from personnel involved in slaughter and meat production
	Contamination from premises and equipment
	Contamination from premises and equipment and personnel
1. Preparation and Transport to Market/Abattoir	
1.1 Selection of pigs and handling operations **(According to dirtiness)**	Dirty pigs may increase the likelihood of pathogen contamination onto carcass from external surfaces during the slaughtering and dressing process. **Notes:** Skin dirtiness is influenced by a number of factors, such as; production system (intensive, extensive, sheds with bedding systems), age, journey time, feeding regime.
1.2 Transport vehicles	Pathogens may contaminate pigs via cross-contamination from the transport vehicle. **Notes**: Transport vehicle may be contaminated with pathogens from previous loads. The washing procedures used for the vehicle may be insufficient for effective pathogen elimination.
	Stress during transportation and associated handling may result in increase shedding of pathogens in faeces. Stress may also induce non-shedding carrier animals to start shedding. **Notes**: Stress factors include noise, smells, mixing with unfamiliar pigs from other rearing pens or farms, high stocking densities, feed and water deprivation, transportation time, change in environment including temperature.
1.3 Feed Curfew	Pathogen load in the animal may increase when they are deprived of feed and water prior to and during transportation. Extended time in lairage off feed may also increase pathogen load in the animal. **Notes**: There was reported correlation with feed withdrawal times with the number of pathogens in the caecal content. APIQ requires pigs to be slaughtered between 6 – 24 hours after they have been removed from feed to minimise possible *Salmonella* contamination of the carcass. May also reduce vomiting during transport.
2. Saleyards	
2.1 Holding and processing	Pathogen transfer between animals in saleyard pens due to mixing animals from multiple sources.

Input/Activity	Comment
	Notes: Saleyards constitute a very small percentage of the domestic farmed pig industry.
3. Lairage	
3.1 Ante- mortem	Diseased, downer and dying animals may get through to slaughter. **Notes**: Identification of animals that may be displaying symptoms of disease or conditions that would make them unfit for human consumption, and/or may compromise the integrity of the slaughterhouse
	Time held in lairage may increase in pathogen load within the animal. **Notes**: Time pigs are held in lairage prior to slaughter can affect the pathogen load in the gastrointestinal tract. There was a reported correlation with feed and water withdrawal times with the number of pathogens in the caecal content in pigs. 'Carrier pigs' (*i.e.* pigs which are infected but not shedding) may start shedding during lairage.
	The lairage environment can become contaminated which may be transferred to pigs. **Notes**: Transfer of potential pathogens can occur between animals via physical contact *eg*. skin soiled with faeces and dust or through oral & nasal contact. The following pathogens have been identified in faeces or rectal samples of animals in lairage:
	Cleaning and disinfection of the lairage pen may not effectively reduce pathogen load. **Notes**: The following pathogens have been identified in the lairage environment: ▪ *Salmonella* spp. ▪ *Salmonella* spp. ▪ *Yersinia enterocolitica*
4. Slaughtering Operations	
4.1 Pig washing	Excessive levels of soil, dust and faeces on animals represent a source of contamination. Washing may not remove all microorganisms from the skin or may spread localised contamination. **Notes**: Microorganisms detected on pigs post-washing include: ▪ *Salmonella* spp.
4.2 Stunning & bleeding	Contamination of the slaughtering and processing environment **Notes**: Stunning method should ensure adverse effects such as blood-splash and fractures are avoided. The following pathogens have been detected on pigs post-bleeding: ▪ *Salmonella* spp. ▪ *Listeria* spp. (*L. monocytogenes*) ▪ Coagulase-positive *Staphylococcus aureus*
	Contamination of animals from abattoir environment **Notes**: Microorganisms detected in the abattoir stunning & bleeding area include: ▪ *Yersinia enterocolitica* ▪ *Listeria monocytogenes* ▪ *Salmonella spp.* ▪ Methicillin resistant *Staphylococcus aureus*
	Sticking may internalise surface bacterial pathogens
4.3 Scalding	Scald tank may not sufficiently reduce pathogen load on carcass. **Notes**: Microorganisms detected on pigs post-scalding include: ▪ *Salmonella* spp. ▪ Coagulase positive *Staphylococcus aureus*
	Contamination of carcase from scald tank environment. **Notes**: Scald tank is a potential source of bacterial contamination if temperature drops or the level of organic matter is high.

Input/Activity	Comment
4.4 Dehairing	Dehairing process may redistribute existing bacterial contamination more evenly over the carcass. **Notes**: Microorganisms detected on pigs post-dehairing include: ▪ *Salmonella* spp. ▪ Coagulase positive *Staphylococcus aureus*
	Contamination of the carcass from the dehairing equipment. **Notes:** Dehairing equipment may force faeces out of the anus, contaminating the equipment and carcass
4.5 Singeing	Pathogen contamination may remain on carcass post singeing especially in skin folds, ears or hair follicles.
4.6 Polishing	The polishing process may redistribute existing bacterial contamination on the skin more evenly over the carcass. **Notes**: Microorganisms detected on pigs post-polishing include: ▪ *Staphylococcus aureus* ▪ *Salmonella* spp. ▪ *Listeria monocytogenes*
	Contamination of animals from abattoir polishing environment
4.7 Pre-evisceration wash	Washing may spread localised microorganisms on the skin to other areas of the carcass **Notes**: Microorganisms detected on pigs post-evisceration washing include: ▪ *Salmonella* spp.
4.8 Bunging	Opportunity for faecal leakage onto carcass and into processing environment. **Notes**: Faeces contains potentially hazardous bacteria which include: ▪ *Listeria* spp. ▪ *Salmonella* spp. ▪ *Toxoplasma gondii* ▪ *Campylobacter jejuni/coli* ▪ *Yersinia enterocolitica*
	Cross contamination between carcasses and bunging equipment and environment. **Notes**: Microorganisms detected on bunging equipment include: ▪ *Salmonella* spp. detected on the rectal pistol (used prior to evisceration)
4.9 Carcase opening	Cross contamination from equipment to carcasses **Notes**: Microorganisms detected in carcase-opening environment include: ▪ *Salmonella* spp. detected on knife blades
4.10 Evisceration	Opportunity for faecal contamination of carcasses, utensils and slaughtering environment if carried out incorrectly. **Notes**: Potential pathogens identified in pigs which may cause carcass contamination if evisceration is carried out incorrectly include: ▪ *Salmonella* spp. ▪ *Toxoplasma gondii* ▪ *Campylobacter jejuni/coli* ▪ *Listeria* spp. ▪ *Yersinia enterocolitica*
4.11 Post-mortem	Macroscopic evidence of disease or faecal contamination of the carcass.
	Incision of tissues during post-mortem inspection may be a source of contamination for the slaughter house environment and the carcasses **Notes**: Microorganisms detected in tissues which may be inspected during post-mortem include: ▪ *Salmonella* spp. ▪ *Campylobacter* spp. ▪ *Yersinia enterocolitica*

Input/Activity	Comment
	Notes: A study in Australia demonstrated similar level of contamination occurred when using either traditional (incision) and risk-based (visual) post-mortem inspection.
	Pathogenic organisms may be present in edible offal. **Notes**: Pathogens detected in pig offal include: ▪ *Yersinia enterocolitica* ▪ *Listeria* spp. ▪ *Salmonella* spp ▪ *Campylobacter* spp. ***Notes:*** *C*ontaminated equipment/environment may transfer microorganisms to edible offal
4.12 Trimming	Carcass contamination. **Notes**: An opportunity to remove tissue and any other contamination, however some contamination may be missed and remain on carcass ▪ Coagulase positive *S. aureus* was detected on neck, belly, back and ham of carcasses
4.13 Washing	Washing may introduce or spread existing contamination over the carcass. It may also provide a moist environment for pathogens to survive. **Notes**: Microorganisms detected post-washing include: ▪ Coagulase positive *S. aureus* ▪ *Yersinia enterocolitica* ▪ *S. aureus* ▪ *Salmonella* spp ▪ *Listeria monocytogenes*
4.15 Storage	Opportunity for outgrowth of pathogens *Refer to Cattle Transport Table* **Notes:** Carcass cooling rate depend on size, air temperature and flow rate and position of the carcase in the cooling chamber.
4.16 Splitting, Boning, packing	Contamination of carcass during the splitting, boning and packaging process **Notes**: Opportunity for cross-contamination between carcasses/portions and the processing environment Possible microbiological contaminants include: ▪ *Listeria monocytogenes* ▪ *S. aureus* ▪ *Salmonella* spp ▪ *Clostridium perfringens* ▪ *Yersinia enterocolitica* ▪ *Campylobacter* spp.
4.18 Storage of packed meat	Potential for outgrowth of pathogens. *Refer to Cattle Transport Table*

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Summary

The microbiological status of meat is influenced by factors along the entire meat supply chain. While a vast array of microbiological hazards could potentially contaminate the carcass, only a small number of these pathogens may present a risk to consumers if unmanaged. The hazard tables list a wide range of microbiological hazards that may be found on the carcasses originating from cattle, sheep, goats and pigs.

The principal microbiological hazards identified in the on-farm phase of meat production and after slaughtering operations include pathogenic *E. coli* and *Salmonella* spp., although there is some variation between meat species. Pathogens which have more commonly been associated with the main species are listed below:

Animal	Principal microbiological hazards
Cattle	Pathogenic *Escherichia coli*, *Salmonella* spp., *Campylobacter jejuni* and *C. coli*,
Sheep	Pathogenic *Escherichia coli* and *Salmonella* spp.
Goats	Pathogenic *Escherichia coli* and *Salmonella* spp.
Pigs	*Salmonella* spp., *Yersinia enterocolitica*, *Toxoplasma gondii*, *Campylobacter jejuni* and *C. coli*.

During the animal production phase, there are a number of key inputs and activities which influence the manner in which hazards may be introduced or amplified. They are summarised below:

Input and/ or activity	Comment	Step in chain where control may be applied
Animal health	Pathogens may exist in the animal with or without exhibiting clinical signs	Animals with clinical signs of disease or illness are identified and managed at: • Dispatch from farm/saleyard • Arrival at abattoir • Ante-mortem inspection Without clinical signs, potential hazards may be identified and managed at: • Slaughter to minimise contamination from external surfaces or internal spillage • Post-mortem inspection
Stress	Animals may be more susceptible to infection and/or have increased faecal shedding. Pathogens colonise the gut	Minimise exposure of animals to stress during: • Transport • Lairage
Feed	Feed has the potential to introduce pathogens into the gut or environment	Management of input of manure and fertiliser onto pasture Control supplements Oversight of ensilage operations
Water	Contributes to internal and external contamination	Access of animals to suitable drinking water
Environment and management of biosecurity	Pathogens may contaminate external surfaces of animal, or can lead to ingestion or infection of the animal	Pasture management Vermin and pest control Good agricultural practices Sound animal husbandry

In summary, there are two main sources of contamination to the meat carcass:

- External contamination - From the animal (hide, skin, fleece, hooves, faeces, etc) and the environment, and;
- Internal contamination - During evisceration and dressing operations and following spillage of gastro-intestinal tract contents.

Abattoir and slaughtering operations are currently mandated under the Australian Standard *AS4696* to ensure that meat produced for human consumption is wholesome and safe. A large number of producers in Australia adhere to a voluntary on-farm quality assurance program (Livestock Production Assurance; LPA). The accreditation system is underpinned by an on-farm property risk assessment component and utilises a voluntary National Vendor Declaration (NVD) and mandated National Livestock Identification System (NLIS) for quality assurance livestock traceability.

One additional concern has been the potential transmission of antimicrobial resistant (AMR) microorganisms to humans via food. Control measures on farm and during processing are designed to reduce the likelihood of microbial contamination of meat, irrespective of the microbial pathogens' resistance profile. The Department of Health is working with the Department of Agriculture to develop a National Antimicrobial Resistance Prevention and Containment Strategy (the National AMR Strategy) under the direction of the Antimicrobial Resistance Prevention and Containment Steering Group. That National AMR Strategy will take a One Health approach, ensuring consistent responses to AMR across sectors. The Steering Group has endorsed seven key elements of the National AMR Strategy: surveillance; international engagement; regulation; governance; communication; infection prevention and control; and research.

During the hazard assessment, a number of pathogenic (zoonotic) microorganisms were identified, and while the oral route may not be the normal route of human infection, it is plausible or potentially possible that consumers may become infected by handling raw meat, through cross-contamination, or by the ingestion of meat which has not been thoroughly cooked. In summary, leptospirosis may be controlled by vaccination of cattle and therefore presents little risk to consumers. There is limited scientific evidence attributing transmission of anthrax, melioidosis and Q fever to humans through ingestion. Available data indicates the primary mode of transmission is via inhalation or cutaneous exposure rather than through ingestion. Although ingestion is plausible as a transmission route for human infection, it is likely to be of minimal risk in Australia.

The findings of this assessment are consistent with the significant body of evidence that exists for the Australian domestic meat industry indicating that domestically-reared red meat (cattle, sheep, goats) and pigs, processed under existing standards, present a low risk to public health. Also evidenced is that industry personnel are fairly mature in their knowledge and management of food safety risks.

Further, considerable data is available to support the safety of meat and meat products produced from beef, sheep and pork in Australia. The evidence suggests that Australian meat from these species has a low microbial load and generally low prevalence of pathogens. Many of the pathogens listed in this assessment occur infrequently or not at all on Australian meat.

Appendix 1: Foodborne Disease Outbreaks Associated with Meat

These data are provisional and subject to change. Please quote as "OzFoodNet Unpublished Data, 2009"Please clear ALL citations of this internal brief in reports for public release.

Prepared by: Katrina Knope, Polly Wallace, and Katie Fullerton
April 2009

Introduction

Meat products are a common cause of foodborne outbreaks in Australia. An analysis of the OzFoodNet Outbreak Register was conducted in order to study the burden, causes and settings of these outbreaks. The OzFoodNet Outbreak Register contains data on outbreaks across Australia from January 2003 to June 2008.

Nature of report

This report summarises outbreaks of human illness associated with meat, not including poultry, which occurred between January 2003 and June 2008.

Data analysis

This analysis was carried out in the following manner:

- Reports of outbreaks were extracted from the database using the following search terms:
- [Field: Year]: >=1 January 2003 And <= 30 June 2008
- [Field: Transmission]: Foodborne Or Suspected Foodborne
- [Field: Food vehicle]: Like *meat* Or Like *lamb* Or Like *pork* Or Like *bacon* Or Like *ham* Or Like *sausage* Or Like *steak* Or Like *frank* Or Like *beef* Or Like *kebab* Or Like *fillet* Or Like *roast* Or Like *carne*
- [Field: Remarks]: Like *meat* Or Like *lamb* Or Like *pork* Or Like *bacon* Or Like *ham* Or Like *sausage* Or Like *steak* Or Like *frank* Or Like *beef* Or Like *kebab* Or Like *fillet* Or Like *roast* Or Like *carne*
- The 'Remarks' field was reviewed and where appropriate data on 'Food vehicle' were recoded to ensure consistency during analysis. Where the food vehicle field was unknown and information was found in the remarks field the food vehicle field was filled in
- Data were cleaned and recoded to provide consistent categories for data fields, including aetiological agents and food vehicles.
- Outbreaks were categorized as Meat, Dish containing meat, Suspected meat, or Suspected dish containing meat
    - Meat: outbreaks with sufficient descriptive or epidemiologic information to implicate a meat product
    - Dish containing meat: outbreaks with sufficient descriptive or epidemiologic information to implicate a dish containing meat
    - Suspected meat: outbreaks with insufficient descriptive or epidemiologic information to implicate a meat product, but high degree of investigator suspicion
    - Suspected dish containing meat: outbreaks with insufficient descriptive or epidemiologic information to implicate a dish containing meat, but high degree of investigator suspicion
- Outbreaks with only chicken as the identified food vehicle were excluded, however, outbreaks where chicken and another meat product, such as lamb or beef, were implicated were included in the analysis.
- Fish as a food vehicle was excluded from analysis.

- Data were analysed in Excel 2000 to summarise the number of people ill and hospitalised for different settings for outbreaks, mode of transmission, pathogen and implicated food vehicle.

Outbreaks associated with meat, January 2003 to June 2008

OzFoodNet epidemiologists reported a total of 653 outbreaks of foodborne or suspected foodborne disease from January 2003 to June 2008, which represented 28% (653/2304) of all outbreaks reported. Ten percent (66/653) of these outbreaks were related to the consumption of meat or dishes containing meat, not including poultry.

In total, there were 66 meat-associated outbreaks affecting at least 1005 people, with 52 people hospitalised and no deaths. The mean number of people affected in these outbreaks was 15 people, with a range of 2 to 100 people. The largest number of meat-associated outbreaks in one year was 19 outbreaks in 2005.

Forty eight percent (32/66) of meat-associated outbreaks occurred in New South Wales, 21% (14/66) in Queensland, 14% (9/66) in Victoria, 6% (4/66) in Western Australia, 5% (3/66) in each of Northern Territory and South Australia, and 2% (1/66) in the Australian Capital Territory.

Forty three percent (29/66) of the outbreaks occurred in restaurants and 14% (9/66) were associated with takeaway food (Figure 1). Eleven percent (7/66) of the outbreaks were associated with a commercial caterer, 8% (5/66) at private residences. In 8% (5/66) of outbreaks investigators listed the setting where the food was prepared as “other unspecified settings”.

An aetiological agent was identified in 55% (36/66) of the meat-associated outbreaks (Table 1). A variety of *Salmonella* serotypes were responsible for 27% (18/66) of the outbreaks, of these 12 (67%) were *Salmonella* Typhimurium. The other *Salmonella* serotypes were Anatum, Bovismorbificans, Johannesburg, Oslo, Zanzibar, and 4,12:d:-. Twelve percent of outbreaks (8/66) were due to *Clostridium perfringens*, 6% (4/66) were due to norovirus, and 5% (3/66) were due to staphylococcal toxin. There were individual outbreaks due to *Campylobacter* (not speciated), *Listeria monocytogenes*, and *Bacillus cereus*.

Of the 66 meat-associated outbreaks, 20% (13/66) had the food vehicle categorised as meat, 35% (23/66) had the food vehicle categorised as a dish containing meat, 17% (11/66) had the food vehicle categorised as suspected meat, and 29% (19/66) had the food vehicle categorised as suspected dish containing meat.

Conclusions

From January 2003 to June 2008 there were 66 outbreaks associated with meat in Australia. The majority of these outbreaks were due to a dish containing a meat product. Meat products cause a considerable amount of foodborne disease in Australia, particularly due to various *Salmonella* serotypes and toxin based poisonings due to *Clostridium perfringens* and *Staphylococcus aureus*. The under cooking of meat and temperature abuse after cooking are major causes of meat-associated outbreaks.

This summary is subject to at least two limitations. First, it is likely that other outbreaks thought to be caused by cross-contamination with meat or meat juices during preparation have not been captured in this summary. Cross-contamination as the cause of an outbreak is very difficult to assess and are not captured in these data. Second, it can be very difficult to categorise and summarise aggregated outbreak data by commodity. In this instance, the commodity 'meat' covers a large variety of different meat products, and, the identification of outbreaks that are due to a meat product or a dish containing a meat product is limited by the quality of the data collected. These data are often free-text, subjective summaries that do not uniformly report food vehicles by commodity type.

Figure 1: Settings where food was prepared in outbreaks of foodborne illness associated with meat, OzFoodNet, January 2003 to June 2008 (*n*=66).

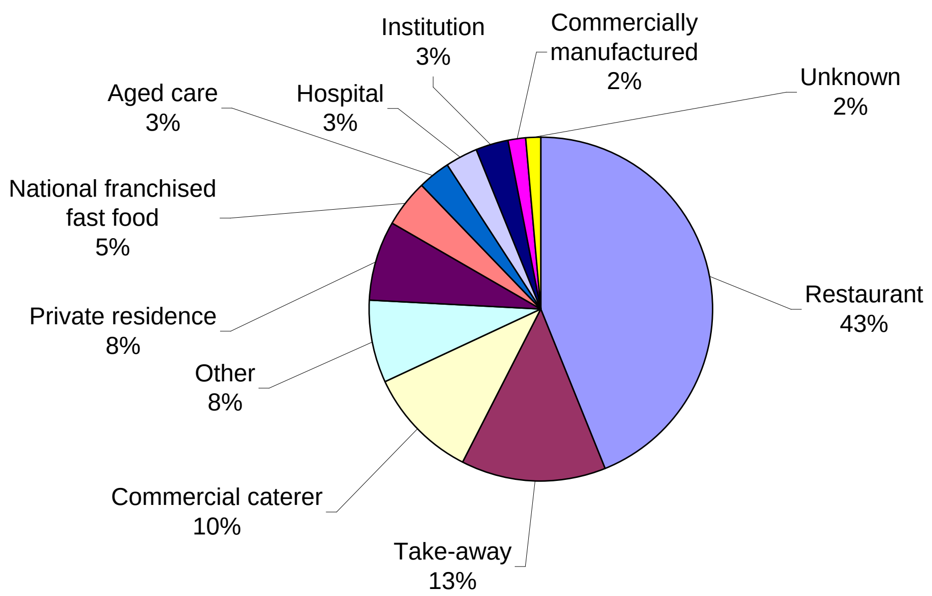

Table 1. Aetiologic agent in outbreaks of foodborne illness associated with meat, OzFoodNet, January 2003 to June 2008 (*n*=66).

Aetiology	Outbreaks
Salmonella Typhimurium	12
Clostridium perfringens	8
Salmonella 'Other'	6
Norovirus	4
Staphylococcus aureus	2
Suspected Staphylococcal toxin	1
Listeria monocytogenes	1
Campylobacter	1
Bacillus cereus	1
Unknown	30
Total	**66**

Table 2: Outbreaks of foodborne illness associated with meat, excluding poultry, in OzFoodNet Sites January 2003 to June 2008 (*n*=66).

State	Year	Setting	Ill	Hospitalised	Category	Food Vehicle	Aetiology
ACT	2005	Commercial Caterer	27	0	Dish containing meat	Roast pork on bruschetta, duck and quince tartlets	Norovirus
NSW	2003	Restaurant	4	1	Meat	Pork	*Salmonella* 4,12:d:-
		Private Residence	6	0	Meat	Sliced soccerball ham	Unknown
		Commercial Caterer	3	0	Suspected dish containing meat	Suspected pies, beef, chicken, tomato & onion	Unknown
	2004	Hospital	5	5	Suspected dish containing meat	Suspected beef curry	Unknown
		Restaurant	20		Suspected dish containing meat	Suspected bacon and mushroom dish	Unknown
		Restaurant	12	0	Suspected meat	Suspected bacon and ham	Unknown
		National Franchised Fast Food	5	1	Suspected dish containing meat	Suspected BBQ Meat Lovers pizza	Unknown
		Other	27	1	Meat	Roast pork	*Salmonella* Typhimurium RDNC, 170
	2005	Restaurant	2	0	Suspected dish containing meat	Suspected chicken and bacon burgers	Unknown
		Take-Away	4	0	Dish containing meat	Roast beef and gravy	Unknown
		Restaurant	2	0	Suspected meat	Suspected beef steak	Unknown
		Restaurant	2	0	Suspected dish containing meat	Suspected beef burger	Unknown
		Restaurant	9	0	Dish containing meat	Ham pizza	Suspected staphylococcal toxin
		Private Residence	43	13	Meat	Lamb's liver	*Salmonella* Typhimurium
		Restaurant	5	0	Suspected meat	Lamb, beef	Unknown
		Restaurant	5	0	Suspected meat	Suspected roasted meats	Unknown

State	Year	Setting	Ill	Hospitalised	Category	Food Vehicle	Aetiology
		Aged Care	10	0	Dish containing meat	Chicken, bacon and mushroom sauce, rice	*Clostridium perfringens*
		Commercial Caterer	13	0	Dish containing meat	Beef casserole	Unknown
	2006	Restaurant	2	2	Suspected dish containing meat	Suspect pork in plum sauce, fried ice cream	*Salmonella* Typhimurium 170 var
		Take-Away	80	0	Meat	Roast pork	*Clostridium perfringens*
		Restaurant	13	0	Suspected dish containing meat	Suspect oysters, lobsters, prawns, rainbow trout, icecream, sashimi, crab, mussels, beef curry	Unknown
		Take-Away	4	1	Suspected dish containing meat	Suspect beef or chicken hamburger with salad, cheese, bacon	*Salmonella* Typhimurium
		Restaurant	24	0	Dish containing meat	Various Indian dishes - rice, beef madras, butter chicken, lamb roagn josh, vege curry	Unknown
	2007	Private Residence	8	2	Meat	Beef patties	*Salmonella* Typhimurium
		Restaurant	14	0	Suspected dish containing meat	Raw capsicum, onions, fresh herbs, chicken and/or beef	Unknown
		Take-Away	4	0	Suspected dish containing meat	Suspected beef or lamb kebab	Unknown
		Restaurant	9	0	Dish containing meat	Chicken stirfry or beef massaman	Unknown
		Take-Away	2	1	Dish containing meat	Meat kebab	*Campylobacter*
	2008	Commercial Caterer	75	0	Suspected dish containing meat	Suspected curry pumpkin, curry chicken, rice with lamb	*Bacillus cereus*
		Restaurant	7	0	Dish containing meat	Suspected chilli beef	*Salmonella* Typhimurium U290

State	Year	Setting	Ill	Hospitalised	Category	Food Vehicle	Aetiology
		Restaurant	4	0	Dish containing meat	Stir fry beef with dried hot chilli and peanut	Unknown
		Restaurant	2	0	Suspected meat	Suspected ham	Unknown
NT	2003	Take-Away	5	4	Suspected dish containing meat	Rice, beef and black-bean sauce.	*Staphylococcus aureus*
		Commercial Caterer	7	1	Meat	Roast meat	*Salmonella* Typhimurium 135
	2007	Commercial Caterer	3	0	Suspected meat	Suspect roast pork	*Salmonella* Oslo
QLD	2003	Restaurant	7	0	Dish containing meat	Beef burgundy	Unknown
		Other	16	0	Dish containing meat	Pasta salad with ham	*Staphylococcus aureus*
		Restaurant	21	2	Suspected meat	Suspected roast pork	*Salmonella* Typhimurium U307
	2004	National Franchised Fast Food	6	0	Dish containing meat	Pizza	*Clostridium perfringens*
	2005	Restaurant	14	0	Dish containing meat	Chicken and / or lamb guvec	*Clostridium perfringens*
		Restaurant	3	0	Dish containing meat	Beef rendang	*Clostridium perfringens*
		Aged Care	36	0	Meat	Braised steak & gravy	*Clostridium perfringens*
	2006	Restaurant	6	0	Suspected dish containing meat	Suspected lamb korma	Unknown
		Take-Away	4	0	Suspected dish containing meat	Suspected doner kebab	Unknown
		Restaurant	13		Dish containing meat	Chicken & lamb guvec	*Clostridium perfringens*
		Restaurant	3	1	Suspected dish containing meat	Suspected hommus, hot & spicy dip, baba ghanoush dip, mussakka, lamb hotpot, lamb cutlets	*Salmonella* Zanzibar
		Restaurant	8		Dish containing meat	Sweet and sour pork, chow mein beef	Unknown
	2007	Institution	45	0	Suspected meat	Ham; salad; bread	Norovirus
	2008	Institution	56	0	Dish containing meat	Deli meat & salad dish	Norovirus
SA	2005	Hospital	5	5	Meat	Silverside-corned beef	*Listeria monocytogenes*
		National Franchised Fast Food	4		Suspected dish containing meat	Suspected chicken and bacon burgers	Unknown

State	Year	Setting	Ill	Hospitalised	Category	Food Vehicle	Aetiology
	2006	Restaurant	7	0	Dish containing meat	Sandwich containing egg and ham	*Salmonella* Anatum
VIC	2003	Other	12	0	Meat	Spit-roasted pork	*Salmonella* Typhimurium 170
		Other	20	4	Meat	Spit-roasted pork	*Salmonella* Typhimurium 170
	2005	Restaurant	20	1	Suspected meat	Suspected roast pork	*Salmonella* Typhimurium 170
		Private Residence	13	0	Suspected meat	Suspected undercooked bbq meat	*Salmonella* Typhimurium 12
		Private Residence	10	0	Suspected dish containing meat	Suspected rice, peppers stuffed with a minced lamb filling, pieces of lamb	Unknown
	2006	Commercially Manufactured	13	4	Meat	Capocollo (cured pork)	*Salmonella* Bovismorbificans 11
		Restaurant	10	0	Suspected meat	Suspected roast meats	Unknown
	2007	Take-Away	17	0	Suspected dish containing meat	Suspected meat curry	Unknown
	2008	Take-Away	14	1	Meat	Roast pork	*Salmonella* Johannesburg
WA	2003	Commercial Caterer	10	0	Dish containing meat	Sandwich meat	Unknown
	2004	Other	100	0	Dish containing meat	Pasta meat sauce	*Clostridium perfringens*
	2006	Unknown	19		Dish containing meat	Beef/salad roll	Unknown
	2007	Restaurant	26	2	Dish containing meat	Café meal (including bolognaise sauce, sliced ham, diced chicken)	Norovirus