Antemortem Inspection of Pigs On-Farm: Impact on Food Safety and Animal Welfare

A thesis
submitted by

Jan Jackowiak
(BSc., BVMS, Murdoch University, Western Australia)

to the
Faculty of Agriculture and Natural Resource Sciences
The University of Adelaide

for the degree of
Master of Agricultural Science

Department of Animal Science
March 2000

TABLE OF CONTENTS page

TABLE OF CONTENTS

page

TABLE OF CONTENTS

page

TABLE OF CONTENTS

page

LIST OF TABLES AND FIGURES

Acknowledgments

The breadth of this study required the cooperation of a large number of abattoir personnel, pig producers, veterinarians and PHMS inspectors. To these people I offer my sincere thanks.

It is clear that the producers, supported by their veterinarians, have applied themselves in a rigorous and conscientious manner, for which they are warmly thanked. There is much in the data to indicate that their standard of stockmanship ranks highly by international standard.

I am grateful to the participating abattoirs for embracing the project objectives so enthusiastically, for providing a facility for conducting the training sessions and for making their staff available.

I am particularly indebted to the state coordinators who recruited the producers, organised the training sessions and coordinated all the tasks required for each test batch of pigs, and monitored the postmortem findings.

The development of the antemortem and post-mortem criteria was made possible by the responsiveness of the survey respondents. Without their willing expertise the criteria could not have been as realistic and relevant to the field situation.

Jo Slade helped in compiling the training manual and video.

Margaret Cargill taught me the intricacies of scientific writing.

Viv Kolega for the competent microbiology.

Apart from the abovementioned, my personal thanks go especially to the following people:

My supervisors, Dr Phil Hynd (Department of Animal Science, University of Adelaide) and Dr Andrew Pointon (South Australian Research and Development Institute), who both provided constructive criticism of this thesis. Phil Hynd also provided guidance in the extent of the experimental studies and literature review, and ensured I met all my university obligations. Andrew Pointon was the driving force behind the whole project. He set it up largely as part of my employment with the South Australian Research and Development Institute and has mentored me all the way along. I wouldn't have got anywhere without him.

Financial support for the study was generously supplied by the Pig Research and Development Corporation.

Declaration

This thesis contains no material previously submitted for the award of any other Degree or Diploma in any other university or institution. To the best of my knowledge, this thesis does not contain any material previously written or published by another person, except where a due reference has been made in the text.

I give consent to this copy of my thesis, when deposited with the University Library, being available for loan and copying.

Date: 10/11/2000

Signature:

Jan Jackowiak

Abbreviations

AAPV	Australian Association of Pig Veterinarians
APIQS	Australian Pig Industry Quality Standards
AQIS	Australian Quarantine and Inspection Service
CCP	Critical Control Point
ELISA	Enzyme Linked Immunosorbent Assay
EHEC	Enterohaemorrhagic *E. coli*
EU	European Union
ECA	Export Control Act
HACCP	Hazard Analysis and Critical Control Point
PHMS	Pig Health Monitoring Scheme
QA	Quality Assurance
TB	Tuberculosis
US or USA	United States of America

Chapter 1

Introduction

Chapter 1 Introduction

In an increasingly demanding consumer society, all sectors of the food producing chain are being held accountable for the quality of their produce and the welfare of their animals. In this marketing climate it is vital that the Australian Pig Industry endeavours to assure consumers that pig meat is both healthy and produced in a welfare-friendly manner.

Antemortem inspection is a simple visual health check that has always been done at the abattoir before slaughter to identify and separate pigs that are suffering or that may not be completely suitable for human consumption (Snijders, 1988). It is assumed that sick pigs are more likely to be shedding organisms of food borne significance, so by slaughtering pigs with grossly detectable abnormalities (suspects) separately, the likelihood of cross-contamination of other pigs is reduced. In-contact surfaces and equipment can then be cleaned before slaughter of apparently healthy pigs is resumed. Improved slaughter chain efficiencies are possible by scheduling extra inspectors and skilled trimmers during the processing of the suspects to maintain normal chain speed.

The adoption of hazard analysis and critical control point (HACCP) quality assurance (QA) systems by the Australian Pig Industry has provided a framework for performance of antemortem inspection on-farm. Removal of suspect pigs on-farm prior to transport constitutes a tangible critical control point (CCP), creating an opportunity to improve their welfare during transport. Feedback on carcase condemnation from abattoirs could then provide producers with details of the extent of transport injury (ie. fractures, bruising). By performing antemortem inspection on-farm, producers can also help abattoirs to meet regulatory requirements. The European Commission Standing Veterinary Committee has endorsed on-farm antemortem inspection as a prerequisite for the adoption of visual only inspection of normal pigs (Snijders and Berends, 1996), with implementation up to the politicians.

A study in The Netherlands (Harbers et al, 1992a) found that producers were better at segregating suspect pigs on-farm than were inspection staff at the abattoir lairage. This is hardly surprising, given that abattoir inspectors are in a relatively short space of time examining large numbers of pigs that are excited/stressed by their new surroundings. In addition, producers can include in their judgement, knowledge of events that had occurred during the finishing period. A field-trial of on-farm antemortem inspection by Australian producers could underpin the national implementation of on-farm antemortem inspection as part of on-farm HACCP based QA.

This project was modelled on the Dutch study (Harbers et al, 1992a), and aimed to verify its findings and determine the impact of the approach on food safety under Australian conditions. As bacon pigs (85-100kg weight range) are seldom culled, and represent the largest proportion of slaughter pigs, they were the choice subset of the pig population to use. Producers in three states (Victoria, Queensland and South Australia) were trained to conduct antemortem inspection on-farm, and their efficiency evaluated against antemortem inspection conducted at the abattoir. Gross abnormalities detected in carcases post-mortem, which resulted in partial/whole carcase condemnation, were recorded and reported back to producers, so they could be compared to antemortem findings. To evaluate the association of antemortem inspection status with contamination of ingesta, caecal samples taken from both suspect and normal pigs were cultured for *Salmonella*.

Chapter 2

Literature Review

Chapter 2 Literature Review

2.1 Introduction

Antemortem inspection is an established routine abattoir procedure considered to be good manufacturing practice (Snijders, 1988). Its main purposes are the prevention of slaughter of pigs that are unfit for human consumption (Edwards et al, 1997), the detection of pigs with gross abnormalities (suspects) for slaughter separate to normal pigs, and the reduction of suffering in injured pigs by early detection and slaughter (Murray, 1986). It has also served as a "second base" for detection of exotic diseases. Harbers et al (1992a) found that producers were better at segregating suspect pigs on-farm than were inspection staff at the abattoir lairage. This raises the possibility that current antemortem inspection procedures could be substantially improved, and warrants trialing under Australian conditions.

The supposition behind antemortem inspection is that suspects are more likely to be contaminated with antibiotic residues, to be harbouring pathogenic microorganisms in lesions and to be shedding organisms of food borne significance (Pointon, 1997a). By slaughtering suspect pigs separately, the likelihood of cross-contamination of normal pigs is thereby reduced. However, normal pigs also harbour food borne pathogens such as *Salmonella* in their gut (Chung and Frost, 1969; Riley, 1970), and pork has been implicated as a significant source of salmonellosis in humans (Linton, 1979; Bean and Griffin, 1990; Mousing et al, 1997a). Therefore, much research has been undertaken to investigate means of controlling *Salmonella* in pigs on-farm (Wilcock and Schwartz, 1992; Fedorka-Cray et al, 1994, 1997; Fedorka-Cray, 1997), during transport and holding prior to slaughter and during the slaughter process (Berends et al, 1996; Morgan et al, 1987; 1988f), to minimise the food safety risk.

This literature review explores the origins of antemortem inspection, its scientific basis and outcomes. It examines the possibility of doing antemortem inspection on-farm, and investigates the impact of this practice on food borne hazards in pigmeat. Because *Salmonella* is widely recognised as the leading cause of bacterial food borne infections (Gronstol et al, 1974a; Maguire et al, 1993; Davies et al, 1997; Fedorka-Cray et al, 1997), its presence in pork, pigs and suspects is reviewed.

2.2 Antemortem inspection

2.2.1 History of antemortem inspection

According to the Holy Scriptures, the consumption of meat by our ancestors was first permitted after Noah survived the great flood in his ark (NIV Study Bible, 1985, Genesis 9:3). Prohibitions against the consumption of certain meats were later recorded by Moses and have been cited by various authors (Burndred, 1924; Melrose and Gracey, 1974) as the origins of meat inspection. In discussing these Israelite prohibitions, Collins (1966) points out that their basis was not sanitary, but rather, sacramental; a view shared by theologians (NIV Study Bible, 1985, footnote to Leviticus 11:2). Collins (1966) also noted that other ancient tribes considered certain animals to be strange, sacred, offensive or demon infested, and would have refrained from eating them for these reasons rather than for health reasons.

Ancient Egypt had the first known meat inspection system (Andriessen, 1987). Collins (1966) reported that sanitary prohibitions also occurred in other civilisations. These include the Roman Emperor Severus prohibiting the sale of meat from dead and obviously sick animals and Pope Zacharius forbidding the consumption of meat from diseased animals, and localised efforts in Europe controlling the sale of diseased meats. When veterinary schools were set up in France late in the 18th century, it was demonstrated that some condemned meat was actually harmless, whilst other apparently insignificant conditions were consumer hazards. Understanding of food borne hazards remains a challenge to scientists to this day.

Antemortem inspection had its beginnings in the Pasteur era when it was realised that some animal diseases were transmissible to humans. A Royal Commission on Tuberculosis (TB) in 1895, to decide the extent to which carcases with TB could be used for human consumption, formed the basis of our present meat inspection system (Melrose and Gracey, 1974; Blamire, 1985). The emergence of antemortem inspection in such a setting is perhaps best illustrated by focussing on the situation in England around this time. Despite modern acts of parliament being instituted as early as 1835, to curb the sale of unwholesome meat, Collins (1966) estimated that in 1862, 20% of the meat consumed in England came from animals that were considerably diseased.

Examples of traffic in diseased meat by “carrion/cagmag butchers” are colourfully described by Walley (1896). This traffic was virtually impossible to control because of the large number of private slaughterhouses in operation. The Public Health Act of 1875 gave certain officers/inspectors the power to seize unsound animals and/or meat for presentation to a justice for disposal (Burndred, 1924; De Vine, 1932), but these powers were not generally applied (Blamire, 1985). The invention of refrigeration made possible the import and export of chilled meat as early as 1877. As this trade grew, England insisted on high standards of meat inspection in exporting countries, even while contentedly consuming her own locally produced uninspected meat (Collins, 1966).

In 1886 the Model Abattoir Society was founded. Its objectives were to abolish private slaughterhouses and erect large public abattoirs where all the best slaughtering practices could be adopted (Blamire, 1985). Only in such centralised abattoirs could economy of scale ensure hygienic processing and adequate inspection (Collins, 1966). Yet decades later animals in Ireland were still being slaughtered for human consumption anywhere, anytime, unsupervised and uninspected (McClure et al, 1923). The authors quoted a resolution of a Sanitary Congress in 1919, which recommended that all private slaughterhouses in Great Britain and Ireland be abolished, and they urged that veterinarians be appointed to perform antemortem and postmortem inspection. Burndred (1924) insisted that control of emergency slaughter of stock was long overdue. He felt that veterinary antemortem inspection of every sick/injured animal was essential and that a veterinary certificate be required to accompany each such animal to the point of postmortem inspection.

When the Ministry of Feed monopolised the buying of all slaughter animals (Blamire, 1985), the number of slaughterhouses was reduced from 20,000 (in 1927) to 495 (in 1951), but antemortem inspection was reported to be the exception rather than the rule (Collins, 1966). Deregulation in 1953 allowed 4,000 old slaughterhouses to reopen, but the Slaughterhouses Act, 1958, required that facilities conform to minimum standards (Blamire, 1985). Thus, England lagged behind other European nations such as France, Belgium, Holland, Denmark, Germany and Scotland, in introducing regulations for veterinary antemortem inspection (De Vine, 1932; Jagger, 1984). In the USA antemortem inspection became mandatory with the introduction of the Wholesome Meat Act, 1967 (Libby, 1975).

In Australia, the Disease Animals and Meat Act of 1892 prohibited consignment of diseased animals in saleyards, in transit, and at slaughtering premises (Hindmarsh, 1971). The Commonwealth Government set up its own inspection service in 1916, then in 1965 in response to political pressures increased veterinary staffing, and required antemortem inspection of all animals intended for export (Collins, 1966). Antemortem inspection was also required at larger domestic abattoirs, but not at limited throughput slaughterhouses. These slaughterhouses were given three years from December 1994 to have a qualified person on the premises to conform to the Australian Standard for Hygienic Production of Meat for Human Consumption. Thus antemortem inspection of all animals intended for domestic consumption was finally achieved in 1998.

2.2.2 Current objectives of antemortem inspection

Although the beginnings of antemortem inspection amounted to an attempt to curb the trade in meat from diseased animals and cadavers, other benefits soon became apparent. High quality butchers had the opportunity to salvage some meats deemed fit by inspection that would otherwise have been condemned in ignorance. More important was the protection of honest butchers from unfair competition. The absence of compulsory inspection had allowed dishonest butchers to purchase diseased animals cheaply with intent to sell the meat, securing an unfair business advantage (Collins, 1966). Honest butchers killing animals at public abattoirs would pay low prices for doubtful animals at risk of condemnation, whereas by using slaughterhouses to escape inspection, dishonest butchers could offer a higher price for the animals (Rabagliati, 1931).

Centralised slaughtering in large abattoirs, with resulting economies of scale, favoured establishment of meat inspection services. With certainty, the push by national veterinary bodies and/or other interested parties to legislate for compulsory antemortem inspection would have been driven with every conceivable argument illustrating the benefits. Once enshrined in legislation, such arguments would typically reflect the aims outlined in the following excerpt from the Australian Standard for Hygienic Production of Meat for Human Consumption (Anon, 1997):

> The specific aims of antemortem inspection are to:
>
> - prevent the processing of animals showing evidence of disease or any other condition that would make the carcase or parts unfit for human consumption;
> - separate animals suspected of having a disease or any other condition that could make the carcase or parts of it unfit for human consumption for segregated slaughter;
> - prevent animals that are grossly contaminated with extraneous matter from entering the slaughter floor;
> - ensure that all animals and, in particular, injured animals are treated humanely;
> - detect the presence of exotic or other notifiable disease.

Other aims which could be added to this list include:

- provide feedback to producers concerning diseases and injuries causing unnecessary losses in livestock
- protect animal and food handlers against zoonoses;
- ensuring animals are correctly identified;
- ensuring animals have been adequately rested.

2.2.3 Limitations of abattoir antemortem inspection

Only a limited number of conditions are detectable by antemortem inspection, and often their detection is much easier postmortem (Table 1). On the other hand, nervous symptoms such as tremor, incoordination, circling and head tilt are obvious antemortem, but postmortem changes may be absent. Compounding this, the value of abattoir antemortem inspection can be further diminished by inspectors' working conditions, inspection technique, and lack of knowledge about the health history of the pigs (Berends et al, 1993).

Table 1 Comparison of efficiency of antemortem and postmortem inspection at detecting conditions which normally warrant segregation prior to slaughter

Grossly detectable abnormality	Antemortem Detection	Removed by Routine Dressing	Postmortem Detection
Gangrenous prolapses	+	+	+/-
Hernia	+	+	+/-
Balanoposthitis	+	+	+/-
Enlarged scrotum	+	+	+
Severe/infected wound	+		+
Erysipelas (Diamond Skin)	-		+
Arthritis	+/-		+
Crippled limb	+		+/-
Foot abscess	+/-		+
Superficial abscesses	+/-		+
Severe tailbite	+		+
Fractures/dislocations	+		+
Cannot walk unassisted	+		+/-
Fever	+/-		+

+ = normally detected - = not detected +/- = detection unreliable

Inspectors at abattoirs perform a rigid legally prescribed inspection procedure on large numbers of pigs (Berends et al, 1993), most of which are normal. Conditions in the lairage are often cramped, noisy and smelly, and with many other tasks to perform elsewhere in more favourable environments, inspectors feel considerably pressured for time, and all these factors combine to reduce their attentiveness during antemortem inspection. Compounding this, pigs awaiting slaughter are often stressed by fasting, unfamiliar surrounds, and mixing with strange pigs, which can induce symptoms such as excessive defecation/diarrhoea, and mask other disease symptoms such as depression. It is hardly surprising that Harbers et al (1992a) found that producers were able to detect at least as many suspects on-farm as veterinary inspectors performing antemortem inspection at the abattoir. In Sweden animals are routinely examined on-farm before they are consigned for slaughter.

Producers are not required to provide details of the diseases occurring or medications used in their pigs. However, if this were mandated, tissue sampling for chemical residues and/or more specific post mortem examination (Jagger, 1984) could result in a higher rate of condemnations, so dishonest producers could be inclined to provide misleading information. Taylor et al (1995) reported that even with on-farm experience of the full health history of pigs, an expert veterinary team was unable to consistently identify any postmortem evidence of *Streptococcus suis* infection in pigs they knew were infected. The scope of antemortem inspection may well be expanded in the future by institution of preslaughter (eg. ELISA) tests to detect latent conditions (Gracey, 1986). Edwards et al (1997) suggest that verification of on-farm quality assurance (QA) programs, and gathering of farm data for regional or national databases, may also become components of antemortem inspection.

Inspection technique may influence the outcome of antemortem inspection. In Australia, legislation for domestic meat stipulates that antemortem inspection must be done, but places no restrictions on the procedure. The export standard, outlined in the Export Meat Orders (Export Control Act, 1982) is much more specific. If the pigs are an even line of baconers from a single producer it is permissible to select a percentage (eg. 10%) of the pigs, examine the back, sides and front of each of these, and pass the whole line if the sample is acceptable. For a mixed line, the back, sides and front of each pig must be observed. Some specific importing countries impose additional requirements, the most restrictive being the European Union (EU). The EU requires that a veterinarian perform the inspection, and that any pigs to be held overnight be inspected at the end of the day as well as on the day of slaughter.

2.2.4 Trialing of on-farm antemortem inspection

As part of a "gate to plate" food safety program to support/encourage change to postmortem inspection procedures, Harbers et al (1992a) undertook a study to assess the ability of pig producers to find suspects on-farm among pigs awaiting transport for slaughter. They found that the pig producers performed the task at least as well as an abattoir veterinary inspector and concluded that preselection is possible. In this investigation, in the Netherlands, 22 farms each voluntarily sent a load of pigs to the same abattoir. On-farm the pigs were inspected by the producer, and independently by an Animal Health Service field veterinarian. At the abattoir, antemortem and postmortem inspection of these pigs was performed by an abattoir veterinary inspector in accordance with EU regulations. Inspection results were compared using three statistical measures: Cohen's Kappa, Attributable Risk and Predictive Capacity. The field veterinarian found the most suspects by far, and the producers found more than the abattoir veterinary inspector. Agreement between these three was poor, with the exception of tailbite lesions.

This study demonstrated that producers are capable of detecting as least as many suspects as abattoir veterinary inspectors. The authors propose several reasons why this may be so, but fail to specify whether or not the abattoir veterinary inspector was aware that his performance was under scrutiny. This awareness could have caused him to inspect more thoroughly than usual, confounding the results. Antemortem inspection standards at the abattoir were clearly defined, but no mention is made of the inspection methods used on-farm, which could impact on the findings significantly. Another confounder is the health status of the herds used, because this may impact on any associations between ante and postmortem findings. Such associations could challenge the criteria used to define suspects, or indeed even the role of antemortem inspection in improving food safety.

Many of the conditions that pigs exhibited in this investigation are not considered to be a significant antemortem inspection finding in Australia. There is no background to how the authors chose to define suspects, nor of the extent of training provided to producers. The authors themselves mention that most of the producers had no experience in antemortem inspection, and a learning effect could be expected. However, the conclusion that on-farm antemortem inspection is possible provides stimulus to try it under local conditions, particularly as the Australian Pig Industry has recently embraced QA.

2.2.5 Impact of quality assurance on antemortem inspection procedures

The World Trade Organisation has recommended that national food safety procedures be risk assessed to meet food safety equivalence standards (Miller et al, 1993). Antemortem inspection is a food safety procedure because it is believed that by slaughtering suspects separately, the potential for cross-contamination of other pigs by pathogens is reduced. One proposal in the EU is to endorse "visual only" postmortem inspection of pigs from QA herds performing on-farm antemortem inspection. Not only would "visual only" postmortem inspection represent a significant cost saving to industry, but cross-contamination of other pigs by pathogens can also be reduced (Snijders and Berends, 1996).

Recognising that meat safety begins on-farm (Edwards et al, 1997), the Australian Pig Industry has embraced QA based on the Hazard Analysis and Critical Control Point (HACCP) system. Encouragement of verified production control practices in QA programs serves to assure concerned consumers that pig meat is both healthy and produced in a welfare-friendly manner. Segregation of suspect pigs on-farm fits the HACCP model, constituting a tangible pre-slaughter critical control point (CCP). Suspects can be penned separately on a truck (thus improving their welfare during transport), or treated/destroyed on-farm if they are unfit for transport or slaughter. As a CCP at the abattoir, antemortem inspection identifies welfare cases for immediate destruction/condemnation, and suspects for separate slaughter.

The qualifications required to perform antemortem inspection is a subject fiercely debated by all interested parties. Jagger (1984) noted that the reasons for involving veterinarians in meat hygiene were essentially political rather than scientific. Placement of a veterinary inspector at every abattoir and/or farm is expensive, and the adoption of QA by the meat industry has provided a means to minimise such expense by using inspectors with lesser qualifications to perform the task. The findings of Harbers et al (1992a) show that qualifications alone do not guarantee a satisfactory result. Abattoir drovers through long experience can readily detect suspects, and at some abattoirs may even mark them so that slaughtermen can be paid penalty rates to process them (Collins, 1966). Where antemortem inspection is done by abattoir drovers only, QA programs require that they be accredited. Both meat inspectors and veterinarians have always appreciated the assistance of experienced abattoir drovers, and of producers who have separated their suspect pigs in advance. The usefulness of separation of suspects on-farm has already been acknowledged by abattoirs that have extended their QA requirements back to participating producers.

The question of integrity is the most fundamental issue arising from QA programs, especially in light of the historical origins of antemortem inspection. While the inspecting party is independent of the operator of the abattoir, then apart from succumbing to bribery, disposition of animals is more likely to be in accordance with legislative requirements (Edwards et al, 1997). At the farm, a dishonest producer could purposely attempt to disguise a sick pig by placing it among a group of normal ones. At the abattoir, non-performance of antemortem inspection by a dishonest accredited company employee is essentially the same as the situation described in England by Walley (1896), and is unlikely to be detected by audit. In its endorsement of "visual only" postmortem inspection, the European Commission Standing Veterinary Committee appears to address these risks by requiring both on-farm inspection and abattoir antemortem inspection, thus achieving both an audit of performance of farms and the safeguard of an independent party at the abattoir.

2.3 Outcomes of antemortem inspection

2.3.1 Conditions commonly detected at antemortem inspection

Australia is fortunate to be free of exotic diseases such as foot and mouth disease and rinderpest (Collins, 1966). Other diseases such as anthrax and tetanus are not encountered because they are so rare, and/or because the pig dies on-farm and therefore never gets to an abattoir. Some conditions of concern in other countries such as necrosis of the ear and atrophic rhinitis (Harbers et al, 1992a) are not considered in Australia to be significant lesions, so affected pigs are passed without any restrictions. Harbers et al (1992a) also mentioned a category of suspects they called “stragglers”. These are the runts of the litter which are often sold as porkers, or kept longer on-farm till they reach slaughter weight several weeks after their littermates have been killed. Thus, in a group of bacon pigs, these “stragglers” would not be noticed.

Some conditions observed at antemortem inspection require emergency slaughter or immediate destruction/condemnation on animal welfare grounds. These include pigs that are dying/dead, or suffering from fractures/dislocations, bloat/rectal stricture, emaciation, and other gross abnormalities that graphically portray cruelty/neglect. In Victoria, 1% of whole carcase condemnations in 1989 and 1990 occurred at antemortem inspection (Pointon, 1997a). In the USA, approximately 0.12% of pigs were dead at the time of antemortem inspection (Taylor et al, 1984).

Fever is generally a difficult condition to discern at antemortem inspection (Andriessen, 1987), but if it is suspected, the pig should be isolated for treatment or destroyed. Because pigs in abattoir lairages are stressed by being in strange surrounds, and mixed with strange pigs, fever symptoms such as dyspnoea and drowsiness (Wouda et al, 1987) are masked. Likewise, excessive defaecation (Wolff, 1953) is easily confused with diarrhoea, unless the faeces also contain blood (Andriessen, 1987) or necrotic tissue. In abattoir condemnation data, the term fever is often used to describe a range of systemic conditions including toxaemia, pyaemia, septicaemia and uraemia; these actually cannot be accurately distinguished in the absence of laboratory testing. It is also used for a range of septic conditions such as gangrene, peritonitis, pericarditis, endocarditis, pneumonia, enteritis, metritis, (poly)arthritis, balanitis and multiple abscesses, where there is evidence of a generalised inflammatory response.

Antemortem inspection is unlikely to disclose any condition that will be overlooked during subsequent slaughter and postmortem inspection (Collins, 1966). An exception is head tilt or other nervous signs, which may be indicative of meningitis due to *Streptococcus* or *Listeria* (Taylor et al, 1995), but such symptoms are rarely seen. The close interrelationship between antemortem and postmortem inspection findings, for conditions commonly detected in suspect pigs at antemortem inspection is illustrated in Table 1. This close interrelationship makes it is possible to relate some antemortem findings to results from studies of risk assessments (Hathaway et al, 1988) of postmortem inspection regimes. In this way it is possible to evaluate the food borne disease implications of gross abnormalities detectable by antemortem inspection.

Although prolapsed rectums may be associated with conditions such as Salmonellosis, Yersiniosis, or Campylobacter (Taylor et al, 1995), affected pigs are generally not segregated at antemortem inspection unless the prolapse has become gangrenous, or if the affected pig is being harassed by others biting at the lesion. During bunging, the prolapse is detached from the carcase and dropped into the abdominal cavity, contaminating other organs. Following evisceration, it ends up on the viscera table, usually buried under the intestines, where it is seldom noticed at postmortem inspection. Prolapse of the uterus is seldom seen in bacon pigs.

Umbilical hernias are seen more commonly than inguinal hernias, and are generally not segregated at antemortem inspection unless they are extremely large and/or pendulous. They are usually removed when the abdominal cavity is first opened up. Occasionally, a section of intestine may be attached to the hernia, with some localised enteritis or peritonitis, which is obvious at postmortem inspection. Sometimes oedematous swelling accompanies scrotal hernias (inguinal herniation extending to the scrotum), orchitis and balanoposthitis. If this is pronounced, the oedema may spread subcutaneously along the belly down into the hindlimbs, requiring extensive trimming and possibly total condemnation. Turner (1977) reported that from 1970-1976, 2.6-5.6% of total pig carcase condemnations at the Newtown abattoir in South Africa were for scrotal sepsis.

Wounds usually result from fighting, transport injury and cannibalistic behaviour (eg. tailbite), and if minor and fresh the pigs are processed normally. If the wounds are severe and/or infected, there is a high chance of abscesses occurring in the carcase, so the pigs are segregated. Soethaut et al (1981) found a higher incidence of multiple abscesses in pigs, which presented with clinical conditions at antemortem inspection. Chiew et al (1991) studied abscesses in slaughter pigs in Singapore from 1983 to 1987. Tail wounds were found in 7.3% of pigs with abscesses, castration wounds in 2.8%, bite wounds in 3.1%, and leg wounds in 2.6%. Tuovinen et al (1994) reported that tailbite was the primary cause of abscessation in pig carcases in Finland. Prevalence of tailbite was 0.2-2.3%, and 38% of the suppliers reported that it occurred on their farm. In another study, it was found that 38% of all pigs condemned at postmortem had tailbite lesions at antemortem inspection (Lee et al, 1993). Harbers et al (1992a&b) reported inflammation of the tail in 0.07-0.6% of pigs.

Abscesses account for 29-51% of all partial pig carcase condemnations and 14-17% of total condemnations (Hill and Jones, 1984; Pointon, 1997a), but only a fraction of abscesses are superficial and thus detectable by antemortem inspection. Export Control Act (ECA-1) cards, used by antemortem inspectors at export abattoirs, may be a useful source of Australian data for comparison of abscess prevalences at both antemortem and postmortem inspection. Abscesses in the viscera are easily detected at Pig Health Monitoring Scheme (PHMS) inspections, but because PHMS inspectors work at the viscera table, many carcase abscesses are missed. Reported prevalences of abscesses range from 0.3-11.8% (Hill and Jones, 1984; Harbers et al, 1992a; reviewed by Pointon, 1997a), with trimming losses calculated as one pound/pig (Norval, 1966); 0.2% of total carcase condemnations and 2% (amounting to 0.08% weight loss) of total carcases requiring trimming (Hill and Jones, 1984). Jones (1980) reported that 62% of carcase abscesses were superficial, and 38% deep seated. Harbers et al (1992a) reported that 6% of abscesses were superficial, 7% deep seated and 87% in the lungs.

Unhygienic vaccination technique may result in abscesses on the neck. Sows often have chronic "bedsore" wounds on the shoulder caused by rupture of subcutaneous abscesses which have formed while lying on concrete for extended periods, but these are rarely seen in bacon pigs. Other skin lesions commonly encountered in pigs are mange and cutaneous erysipelas (diamond skin disease), but these are not usually noticed until after scalding and dehairing. According to Australia abattoir data, wounds account for 1.6% of all partial condemnations, and diamond skin disease for 0-1% (Pointon, 1997a).

Lameness is a clinical sign commonly encountered in pigs. Sometimes it is due to excessive wear of hooves during transport, but if the affected pig is able to walk it would be processed normally. Crippled limbs are only evident at postmortem if there is associated swelling or some other visible lesion, so it is useful to segregate affected pigs at antemortem inspection. Foot abscesses may also be encountered, and have been associated with pyaemia in the carcase (Edwards et al, 1997). Pigs which cannot walk unassisted (ie. "downers") often have no external lesions, but postmortem examination may reveal a cause such as a broken back. "Downers" and pigs with severe lameness due to fractures or dislocations must be destroyed on welfare grounds if detected on-farm, or processed as an emergency kill if found at the abattoir.

Arthritis is easily confused with bursitis at antemortem inspection. Bursitis is not considered a significant lesion because it is easily trimmed, whereas detection of arthritis at postmortem inspection will result in partial or complete condemnation. Turner et al (1991) found that a third of lesions diagnosed as arthritis were actually normal, a third were osteochondrosis, a quarter were traumatised (probably during transport) and 6% had an infectious cause. Lymph nodes draining joints with osteochondrosis were generally normal, whereas joints with infectious arthritis generally had reactive draining nodes.

The prevalence of arthritis in Australia (Pointon, 1997a) and overseas (Harbers et al, 1992a&b; Hill and Jones,1984) is reported to range from 0.01%-4%. It accounts for 18-46% of all partial pig carcase condemnations and 9-10% of total condemnations (Hill and Jones, 1984; Pointon, 1997a). Cross and Edwards (1981) found that 16.5% of arthritic pig shoulders, 31% of arthritic elbows, 9% of arthritic hips and 8% of arthritic stifles were not detected at postmortem inspection. Because PHMS inspectors work at the viscera table, PHMS records of arthritis depend entirely on the findings of the postmortem inspector. The removal of a joint is recorded as arthritis, but the cause may actually be an abscess or wound.

2.3.2 Food safety significance of antemortem inspection

Pathogens have always existed in our food, yet food borne diseases are the exception rather than the rule. In Australia, meat from small slaughterhouses was never inspected until just a few years ago. Whenever outbreaks of food poisoning do occur, most people who eat the incriminated contaminated foodstuff experience no ill effects (McCullough and Eisele, 1951). Why this is so remains a challenge for health authorities. Perhaps in the process of time people with poor personal hygiene and food handling habits become inadvertently "immunised", whereas those who have scrupulously clean habits are seldom immunologically challenged by their environment. When a contaminated foodstuff is widely distributed, those naturally "immunised" would not be overcome by the disease. In such a scenario, it would be undesirable for food to be totally free of contaminants, as this could lower the nation's general resistance to food borne disease, thus inviting increased severity of outbreaks. A close watch should be kept on patterns of outbreaks in nations such as Sweden and Denmark that have demonstrated lower prevalences of pathogens in their foodstuffs, to see if any such patterns become evident. Can we get too clean?

Most cases of food poisoning can be attributed to the final preparation of food (Galton et al, 1954; Bergdoll, 1989; Berends et al, 1995; Pointon, 1997a). A farm-to-table approach towards minimisation of food borne hazards is currently favoured over ineffective methods of abattoir inspection (Edwards et al, 1997; Mousing et al, 1997b), with reallocation of resources towards identification and control of the hazards shown to be of greatest public health importance (Hathaway, 1993). Attempts to shift efforts to preslaughter (Funk et al, 1999; van der Wolf et al, 1999) may prove ineffective due to increased shedding and cross-contamination during transport (Morgan et al, 1988f; Berends et al, 1996; Sischo et al, 1996) and at the abattoir (Hansen et al, 1964; Morgan et al, 1987; Wilcock and Schwartz, 1992; Berends et al, 1996). For a move from traditional inspection methods to be successful, there must be a real assessment of the proposed new role of the inspection staff (Edwards et al, 1997). Perhaps the overalls, gumboots, knives and aprons should be replaced with briefcases, so that inspectors could be used to teach the public safe food-handling skills, at luncheons and door-to-door.

The scientific validity and cost effectiveness of current meat inspection procedures as a means of protecting public health has been challenged (Hathaway et al, 1988; Harbers et al, 1992b; Berends et al, 1993; Gill, 1995; Mousing et al, 1997b; Edwards et al, 1997; Pointon, 1997a; Mousing and Pointon, 1997). Pointon et al (2000) showed that levels of microbiological hazards in carcases were not significantly reduced by the detection and removal of gross abnormalities. Antemortem inspection can sometimes detect acute enteritis and septicaemia (Pointon, 1997a), or meningoencephalitis (Rahman et al, 1985; Ossowicz et al, 1989; Akkermans and Vetch, 1994; Taylor et al, 1995), but the affected pigs should be withheld for treatment or condemned, and thus not reach the slaughter floor. Segregation of pigs with diarrhoea or fever on-farm for treatment or destruction minimises potential for microbiological hazards reaching the abattoir.

The major microbial food borne hazards found in pigmeat are considered to be *Salmonella, Toxoplasma, Yersinia,* enterohaemorrhagic *E. coli* (EHEC), *Campylobacter* and *Listeria* (Anon, 1995; Edwards et al, 1997; Pointon, 1997a; Willeberg et al, 1997). These are rarely cultured from grossly detectable abnormalities in pigs (Engel et al, 1987; Pointon, 1997b; Mousing and Pointon, 1997; Pointon et al, 2000), both in Australia and internationally, but are common gut inhabitants. When compared quantitatively with other sources/pathways of carcase contamination, grossly detectable abnormalities constitute a relatively minor source of pigmeat pathogens when compared to inadvertent faecal contamination during slaughter and dressing (Hathaway and McKenzie, 1991; Gill, 1995). Davies and Funk (1999) found that 8.4% of stomachs and 0.9% of caeca (which harbour *Salmonella* twice as often as stomachs) were lacerated during slaughter. The risk of spillage of gut contents, with subsequent cross-contamination of meatworkers, their tools, and the abattoir environment, is increased with filled stomachs (Mousing et al, 1997b; Oosterom and Notermans, 1983).

A risk assessment approach (Hathaway et al, 1988; Hathaway, 1993; Edwards et al, 1997) quantifies the contribution of inspection procedures to elimination of food borne hazards (Harbers et al, 1992b). Several authors have risk assessed postmortem inspection procedures but not antemortem inspection procedures. However, separate risk assessments are unnecessary because the gross abnormalities typically detected at antemortem inspection are subsequently removed during routine dressing and/or detected at postmortem inspection (Table 1). Thus results of risk assessments of postmortem inspection procedures (Hathaway et al, 1988; Bettini et al, 1996; Mousing et al, 1997b; Pointon et al, 2000) can be used to evaluate the food borne disease risk associated with gross abnormalities detectable by antemortem inspection.

Combining abattoir condemnation reports and PHMS results with prevalence and culture data from published papers to determine the food borne significance of gross abnormalities detected at postmortem inspection (Pointon, 1997a), it was estimated that 5-10/100,000 carcases have arthritic lesions containing enterotoxigenic *Staphylococcus aureus,* and on this basis arthritis was rated as an aesthetic defect. *Erysipelas* and *Staphylococcus* species were frequently isolated from arthritic lesions in pigs, but were considered to be occupational hazards rather than food borne hazards. It was also estimated that 1-6/100,000 carcases have abscesses containing enterotoxigenic *Staphylococcus aureus,* and on this basis abscesses were rated as aesthetic defects. However, isolation of *Salmonella* from abscesses in a subsequent risk based assessment (Pointon et al, 2000) led to the reversal of this recommendation. By culturing 54 swollen joints the low risk previously associated with arthritis was verified. Whether the affected joints had reactive draining nodes was not specified. Culture of swollen joints with normal draining nodes may have reduced the likelihood of isolating pathogens (Turner et al, 1991).

2.3.3 Impact of antemortem inspection on the slaughter process

Carcases are hung on gambrels through the metatarsal tendons, so removal of leg portions for any reason (eg. fractures, arthritis, bruising or deep abscesses) requires the carcase to be re-hung by strings. Conditions such as prolapses, hernias, balanoposthitis, wounds, superficial abscesses and enlarged scrotums are easily dealt with during normal slaughtering procedures, unless there are secondary complicating factors. For example, oedema associated with scrotal swelling may spread subcutaneously, requiring extensive trimming. Loops of intestine may adhere to hernias, increasing the risk of rupture and carcase contamination with intestinal contents. Risk of intestinal rupture is also high in bloated pigs (ie. with rectal strictures) that have not been detected at antemortem inspection.

Several conditions that are not detectable at antemortem inspection also require extra trimming effort. These include shaving of hair that escaped the dehairing process, stripping of pleura to remove pleurisy or visible contamination, and excision of carcase parts (eg pelvis) to remove internal abscesses and visible contamination. Severe cases of mange and erysipelas (diamond skin disease) require skinning of the carcase, which is both labour intensive and time consuming. PHMS records (Pointon et al, 1992) can be a useful guide to predicting the extent of pleurisy and mange that can be expected at slaughter.

Segregation of suspects at antemortem inspection is a means of grouping pigs which will need extra trimming on the retain rail, so slaughter chain efficiencies are possible by scheduling extra inspectors and trimmers during the processing of the suspects (Edwards et al, 1997), to maintain normal chain speed. In-contact surfaces and equipment can then be cleaned before slaughter of normal pigs is resumed. The actual efficiency gains that are likely to result by grouping pigs likely to need extra trimming are dependant on the skill and experience of the trimmers. By actually measuring the extra labour required on the retain rail for each group of conditions, the economics of re-positioning staff can be investigated.

Removal of portions of carcases results in losses from direct loss of weight of meat available for sale, as well as downgrading of primal cuts on the remainder of the carcase. An estimate of the weight loss, as a % of total hot standard carcase weight, for various commonly trimmed parts are as follows: hindquarter 26%, forequarter 26%, leg (ham) 16.7%, shoulder 16.7%, half shoulder (radius and elbow) 9.3%, pelvis 9.3%, backbone 9.3%, ribs 7.3%, head 7.3%, half leg (distal to stifle) 3.7%, stifle 1.9% and hip 1.5%.

2.4 *Salmonella* – its role in food poisoning

2.4.1 Importance of *Salmonella* as a food borne pathogen

Salmonella has been implicated as the main microbiological threat to pork consumers (Beran, 1996; Pointon, 1997a), and other authors have highlighted many serotypes common to humans and pigs (Galton et al, 1954; Harvey et al, 1977). A recent German study (Steinbach and Hartung, 1999) estimated that 20% of human *Salmonella* infections originated from pigs. In Denmark, pork is estimated to be responsible for 15% of human cases of salmonellosis (Mousing et al, 1997a), and over half of human sporadic *Salmonella typhimurium* infections investigated by phage type analyses were attributable to pork consumption (Baggesen and Wegener, 1994; Baggesen et al, 1996; Mousing et al, 1997a). In contrast, laboratory data in Australia implicate beef, mutton and chicken as the major sources of *Salmonella* (Murray, 1994). In the US from 1973 to 1987, 790(42%) of bacterial food poisoning outbreaks were due to *Salmonella*. The origin of the infection was determined in 470 of these outbreaks, and pork was implicated in 25(5%) (Bean and Griffin, 1990). Wegener and Baggesen (1996) used pulsed field gel electrophoresis to investigate an outbreak of salmonellosis in over 500 people, and traced the source of infection back to a pig abattoir.

It is difficult to predict the risks associated with the consumption of contaminated foods. McCullough and Eisele (1951) found that there was a large variation in the doses of *Salmonella* that had to be fed to human volunteers to cause clinical disease. Of 33 people who consumed contaminated food during a *S. brandenburg* outbreak in England in 1963, 13(39%) became ill and a further 7(21%) became symptomless excretors (Burns et al, 1965). Wegener and Bager (1997) reporting on an overall increase in the incidence of food borne salmonellosis in Denmark over the last decade, noted that high levels of sporadic cases resulting from pork consumption occurred at times when *Salmonella* levels in retail pork were 2-3%. Although levels in poultry meat at these times were 5-10 times greater than in pork, fewer people were affected by eating poultry.

Most cases of *Salmonella* food poisoning can be attributed to the final preparation of food (Berends et al, 1995; Pointon, 1997a). This includes inadequate cooking of meat, contamination or recontamination after cooking, and improper cooling, storage and reheating. *Salmonella* serotypes differ in their pathogenicity and heat-tolerance (McDonagh and Smith, 1958); some can grow on meat at temperatures ranging from 7-45^0 C and survive freezing and desiccation (Gronstol et al, 1974a). Classical examples of salmonellosis due to improper handling/preparation of pork occurred in Melbourne in March 1997, where *S. muenchen* was traced to ham, and *S. typhimurium* to Vietnamese pork rolls (Lester et al, 1997). The trend towards wide distribution of processed foods from large centralised facilities can result in serious and widespread outbreaks of salmonellosis (Tauxe, 1991).

2.4.2 Carcase contamination by *Salmonella* organisms

The prevalence of *Salmonella* in slaughter pigs has been reported in many studies, some of which are summarised in Table 2.

Cross-contamination in abattoir lairages and during processing can account for some of the high prevalences of *Salmonella* in Table 2 (Wilcock and Schwartz, 1992). Morgan et al (1987) noted that the spread of *Salmonella* in the lairages could be reduced by good hygiene and by using smaller pens. Slaughter of soiled pigs is not a significant risk factor because after scalding the number of contaminated carcases is greatly reduced (Galton et al, 1954; Berends and Snijders, 1997). During subsequent dehairing, the carcase is subjected to vigorous treatment, and some contamination by faecal leakage from the relaxed anus is inevitable. Galton et al (1954) found that carcase swabs were negative for *Salmonella* after scalding, but after dehairing a high proportion were positive. In addition 40% of swabs of the dehairing machinery were positive for *Salmonella.* During singeing the number of contaminated carcases was again greatly reduced, although subsequent polishing was estimated to contribute to 5-15% of total carcase contamination (Berends and Snijders, 1997). The *Salmonella* organism can still survive within deep skin folds such as at the base of the ear, acting as a source of low level contamination during polishing. However, heavy intestinal loads are the most substantial source of *Salmonella* contamination present on abattoir staff, utensils, facilities or equipment (Berends et al, 1995).

The main source of carcase contamination by *Salmonella* is the gastrointestinal tract (Morgan et al, 1987, 1988f; Mousing and Pointon, 1997). Galton et al (1954) found that 74% of swabs of tables/containers in the evisceration area were positive for *Salmonella*. Shotts et al (1962) found that during evisceration, isolation of *Salmonella* on carcases increased from 29% to 50%. Berends and Snijders (1997) estimated that 85-95% of total carcase contamination was due to routine evisceration, meat inspection and dressing procedures. Although *Salmonella* commonly occur in tonsils, mesenteric nodes and faeces (Wood et al, 1989; Berends et al, 1996), the number of contaminated carcases related statistically only to the number of faecal carriers (Berends and Snijders, 1997). They recommended that to reduce *Salmonella* contamination of carcases, both the disease status of incoming pigs and the slaughter process should be critical control points. *Salmonella* contamination was able to be reduced from 46% of carcases to 7%, by improving singeing and evisceration practices (Oosterom and Notermans, 1983).

Table 2 Some studies on the prevalence of *Salmonella* in slaughter pigs

Year	Location	Source	Sampled	Positive	Reference
	United States of America	Colon contents	60 72	10% 35%	Hansen et al (1964)
1965/ 1966	Australia	Faeces, spleen, bile, lymph nodes, livers	1000	8.7% (26 serotypes)	Chung and Frost (1969)
1968	Australia	Intestinal contents	200	27% (10 serotypes)	Riley (1970)
	United States of America	Caecal contents	658	45% (12 serotypes)	Gustafson et al (1976)
1978	Australia	Lymph nodes	45	17.8%	Moo et al (1980)
	United States of America	Caecal contents	874	13.5% (16 serovars)	Currier et al (1986)
1986	Australia	Caecal contents Carcase swabs	445 448	18.5-47.7% 9.3-27.3%	Morgan et al (1987)
	Australia	Jowls	80	43.7%	Morgan et al (1988a)
	Australia	Carcase swabs	100	12-30%	Morgan et al (1988b)
	Australia	Carcase swabs	500	5.6-11.6%	Morgan et al (1988c)
	Australia	Carcase swabs	300	0-40%	Morgan et al (1988d)
	Australia	Faeces	1760	23%	Morgan et al (1988e)
1983/ 1984	United States of America	Lymph nodes and caecal contents	200	84% (9 serovars)	Tay et al (1989)
	Hungary	Faeces		1-34% (5 serotypes)	Biro et al (1989)
1992	United States of America	Carcase swabs	225	29%	Epling et al (1992)
1992/ 1993	Denmark	Caecal contents	687	9.8% (10 serotypes)	Holst (1993)
1993/ 1994	Denmark	Caecal contents	13,468	6.2% (30 serotypes)	Baggesen et al (1996)
	United States of America	Faeces and caecal contents	1591	8% (14 serotypes)	Bahnson and Fedorka-Cray (1996)
	United States of America	Intestinal contents	118	12%	Sischo et al (1996)
1994/ 1995	United States of America	Faeces	2288	24.6% (19 serotypes)	Davies et al (1997)
	United States of America	Faeces Carcase Fresh meat Organ Meat Ground Meat	715	3.8-93% 16.2% 14.7% 30% 40.3%	Beran (1996)
	Australia	Retail meat Carcase swabs	120 680	<3% 1%	Widders et al (1997)
1995/ 1996	Canada	Caecal contents	1420	5.2% (12 serotypes)	Letellier et al (1997a)
1996	Germany	Faeces, lymph nodes, and carcase swabs	11942	6-10%	Kasbohrer et al (1997)

Current meat hygiene and inspection requirements must be tailored to modern animal husbandry practices and changing patterns of meat processing and retailing (Melrose and Gracey, 1974). Bacteria isolated from the pathological abnormalities that are actually detected are generally harmless to humans (Mousing and Pointon, 1997), or are occupational disease hazards rather than food borne hazards (Bettini et al, 1996) and the adequacy of current meat inspection procedures in protecting public health has been questioned (Hathaway et al, 1988; Harbers et al, 1992b; Berends et al, 1993; Gill, 1995; Mousing et al, 1997b; Edwards et al, 1997; Pointon, 1997a). *Salmonella* and other significant food borne organisms cannot be detected visually or by incision of lymph nodes. Taylor et al (1995) showed that an expert veterinary team fully conversant with on-farm history, and with antemortem details, were unable to consistently identify postmortem lesions in pigs they knew were infected with *Streptococcus suis*. Current postmortem procedures fail to detect one out of five abnormalities actually present (Mousing and Pointon, 1997).

Because *Salmonella* are frequently present in lymph nodes (Jones and Hobbs, 1964; Harvey et al, 1977; Moo et al 1980; Tay et al, 1989; Wood et al, 1989; Tran Xuan Hanh, 1995) their routine incision may in fact be a means of contaminating meat (Murray, 1986; Berends et al, 1993; Bettini et al, 1996; Edwards et al, 1997). Pointon et al (2000) showed that on a carcase throughput basis, incision of normal lymph nodes was a greater hazard than incising grossly abnormal lymph nodes. There were no statistically significant differences in the contamination rates of grossly abnormal and normal lymph nodes with the major food borne hazards of animal origin. Berends and Snijders (1997) recommend that lymph nodes not be incised during meat inspection, and that all gut-associated lymph nodes be removed.

In an effort to quantify the extent to which *Salmonella* were present in the preslaughter stages of pork production in Denmark, Berends et al (1996) constructed a descriptive epidemiological model. In this model, risk factors were quantified as odds ratios. They concluded that poor farm hygiene was by far the most important risk factor affecting *Salmonella* levels in slaughter pigs. This view is supported by the findings of Mousing et al (1997a), who reported that the reduction of *Salmonella* levels in problem herds resulted in a reduction in contamination of retail pork from 2% to 0.5%. This same the Danish *Salmonella* Control Program has reduced herd seroprevalence from 22.2% in 1994 to 11.4% in 1998, and caecal isolation rates from 6.2% in 1994 to 3.4% in 1998 (Christensen et al, 1999).

Another school of thought is that the most important strategy in reducing *Salmonella* levels in pigmeat is manipulation of preslaughter handling to reduce cross-infection and minimise multiplication/shedding of the organism (Galton et al, 1954; McDonagh and Smith, 1958; Hansen et al, 1964; Jones and Hobbs, 1964; Burns et al, 1965; Craven and Hurst, 1982; Morgan et al, 1987). Those of this school of thought readily admit that *Salmonella* infected farms are a problem, but should not be the first step of control (Williams and Newell, 1967).

Infected herds, long transport distances and extended abattoir lairage times are a commercial reality in Australia. Many piggeries are distant from abattoirs, and many pigs arrive via transit yards and markets. Although the Australian Pig Industry Quality Standards (APIQS) stipulate slaughter <24 hours off-feed (Pointon, 1997b), abattoirs insist on early delivery to ensure that they do not run out of pigs, thus avoiding costly gaps in production. Early deliveries place pressure on limited lairage space, but this is balanced by arranging for nearby regular large suppliers to deliver pigs mid-morning. With shedding of *Salmonella* organisms being possible within hours of oral exposure (Williams and Newell, 1967; Baggesen et al, 1996), the opportunities for buildup of organisms are considerable. If concerned consumers begin to demand sterile food, the ideals of *Salmonella* free pigs (Oosterom and Notermans, 1983; Berends and Snijders, 1997; Davies et al, 1997) and optimal abattoir handling practices (Hathaway, 1993) are a long way off. Berends and Snijders (1997) concede to this reality, and recommend that carcases be decontaminated (eg. with lactic acid sprays) to reduce *Salmonella* loads.

2.4.3 *Salmonella* in pigs

Salmonella species occur as intestinal pathogens in virtually all vertebrates, and infection is widespread in the pig industry. Although over 2,000 serotypes have been found in pigs, most infections are subclinical, serving as a hidden reservoir that is readily transmissible (Wilcock and Schwartz, 1992). In the US, Davies et al (1997) reported that pigs on 83% of farms were found to be infected with a variety of *Salmonella* serovars. Berends et al (1996) reported that about 65% of Dutch pig farms have endemic *Salmonella* infection, and 85% of the pigs on those farms are likely to be infected at some stage in their lives. The incidence of *Salmonella* infection increases with intensive farm management practices (Corrier et al, 1990; Edwards et al, 1997), and prevalence increases with herd size (Mousing et al, 1997a; Baggessen et al, 1996). Membership of an Integrated Quality Control production group has been associated with a decreased risk of infection (van der Wolf et al, 1999).

Clinical disease is generally only caused by *S.choleraesuis var kunzendorf* or *S. typhimurium* (Wilcock and Schwartz, 1992). Enterocolitis (usually *S. typhimurium)* and septicaemia (usually *S.choleraesuis)* manifest in postweaning pigs as diarrhoea, reduced feed efficiency and decreased weight gain. Pneumonia, meningitis, encephalitis, caseous lymphadenitis or abortion may also occasionally occur. Salmonellosis is a major economic disease of pigs in the US, resulting in millions of dollars of lost income to the pork industry (Fedorka-Cray et al, 1997).

Salmonella infection is basically a faecal/oral cycle, with infected shedding pigs being the major source (Wilcock and Schwartz, 1992). During acute disease pigs shed up to 10^7 bacteria per gram of faeces (Gutzmann et al, 1976), whereas subclinical carriers shed intermittently (Larkin and Hicks, 1967) and at a lower level (Baggesen et al, 1996). The organism can also survive, proliferate and persist in/on building surfaces, soil, dust, water, feed, rodents and insects, and farms generally have strong contamination cycles with their own endemic serotypes (Berends et al, 1996). Shedding of organisms occurs as early as one (Williams and Newell, 1967) to four hours after oral exposure (Baggesen et al, 1996), or three hours after respiratory exposure (Fedorka-Cray, 1997). In another study, 90% of a group of pigs were serologically positive for *Salmonella* by one week of age (Fedorka-Cray et al, 1997), although culture negative, presumably due to colostral immunity. Infection rates usually peak at 80-100% within 3 weeks of weaning (Berends et al, 1996), then fluctuate (Fedorka-Cray et al, 1997), with 5-30% of the pigs still excreting *Salmonella* when they reach slaughter weight (Berends et al, 1996).

In studies in mice, Van der Waaij (1992) showed that natural immunity offers less protection against colonisation and infection than a well balanced gut flora, but this balance can be disturbed by antibiotic treatment (Berends et al, 1996). Nisbet et al (1997) found that probiotics reduced shedding, whereas Letellier et al (1997b) found that probiotics prevented tissue invasion, but had no effect on shedding. Oosterom and Notermans (1983) noted a drop in the number of *Salmonella* isolated during a two week period of antibiotic feeding, followed by a steady rise when normal feed was restored. Williams and Newell (1970) failed to isolate *Salmonella* from pigs fed antibiotics for two months. Evidence from previous studies on the same farm indicated the pigs would have been infected with *Salmonella* prior to treatment.

Shedding of *Salmonella* organisms is erratic (Williams-Smith, 1960), so the likelihood of infected pigs contaminating others can vary during the marketing process (Williams and Newell, 1967). Williams and Newell (1970) took 20 "*Salmonella* free" pigs for a joy ride on a clean truck, and returned to the same farm. *Salmonella anatum* were subsequently found on the truck and in rectal swabs from six of the pigs. Two weeks later, the same pigs (one of which swabbed positive for *Salmonella anatum*) were taken to an abattoir. *Salmonella anatum, newington and derby* were subsequently found on the truck, and *Salmonella anatum* in rectal swabs from four of the pigs. The pigs were then unloaded into, and left to soil, a clean raceway, where *Salmonella newington, typhimurium, bredney* and *derby* were subsequently isolated from faeces. At slaughter, *Salmonella anatum, norwich, newington* and *derby* were isolated from caecal swabs from six of the pigs. The implications of this study are that not only is shedding intermittent, but also that a pig can at different times shed one or more of the many serotypes it may be carrying. Thus conclusions from experiments based on measurement of *Salmonella* infection in undisturbed pigs must be open to question.

2.4.4 Effect of stress on *Salmonella* levels

Stress is anything perceived as a threat to well-being, and in pigs is generally associated with temperature extremes, air pollution, feed deprivation, new surrounds, rough handling, overcrowding and mixing with strange pigs, much of which occurs during marketing and transport and while pigs are held in abattoir lairages awaiting slaughter. Multiple stressful stimuli exert an additive effect (Wolff, 1953). The body responds to stress by releasing hormones from the hypothalamus and pituitary, and cytokines from the immune system, in an attempt to maintain homeostasis (Elsasser et al, 1995). As the severity of the stress varies, there is a continuum of tissue responses ranging from enhanced/anabolic to stagnant/catabolic.

The interaction between hormone systems, described by Elsasser et al (1995) as the somatotrophic axis and the adrenocorticotrophic axis, determines to what extent nutrients are diverted from growth processes to maintain homeostasis. The somatotrophic axis maintains tissue stability and directs nutrient flow into tissues, especially in growing animals. However, under disease stress, it appears to change its role to maintenance and enhancement of immune function. The adrenocorticotrophic axis mobilises nutrient pools from within the tissues to the extent required to resist an imposed stress. Cytokines enhance adrenocorticotrophic activity, immune function, inflammatory processes and pyrogen release, and depress appetite and somatotrophic activity (Elsasser et al, 1995).

Physiological responses to stress induce shedding in *Salmonella* carriers (Williams and Newell, 1967, 1970; Edwards et al, 1997) and increase susceptibility to infection (Gronstol et al, 1974b). Release of catecholamines reduces stomach acidity, promoting survival of *Salmonella* during passage, and increases intestinal motility, thus accelerating contamination of surrounds with faeces. Adrenalin and corticosteroid release reduce white blood cell activity, allowing increased translocation of *Salmonella* (Berends et al, 1996). Isaacson et al (1999a) found more neutrophils and less lymphocytes in transported pigs than in non-transported pigs, but neutrophil and lymphocyte counts did not differ between pigs found to be shedding *Salmonella*, and those not shedding. Wolff (1953) found that stress caused gastric and colonic hyperfunction, manifested as increased motility and blood flow. Under such circumstances the mucous membranes were found to be unusually fragile, possibly providing favourable circumstances for microbial invasion. Infectious agents can trigger the release of cytokines (Elsasser et al, 1995), affecting the permeability of intestinal mucosa, and translocation of microbes and their antigenic components from the gut; when the intestine is inflamed, water & mucus secretion increase, infected/damaged intestinal epithelial cells exfoliate, and propulsive contraction of intestinal smooth muscle increases (Wannemuehler, 1995).

Nielsen et al (1997) found that fasting had no effect that on *Salmonella* carriage rates unless pigs were subsequently transported and mixed with strange pigs. Conversely Morrow et al (1999) failed to observe any significant effect with fasting, even in transported and mixed pigs. However, in the latter study, the prevalence of *Salmonella* was already very high (62%), possibly due to groups of pigs sharing the same truck and lairage for five hours. Isaacson et al (1999a) reported that transport stress increased *Salmonella* carriage rates only if pigs remained on feed, but in a subsequent study (Isaacson et al, 1999b) found that *Salmonella* carriage rates in transported pigs rose as time off-feed increased. Caecal concentrations of *Salmonella* organisms in culture positive pigs, that had been subjected to various fasting/transport regimes, were consistently low (Isaacson et al, 1999a). Whether such low levels represented a true risk factor for food borne illness associated with consumption of processed foods was questioned.

Most studies have found that *Salmonella* carriage rates increase during transport (Morgan et al, 1988f; Berends et al, 1996; Sischo et al, 1996), and levels are positively associated with the time pigs are held in abattoir lairages awaiting slaughter (McDonagh and Smith, 1958; Hansen et al, 1964; Jones and Hobbs, 1964; Burns et al, 1965; Morgan et al, 1987; Berends et al, 1996). This buildup may be a result of physiological changes rather than active infection (Williams and Newell, 1967, 1970). A rise in the prevalence of *Salmonella* in pigs transported directly from farm to abattoir has been demonstrated in several studies (Galton et al, 1954; Williams and Newell, 1967, 1970; Newell and Williams, 1971). Morgan et al (1988f) found that levels of *Salmonella* on-farm were lower than in pigs from dealers and saleyards and doubled in the farm pigs that were subsequently transported more than 200km for slaughter. Prevalences of caecal *Salmonella* were 20%, 33.4%, 60.3%, and 56%, in pigs transported <100km, 100-199km, 200-299km, and >300km respectively.

Holding pigs in abattoir lairages prior to slaughter results in a progressive increase in the excretion of *Salmonella* (McDonagh and Smith, 1958). Their findings are substantiated by many other studies, summarised in Table 3. However, Williams and Newell (1967) and Craven and Hurst (1982) noted a drop *Salmonella* levels during prolonged abattoir lairage time. Williams and Newell (1967) used rectal swabbing, which is less effective than caecal culture (Harvey et al, 1977; Nielsen and Baggesen, 1997; Funk et al, 1997), and studied an earlier time period (0-19 hours after transport) than the others. In the study by Craven and Hurst (1982), staggered pick-up, mixing and transport over a 24 hour period provided ample stress and contact time to cause the high rate of infection that was observed. This initial high infection rate, not observed in the other studies, may explain the contrasting conclusions reached. Morgan et al (1987) suggests that to minimise contamination of pigmeat with *Salmonella,* pigs with a low prevalence of infection should be slaughtered quickly, and slaughter of those with high prevalence should be delayed. The Australian Pig Industry Quality Standards (slaughter pigs less than 24 hours off feed) are based on these observations to minimise *Salmonella* build up immediately preslaughter (Pointon, 1997b).

Table 3 Effect of length of stay in abattoir lairages on prevalence of *Salmonella* (as % of caeca sampled) in slaughter pigs

Time held in lairage	Hansen et al, 1964 *	Burns et al, 1965	Craven and Hurst, 1982	Morgan et al, 1987	Morgan et al, 1988f
0-3 hours	10%*	-	-	-	10%
11-14 hours	-	-	-	-	35.1%
18 hours	-	3.2% (<24 hrs)	-	18.5%	-
1 day	-	4%	70%	-	-
36-43 hours	-	-	-	24.1%	47.5%
2 days	-	6.6%	49%	-	-
3 days	35%*	21.2%	41%	47.7% (66 hrs)	-
4 days	-	19%	-	-	67.1% (115-150 hours)
6 days	-	19.2%	-	-	
7 days	-	0%	-	-	-
Notes	X-sectional study, fed	only *S. brandenburg*	longitudinal study, not fed	longitudinal study, fed	X-sectional study

*samples were from colon rather than caecum.

Several studies suggest that disease itself is a stressor. It is believed that because suspects are sick, they are more likely to be shedding *Salmonella* and other significant food borne organisms (Wray and Sojka, 1977; Pointon, 1997a). Radan (1964) isolated *Salmonella* from 9.2% of emergency-slaughtered cows, and found that muscle tissue (meat) contained *Salmonella* only if other viscera were also infected. Mousing et al (1997b) found that 16% of pigs with pneumonia also harboured bacteria in a joint or in the liver, compared to 2% in pigs without pneumonia. In contrast, Robinson (1965) found *Salmonella* in 6% of suspect calves, which was comparable to 5.5% found in normal calves. Harbers et al (1992a) demonstrated that there were more postmortem lesions in suspects than in normal pigs, but whether these were associated with food borne hazards was not demonstrated. Subsequently *Salmonella* were detected in 3% of 70 abscesses in Australia (Pointon *et al*, 2000), and cases of arthritis did not contain major food borne hazards.

2.5 Summary

Antemortem inspection had its beginnings in the Pasteur era when it was realised that some animal diseases were transmissible to humans, and remains a routine abattoir procedure to identify and separate pigs that are suffering or that may not be completely suitable for human consumption. A study in the Netherlands (Harbers et al, 1992a) found that even after minimal training, producers were better at segregating suspect pigs on-farm than were inspection staff at the abattoir lairage. This indicates potential for enhancement of current abattoir antemortem inspection outcomes, so the ability of Australian producers to perform antemortem inspection on-farm needs further investigation.

Common gut inhabitants (*Salmonella, Toxoplasma, Campylobacter, Yersinia, Listeria* and enterohaemorrhagic *E. coli* (EHEC)) are considered to be the major microbial food borne hazards found in pigmeat (Anon, 1995; Edwards et al, 1997; Pointon, 1997a; Willeberg et al, 1997) but these are rarely cultured from grossly detectable abnormalities in pigs (Engel et al, 1987; Mousing and Pointon, 1997; Pointon et al, 2000). When compared quantitatively with inadvertent faecal contamination during slaughter and dressing, detection of gross abnormalities at ante/postmortem inspection, and their subsequent removal, does not significantly reduce levels of microbiological hazards in carcases (Hathaway and McKenzie, 1991; Gill, 1995; Davies and Funk, 1999, Pointon et al, 2000). If these outdated techniques are not protecting human health (Hathaway et al, 1988; Harbers et al, 1992b; Berends et al, 1993; Gill, 1995; Mousing et al, 1997b; Edwards et al, 1997; Pointon, 1997a; Mousing and Pointon, 1997), resources are being wasted (Murray, 1986). If current abattoir antemortem inspection outcomes could be enhanced by performing them on-farm, the role of abattoir inspectors could be limited to audit of on-farm antemortem inspection, and detection of transport injury (Pointon, 1997a).

Salmonella is implicated as the major microbiological threat to pork consumers (Beran, 1996; Pointon, 1997a), and efforts to eliminate it on-farm have met with limited success. Even if it were commercially realistic to eradicate *Salmonella* from most pig herds, increased shedding and cross-contamination during transport and lairage remains a certainty. Prevalence studies repeatedly find a high incidence of *Salmonella* in pigs/pork (Table 2), which is not detectable by current meat inspection techniques. Whether or not the stress of disease affects gut carriage of *Salmonella* and other gut pathogens remains unknown, so it is currently difficult to ascribe any food safety benefit to procedures such as antemortem inspection.

Chapter 3

Methods Development

Chapter 3 Methods Development

3.1 Introduction

A study in the Netherlands to assess the ability of pig producers to find suspects on-farm among pigs awaiting transport for slaughter was undertaken by Harbers et al (1992a). It was found that pig producers performed the task at least as well as an abattoir veterinary inspector and concluded that on-farm preselection for slaughter is possible. Most of the producers had no experience in antemortem inspection, with the authors mentioning that a learning effect could be expected. The authors also failed to specify whether or not the abattoir veterinary inspector was aware that his performance was under scrutiny. This awareness could have caused him to inspect more thoroughly than usual, confounding the results.

Prior to training Australian producers to conduct antemortem inspection on-farm, and evaluating their efficiency against abattoir antemortem inspection, it was necessary to define the procedures in simple terms that producers could understand. To ask abattoir inspectors to alter their inspection routines with trial batches of pigs would limit the relevance of the results to the broader industry. To inform abattoir inspectors when trial batches of pigs were being presented for inspection would cause them to be aware when their performance was being compared to that of producers, confounding the results. For all these reasons the defined procedures had to match current abattoir antemortem inspection practices as closely as possible. The process used to define antemortem inspection for pig producers is described in this chapter.

3.2 Classification of grossly detectable abnormalities

Grossly detectable abnormalities of pigs that require segregation at abattoir antemortem inspection are described in the Export Meat Orders (Anon, 1982) and the Australian Standard for Hygienic Production of Meat for Human Consumption (Anon, 1997). These descriptions are somewhat complex, lengthy and open to interpretation, as could reasonably be expected in a legal publication attempting to provide sufficient scope for scientific judgements to be made. Provision of such descriptions to producers was considered to be detrimental to their understanding, so the first challenge was to reduce the legislative parameters to simple terms that producers could understand. No attempt was made to ascribe public health risk to any abnormalities, nor would this be possible with our current knowledge vacuum in this area. Rather it was decided to replicate current abattoir practises as closely as possible, and allow science to catch up and mould future practices.

The principal investigator was a veterinarian with ten years of practical experience in antemortem inspection at export abattoirs in South Australia, New South Wales, and Tasmania. Drawing on this experience, the principal investigator reduced the intent of the legislation to criteria which were representative of actual abattoir practices. These criteria were then circulated to all the major pig slaughtering abattoirs (both export and domestic) in Australia. Staff performing antemortem inspections were asked to compare the criteria with what was actually occurring at their workplace. Responses were received from 11 abattoir veterinarians, inspectors and QA personnel in four states (Table 4).

Table 4 Feedback from Australian abattoirs on simplified criteria for classification of grossly detectable abnormalities at abattoir antemortem inspection

PROPOSED ANTEMORTEM CRITERIA	ABATTOIR IDENTIFICATION CODE										
	1	2	3	4	5	6	7	8	9	10	11
Pass Unrestricted											
Fresh prolapses	👍	👍	👍	sus	sus	sus	👍	sus	👍	👍	👍
Small hernias	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍
Fresh minor injuries	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍
Mange	👍	👍	sus	👍	👍	👍	👍	👍	👍	👍	👍
Can't walk unassisted (no visible cause)	sus	EK	sus	👍	sus	sus	EK	EK	👍	👍	👍
Sore feet/bursitis	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍
Vaccination lesions	👍	👍	👍	👍	sus	👍	👍	👍	👍	👍	👍
Suspect											
Severe tailbite (no tail)	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍
Erysipelas (diamond skin)	👍	👍	👍	👍	👍	👍	👍	pass	👍	👍	👍
Hernias as big as a football	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍
Gangrenous prolapses	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍
Abscesses on sides/back	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍
Infected injuries	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍
Fever (dull/breathing heavily/diarrhoea)	👍	👍	con	👍	con	con	👍	👍	👍	👍	👍
Fractures/dislocations	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍
Swollen/crippled limb/(poly)arthritis/foot abscess	👍	👍	con*	👍	👍	EK	EK	👍	👍	👍	👍
Shoot											
Dying pigs	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍	👍
Stressed pigs that don't recover	EK	EK	👍	👍	EK	👍	👍	👍	👍	👍	👍
Emaciation (skinny backs, hairy)	👍	👍	👍	sus	👍	👍	👍	👍	👍	👍	👍
Bloated guts	👍	sus	👍	👍	sus	sus	👍	sus	👍	👍	👍
Polyarthritis/pressure sores, if in poor condition	👍	👍	👍	👍	👍	👍	👍	EK	👍	👍	👍
Graphic lesions/cruelty cases (extensive gangrenous wounds/gross arthritis)	👍	👍	👍	👍	EK	👍	👍	👍	👍	👍	👍

👍 = agreement sus = suspect EK = emergency kill con = condemn
* = polyarthritis only

To make the criteria as realistic and relevant as possible, the feedback from the surveyed abattoirs was collated and then presented at a standardisation workshop to personnel from the three abattoirs that had agreed to participate in the trials. (These personnel included a veterinarian, a meat inspector, a QA officer, a production manager, and a lairage foreman). Following discussion, the workshop participants agreed on a set of standard antemortem criteria (Table 5) taking into account that the result had to be relevant to circumstances on-farm. For example, at the abattoir, severely injured pigs can be processed as an emergency kill whereas on-farm they would have to be destroyed. Another consideration was that producers might choose to hold back some pigs (eg. fevered) to attempt treatment rather than destroy them.

Table 5 Criteria for antemortem inspection of baconers (as amended)

Pass Unrestricted *(These do not usually affect the condition of the pig, or complicate slaughter)* Fresh prolapses Small hernias Fresh minor injuries Mange-*usually only noticed after the scald* Sore feet/bursitis Minor vaccination lesions Minor tailbite (and other minor lesions on extremities)-*easily trimmed off*
Suspect - these are the pigs we are looking at in this project *(These usually affect the condition of the pig, and complicate slaughter. They may need extra trimming or be condemned. They are a potential source of food poisoning germs, and may contaminate the scald water, slaughtering equipment, the workers and other carcases.)* Gangrenous prolapses-*ignore if fresh* Hernias/pizzles/scrotums as big as a football-*ignore if smaller* Severe/infected/chronic injuries-*ignore if fresh/minor* Erysipelas (diamond skin)-*usually only noticed after the scald* Arthritis/polyarthritis/foot abscess/crippled limb-*pig still in reasonable condition* Abscesses on neck/sides/back (as big as a golf ball)-*ignore smaller ones, or any on the extremities (ie. on ears, head or lower limbs), which will not affect carcase value if trimmed.* Severe tailbite (no tail)-*ignore if minor*
Shoot (or treat) *(These should never leave the farm)* Can't walk unassisted (no visible cause)-*often pigs which cannot support their own body weight have lesions which can only be seen at postmortem, (eg. broken back). Usually an emergency kill if found at the abattoir.* Graphic lesions/cruelty cases (extensive gangrenous wounds/gross arthritis) Dying pigs (includes stressed ones that don't recover) Emaciation (skinny backs, hairy) Polyarthritis/pressure sores, if emaciated Fever (dull/breathing heavily/diarrhoea/nervous signs) Bloated guts (pot belly) Fractures/dislocations/split pelvis

THESE CRITERIA ARE CONSISTENT WITH THE EXPORT MEAT ORDERS (Anon,1982*) AND THE AUSTRALIAN STANDARD FOR HYGIENIC PRODUCTION OF MEAT FOR HUMAN CONSUMPTION* (Anon,1997)

Amendment of the standard criteria was necessary because at the standardisation workshop pigs that could not walk unassisted had been considered suitable for transport. However, at the final producer training session, it was brought to the attention of the principal investigator that this was in breach of the Australian Association of Pig Veterinarian (AAPV) Guidelines for the Care of Sick and Injured Pigs (Anon, 1999). After consulting the AAPV guidelines the necessary amendments were made to the standard antemortem criteria (Table 5). These amendments were provided to the consultant veterinarians for distribution and instruction at their two follow up farm training visits, so all the producers were aware of the changes before they sent their first trial batch of pigs for slaughter.

After the standardisation workshop, the principle investigator photographed a range of common grossly detectable abnormalities in live pigs, concentrating particularly on borderline examples to provoke discussion at the producer training sessions. Although far simpler than its legislative origins, the standard classification of grossly detectable abnormalities was by its very nature open to interpretation and still required judgements to be made by producers, so borderline cases could legitimately fit in more than one category. A selection of the photographs used in the training sessions is included in section 3.6.

3.3 Standardisation of protocols

Another challenge was to produce instructions in simple terms that producers could understand. A solid starting point was a phone call to initiate each trial batch, providing producers with an opportunity to clarify matters where necessary. Although producers were exposed to various antemortem inspection techniques during training, they were allowed to choose their own methods on-farm, as long as a defined minimum standard was achieved. A simple set of instructions (Table 6) was developed for producers to take home from their abattoir training session in a plastic folder with a copy of the standard criteria for classification of grossly detectable abnormalities.

Table 6 Instructions for producers

Antemortem Inspection Project

WHAT DO I HAVE TO DO ?

1) (State coordinator) **will advise you** when to send in a test batch (= a load) of pigs, to ensure follow up can occur on that batch at the abattoir. Expect 3 test batches for slaughter (March, June, and September).
(To maintain uniformity throughout the project, only trained personnel can be involved - so if anyone is absent that day, that batch can not be used).

2) Antemortem inspection of pigs on-farm must be done by you prior to loading the pigs onto the truck for transport to the abattoir. The minimum requirement for inspection will be to briefly observe the pigs at rest, then to get them up on their feet and observe each one as they move around. This is probably most practical to do while the pigs are being branded.

3) When you find a suspect, place a unique tattoo on it, and record this brand and the associated lesion/symptoms on the recording sheet. The suspect pigs are left mixed in with the others and loaded normally

4) Fax the sheet to (state coordinator).
If no suspects are found, phone him (ph * * * * * * * *) to organise another batch.

At the standardisation workshop, the participants also agreed on a standard farm/abattoir reporting sheet format. Four copies were provided to producers to take home from their abattoir training session. Amended sheets that met the AAPV guidelines (Table 7) were provided to the consultant veterinarians for distribution at their first follow up farm training visit. The consultant veterinarians were instructed to discard the previous sheets and insert the amended ones into the plastic folder.

Table 7 Standard farm/abattoir reporting sheet

Pass Unrestricted	**Suspect**	**Shoot (or treat)**
Fresh prolapses Small hernias Fresh minor injuries Mange Bursitis Sore feet Tailbite & other minor lesions on extremities Vaccination lesions	**Gangrenous prolapses** **Hernias/scrotums as big as a football** **Infected/severe/chronic injuries** **Erysipelas (diamond skin)** **Arthritis/polyarthritis/foot abscess/swollen/crippled limb** **Severe tailbite (no tail)** **Abscesses on neck/sides/back (as big as a golf ball)**	Graphic lesions/cruelty cases(big/bad/ugly) Can't walk unassisted (no visible cause) Dying pigs(and stressed pigs that don't recover) Emaciation (skinny backs, hairy) Polyarthritis/pressure sores, if emaciated Fractures/dislocations/split pelvis Fever (dull/breathing heavily/diarrhoea) Bloated guts (pot belly)

PRODUCER REPORT(to State coordinator, fax:* * * * * * * *) Date:_______________

Tattoo:______ Number of pigs in batch:______ Number of suspects:______

Unique suspect tattoo	Antemortem lesion	Comments

QA OFFICER REPORT (to J. Jackowiak, fax 08 82077909)

Number of pigs dead in yards:(unique tattoo?)________________ Number of suspects:______

Number of pigs shot: (explain, unique tattoo?)________________ Number of emergency kills:______

Abattoir suspect tattoo	Antemortem lesion	Comments

Suspect tattoo(s)	Postmortem disposition	Comments

Other Postmortem findings:

3.4 Postmortem classification of grossly detectable abnormalities

The abattoirs which had previously commented on the proposed criteria for classification of grossly detectable abnormalities were asked to provide copies of their systems of recording post-mortem findings and partial condemnation figures. The national coordinator collated the feedback to design a standard reporting format (Table 8) to be used by state coordinators when recording/reporting their findings.

Table 8 Post-mortem criteria and codes to be used at participating abattoirs

CODE	PART CONDEMNED	CODE	REASON
SKN	SKUN	ABS	ABSCESS
PS	PARTIAL SKUN 50-80%	ANM	ANAEMIA
DOG	DOWNGRADED	ART	ARTHRITIS
SMA	SMALLGOODS	BRK	BROKEN BONES
ET	EXCESSIVE TRIM (Multi primals)	BRU	BRUISING
L	1 (hind) LEG	BSP	BLACKSPOT
HL	HALF LEG	CAN	CANCER
2L	BOTH LEGS	CON	CONTAMINATION (ingesta/faeces)
S	1 SHOULDER	DOG	POOR QUALITY
HS	HALF SHOULDER	EC	ECCHYMOSIS (Blood splash)
2S	BOTH SHOULDERS	EMA	EMACIATION
LS	1 LEG 1 SHOULDER	ENT	ENTERITIS
L2S	1 LEG 2 SHOULDERS	ERY	ERYSIPELAS
2LS	2 LEGS 1 SHOULDER	JAU	JAUNDICE
4L	2 LEGS 2 SHOULDERS	MET	METRITIS
HQ	HINDQUARTER	MM	MACHINERY MUTILATION
BB	BACKBONE	MNG	MANGE
PEL	PELVIS	OED	OEDEMA
RC	RIBCAGE	PER	PERITONITIS
HRC	HALF RIBCAGE	PLE	PLEURISY
TK	TRUNK	PNM	PNEUMONIA
HED	HEAD	PSE	FISH MUSCLE
CAR	CARCASE	SPA	SPARGANOSIS
HCA	HALF CARCASE	SPT	SEPTIC WOUND (Gangrene)
ST	STIFLE	URE	URAEMIA
2ST	BOTH STIFLES	FEV	FEVER
PIG	DEAD IN YARDS		(Septicaemia/Toxaemia/Pyaemia)
MID	MIDDLE		
2MD	BOTH MIDDLES		

Use of these post-mortem criteria and codes by the state coordinators for feedback to the national coordinator and producers proved cumbersome. Lack of familiarity with such codes led to a preference to write out post-mortem findings and meat rejection details in full, which was probably more useful for the producers anyway.

Codes are normally used by abattoir personnel stationed at the scales, where they input meat rejection details onto the computer at normal chain speeds. Abattoir managers were curious about the proposed codes, but preferred to maintain their own systems. Each abattoir has unique destinations for its carcase product (eg. boning/smallgoods, service kill for local butchers/wholesalers, export of primal cuts). Thus the method of recording trimming losses, and subsequent calculation of financial losses from trimming, vary with every slaughtering establishment.

3.5 Pretesting

Once all the procedures, protocols and reporting mechanisms were standardised, it was decided to trial one batch of pigs in advance to ensure all systems would work smoothly. At the first producer training session, a producer volunteered to run a pretest, prior to initiation of the remainder of the trial. All the procedures proved workable and protocols worked effectively. Some minor amendments were made to the standard farm/abattoir reporting sheet when some details (eg. the date) were noted to be omitted. Amended reporting sheets (Table 7) were distributed to all the producers via their consultant veterinarians before the first trial batch of pigs was sent for slaughter.

Chapter 4

Comparison of On-farm and Abattoir Antemortem Inspection

Chapter 4 Comparison of On-farm and Abattoir Antemortem Inspection

4.1 Introduction

Researchers (Hathaway et al, 1988; Harbers et al, 1992b; Berends et al, 1993; Gill, 1995; Pointon, 1997a; Mousing and Pointon, 1997; Pointon et al, 1998) are currently questioning the extent to which current meat inspection procedures, including antemortem inspection, are able to protect consumers against the major causes of food borne disease such as *Salmonella* (Gronstol et al, 1974a; Maguire et al, 1993; Davies et al, 1997; Fedorka-Cray et al, 1997; Mousing et al, 1997b; Edwards et al, 1997). Antemortem inspection has always been done at the abattoir (Snijders, 1988) before slaughter to identify and separate pigs that are suffering or that may not be completely suitable for human consumption.

A study in the Netherlands (Harbers et al, 1992a) found that even after minimal training, producers were better at segregating suspect pigs on-farm than were inspection staff at the abattoir lairage. This indicated potential for enhancement of current abattoir antemortem inspection outcomes by inspecting the pigs on-farm. As a consequence, the role of abattoir inspectors could be limited to audit of on-farm antemortem inspection, and detection of transport injury (Pointon, 1997a).

This trial was modelled on the Dutch study (Harbers et al, 1992a) and aimed to assess the opportunity for improvement in effectiveness of antemortem inspection under Australian conditions. Producers were trained to conduct antemortem inspection on-farm, and their performance was evaluated against antemortem inspection conducted by inspection staff at the abattoir.

4.2 Methods

4.2.1 Selection of Herds

Three state coordinators (South Australia, Victoria and Queensland) were selected to recruit between five and ten producers, and coordinate all aspects of the trials with participating abattoirs. The required sample for each state was a total of at least 900 pigs, based on each producer delivering three loads (batches) of pigs to the abattoir. Minimum batch size was 30 bacon pigs (85-100kg weight range); these are seldom culled and represent the largest proportion of slaughter pigs. The national target was a total sample size of at least 2,700 pigs. This was to be achieved by recording full data on at least 900 pigs at each abattoir, by inspecting three batches from each farm over a seven month period (ie. three batches, three months apart). Batches could be larger, particularly to compensate for fewer farms. Alternatively, additional batches could be included to ensure sufficient numbers of pigs.

It was necessary to involve regular clients that branded their pigs legibly and had a fax machine. Producers had to use consultant veterinarians that were willing to participate, but it was preferable to minimise the number of consultant veterinarians involved, to optimise uniformity. Herds which were treated generally as suspects (eg. for meliodosis), and herds which were so healthy that they wouldn't have suspects, were avoided.

Pig Health Monitoring Scheme (PHMS) membership was optional. Each herd had three free PHMS inspections done over the trial period, to provide a benchmark of the prevalence and range of diseases present among trial batches, thus enabling extrapolation of results to the broader industry. The state coordinators liased with the PHMS monitors to advise them when trial batches were anticipated. Ideally the actual trial batch was monitored, but where this was not possible, another load from that same farm was monitored on a nearby date. This provided snapshots of the health of the herds throughout the trial period.

4.2.2 Training

Training in identification of gross abnormalities at antemortem inspection was initially conducted at the three participating abattoirs, then followed up by two farm training visits by consultant veterinarians. The abattoir training session took two hours, and included an overview, specific instruction, a display of photographs of common gross abnormalities, discussion/question time, and a practical session inspecting pigs in the abattoir lairages. Participants in the initial training sessions were the national coordinator (the trainer), the state coordinator, the abattoir personnel that performed antemortem inspections, the consultant veterinarians, and the personnel responsible for inspecting and shipping pigs at each participating farm. Two follow up sessions then occurred at each participating farm where the consultant veterinarian reviewed the training procedure with the producer/employee.

Only three herds were able to be recruited in Victoria by the scheduled training date so the consultant veterinarian in attendance at the training session agreed to find at least two more herds and train them on behalf of the national coordinator. This was in addition to two follow up visits on those farms.

During the period of the study veterinary staffing at the two export abattoirs changed several times. As the antemortem inspection was performed by these incoming veterinarians the state coordinator provided them with information and photos used in the original abattoir training sessions to make them aware of the project. The national coordinator then followed up with a phone conversation to discuss any ambiguities and answer questions.

4.2.3 Inspection on-farm

Once producers had been trained, and standard protocols pretested, each producer sent test batches for slaughter over a nine month period. Antemortem inspection of pigs on-farm was done by the trained producer/employee prior to loading the pigs onto the truck for transport to the abattoir. Prior to inspecting each load of pigs on-farm, the state coordinator contacted the producer to ensure follow up would occur on that batch at the abattoir (to maintain uniformity throughout the trials, only trained personnel could be involved-so if any of them were absent that day, that batch was not used). The minimum requirement for inspection was to briefly observe the pigs at rest, then to get them up on their feet and observe each one as it moved around. This could be done while the pigs were being branded, if practical.

During inspection, the trained person placed a unique tattoo on each pig classified as suspect, and recorded this brand and the associated grossly detectable abnormality on the recording sheet. The sheet was then faxed to the state coordinator. The suspect pigs were left mixed in with the others and loaded normally. If no suspects were found, the state coordinator was notified and the procedure repeated on another batch.

4.2.4 Inspection at abattoir

Antemortem inspection at the export abattoirs was performed by government veterinarians, with works employees assisting by moving the pigs about as directed. At the domestic abattoir, antemortem inspection was performed by a QA accredited works employee, who observed the pigs when he moved them out of their pens. As these trained inspection staff were unaware of the arrival of a project batch, normal routine antemortem procedures were performed on the project pigs at the abattoirs.

When antemortem inspection was completed, the state coordinator approached the trained antemortem inspector to ask how many pigs had been segregated (to be destroyed, or processed as suspects or emergency kills). The coordinator identified any unique farm tattoo on any dead pigs, and a unique abattoir tattoo was placed on each suspect pig. The trained inspector was asked to classify the grossly detectable abnormality for each pig segregated from that batch and this was noted alongside the unique tattoo on the recording sheet.

The state coordinator then observed/recorded unique farm/abattoir tattoos of slaughtered pigs, and the postmortem dispositions/trimming of the batch/suspects, noting especially individual dispositions of the uniquely tattooed pigs. The completed recording sheets were then faxed to the national coordinator as well as the farm of origin.

Carcase trimming losses (as a % of total hot standard carcase weight) following postmortem inspection dispositions were calculated as follows: hindquarter 26%, forequarter

26%, leg (ham) 16.7%, shoulder 16.7%, half shoulder (radius and elbow) 9.3%, pelvis 9.3%, backbone 9.3%, ribs 7.3%, head 7.3%, half leg (distal to stifle) 3.7%, stifle 1.9% and hip 1.5%. Condemnation of a pig at antemortem inspection, or a carcase at postmortem inspection, was calculated as a trimming loss of 100%. The losses from suspects were tallied and compared to the tallied losses from normal pigs in the same batches. This showed the extent to which gross abnormalities detectable on-farm by antemortem inspection can disrupt normal dressing procedures and translate into meat rejection.

Grossly detectable abnormalities in offal were only recorded by the state coordinator if specifically associated with an antemortem finding (eg. an internal abscess in a tailbitten pig) in a suspect. It is normal practise in Australia to discard variable amounts of healthy offal, so recording of offal disposition was impractical. PHMS inspectors record gross abnormalities detected in offal, (and less reliably in carcases), and wherever possible, PHMS findings of individual suspects were also noted. This required direct communication between the state coordinator, who moved around the floor as required to find/follow suspects, and the PHMS inspector positioned at the viscera table. The findings of monitored suspects were pooled and compared to the pooled findings from normal pigs in the same batches. This allowed some direct comparison of prevalence of organ pathology in suspects and normal pigs.

4.2.5 Analysis of Results

Kappa was the statistic used to measure agreement between the inspectors in the Dutch study (Harbers et al, 1992a) and the producer and abattoir antemortem inspector in this study. It is held to be a better indicator of agreement because it takes into account chance or “fluked” agreement.

Using the tabulated findings of producer and the abattoir antemortem inspector:

		abattoir inspector	
	Pigs	Normal	Suspect/reject
producer	Normal	a	b
	Sus/reject	c	d

the formula to calculate kappa is:

$$\frac{(a+d) - (a+b)(a+c)-(b+d)(c+d)}{(a+b+c+d)-(a+b)(a+c)-(b+d)(c+d)}$$

Guide to interpretation of kappa values:

> 0.75 : Excellent agreement beyond chance

0.4 - 0.75 : Fair to good agreement

< 0.4 : Poor agreement

A negative kappa value means that agreement was less than that expected purely by chance.

4.3 Results

4.3.1 Herd and batch characteristics

A total of 9597 pigs from 20 herds from three states of Australia were inspected. PHMS inspections revealed a marked variation in herd health status, with some herds experiencing disease outbreaks during the trial period, but no corresponding change in the number of suspects detected was evident. Herds J and N were experiencing a dramatic increase in pneumonia severity over the trial period, whilst herds E, R and V experienced transient fluctuations in pneumonia levels. Transient fluctuations were also noted in prevalences of pleurisy (herds C, E, L, R, S, V and W), dermatitis (herds A, B, N, V and W), nephritis (herds A, B, K, M, P and R), arthritis (herd B) and abscesses (herd W).

Comparison between on-farm and abattoir antemortem inspection was conducted on 58 batches. Details of batches are represented in Table 9.

Table 9 Number of herds, batches and pigs inspected

Herd ID		Herd size (no. of sows)	Grower/finisher management	Health status	No. of batches	Total no. of pigs inspected
SA	A	1,600	Continuous	Open	4	765
	B	1,500	Continuous	Open	4	944
	C	650	Continuous	SPF*	4	740
	D	200	All in/all out	Open	4	306
	E	200	Continuous	Open	2	120
	F	115	All in/all out	Open	1	50
	G	200	Continuous	Closed	4	163
	H	500	All in/all out	Open	2	404
Vic	J	1,450	All in/all out	Open	3	646
	K	2,500	All in/all out	SEW**	3	720
	L	400	Continuous	Closed	3	359
	M	1,240	Continuous	SPF	3	648
	N	1,650	Continuous	Closed	3	630
	P	75	Continuous	SPF	3	81
	R	1,350	Continuous	SPF	3	641
Qld	S	860	Continuous	Closed	3	580
	T	860	Continuous	Closed	3	580
	V	3,600	All in/all out	Closed	3	590
	W	2,500 finishers	All in/all out	SEW	2	420
	X	2,500 finishers	All in/all out	SEW	1	210
Total	20				58	9,597

* Specific pathogen free
** Segregated early weaning

Data presented in Table 9 does not include seven batches which were rejected from this comparative trial. Four of these batches (J2, S2, T2 and V2) were rejected because the antemortem veterinarian working that day was untrained. Batch N1 was rejected because the suspects were segregated during transport. Batch X2 was rejected because abattoir personnel separated the suspects prior to the inspection by the antemortem inspector. Batch W1 was rejected because it was apparent that producer training had been ineffective (four of five pigs could not walk and should have been destroyed on-farm).

Although N1, S2, X2 and W1 were not used in the comparative trial, some findings from these batches are shown in Table 12 in which transport injuries are recorded.

4.3.2 Suspects detected on-farm and at abattoir

Overall 203 (2.1%) of 9,597 pigs were classified as suspect at on-farm antemortem inspection compared to only 13 pigs at abattoir antemortem inspection (Table 10). No pigs were classified as suspect at antemortem inspection at the abattoir in Victoria.

Table 10 Distribution of major causes of pigs being classified as suspect by producers on-farm and by antemortem inspectors at the abattoir

Farm ID	No. of suspects detected*	Type and number of causes of suspects detected by producers (and by abattoir inspectors)								
	(total inspected)	Arthritis	Hernia	Lame	Prolapse	Abscess	Tailbite	Wound	Foot Abscess	Other**
SA										
A	15 (765)	4	4	2	1	2	0	1	1	0
B	16 (944)	2	3	0	3	4	0	2	2	0
C	10 (740)	7	3	0	0	0	0	0	0	0
D	13 (306)	5	2	0	0	5	0	1	0	0
E	2 (120)	2	0	0	0	0	0	0	0	0
F	1 (50)	0	0	0	0	0	1	0	0	0
G	8 (163)	4	0	1	0	2		0	0	1 (1)
H	7 (404)	2 (2)	0	0	1	1	3	0	0	0
Total	72(3,492)	26 (2)	12	3	5	14	4	4	3	1
Qld										
J	12 (646)	6 (1)	0	0	2 (1)	0	2	1	1 (1)	0
K	8 (720)	2	1	1	1	0	3	0	0	0
L	9 (359)	3 (2)	2 (1)	1	0	2	0	0	0	1
M	15 (648)	1	1	2	2	1 (1)	6 (2)	2	0	0
N	18 (630)	2	0	2	13	0	0	1	0	0
P	5 (81)	1	1	1	0	1 (1)	1	0	0	0
R	19 (641)	1	5	4	2	2	1	2	0	2
Total	86(3,725)	16 (3)	10 (1)	11	20 (1)	6 (2)	13 (2)	6	1 (1)	3
Vic										
S	9 (580)	1	4	4	0	0	0	0	0	0
T	8 (580)	2	0	6	0	0	0	0	0	0
V	10 (590)	0	0	6	0	2	0	0	2	0
W	9 (420)	0	5	3	0	1	0	0	0	0
X	9 (210)	0	4	0	1	0	1	0	0	3
Total	45(2,380)	3	13	19	1	3	1	0	2	3
Nat.	203(9,597)	45 (5)	35 (1)	33	26 (1)	23 (2)	18 (2)	10	6 (1)	7 (1)

* sum of suspects detected in all batches
** comprised 1 pot belly, 2 head tilt, 3 fever, 1 shaking

The most common cause of pigs being classified as suspect was for locomotor problems; comprised of arthritis (22% of 203 suspects), lameness (16%) and foot abscess (3%). Classification as suspect due to hernia accounted for 17% of cases, prolapse 13%, abscess 11% and tailbite 9%. There were 19 pigs falsely classified by producers as suspects, as judged by the principal investigator from the reports received; they are not listed as suspects in Table 10. Four had fresh prolapses, four were runts, four had minor tailbite, three were in poor condition, three had small hernias and one had pleurisy.

The extent of agreement between the different inspections, Kappa, measured on the findings of all 9,597 pigs, is presented in Table 11. There was very poor agreement between classification of animals on-farm by producers and by abattoir antemortem inspection.

In total, only 6.4% of 203 suspects detected by producers were detected by abattoir antemortem inspection.

Table 11 Cross-classification of the results of inspection for abnormalities by producers on-farm and by antemortem inspectors at abattoir (n=9,597)

Abnormality	++	+ -	- +	- -	Kappa
Arthritis	5	40	0	9,552	0.199
Hernia	1	34	0	9,562	0.055
Lame	0	33	0	9,564	0
Prolapse	1	25	0	9,571	0.074
Abscess	2	21	0	9,574	0.160
Tailbite	2	16	0	9,579	0.200
Wound	0	10	0	9,587	0
Foot abscess	1	5	0	9,591	0.286
Other	0	7	0	9,590	0
All abnormalities	12	191	0	9,394	0.110

Interpretation of Kappa: <0.4=poor agreement
Results of inspections:
++ both inspections detected suspects
+ - on-farm positive, abattoir negative
- + on-farm negative, abattoir positive
- - no suspects detected

4.3.3 Impact on animal welfare

Nineteen pigs were diagnosed as having suffered injury during transport (Table 12). Sixteen of these had been classified as suspect during on-farm antemortem inspection; three of these died during transport, five were destroyed on arrival and eight were submitted for emergency kill. Of 9,394 pigs judged to be normal on-farm, 0.0146% suffered major trauma during transport (Table 12).

Table 12 Exacerbation of injuries of suspect and normal pigs during transport

Type of pig	Previous condition	Injury following transport
Suspect	Polyarthritis	Died on truck
	Lame	Died on truck
	Prolapse	Died on truck
	Arthritis (2 pigs)	Couldn't walk - destroyed
	Lame (3 pigs)	Couldn't walk - destroyed
	Fresh prolapse	Couldn't walk - EK
	Swollen hindlimb	Lame - EK
	Arthritis	Lame - EK
	Broken shoulder*	Broken shoulder - EK
	Couldn't walk unassisted (4 pigs)*	EK (2 with broken pelvis and 2 with bruised legs at post-mortem inspection)
Normal	N/A	Couldn't walk - destroyed
	N/A	Broken leg - EK
	N/A	Broken pelvis (found at post-mortem inspection)

* should have been destroyed on-farm; transport was in breach of AAPV guidelines
EK: Emergency kill N/A: Not applicable

4.3.4 Impact on meat rejection and carcase disposition

A slightly different subset was used in this analysis because the suspects in batches A4, B3, B4 and S4 were not able to be distinguished from the normal pigs after slaughter. Batch W1 was also omitted because the suspects should have been destroyed on-farm.

Meat rejection from suspects amounted to the equivalent of 19 (9.3%) of 205 carcases, compared to the equivalent of 28 (0.3%) of 9,494 normal carcases. The 19 carcase equivalents was made up of five pigs that were destroyed in the abattoir lairages during abattoir antemortem inspection, six carcases totally condemned at postmortem inspection, and an approximate weight in trimmings of eight carcases. Processing of suspects with locomotor problems resulted in antemortem condemnation of three pigs, total postmortem condemnation of four carcases and partial condemnation of trimmings equivalent to five carcases. Other contributors to meat rejection included hernia (three carcases plus one carcase equivalent), tailbite (one pig), abscesses (one carcase equivalent) and potbelly (one pig).

Processing of the 9,494 normal carcases resulted in resulted in antemortem condemnation of two pigs that could not walk, total postmortem condemnation of 18 carcases (triple the number of suspects condemned) and partial condemnation of trimmings equivalent to eight carcases. Reasons given for total postmortem condemnation of the 18 normal carcases were three locomotor (bruising/arthritis), seven enteritis, five fever and three other (cancer, abscess and pneumonia).

4.3.5 PHMS findings in suspect and normal pigs

PHMS inspection findings were available for 72 suspects from 26 batches, and were compared to the PHMS findings for their 4,005 companion pigs. The average lung score was 4.8 in these 72 suspects, compared to 5.3 for their normal companion pigs. Prevalence of pneumonia lesions was 41% (suspect) versus 48% (normal); pleurisy prevalence was 20% (suspect) versus 15% (normal); nephritis prevalence was 7% in both; pericarditis prevalence was 5% (suspect) versus 2% (normal); peritonitis prevalence was 6% (suspect) versus 1% (normal); arthritis prevalence was 35% (suspect) versus 2% (normal); abscess prevalence was 26% (suspect) versus 2% (normal). The 26% prevalence of abscesses in the suspects could be further described as internal (12%) and external (14%), ie. approximately half of them were visible at antemortem inspection.

Corresponding PHMS findings, with no differentiation between suspect and normal pigs, were available on the South Australian PHMS database. This represented 24,000 pigs inspected in South Australia in 1998. Prevalence of pneumonia was 46.7%, pleurisy 20.1%, nephritis 5.4%, pericarditis 3.2%, peritonitis 1.3%, arthritis 3.2% and abscesses 1.1%.

4.4 Discussion

4.4.1 Effectiveness of on-farm antemortem inspection

Following training sessions on antemortem inspection at the abattoir by the national coordinator, and reinforced on-farm by a consultant veterinarian, producers clearly demonstrated that they can effectively conduct antemortem inspection. The considerable difference between producers on-farm and antemortem inspectors at the abattoir may have been due to many reasons, including:

- producers were aware of the health history of their pigs during the growing/finishing period. Many of the suspect pigs may already have had individual attention for problems in the herd's hospital pen(s).
- during inspection on-farm pigs were not stressed due to the effects of transport, mixing with strange pigs and new surroundings.
- producers selected for this study may have caused some bias as their participation was largely voluntary and they were known to be progressive and keen to adopt new technologies and innovation.
- abattoir antemortem inspection, whether domestic or export, was not performed rigorously, or suspect stock were not segregated once detected.

- producers over-reacted to minor abnormalities and incorrectly recorded some pigs as suspects (ie. false positives).

Antemortem inspection was ineffective at both domestic and export abattoirs. Under any interpretation of the above reasons and data, the detection at the abattoir of only 6.4% of suspects detected by producers is clearly a very poor result. At one abattoir no suspects were detected among 2,380 pigs which contained 45 pigs classified as suspects by producers. The findings were consistent across all three states (Table 10) with low numbers of pigs detected as suspects at all three of the abattoirs. This finding and the variation in judgement of suspects and emergency kills between abattoirs (Table 4) highlights a need for regulatory authorities to develop competency standards for inspection personnel and implement quality systems.

Clearly, the surprising performance of the producers raised questions of the specificity, and for that matter, sensitivity of producer and abattoir conducted antemortem inspection. Consequently, a further study (Chapter 5) was conducted to establish any major biases associated with producer and abattoir observations. This also aimed to resolve the finding for some suspect categories where abattoir inspector findings of agreement with the producers were disturbingly poor (Table 11).

In The Netherlands producers, who mostly had no experience in inspecting animals, failed to perform as well as abattoir antemortem inspectors. In that study the abattoir inspectors performed well against a reference inspector. Producers performed well for tailbite but poorly for other abnormalities (at their first, untrained, antemortem inspection on-farm). In comparison, after two training sessions, piggery staff in Australia performed well (Table 10, validated in Chapter 5).

4.4.2 Animal welfare benefits of on-farm antemortem inspection

A total of 2.1% of 9,597 pigs were classified by producers on-farm as suspects. The most common cause of pigs being classified as suspect in Australia was for locomotor problems due either to arthritis (22% of 203 suspects), lameness (16%) or foot abscesses (3%). On this basis approximately 100,000 of five million bacon pigs submitted for slaughter in Australia annually are suspects, of which 41,000 suffer locomotor disorders. Of all abnormalities, these are the most likely to lead to poor welfare during transport. This is supported by the observation of the effect of transport on 16 pigs classified as suspect pre shipment (Table 12). Three pigs dying during transport, and two more having to be destroyed apart from submitting the others for emergency kill, demonstrates that arthritic and/or lame pigs are at risk when transported.

In the meat rejection data, 7 (23%) of 31 total carcase condemnations occurred at antemortem inspection. This is considerably higher than the 1% reported by Pointon (1997a). The carcase condemnation data used by Pointon (1997a) was compiled from Monthly Returns (Form E6). The principal investigator has observed that the column on the E6 form, designed for entering antemortem condemnation details, is usually left blank due to poor communication between the antemortem inspector and inspector that does the paperwork.

On-farm antemortem inspection procedures can in a very practical way, make a positive contribution to pig welfare, especially during transport. Segregation from normal pigs and transport in a separate pen can be a practical way to minimise severe pain and suffering. Fortunately only 0.015% of pigs in this trial suffered any detectable transport injury/exacerbation (Table 12). However, one in 50 pigs presented for slaughter from these herds was a suspect. Raising staff awareness of pig welfare by training may improve health care provision to individual grower/finisher pigs in all production areas of the piggery. By implementing on-farm antemortem inspection producers can assure consumers that procedures to improve pig welfare have been implemented as part of normal production. The pig industry has the opportunity to address this situation through the framework provided by the APIQS, which provides a framework for implementing industry, and welfare, best practice.

4.4.3 Potential impact of on-farm antemortem inspection on carcase disposition

PHMS results for this subset reflect overall South Australian (1998) PHMS data. However a markedly higher prevalence of arthritis and abscesses was recorded in suspects than in normal pigs. These two grossly detectable abnormalities have been reported as the most significant causes of abattoir total and partial condemnations (Hill and Jones, 1984). More modest rises in prevalence were observed for peritonitis and pericarditis, which can always be regarded as potentially hazardous (Pointon et al, 2000). Harbers et al (1992a), also demonstrated that there were more postmortem lesions in suspects than in normal pigs.

If antemortem inspection was conducted on-farm with segregation of suspects, a considerable proportion of pigs requiring substantial additional trimming, and those which may cause major contamination during dressing, can be slaughtered at the end of the kill or shift. The remaining large lines of normal pigs would meet abattoir client specifications, and may be eligible for branding with a quality logo. Seven of 11 suspects condemned at ante/postmortem inspection had locomotor problems and 64% of all meat rejection from suspect carcases was from pigs with locomotor problems. The remaining 36% of meat rejection from suspect carcases was from pigs with hernias and abscesses.

On an abattoir throughput basis, approximately 200 pigs per 10,000 killed will be suspects if antemortem inspection is done on-farm. If the meat rejection and PHMS data above is typical, what could be expected if these are slaughtered separately to normal pigs?

- A quarter of total postmortem carcase condemnations would occur during 2% of the kill.
- Half of the weight of offcuts from trimming would be removed during 2% of the kill. Stripping of pleura for pleurisy would be largely unaffected.
- 35% (70) of 200 suspects and 2% (196) of 9,800 normal pigs are likely to have arthritis. One of the 10,000 pigs is likely to harbour enterotoxigenic *Staphylococcus aureus* in an arthritic joint (Pointon, 1997a), with a one in three chance of it being a suspect.
- 26% (52) of the 200 suspects and 2% (196) of the 9,800 normal pigs are likely to have abscesses. Twenty (range 1-20) of the 10,000 pigs are likely to harbour *Salmonella* in abscesses (Pointon et al, 2000), and four of these are likely to be suspects.
- 20% of hazardous abscesses would be removed during 2% of the kill.

It is clear that accurate classification and segregation of suspects on-farm creates considerable opportunity for improved efficiency at the abattoir. In addition to minimising exacerbation of transport injury, the substantial additional trimming required with suspects can be expedited by appropriate scheduling of staff during slaughter of the suspects as a group.

Chapter 5

Verification of Producer and Abattoir Antemortem Inspection Classification of Pigs

Chapter 5 Verification of Producer and Abattoir Antemortem Inspection Classification of Pigs

5.1 Introduction

Abattoir antemortem inspection is performed as an established routine procedure to prevent slaughter of unfit pigs, and to detect pigs with gross grossly detectable abnormalities for separate slaughter as suspects. Harbers et al (1992a) undertook a study in the Netherlands to assess the ability of pig producers to find suspects on-farm among pigs awaiting transport for slaughter. They found that the pig producers performed the task at least as well as an abattoir veterinary meat inspector and concluded that preselection is possible.

In the Dutch study, the pigs were inspected independently on-farm by both the producer and by an Animal Health Service field veterinarian. To check the ability of Australian producers to detect suspects and classify pigs accurately, a similar independent study using a reference inspector needed to be undertaken to define their performance in statistical terms. This was especially relevant in light of the producers detecting 16 times as many suspects relative to abattoir antemortem inspectors.

Potential confounders leading to this result include false positive suspect classifications by producers (ie. low specificity) and/or false negative classifications by abattoir antemortem inspectors (ie. low sensitivity). In order to verify this result the performance of producers and antemortem inspectors needed to be checked.

5.2 Methods

5.2.1 Selection of herds

The sample of producers used in this trial was three of the South Australian producers who had been trained and had participated in the on-farm trials of antemortem inspection (Chapter 4). As one of the three producers worked with three participating herds, this sample represented 25% of the herds, and 20% of the pigs used in the whole study. To maximise the sample size in this verification exercise, all the pigs on the farms which were approaching a marketable weight (ie. larger growers in the 60-85 kg weight range and finishers in the 85-100 kg weight range) as well as pigs kept in hospital pens were examined.

5.2.2 Reference inspector

The principal investigator, who had directly trained the three participating producers a year earlier for the on-farm antemortem inspection trials, was the reference inspector. The principal investigator had ten years of practical experience in antemortem inspection at abattoirs in South Australia, New South Wales, and Tasmania. On-farm visits were arranged with the three participating producers to compare their performance against the principal investigator.

5.2.3 On-farm verification protocols

The pigs were submitted to two independent inspections, immediately followed by a comparison of the findings. The reference inspector first examined every pig approaching a marketable weight, noted any grossly detectable abnormalities (description, location, pen number), and classified them as "pass unrestricted" (normal), "suspect" or "shoot/treat". This was done in the absence of the producer, so that the performance of the producer would not be biased by observing the reference inspector.

The producer was then asked to examine the same pigs in the presence of the reference inspector. The objective was to pretend they were about to be marketed as a trial batch, except that instead of marking suspect pigs, the producer immediately conveyed his conclusions to the reference inspector, who recorded the necessary details. No discussion about classifying pigs was entered into until the whole exercise was completed.

When the producer had finished examining all the pigs, the findings were compared to investigate any disagreement. Subsequent discussion stemming from comparison of results served to further reinforce the training provided at the outset of the project, by providing the opportunity for both parties to show each other pigs that they had missed, or misclassified.

5.2.4 Abattoir verification protocols

To avoid arousing the suspicion of the antemortem inspector, the reference inspector pretended to collect faecal samples from pigs awaiting slaughter. In actual fact antemortem inspection was occurring and all suspects were noted. The reference inspector then waited to see if any pigs were segregated as suspects by the antemortem inspector prior to slaughter.

5.2.5 Statistical analysis

Comparison of results of the inspections were done using Cohen's Kappa (see 4.2.5) and scores of agreement between the producer and the reference inspector. The accuracy of the findings of the producer were defined in terms of sensitivity and specificity.

Using the tabulated findings of the producer and the reference inspector:

		reference inspector	
	Pigs	Normal	Suspect/reject
producer	Normal	a	b
	Sus/reject	c	d

Formulae used to analyse the findings of the producer and the reference inspector were as follows:

Agreement

Agreement occurred on a + d pigs

Total pigs = a + b +c +d

Agreement is calculated: $\frac{a + d}{a + b + c + d}$ (target > 0.9)

Sensitivity

A measure of the extent of recognition of grossly detectable abnormalities in suspects.

Suspects which producer recognised = d

Suspects which exist = b + d

Sensitivity is calculated: $\frac{d}{b + d}$

Specificity

A measure of the extent of over-reaction to grossly detectable abnormalities in normal pigs.

Normal pigs which producer recognised = a

Normal pigs which exist = a + c

Specificity is calculated: $\frac{a}{a + c}$

5.3 Results

5.3.1 Comparisons between producers and the reference inspector

Findings on the three farms are summarised in Table 13. Producers demonstrated a high level of expertise in classifying pigs.

Table 13 Results of antemortem comparisons between producers A, E and D, and the reference inspector

Producer antemortem scores	Ante mortem status	Reference inspector antemortem scores						
		Normal	Suspect	Reject	Kappa	Agree-ment	Sensit-ivity	Specif-icity
Producer (Farm A)	Normal	1587	6*	0	0.61	0.98	0.83	0.73
	Suspect	28**	23	1				
	Reject	0	0	5				
Producer (Farm E)	Normal	395	3	0	0.32	0.96	0.73	0.97
	Suspect	13^{+}	3	0				
	Reject	0	0	1				
Producer (Farm D)	Normal	419	0	0	0.72	0.99	1.00	0.99
	Suspect	4^{++}	4	0				
	Reject	0	1	2				
Total (All farms)	Normal	2401	9	0	0.57	0.98	0.82	0.98
	Suspect	45	30	1				
	Reject	0	1	8				

* The producer correctly classified one of these as normal
** The producer correctly classified nine of these as suspects
\+ The producer correctly classified six of these as suspects
++ The producer correctly classified one of these as normal

Guide to interpretation of Kappa:
- >0.75: Excellent agreement beyond chance
- 0.4-0.75: Fair to good agreement
- <0.4: Poor agreement

Agreement, sensitivity and specificity were generally high on all three farms against the reference inspector scores. Kappa scores reflected fair to good agreement. An exception is the poor Kappa score on farm E, which was mainly due to the reference inspector missing several suspects and to Producer E classifying several lame pigs without visible grossly detectable abnormalities as suspects. The slight lameness observed was considered to be a temporary response to the prior inspection by the reference inspector.

On farm A, the reference inspector classified a pig with a small chronic wound on the hock as a suspect, but it was later agreed that it was too small to be significant. Producer A missed two suspects with hock lesions and three with abscesses and classified another pig with multiple large arthritic lesions as suspect, which was actually unfit for slaughter.

Of the 19 pigs which were incorrectly classified as suspects by producer A, 11 were runts (ie. had retarded growth rate relative to litter mates) which would have passed abattoir antemortem inspection as normal porkers. Another five pigs were only slightly lame; the producer thought these had arthritic hips, but no muscle wasting was evident. Producer A also misclassified three small hernias. Another nine suspects were not detected by the reference inspector (four with foot abscesses, four with hock lesions, and one with orchitis).

On farm E, the producer missed three suspects with leg lesions. The reference inspector classified an abscess on the flank of a certain pig as insignificant, but the producer later pointed out that it was larger than a golf ball, and therefore by definition a suspect. The reference inspector failed to notice lesions on the limbs of five suspects.

Of the seven pigs which were incorrectly classified as suspects by producer E, five were only slightly lame and another pig had an unusual gait, which the producer thought was due to meningitis. Producer E also misclassified a small abscess on a shoulder.

On-farm D, the reference inspector failed to notice a suspect with an arthritic hock lesion. Producer D misdiagnosed a case of sore feet and a case of bursitis as being arthritis. A third pig was in poor condition, but not sufficiently poor to warrant segregation as a suspect. The producer was also ready to shoot a pig with arthritis. This pig could have been salvaged by marketing it earlier.

By pooling the data from the three farms, it was possible to investigate the contribution of individual classes of grossly detectable abnormalities to the data set. Statistical comparisons were then possible for some of the classes of grossly detectable abnormalities with higher prevalences. The breakdown of the grossly detectable abnormalities found, and the statistical results for those grossly detectable abnormalities for which meaningful comparisons could be made, are presented in Table 14. Agreement, sensitivity and specificity were generally high. Kappa scores showed fair to good agreement. The lowest score was for 'other' abnormalities, and was attributable to producer A over-reacting to 11 runts and 3 hernias.

Table 14 Breakdown of the grossly detectable abnormalities found by producers on the three farms, and the statistical comparisons with the reference inspector

Grossly detectable abnormality	Farm E (n=415)			Farm A (n=1650)			Farm D (n=430)		Totals (E+A+D) (n=2,495)				Kappa	Agree -ment	Sensit -ivity	Specif -icity
	++	+-	-+	++	+-	-+	++	-+	++	+-	-+	- -				
Arthritis	1	2	4	12	1	7	6	3	19	3	14	2459	0.688	0.993	0.864	0.994
Other leg	2	1	6	8	2	6	0	0	10	3	12	2470	0.569	0.994	0.769	0.995
Total leg	3	3	10	20	3	13	6	3	29	6	26	2434	0.638	0.987	0.829	0.989
Runt	0	0	0	0	0	11	0	0	0	0	11	2484				
Abscess	1	0	2	1	3	0	1	0	3	3	2	2487				
Hernia	0	0	0	0	0	4	0	0	0	0	4	2491				
Pot Belly	0	0	0	3	0	0	0	0	3	0	0	2492				
Meningitis	0	0	1	2	0	0	0	0	2	0	1	2492				
Prolapse	0	0	0	2	0	0	0	0	2	0	0	2493				
Emaciation	0	0	0	1	0	0	0	1	1	0	1	2493				
Other	1	0	3	9	3	15	1	1	11	3	19	2462	0.496	0.991	0.786	0.992
Total	4	3	13	29	6	28	7	4	40	9	45	2401	0.587	0.978	0.816	0.982

++ = suspect/reject detected by both producer and reference inspector;
+- = suspect/reject detected by reference inspector only;
-+ = normal pigs incorrectly classified as suspect/reject by producer;
- - =no suspect/reject detected.
Total leg = Arthritic lesions plus 'other leg' (foot abscess, lame, swollen, crippled).
Hernia included orchitis. Prolapses were gangrenous.
Other = Runt, abscess, hernia, pot belly, meningitis, prolapse and emaciation.

5.3.2 Comparisons between an abattoir inspector and the reference inspector

To evaluate the accuracy of the abattoir antemortem inspector in the same state as the producer verification, a total of 1,181 pigs were inspected; 206 from farm E, 75 from farm D and 900 from farm A. The reference inspector detected 16 suspects; seven from farm E (six were arthritic and one had a chronic wound on its hock), one from farm D (with arthritis) and eight from farm A (three were arthritic, two had abscesses, two had foot abscesses and one had a severe shoulder injury). No suspects were detected by the abattoir antemortem inspector. Table 15 shows the extent of agreement between the reference inspector and abattoir antemortem inspector.

Table 15 Results of antemortem comparisons at one of the project abattoirs between one of the trained antemortem inspectors and the reference inspector

Antemortem inspector findings	Reference inspector findings: Normal	Reference inspector findings: Suspect/ Reject	Kappa	Agreement	Sensitivity	Specificity
Normal	1165	16	0	0.99	0	1
Suspect/Reject	0	0				

5.4 Discussion

The most significant result of this verification exercise was the good concordance observed between producers and the reference inspector, unlike that observed by Harbers et al (1992a). The specificity of the producer against the reference inspector is high, and confirmed the validity of the previous finding of the producers who detected 16 times as many "suspect" pigs as abattoir antemortem inspectors. Even if specificity had been poor on-farm, it would not be of concern to consumer safety, because it is more desirable that producers/inspectors be perceived as overcautious than incompetent. Only 29 pigs were incorrectly classified as suspects by producers, as shown in the "-+" totals column of Table 14. In comparison the sensitivity of the abattoir inspection was zero (Table 15).

The strong agreement observed between producers and the reference inspector in this study emphasises the value of training. Good concordance was achieved over a range of grossly detectable abnormalities, whereas in the Dutch study this was only observed with tailbite. This exercise was carried out about a year after the reference inspector had initially trained the producers at the abattoir, followed up on-farm by their consulting veterinarians. Since being trained each producer had performed on-farm antemortem inspection on two to seven loads of slaughter pigs. In the study conducted by Harbers et al (1992a) most of the producers had no experience in inspection and were performing on-farm antemortem inspection for the first time. The ability of producers to find suspects was highlighted in this exercise by the fact that they only missed five, three and zero legitimate suspects, whereas the reference inspector missed nine, six, and one. The producer over-reaction to mild lameness and suitability of runts for slaughter shows that more emphasis could have been placed on these aspects of the training.

The low prevalences in this study limited the usefulness of some statistical comparisons (eg. In Table 16, dyspnoea and general illness had to be compared with meningitis and pot belly). Tailbite, the only condition for which Harbers et al (1992a) found fair to good agreement, was not observed in this exercise. Because the Australian study was limited to "major abnormalities, relative to the Dutch study, it was reasonable to expect higher levels of agreement between inspection methods. This underscores the significance of the poor sensitivity of abattoir inspection.

Table 16 Comparison of prevalences of grossly detectable abnormalities detected in the Netherlands (Harbers et al, 1992a) and Australia (this trial)

Holland (Harbers et al, 1992a) n=1,978				Australia n=2,495	
Description of findings	Producer	Reference inspector	AM inspector	Producers	Reference inspector
Normal	85.6%	65.2%	91.8%	96.6%	98%
Leg lesions/lameness	3.6%	19.6%	3.8%	2.2%	1.4%
Dyspnoea/general illness*	2.6%	3.4%	0.6%	0.2%	0.2%
Straggler**	5.1%	9.1%	0.5%	0.5%	0.05%
Other	5.2%	10.6%	3.8%	0.4%	0.3%

* = meningitis and pot belly in this exercise. ** includes emaciation

NB. The totals for some columns add up to >100% because some pigs had more than one grossly detectable abnormality.

Another finding was that the prevalence of suspects was low compared to Harbers et al (1992a). They detected abnormalities in 14.4% (producer), 34.8% (reference inspector) and 8.2% (antemortem inspector), compared to 3.4% or less in this exercise (Table 16). When interpreting the significance of this, it must be pointed out that in Australia some of the categories (ie. inflamed skin, ear lesions and snout deformation) listed by Harbers et al (1992a) are not considered to be significant grossly detectable abnormalities, so affected pigs are passed without any restrictions.

The potential animal welfare benefits of on-farm antemortem inspection are clear; enhanced detection of suspects enables segregation of welfare risks during transport, minimising exacerbation of problems. Locomotor problems were the most common cause of pigs being classified as suspect, and these are prone to injury during transport. As producers were very good at detecting (they found more arthritic pigs than the reference inspector) and assessing these, the results demonstrate that potential exists to improve the welfare of these pigs by penning them separately during transport.

In conclusion, the data from this exercise indicates good concordance between producers and the reference inspector. Observed discrepancies in the detection of suspects by producers on-farm and by inspectors at the abattoir is due to poor detection (poor sensitivity) by abattoir antemortem inspectors; a major problem in current systems of meat inspection (Berends et al, 1993).

Chapter 6

Salmonella Levels in Suspect Pigs

Chapter 6 *Salmonella* Levels in Suspect Pigs

6.1 Introduction

Despite modern slaughtering practices, a high incidence of *Salmonella* is repeatedly detected in pigs/pork in prevalence studies (Table 19). Researchers (Berends *et al*, 1993; Gill, 1995; Pointon, 1997a) are currently questioning the extent to which current meat inspection procedures such as antemortem inspection are able to protect consumers against the major causes of food borne disease such as *Salmonella* (Gronstol *et al*, 1974a; Maguire *et al*, 1993; Davies *et al*, 1997; Fedorka-Cray *et al*, 1997; Mousing et al, 1997b; Edwards et al, 1997).

A supposition behind antemortem separation of suspects is the likelihood that they harbour pathogenic microorganisms in grossly detectable abnormalities, and because they are sick they are more likely to be shedding *Salmonella* and other significant food borne organisms (Wray and Sojka, 1977; reviewed by Pointon, 1997a). However, the weight of scientific evidence indicates that the major microbial food borne hazards found in pigmeat are rarely cultured from grossly detected abnormalities in pigs (Engel *et al*, 1987; Mousing and Pointon, 1997; Pointon *et al*, 2000). Rather, the gut is recognised as the most important source of pigmeat pathogens (Hathaway and McKenzie, 1991; Gill, 1995), even in healthy pigs (Chung and Frost, 1969; Riley, 1970). It is vital that limited inspection resources be used efficiently (Murray, 1986) and that the Australian Pig Industry endeavours to assure consumers that pig meat is healthy.

As the impact of disease on shedding of *Salmonella* in the gut is poorly understood, this study focussed on the respective *Salmonella* contamination rates of ingesta of suspect versus normal pigs. Two hundred samples of caecal contents from pigs with grossly detectable abnormalities (suspects) and normal pigs (controls), at a ratio of one suspect:two controls, were collected and cultured to determine whether the suspects had a higher carriage rate of *Salmonella*. This data was used to ascertain whether antemortem inspection is a critical control point for minimising cross contamination and therefore whether food safety outcomes could be enhanced by improvements to antemortem inspection.

6.2 Methods

6.2.1 Choice of sample type

Caecal culture was chosen for this study in preference to tissue culture or ELISA testing. Although ELISA is suitable for detection of *Salmonella* in farm prevalence studies (Burkhart et al, 1997; Humbert et al, 1997), ELISA testing does not predict the likelihood that

Salmonella will be present on the carcase (Christensen, 1997; Fedorka-Cray et al, 1997; Widders et al, 1997). Faeces or caecal contents yield better results than swabs (Harvey et al, 1977; Nielsen and Baggesen, 1997; Funk et al, 1997), and caecal contents yield better results than faeces (Wood et al, 1989; Bahnson and Fedorka-Cray, 1997). Tissue culture was avoided because sampling and culture procedures are more difficult.

6.2.2 Collection of specimens

The piggeries used in this study had between 2-25% seroprevalence of *Salmonella,* as determined by a concurrent ELISA screening (Hamilton, personal communication). Prior to slaughter antemortem inspection was performed by the principal investigator, as per the criteria agreed upon in Table 5 and any suspects isolated. A unique tattoo was placed on each suspect pig, so that it could be identified on the slaughter floor. After slaughter 25 grams of caecal faeces were collected by expression through a slit in the caecal wall into individual polypropylene containers.

The control pigs (for each suspect) were from the same batch, and thus controlled for transport distance, time off-feed to slaughter and lairage time. At the same time a suspect was sampled, two of its companions were sampled as controls. Companions were from the same load of pigs, so transport and lairage times, and weight ranges would be similar. Carcase weight, fat score and sex were noted for each pig sampled. The length of time the pigs had been off feed was determined by phoning the producers and asking them when the pigs had been removed from feed prior to transport.

6.2.3 Culture of specimens

The samples were cultured as per Australian Standards, described by Quinn et al (1994), on the day of collection. Briefly, selective enrichment was performed by adding approximately one ml or one gram amounts of caecal contents to Mannitol Selenite broth and approximately 0.1 ml or 0.1g amounts to the Rappaports medium and incubating for 24 hours at 37°C and 42°C respectively. An aliquot of each was subcultured onto xylose lysine desoxycholate agar and incubated for 24 hours at 37°C. Any colonies displaying typical morphology were confirmed using the Serobact *Salmonella* Latex agglutination test and serotyped at the *Salmonella* Reference Laboratory, Institute of Medical and Veterinary Science.

6.2.4 Analysis of results

The Pearson chi-squared test was used to test associations between *Salmonella* detections in suspect and normal pigs.

6.3 Results

Caecal contents were submitted for culture from a total of 67 suspect pigs and 133 normal (matched control) pigs. *Salmonella* species were recovered from 20.9% and 18.8%, respectively (Table 17).

Table 17 Incidence of *Salmonella* isolated from caecal contents of suspect and normal pigs relative to health status and time off-feed prior to slaughter

Health status	Salmonella status	0-6 hrs	>6-12 hrs	>12-18 hrs	>18-24 hrs	>24-30 hrs	>30 hrs	Totals (% positive)
Suspect	+	0	0	0	6	7	1	14 (20.9%)
	-	15	0	4	11	22	1	53
Normal	+	1	0	0	15	9	0	25 (18.8%)
	-	29	0	8	19	48	4	108
Total farms	+	1	0	0	21	16	1	39 (19.5%)
	-	44	0	12	30	70	5	161

No significant difference between *Salmonella* recovery from suspects and normal pigs, using Pearson's chi-squared test (p=0.724)

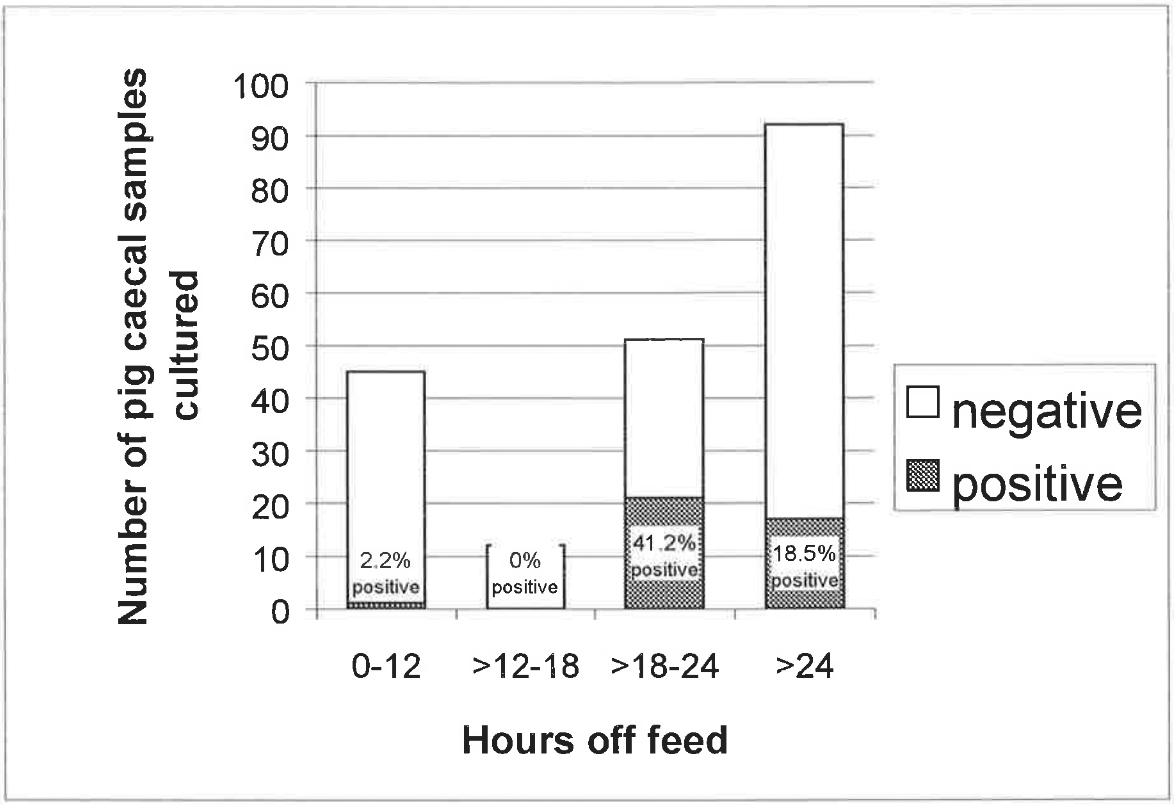
Salmonella species were isolated from the caecal contents of 39 (19.5%) of 200 pigs, all from herds A and B (Table 18). In pigs slaughtered between 18-24 hours off feed 21 (41%) of 51 pigs were positive for *Salmonella* species, while after 24 hours 17 (18.5%) of 92 pigs were positive (Figure 1).

Table 18 Incidence of *Salmonella* isolated from caecal contents of pigs relative to origin and time off-feed prior to slaughter

Origin	Salmonella status	0-6 hrs	>6-12 hrs	>12-18 hrs	>18-24 hrs	>24-30 hrs	>30 hrs	Totals (% positive)
SA Farm A	+	0	0	0	11	5	1	17(31.5%)
	-	3	0	0	10	22	2	37
SA Farm B	+	1	0	0	10	11	0	22(19.5%)
	-	38	0	3	20	27	3	91
Other farms*	+	0	0	0	0	0	0	0 (0%)
	-	3	0	9	0	21	0	33
Total farms	+	1	0	0	21	16	1	39 (19.5%)
	-	44	0	12	30	70	5	161

* Combined data from four farms

Figure 1 Effect of fasting, transport and lairage on *Salmonella* levels



The most commonly isolated serovars (Table 19) were *S. derby* (4.5% of 200 pigs), *S. infantis* (4%), *S. seftenberg* (4%) and *S. bredeney* (3.5%). Only one serovar was isolated from each of the positive samples.

Table 19 Prevalence of *Salmonella* serovars isolated from caecal contents in other studies

Salmonella Serovar	Australia (This study) n=200	England Harvey et al, 1977 n=4,244	Australia Craven and Hurst, 1982 n=423	Australia Morgan et al, 1987 n=445	Denmark Baggesen et al, 1996 n=13,468	Canada Letellier et al, 1997a n=1,420
S. typhimurium	0	4.9%	7.8%	0.7%	4%	0.4%
S. derby	4.5%	1.1%	13.7%	11.2%	0.3%	0.5%
S. seftenberg	4%	0.1%	0	0	0.02%	0
S. infantis	4%	0.2%	2.4%	0.2%	0.4%	0.8%
S. bredeney	3.5%	0.7%	14.2%	0.7%	0.06%	0
S. anatum	1%	0.2%	10.2%	5.8%	0.01%	0
S. chester	1%	1.8%	0	0	0	0
S. give	0.5%	0.3%	0	3.4%	0.01%	0
Other	1%	7.2%	17.7%	8.3%	1.3%	3.5%
Total	19.5%	7.2%	* 53.7%	30.3%	** 6.2%	5.2%

* 51 of the caeca yielded more than 1 serovar (ie. 227 caeca yielded 279 isolates)
** 18 of 302 herds were infected with 2 serovars

6.4 Discussion

6.4.1 Culture results

The isolation rate of *Salmonella* species from the caecal contents was not significantly different between pigs classified as suspect or normal at antemortem inspection by the reference inspector. The isolation rate from these two populations of pigs was 20.9% and 18.8% respectively. The rise in caecal contamination rate commenced after 18 hours off-feed and at the same rate for both groups. Thus assuming that the concentration of *Salmonella* in the ingesta of suspect and normal pigs is the same and that spillage of ingesta occurs equally on suspect and normal carcases, spilled ingesta from suspect pigs is unlikely to constitute a greater threat of carcase contamination by *Salmonella* than spilled ingesta from normal pigs. As a result, little food safety benefit is likely to result from slaughtering suspect pigs last with respect to *Salmonella* contamination.

A potential limitation of this study is that organs of suspects were not cultured for *Salmonella* to evaluate fully the food safety status of suspects. In Australia a large amount of offal is discarded after inspection purely on economic grounds; labour costs of organ collection/packaging often exceed the market value of the organs. Nevertheless, the same logic still applies when comparing the relative importance of pathways of contamination on a carcase throughput basis; within-carcase contamination is likely to be proportionally much less than external contamination from ingesta spillage (Pointon et al, 2000). Although *Salmonella* can be isolated from many porcine organs (Wood et al, 1989; Berends et al, 1996), especially tonsils and mesenteric nodes, Berends and Snijders (1997) found that the number of contaminated carcases related statistically only to the number of faecal carriers.

A concern regarding the design of this study was that selection of herds with high *Salmonella* seroprevalence may overpower the effect of the stress/*Salmonella* relationship. This turned out to be a non-issue, because *Salmonella* was only isolated from one of 57 pigs slaughtered less than 18 hours off-feed, and this particular serotype was not subsequently isolated from any other pig in the study. Thus medium to high seroprevalence herds had very low caecal isolation rates <18 hours off-feed.

The main *Salmonella* serovars isolated were *S. derby, S. seftenberg, S. infantis and S. bredeney*. *S. derby,* and to a lesser degree *S. infantis*, are consistently common isolates from the Australian Pig Industry (Table 19). When compared with common serovars chosen to provide antigens for the *Salmonella* (mix) ELISA used in the concurrent study, only *S. infantis* and S. *anatum* were represented, but all the serovars recovered in this study were represented antigenically in the Australian (mix) ELISA (Widders, 1997).

Since completion of this study, new research in the USA (Davies et al, 1999) has shown that sensitivity of faecal culture is greatly affected by both storage temperature and sample size, so in future studies laboratory procedures must be adjusted accordingly. Although samples collected were of adequate size (25g), pre-enrichment in buffered peptone water was not carried out, and only small sample homogenates (0.1g and 1g) were directly cultured in the primary enrichment steps. Pre-enrichment of 10g quantities could have increased the sensitivity from 30% to 60%, and delayed secondary enrichment could have increased detection by 25% (Davies et al, 1999). These prevalences, therefore, probably underestimate the contamination rate of ingesta with *Salmonella* in Australia.

6.4.2 Effect of time off-feed

Emphasis should be directed toward slaughter of pigs <24 hours off-feed at the start of each day or start of each shift. It is critical for producers to provide the time pigs were removed from feed to the truck driver/abattoir lairage staff. Edwards et al (1997) suggested that verification of on-farm quality assurance (QA) programs may become components of antemortem inspection. As well as verifying detection of suspects on-farm by producers, abattoir antemortem inspection could include audits to ensure pigs are slaughtered 6-24 hours off-feed.

Time off-feed is confirmed in this study as being a major determinant of ingesta contamination with *Salmonella*, supporting previous findings of McDonagh and Smith (1958), Hansen et al (1964), Burns et al (1965), and Morgan et al (1987 and 1988f). Pigs from herds with low *Salmonella* infection rates can become a serious source of contamination if not appropriately managed in transit and in lairage. This concept was adopted in the APIQS where it is stipulated by Pointon (1997b) that pigs should be slaughtered between 6 and 24 hours off-feed, to minimise potential for carcase contamination with *Salmonella* from spilled ingesta (Davies and Funk, 1999). While these latest data demonstrate a substantial rise, this commences after 18 hours off-feed at this abattoir. Therefore, it is recommended that in subsequent reviews of the APIQS reducing the period off-feed to between 6 and 18 hours should be considered.

6.4.3 Potential food safety significance

Pigs with grossly detectable abnormalities contaminated with *Salmonella* represent a minor source of potential carcase contamination with *Salmonella* (Pointon et al, 2000). While grossly detectable abnormalities specifically from suspect carcases were not tested for *Salmonella* in this study, Pointon et al (2000) found 2.8% of 70 abscesses were contaminated with *Salmonella* species. No *Salmonella* were isolated from 54 cases of arthritis, a common reason for classifying pigs as suspect. When comparing the relative importance of pathways of contamination on an abattoir throughput basis, approximately 1,950 pigs per 10,000 killed have *Salmonella* contaminated ingesta (Table 18), compared with 5 pigs per 10,000 with abscesses contaminated with *Salmonella* (1.7% had abscesses x 2.8% of abscesses had *Salmonella;* Pointon et al, 2000). Therefore, assuming equal concentrations of *Salmonella* in abscesses and ingesta, spilled ingesta represents by far the greatest source of potential carcase contamination with *Salmonella.* Consequently, to minimise carcase contamination with *Salmonella* at slaughter, emphasis must be placed on minimising contamination of ingesta and avoiding spillage of ingesta. This is likely to have a far greater impact than slaughtering suspect pigs at the end of the shift or day to minimise carcase contamination with food borne hazards. Avoidance of full gut sets and spillage at evisceration must be addressed in abattoir HACCP plans.

What was not determined is whether there is any association between suspect pigs and gut spillage. This is an obvious risk with the dilated gut of pot bellied pigs, and perhaps gut adhesions due to hernia. Increased risk of gut spillage in suspects would increase the food safety risk, but since 20% of normal pigs are carriers, the proportional effect is likely to be minor anyway.

Salmonella status of a farm, either judged by prevalence rates or serotype distribution, is not static, but in fact highly variable within and among cohorts of pigs on the farm (Funk et al, 1999). This within-herd variation underscores the value of longitudinal studies such as this one, and is further supported by Davies and Funk (1999) who reason that because slaughter pigs represent a normal marketing from a herd, they can be thought of as a sample in time of the output of the herd, which is arguably more relevant in terms of potential public health risk than a random sample of the farm population. *Salmonella* isolation rates in Australia and overseas for the past 20 years, sampled over a range of transport/lairage regimes, are reported in Table 19. Comparing prevalence rates and serotype distribution a great deal of variation is apparent. However recent US data (Davies and Funk, 1999) indicates such variation could be possible even in a single herd.

In this Australian study pigs from the same herds were sampled over a nine week period and the results are best viewed as the common serovars at one abattoir over a nine week period and little more than this. *S. infantis* was isolated from four pigs from farm A in week two, then twice from each farm in week three. This may have resulted from an outbreak on-farm A, followed by cross-contamination of farm B pigs through use of the same truck, or holding in the same lairage pens. Likewise, *S. seftenberg* was isolated from one farm A pig early in week nine, then from six farm B pigs two days later. This may have resulted from cross-contamination of farm B pigs during transport or lairage, or from an outbreak on-farm B. Isolations of *S. derby* and *S. bredeney* were spread throughout the collection period, with most

S. derby isolated from farm B and most *S bredeney* isolated from farm A. However, in the absence of farm data, these possibilities cannot be explored.

With respect to *Salmonella* contamination, little food safety benefit is likely to result from slaughtering suspect pigs last. As ingesta contamination with *Salmonella* increases with time off-feed, pigs must be appropriately managed in transit and in lairage to meet preslaughter time off-feed to slaughter HACCP requirements. In post-slaughter HACCP plans, emphasis must be placed on avoiding spillage of ingesta.

Chapter 7

Records of Partial/Total Condemnations in Abattoir Data

Chapter 7 Records of Partial/Total Condemnations in Abattoir Data

7.1 Introduction

When gross abnormalities are detected at postmortem inspection, the carcase may be passed after condemnation of the affected organs/tissues (Andriessen, 1987). If the inflammatory response is generalised, this is called fever. When septic conditions such as gangrene, peritonitis, pneumonia, enteritis, metritis, (poly)arthritis, balanitis and multiple abscesses are listed in abattoir condemnation data as reasons for total carcase condemnation, it is reasonable to assume that there was evidence of a generalised inflammatory response (fever). The term fever is also used in abattoir condemnation data to describe a range of systemic conditions including toxaemia, pyaemia, septicaemia, uraemia and polyserositis. A fevered carcase can always be considered a potential food borne hazard (Mousing et al, 1997b; Pointon, 1997).

The risk assessment approach (Hathaway et al, 1988; Hathaway, 1993; Edwards et al, 1997) has been used to quantify the contribution of abattoir procedures to elimination of food borne hazards. Several authors (Hathaway et al, 1988; Bettini et al, 1996; Mousing et al, 1997b; Pointon et al, 2000) have risk assessed the food safety significance of postmortem inspection procedures but not antemortem inspection procedures. Only a limited number of gross abnormalities are detectable by antemortem inspection, and often their detection is much easier during routine dressing and/or postmortem inspection (Table 1). Levels of microbiological hazards in fresh pork are not likely to be significantly reduced by the detection and removal of gross abnormalities at postmortem inspection (Pointon et al, 2000).

One method of estimating the contribution of antemortem inspection to reducing the level of food borne hazards of pig carcases is to relate findings at antemortem inspection to gross abnormalities of food safety significance detected in the carcase at postmortem inspection. The prevalence of food borne hazards in some types of gross abnormalities has recently been reported (Pointon et al, 2000) as part of a risk based assessment of postmortem inspection in Australia.

This study takes a retrospective risk based approach to attempt to assess the proportional impact of antemortem inspection on carcase contamination by comparing the findings of antemortem inspection with those of postmortem inspection.

7.2 Methods

7.2.1 Sources of data

A specific data source of antemortem inspection findings is Export Control Act (ECA-1) cards, used by antemortem inspectors at export abattoirs. The antemortem inspector is required to fill out an ECA-1 card for each animal condemned or withheld from slaughter, or classified as an emergency kill or suspect. For the latter two classifications, the postmortem disposition is recorded on the back of the card. Some export abattoirs operate under project 2 conditions, where AQIS has approved an increased level of self-regulation. ECA-1 cards are not used at these abattoirs, but data relating to antemortem inspection is recorded in other paperwork.

Total number of pigs inspected, separated into pork, bacon and choppers, and total number of pigs condemned, separated into the most common reasons for total condemnation, are recorded on monthly and yearly returns.

7.2.2 Selection of abattoirs

The regulatory government authority at export abattoirs is the Australian Quarantine and Inspection Service (AQIS). The central office of AQIS was contacted to obtain permission for the principal investigator to receive ECA-1 cards for data collection. Five large export pig abattoirs in four states were selected to reflect national production. Initial contact with the abattoir was made by AQIS central office, and if the abattoir was willing to cooperate, the contact details were then passed on to the principal investigator. The principal investigator then liased with abattoir personnel to send as many ECA-1 cards as were available, as well as any available kill figures and condemnation records for the corresponding period. After compiling the available data, the principal investigator returned the cards/records to the cooperating abattoir, and contacted AQIS central office to initiate the process with the next abattoir. One of the abattoirs felt that the data was too commercially sensitive to post, but allowed the principal investigator to visit personally and access whatever was available on-site.

7.2.3 Analysis of data

The quality and availability of data dictated the usefulness of the records obtained. Where the total number of suspects could be compared with total kill figures, the prevalence of suspects/emergency kills was calculated. Where possible, suspects were categorised by reason for their classification as a suspect, and if subsequently trimmed/condemned, by their reason for partial/complete condemnation. By comparison with defined food safety risks of gross abnormalities detectable by postmortem inspection (Pointon et al, 2000), an attempt was made to assess the food safety significance of antemortem inspection findings.

7.3 Results

7.3.1 Abattoir A, C and D

Data was obtained from five abattoirs in four states, with a total weekly throughput of 32,000 pigs (29,000 bacon, 2,000 pork and 1,000 choppers). The most comprehensive data sources were the abattoirs that operated under project 2 conditions (abattoirs B and E). Abattoirs A, C and D had major gaps in their ECA-1 records, described below, limiting the ability to draw meaningful conclusions from the data.

Abattoir A provided ECA-1 cards of a very poor standard for a nine month period from April to December, 1998. Most of the chopper pigs (ie. cull sows and boars) recorded on the cards had to be shot simply because they were too large for the restrainer. The overall impression was that antemortem inspection at this establishment amounted to assistance in salvage of recumbent pigs, and not much else. The data was rejected for the purposes of evaluation of the food safety significance of antemortem inspection.

Abattoir C provided ECA-1 cards of a good standard, but covering only about half the production days scattered throughout the 17 month period from August 1997 to December 1998. About a quarter of the suspects had prolapse-none of these were subsequently condemned or extensively trimmed. The data was rejected for the purposes of evaluation of the food safety significance of antemortem inspection.

Abattoir D provided ECA-1 cards of a poor standard over a four year period from 1995 to 1998, plus a diary for 1997. It was estimated that about 90% of the 1995 and1998 cards were missing as well as about 70% of the 1996 cards. The diary data was more comprehensive, but no entries were made on 49 production days (20% of the year). The incomplete data showed a strong association of hernia/phimosis at antemortem inspection with fever/multiple abscesses at postmortem inspection. Likewise, locomotor conditions detected at antemortem inspection showed a strong association with polyarthritis detected at postmortem inspection. The data was rejected for the purposes of evaluation of the food safety significance of antemortem inspection.

7.3.2 Abattoir B

Abattoir B slaughtered 5,640 pigs per week, and provided comprehensive data for 1998. Records were made available of total pork/bacon/choppers killed, total pork/bacon/choppers made suspect (including the reason for classification as a suspect), total pigs condemned at postmortem inspection and total pork/bacon/chopper suspect pigs condemned at postmortem inspection (including the reason for total condemnation). Partial condemnation data was not available.

In Table 20, the reasons for classification as a suspect at abattoir B are listed alongside the national trial figures from Table 10. The results are very comparable, especially if the 324 joint ulcers (infected bursae) at abattoir B have been misclassified as arthritis by the antemortem inspector. PHMS data from 13,783 pigs inspected at abattoir B over the same period yielded a prevalence of 2.5% arthritis and 0.5% abscesses.

Table 20 Reasons for classifying bacon pigs as suspect at abattoir B #

Source		Arthritis	Hernia	Lame	Prolapse	Abscess	Tailbite	Wound	Other**	Total
Abattoir	%	2%	29%	19%	13%	6%	10%	15%	6%	100%
B	(no.)	(57)	(905)*	(587)	(396)	(189)	(297)	(479)**	(191)***	(3101)
Table	%	22%	17%	16%	13%	11%	9%	5%	6%	100%
10	(no.)	(45)	(35)	(33)	(26)	(23)	(18)	(10)	(13)	(203)

This data was not available from abattoir E.
* includes 78 orchitis ** includes 324 joint ulcers *** includes 15 potbelly

Although the data included reasons for classification as a suspect, and reasons for total condemnation of suspects, it was seldom possible to link the two records in the way ECA-1 cards do. From the limited amount of linking that was able to be achieved, condemnation for polyarthritis could be associated with suspects having lameness, arthritis and chronic leg ulcers. Condemnation for pyaemia could be associated with suspects having wounds, tailbite and abscesses. Condemnation for peritonitis could be associated with suspects having hernias and bloat.

Pyaemia, (poly)arthritis and peritonitis/pot belly were the leading causes of total carcase condemnation at abattoir B (Table 21).

Table 21 Reasons for postmortem condemnation of suspects at abattoirs B and E

Reason for condemnation	Pork (B)	Bacon (B)	Choppers (B)	All ages (B)	Abattoir E
Peritonitis	58% (235)	11% (32)	9% (4)	36% (271)	-
Polyarthritis	14% (58)	30% (92)	5% (2)	20% (152)	18% (7)
Pyaemia	19% (76)	41% (125)	64% (28)	31% (229)	-
Other (major) hazards*	3% (13)	14% (41)	18% (8)	8% (62)	72% (29)#
Other (marginal) hazards**	5% (22)	4% (12)	5% (2)	5% (36)	10% (4)##
Total	100% (404)	100% (302)	100% (44)	100% (750)	100% (40)

* includes 28 fever, 14 uraemia, 10 pneumonia, 5 enteritis, 3 gangrene and 2 contamination
** includes 23 emaciation, 6 jaundice, 4 neoplasia and 3 anaemia
# 29 fever ## 4 bruising

Causes of total carcase condemnation at postmortem inspection at abattoir B were provided on a yearly return form. Of the 1,585 (suspect and normal) pigs of all ages that were condemned, 70% (587 "septic/fever/absc." + 521 polyarthritis + 2 contamination) could be categorised as potentially hazardous, and 64% (271 peritonitis + 229 pyaemia + 152 polyarthritis + 62 other major hazards) of these were suspects. The other 30% of pigs condemned could be categorised as non-hazardous; these included 390 for "other causes" and 85 for other listed aesthetic problems (ie. 42 jaundice, 29 emaciation and 14 malignancy). Because the 390 "other causes" were not included in "septic/fever/absc.", nor in any of the other categories, it was presumed that these were condemned for aesthetic reasons. It was not possible to separate ages, or determine specifically which of the pigs were suspect or normal.

On a carcase throughput basis, the number of pigs condemned at abattoir B that were categorised as potentially hazardous was 1,110 per 370,331 pigs killed, which is 30 pigs per 10,000. Following segregation at antemortem inspection, this becomes 714 hazards per 5,205 suspects killed, which is 1,372 per 10,000; and 396 hazards per 365,126 normal pigs killed, which is 11 per 10,000. Effective performance of antemortem inspection was a useful method of grouping pigs which contributed to postmortem condemnation.

The suspect data and abattoir condemnation records from abattoir B is shown in Table 22. There is a substantially higher rate of carcase condemnations in suspect pigs (10%) than in normal pigs (0.2%).

Table 22 Comparison of suspect records with condemnation records

Abattoir ID	###% and (no.) of suspects killed	##% (and no.) of suspects condemned	No. of normal pigs killed	#% (and no.) of normal pigs condemned
B (pork)	2.6% (1,742)	23% (404)	64,399	-
B (bacon)	1.1% (3,101)	10% (302)	290,174	-
B (choppers)	3.3% (362)	12% (44)	10,553	-
B (all pigs)	1.4% (5,205)	14% (750)	365,126	0.2% (835)
E (bacon)	0.17% (346)	11.6% (40)	200,938	0.3% (645)
Total bacon (B+E)	0.7% (3,447)	9.9% (342)	491,112	0.3% (1,309)

###% percentage of total (normal and suspect) pigs killed in that age group at that abattoir
##% percentage of suspect pigs killed in that age group at that abattoir
#% percentage of normal pigs killed in that age group at that abattoir

7.3.3 Abattoir E

Abattoir E slaughtered 3,870 pigs per week, which were almost exclusively bacon pigs. During a visit by the principal investigator, 1998 data of very good quality was made available. Daily records showed total pigs killed, total dead in lairage, total classified as emergency kill (but not including the reason for such classification) and total condemned at postmortem inspection (including the reason, and whether or not the carcase was from an emergency kill). 201,377 pigs were received for slaughter, of which 93 (0.05%) died in the lairages. Of the remaining 201,284 pigs, 346 (0.17%) were classified as emergency kills. Forty (11.6%) of these emergency kill pigs (called suspects in Table 21) were subsequently condemned, and 645 (0.32%) of the remaining 200,938 normal pigs were subsequently condemned.

Breakdown of reasons for postmortem condemnation of normal pigs at abattoir E is shown in Table 23, and for suspect pigs in Table 21. The 21% of 645 normal pigs condemned for polyarthritis is proportionally similar to the 20% of 750 suspect pigs condemned for polyarthritis.

Table 23 Reasons for postmortem condemnation of normal pigs at abattoir E#

Abattoir E (n=200,938)	Fever	Potbelly	Pyaemia	Gangrene	Other hazards	(Poly) arthritis	Other	Total
% and (no.) condemned	53% (344)	9% (60)	1% (9)	3% (21)	2% (11)*	21% (133)	10% (67)**	100% (645)

this breakdown of data was not available from abattoir B
* includes 8 contaminated, 1 enteritis, 1 balanitis and 1 hernia
** includes 37 unknown, 15 cancer, 4 bruising, 6 jaundice, 3 emaciation and 2 oedema

Of the 685 (suspect and normal) pigs that were condemned at abattoir E, 90% (344 fever + 140 polyarthritis + 60 potbelly + 21 gangrene + 9 pyaemia + 40 other major hazards) could be categorised as potentially hazardous, and 5.9% (7 polyarthritis + 29 other major hazards) of these were suspects.

On a carcase throughput basis, the number of pigs condemned at abattoir E that were categorised as potentially hazardous was 614 per 201,284 pigs killed, which is 30 pigs per 10,000. Following segregation at antemortem inspection, this becomes 36 hazards per 346 suspects killed, which is 1,040 per 10,000, and 578 hazards per 200,938 normal pigs killed, which is 29 per 10,000. Effective performance of antemortem inspection was a useful method of grouping pigs which contributed to postmortem condemnation.

7.3.4 Impact of antemortem inspection on food safety

Antemortem inspection appears to have been performed effectively at abattoir B. Classification of 0.17% of pigs at abattoir E as emergency kill also compares well with the 0.13% found by abattoir inspectors in section 4.3.2, whereas the 1.4% detected by inspectors at abattoir B compares well with the 2.1% found by producers. Both abattoirs had an identical proportion (0.3% of the total kill) of potentially hazardous carcases condemned at postmortem inspection, but 11 times as many (64% versus 5.9%) were removed during the suspect kill at abattoir B. This resulted in a lower prevalence (11 per 10,000 compared to 29 per 10,000) of potentially hazardous condemned carcases during normal slaughter at abattoir B.

7.4 Discussion

7.4.1 Potential impact of on-farm antemortem inspection on food safety

It was not possible to relate antemortem inspection findings with postmortem inspection findings on a pig by pig basis at abattoirs B and E. While the overall reliability of the data was best at these abattoirs, neither used ECA-1 cards, which would have allowed this evaluation. Thus the main aim of the study was not achievable. However, by pooling the suspect data from these abattoirs, useful comparisons were able to be made with kill statistics recorded on monthly and yearly returns.

On examination of postmortem condemnation data from abattoir B, 64% of condemned pigs that were categorised as potentially hazardous were suspects. By segregating suspects it allows, in this case, 64% of condemnations of potentially hazardous pigs to be handled in 1.4% of the kill. This procedure offers abattoir operators the opportunity of scheduling extra trimmers to match work loads (eg. cutting down fevered carcases). Currently, potentially hazardous carcases are detected by intensive postmortem inspection of both suspect and normal pigs. However, similar analyses of more reliable datasets may prove useful to argue a case for limiting postmortem inspection tasks to suspects, leaving disposition of normal pigs to trained abattoir employees.

Similar calculations for abattoir E are less spectacular; 5.9% of condemned pigs that were categorised as potentially hazardous were suspects. By segregating suspects it allows, in this case, 5.9% of condemnations of potentially hazardous pigs to be handled in 0.17% of the kill.

At abattoir E the association between postmortem condemnation and classification as suspect at antemortem inspection is much poorer; 5.9% of all condemnations of potential hazards were classified as suspect. This suggests low sensitivity of the detection of suspects at routine abattoir antemortem inspection, which was previously indicated in sections 5.3.2. Sensitivity of antemortem inspection would be improved if suppliers of pigs to abattoir E were performing on-farm antemortem inspection.

On a carcase throughput basis, 1,372 (abattoir B) and 1,040 (abattoir E) potentially hazardous carcases were condemned per 10,000 suspects killed. If these condemned suspects harbour higher contamination of food borne hazards the subset of segregated suspects condemned at postmortem inspection represent a significant "pocket" of contamination. More knowledge of the actual hazard loads (prevalence <u>and</u> concentration) would help better define the extent of risk.

However, in terms of the overall pig slaughterings, condemned suspects probably represent a minor pathway of food borne contamination. Following segregated slaughter of the suspects, 11 (abattoir B) and 29 (abattoir E) potentially hazardous carcases were condemned per 10,000 normal pigs killed. Therefore, the performance of antemortem inspection created a subset of slaughter pigs in which potentially hazardous condemned carcases represented a minor pathway of contamination of pork with food borne hazards, when compared with carcase surface hygiene (Coates et al, 1997) and even background contamination of normal lymph nodes in normal carcases nodes (Pointon et al, 2000). Improving the efficiency of antemortem inspection by performing the procedure on-farm would further enhance this outcome.

7.4.2 Comparison of suspect data with condemnation records

There is a substantially higher rate of carcase condemnations in suspect pigs (10% versus 0.3%) at abattoirs B and E (Table 22). This supports the findings of Harbers et al (1992a) who demonstrated that there were more postmortem lesions in suspects than in normal pigs. In the meat rejection data from the antemortem trials (section 4.3.4) trimming losses from normal pigs amounted to the equivalent of 26 (0.3%) of 9,494 carcases, compared to 14 carcase equivalents (6.8%) trimmed from 205 suspects.

It was initially proposed that only a limited number of conditions are detectable by antemortem inspection, and often their detection is much easier at postmortem inspection (Table 1). Results presented in Tables 21 and 23 support this proposal. For example, total postmortem carcase condemnation for (poly)arthritis at abattoir E was proportionally similar in both suspect and normal pigs. Although antemortem inspection may be able to concentrate a significant proportion of grossly detectable abnormalities into a fraction of the days production, postmortem inspection is still required to actually detect them.

Some age related differences are apparent in Table 22. The bacon age group had the least suspects (1.1%) versus 2.6% of porkers and 3.3% of choppers, and the lowest suspect condemnation rate (10% versus 12% in choppers and 23% in porkers). Further to this, porkers were more often condemned for peritonitis, and choppers for pyaemia/fever (Table 21). These differences reflect the industry practice of marketing poor growers and choppers as culls.

About a quarter of the suspects in Abattoir C had prolapse, compared to an eighth of the suspects in Table 10. Condemnation and trimming losses were insignificant in both cases, indicating that prolapse is essentially an animal welfare issue. If all pigs with prolapse are slaughtered as emergency kills, this will reduce the number of suspects. In the scenario described in section 4.4.4, emergency slaughter of pigs with prolapse could result in realisation of the same trimming impacts in an even smaller subset of pigs.

Total condemnations for polyarthritis were 0.14% of pigs killed at abattoir B, which is similar to levels reported by Pointon (1997a). The 0.05% of pigs found dead in the lairage at abattoir E is comparable to the findings of Taylor et al (1984).

7.4.3 Regulatory issues

Following segregation of suspects at antemortem inspection, only 11 potentially hazardous carcases were condemned per 10,000 normal pigs killed. This represents a minor pathway of contamination when compared with carcase surface hygiene and background contamination of normal lymph nodes. Thus routine postmortem inspection of such pigs may prove an inefficient use of inspection resources, and future research should explore transferring this task to trained abattoir employees. Inspection staff would then be available for performance of other tasks more critical to improving pork safety.

The large number of missing ECA-1 cards highlights the need for regulatory authorities to implement quality standards for tasks performed by inspection personnel. This is reinforced by the superior quality of the data held by the two abattoirs operating under project 2 conditions. In addition to missing data, other causes for concern include inconsistencies in classification/interpretation of pathological conditions observed. This was initially evident in Table 4, but was again seen in examples such as the large number of condemnations for peritonitis at abattoir B (but not at any other abattoir). Some reasons given for postmortem condemnation such as pyaemia, septicaemia and toxaemia can actually only be differentiated in a laboratory, so although some variation in interpretation of such conditions is inevitable, any attempt to discuss differences and aim for national standardisation would begin to address the obvious discrepancies, and bring greater credibility to the role of regulatory authorities in protecting public health.

In summary, these findings indicated that detection of abnormalities at antemortem inspection is likely to have some impact on reducing the overall level of contamination of normal carcases with food borne hazards. As expected, the levels of condemnation are substantially higher in suspect pigs which provides processors with the opportunity of reallocation of staff to process suspect pigs as a group. If antemortem inspection is performed on-farm, it may even be possible to limit postmortem inspection tasks to suspects, leaving disposition of normal pigs to trained abattoir employees. This would release inspection staff to perform more critical duties such as audits of ingesta spillage. Current methods of recording suspects detected at antemortem inspection, and their subsequent disposition at postmortem inspection, are of very poor quality at most abattoirs; a case for either improving or abandoning the practice.

Chapter 8

Conclusions

Chapter 8 Conclusions

8.1 Major findings

- Following training in antemortem inspection theory and practice, reinforced on-farm by a consultant veterinarian, producers were found to be highly accurate at detecting and classifying pigs correctly. In comparison to abattoir inspectors they were capable of detecting 16 times as many suspect pigs.

- This was further verified by the good concordance observed between producers and the reference inspector.

- Thus national implementation of on-farm antemortem inspection could be confidently adopted as part of on-farm QA. A draft training video has been produced and is being reviewed by PRDC and selected experts to support the implementation of this procedure throughout industry. A manual has also been produced (see Chapter 10) and distributed to producer groups, some of whom have already commenced demonstration projects.

- The study also evaluated whether suspect pigs are more likely than normal pigs to be sources of *Salmonella* contamination. Both were found represent an equal risk of contamination, so the detection of suspects at antemortem inspection and their segregation in the slaughter process is unlikely to reduce contamination of carcases with *Salmonella* via spilled ingesta. As approximately 20% of both suspect and normal pigs had *Salmonella* contaminated caecal ingesta, spillage during evisceration represents the major pathway for carcase contamination at slaughter. Abattoir HACCP plans need to emphasise avoidance of ingesta spillage during evisceration.

- The period of time off feed to slaughter is critical in minimising the build-up of *Salmonella* in ingesta. The increase in *Salmonella* levels rose equally in suspect and normal pigs from 18 hours off-feed. Avoidance of protracted lairage times is likely to have a far greater effect of reducing potential for carcase contamination with *Salmonella* than slaughtering suspect pigs last in the kill or shift. It is critical that lairage staff receive the dispatch sheet from the farm for each batch, which records the time pigs were removed from feed. The rise in *Salmonella* contamination of ingesta with increasing time off-feed supports the APIQS recommendation to avoid protracted transport/lairage times. However, consideration should be given to tightening the standard to slaughter between 6-18 hours off-feed.

- This study indicates that every year approximately 41,000 pigs submitted for slaughter in Australia are suspects suffering locomotor problems. As these cases are particularly prone to further injury during transport, tangible welfare benefits can be achieved by preselecting and segregating these pigs from normal pigs during transport. Adoption of on-farm antemortem inspection by the pig industry through the welfare module of the APIQS should be considered.

- A significant proportion of pigs condemned for fever at postmortem inspection were suspects. Following segregation of suspects at antemortem inspection, fevered carcases represented a significant source of food borne hazards on a carcase throughput basis during slaughter of the suspects. Consequently, fevered carcases represented a proportionally minor risk during slaughter of the remaining large lines of normal pigs.

8.2 Significance for producers

The most common cause of pigs being classified as suspect in Australia was for locomotor problems. Of all abnormalities, these are the most likely to lead to poor welfare during transport. The pig industry has the opportunity to address this situation through the framework provided by the APIQS, which provides a mechanism for implementing industry, and welfare, best practice. The potential animal welfare benefits of on-farm antemortem inspection are clear; enhanced detection of suspects enables segregation of welfare risks during transport, minimising exacerbation of problems.

As contaminated ingesta represents a major potential pathway for *Salmonella* carcase contamination, it is critical for producers to provide the time pigs were removed from feed to the truck driver/abattoir lairage staff to ensure pigs are killed 6-24 hours off-feed.

8.3 Significance for abattoirs

Although the adoption of on-farm antemortem inspection would have minimal food safety benefits overall, it can reduce the role of abattoirs as a carcase sorting point. If suspects are killed separately to normal pigs, this could result in removal of a fifth of hazardous abscesses during 2% of the kill, as well as most of the fevered carcases and about half of the carcases that will need trimming. Slaughter chain efficiencies are possible by scheduling experienced trimmers during slaughter of suspects, to remove the grossly detectable abnormalities and cut down fevered carcases. Optimal allocation of inspection personnel will minimise costs of meat inspection.

Potential for *Salmonella* contamination may rise rapidly if pigs are held for long periods in the lairages; pigs should be slaughtered between 6 and 18/24 hours off-feed. Normal pigs represent the same potential for *Salmonella* contamination as suspects from spilled ingesta. Avoidance of spillage at evisceration must be emphasised in abattoir HACCP plans.

8.4 Significance for regulators

Because pathogen loads in grossly detectable abnormalities are low (Pointon et al 2000), and potentially hazardous carcases are detected at postmortem inspection regardless of their antemortem status, the current emphasis on segregating suspect pigs from normal pigs is unlikely to improve food safety overall. Regulators, however, should be concerned at poor record keeping, inconsistencies in classification/interpretation of pathological conditions, and the low sensitivity of detection of suspects at the abattoir. Antemortem inspection was ineffective at both domestic and export abattoirs across all three states, with low numbers of pigs detected as suspects at all three of the abattoirs participating in the antemortem trials. Inconsistencies in classification/interpretation of pathological conditions were evident in Table 4 and in the abattoir condemnation data (Chapter 7). National standardisation of classification/interpretation of pathological conditions would bring greater credibility to the role of regulatory authorities in protecting public health.

Effective detection and segregation of suspects concentrates additional disposition judgements into a fraction of the kill. Consequently, grossly detectable abnormalities represent a proportionally minor pathway of contamination during processing of normal pigs. This behoves further research to evaluate any food safety risks associated with the implementation of less intensive postmortem inspection procedures for normal pigs (eg. Visual postmortem inspection of such pigs by trained abattoir employees). Such procedures could release inspectors to monitor the major pathways of carcase contamination with *Salmonella* and other pathogens at the abattoir. Regular audits of ingesta spillage and time off-feed prior to slaughter as routine food safety procedures could be done as verification steps within the abattoir HACCP plan. These two critical control points would probably address the major pathways of carcase contamination with the major microbial foodborne hazards at the abattoir, thus optimising allocation of inspection resources to maximise food safety.

8.5 Significance for consumers

If antemortem inspection was conducted on-farm with segregation of suspects, the resulting large even lines of normal pigs would meet abattoir client specifications, and may be eligible for branding with a quality logo. Consumers can have greater confidence in the safety of pig meat delivered through HACCP based QA programs and should be encouraged to purchase products from pigs which meet APIQS. Branding such products with a quality logo is a way to indicate QA status.

Enhanced detection of suspects enables segregation of welfare risks during transport, minimising pig welfare problems during transport. Implementation of on-farm antemortem inspection by producers provides assurance to consumers that procedures to improve pig welfare have been implemented as part of normal production.

8.6 Issues raised

Approximately 10% of pigs in Australia are sold at market by auction, causing considerable delays before slaughter, extra handling, mixing and transport. The effect of this on welfare and *Salmonella* levels deserves further investigation. As consignments of pigs are split up and slaughtered on different days, it would be possible to conduct longitudinal studies. The latest laboratory techniques should be adopted.

There is considerable evidence to suggest that current resource intensive postmortem regimes for normal pigs are unjustifiable if antemortem inspection of pigs is carried out on-farm. To prepare a robust case to argue this, more needs to be learned about pathogen concentrations in both ingesta and grossly detectable abnormalities, to comprehend the actual pathogen load (ie. prevalence and concentration) in different hazard pathways. Quality data, comparing the ability of inspectors and other trained personnel to identify hazards, is needed to help decide who does what to enhance food safety.

Chapter 9

References

Chapter 9 References

Andriessen, E.H. (1987) Meat Inspection and Veterinary Public Health in Australia. Rigby, Sydney, Auckland, London.

Anon (1982) Export Meat Orders (Export Control Act, 1982). Edmund Barton Building, Barton, Canberra, Australian Quarantine Inspection Service.

Anon (1995) Ranking the severity of human disease for food borne organisms. TAG Report, US.

Anon (1997) The Australian Standard for Hygienic Production of Meat for Human Consumption. Australian Standard 4461. Canberra.

Anon (1999) The Australian Association of Pig Veterinarian (AAPV) Guidelines for the Care of Sick and Injured Pigs, June 1999.

Baggesen, D.L. and Wegener, H.C. (1994) Phage types of *Salmonella enterica ssp. enterica* serovar *typhimurium* isolated from production animals and humans in Denmark. *Acta Veterinaria Scandinavica.* **35:** 349-354.

Baggesen, D.L., Wegener, H.C., Bager, F., Stege, H. and Christensen, J. (1996) Herd prevalence of *Salmonella enterica* infections in Danish slaughter pigs determined by microbiological testing. *Preventative Veterinary Medicine.* **26:** 201-213.

Bahnson, P.B. and Fedorka-Cray, P.J. (1996) Farm level risk factor assessment for infection with *Salmonella* spp. In; Proceedings of the First International Symposium on Ecology of *Salmonella* in Pork Production. Ames, Iowa, March 11-13, 1996, p 45.

Bahnson, P.B. and Fedorka-Cray, P.J. (1997) The association between herd characteristics and *Salmonella* prevalence in slaughter age pigs. In; Proceedings of the Second International Symposium on Epidemiology and Control of *Salmonella* in Pork. Copenhagen, Denmark, August 20-22, 1997, pp 145-147.

Bean, N.H. and Griffin, P.M. (1990) Food borne disease outbreaks in the United States, 1973-1987: pathogens, vehicles, and trends. *Journal of Food Protection.* **53:** 804-817.

Beran, G.W. (1996) Report on *Salmonella* studies of the Food Consortium. In; Proceedings of the First International Symposium on Ecology of *Salmonella* in Pork Production. Ames, Iowa, March 11-13, 1996, pp50-56.

Berends, B.R., Snijders, J.M.A. and van Logtestijn, J.G. (1993) Efficacy of current EC meat inspection procedures and some proposed revisions with respect to microbiological safety: a critical review. *The Veterinary Record* **133:** 411-405.

Berends, B.R., Burt, S. and Snijders, J.M. (1995) Critical points in relation to breaking *Salmonella* and *Listeria* cycles in pork production. In; New challenges in meat hygiene: specific problems in cleaning and disinfection. pp.9-18. Editors, S. A. Burt and F. Bauer, European Consortium for Continuing Education in Advanced Meat Science and Technology, Utrecht, The Netherlands.

Berends, B.R., Urlings, H.A.P., Snijders, J.M.A. and van Knapen, F. (1996) Identification and quantification of risk factors in animal management and transport regarding *Salmonella* spp. in pigs. *International Journal of Food Microbiology.* **30:** 37-53.

Berends, B.R. and Snijders, J.M.A. (1997) Risk factors and control measures during slaughter and processing. Proceedings of the Second International Symposium on Epidemiology and control of *Salmonella* in Pork, Copenhagen, 20-22 August 1997, pp 36-41.

Bergdoll, M.S. (1989) *Staphylococcus aureus*. In; Food borne Bacterial pathogens. p 512. (Ed. Doyle, M.P.) Marcel Dekker, Inc. New York, USA.

Bettini, G., Marcato, P.S., Zaghini, I., Ingra, L., Sanguinetti, V. and Grande, V. (1996) An anatomohistopathological evaluation of visual and traditional postmortem meat inspection procedures in Italian heavy pigs. Proceedings of the 14th IPVS Congress, Bologna, Italy, 17-10 July, 1996.

Biro, G., Jayarao, B.M. and Kovacs, S. (1989) Asymptomatic *Salmonella* infection of swine herds. *Magyar Allatorvosok Lapja.* **44:** 479-484.

Blamire, R.V. (1985) Meat Hygiene: The Changing Years. *State Veterinary Journal.* **114:** 3-13.

Burkhart, K., Oppedahl, A., Roof, A., Kolb, J. and Nielsen, B. (1997) Correlation of *Salmonella* spp. in pigs at slaughter as determined by bacterial culture and *Salmonella* ELISA. In; Proceedings of the Second International Symposium on Epidemiology and Control of *Salmonella* in Pork. Copenhagen, Denmark, August 20-22, 1997, pp 126-128.

Burndred, E.J. (1924) Uniformity of Method, Standard and action in Meat Inspection. *The Veterinary Record.* **4:** 715-726.

Burns, C., Mair, M.B. and Hooper, W.L. (1965) An outbreak of *Salmonella brandenburg* infection caused by infected pork products. *Monthly Bulletin, Ministry of Health.* **24:** 9-14.

Chiew, K.T., Chua, S.B. and Singh, D. (1991) Pyaemia in pigs. *British Veterinary Journal.* **147:** 256-269.

Christensen, J. (1997) The prevalence of *Salmonella* antibodies in pigs at slaughter and detection of *Salmonella enterica* in pork. In; Proceedings of the Second International Symposium on Epidemiology and Control of *Salmonella* in Pork. Copenhagen, Denmark, August 20-22, 1997, pp 228-231.

Christensen, J., Baggesen, D.L., Nielsen, A. and Nielsen, B. (1999) The prevalence of *Salmonella enterica* in pigs before the start of the Danish *Salmonella* Control Program (1993/94) and four years later (1998). In; Proceedings of the Third International Symposium on the Epidemiology and Control of *Salmonella* in Pork. Washington DC, USA, August 5-7, 1999, pp 333-335.

Chung, G.T. and Frost, A.J. (1969) The occurrence of salmonellae in slaughtered pigs. *Australian Veterinary Journal.* **45:** 350-353.

Coates, K.J., Kolega, V., Barton, M., Barlow, S., Groves, M., Hamilton, D., Widders, P.R. and Pointon A.M. (1997) Level of food-borne pathogens on Australian pig meat and carcases. Manipulating Pig Production VI, Australian Pig Science Association, P147.

Collins, F. V. (1966) Meat Inspection. Rigby Limited, Adelaide.

Corrier, D.E., Purdy, C.W. and DeLoach, J.R. (1990) Effects of marketing stress on fecal excretion of *Salmonella* spp in feeder calves. *American Journal of Veterinary Research.* **51:** 866-869.

Craven, J.A. and Hurst D.B. (1982) The effect of time in lairage on the frequency of *Salmonella* infection in slaughtered pigs. *Journal of Hygiene, Cambridge.* **88:** 107-111.

Cross, G.M. and Edwards, M.J. (1981) The detection of arthritis in pigs in an abattoir and its public health significance. *Australian Veterinary Journal.* **57:** 153-158.

Currier, M., Singleton, M., Lee, J. and Lee, D.R. (1986) *Salmonella* in swine at slaughter: Incidence and serovar distribution at different seasons. *Journal of Food Protection.* **49:** 366-368.

Davies, P.R., Morrow, W.E.M., Jones, F.T., Deen, J., Fedorka-Cray, P.J. and Harris, I.T. (1997) Prevalence of *Salmonella* in finishing swine raised in different production systems in North Carolina, USA. *Epidemiology and Infection.* **119:** 237-244.

Davies, P.R., Funk, J.A., Nichols, M.G., O'Carrol, J.M., Turkson, P.K., Geybreyes, W.A., Ladely, S. and Fedorka-Cray, P.J. (1999) Effects of some methodologic factors on detection of *Salmonella* in swine faeces. In; Proceedings of the Third International Symposium on the Epidemiology and Control of *Salmonella* in Pork. Washington DC, USA, August 5-7, 1999, pp 30-32.

Davies, P.R. and Funk, J. (1999) Epidemiology and control of *Salmonella* in pork-some of the questions. In; Proceedings of the Third International Symposium on the Epidemiology and Control of *Salmonella* in Pork. Washington DC, USA, August 5-7, 1999, pp 3-11.

De Vine, B. (1932) The Law Relating To Meat Inspection. *The Veterinary Record.* **12:** 928-935.

Edwards, D.S., Johnston, A.M. and Mead, G.C. (1997) Meat inspection: an overview of present practices and future trends. *The Veterinary Journal.* **154:** 135-147.

Elsasser, T. H., Steel, N. C. and Fayer, R. (1995) Cytokines, stress and growth modulation. In; Cytokines in Animal Health and Disease. pp.333-356. Editors, M. J. Myers and M. P. Mutaugh M. P., Marcel Dekker, New York.

Engel, H.W.B., van den Berg, J., Fenigsen-Narucka, U., van Leusden, M., Nouws, J.F.M., Okma, B.D., Peelen, J.P.J. and Soethout, A.E.E. (1987) Reconsidering of "Bacterial Examination" of slaughtered animals. *Tijdschrift voor diergeneeskunde* **112:** 536-540.

Epling, L.K., Carpenter, J.A. and Blankenship, L.C. (1993) Prevalence of *Campylobacter* spp. and *Salmonella* spp. on pork carcasses and the reduction effected by spraying with lactic acid. *Journal of Food Protection.* **56:** 536-537,540.

Fedorka-Cray, P.J., Whipp, S.C., Issacson, R.E., Nord, N. and Lager, K. (1994) Transmission of *Salmonella typhimurium* to swine. *Veterinary Microbiology.* **41:** 333-344.

Fedorka-Cray, P.J. (1997) Mechanisms of host-agent interactions in subclinical *Salmonella* infection in pig herds. In; Proceedings of the Second International Symposium on Epidemiology and Control of *Salmonella* in Pork. Copenhagen, Denmark, August 20-22, 1997, pp 9-18.

Fedorka-Cray, P.J., McKean, J. and Beran, G. (1997) Tracking *Salmonella* on the farm: a farrow to finish study. In; Proceedings of the Second International Symposium on Epidemiology and Control of *Salmonella* in Pork. Copenhagen, Denmark, August 20-22, 1997, pp 196-198.

Funk, J.A., Davies, P.R. and Nichols, M.G. (1997) Evaluation of sample weight for the isolation of *Salmonella spp. from swine faeces.* In; Proceedings of the Second International Symposium on Epidemiology and Control of *Salmonella* in Pork. Copenhagen, Denmark, August 20-22, 1997, pp 97-99.

Funk, J.A., Davies, P.R. and Nichols, M.A. (1999) Longitudinal study of *Salmonella* shedding in 2 three-site swine production systems. In; Proceedings of the Third International Symposium on the Epidemiology and Control of *Salmonella* in Pork. Washington DC, USA, August 5-7, 1999, pp 131-136.

Galton, M.M., Smith, W.V., McElrath, H.B. and Hardy, A.B. (1954) *Salmonella* in swine, cattle and the environment of abattoirs. *Journal of Infectious Disease.* **95:** 236-245.

Gill, C.O. (1995) Current and emerging approaches to assuring the hygienic condition of red meats. *Canadian Journal of Animal Science.* **75:** 1-13.

Gracey, J.F. (1986) Veterinary Ante-mortem Inspection. In; Meat Hygiene. Balliere Tindall, Eastbourne, England.

Gronstol, H., Osborne, A.D. and Pethiyagoda, S. (1974a) Experimental *Salmonella* infection in calves. 1. The effect of stress factors on the carrier state. *Journal of Hygiene, Cambridge.* **72:** 163-168.

Gronstol, H., Osborne, A.D. and Pethiyagoda, S. (1974b) Experimental *Salmonella* infection in calves. 2. Virulence and spread of infection. *Journal of Hygiene, Cambridge.* **72:** 163-168.

Gustafson, R.H., Kobland, J.D. and Langner, P.H. (1976) Incidence and antibiotic resistance of *Salmonella* in market swine. In; Proceedings of the Fourth International Congress of the Pig Vet Society, Ames, p.M2.

Gutzmann, F., Layton, H., Simkins, K. and Jarolmen, H. (1976) Influence of antibiotic-supplemented feed on occurrence and persistence of *Salmonella typhimurium* in experimentally infected swine. *American Journal of Veterinary Research.* **37:** 649-655.

Hansen, R., Rogers, R., Emge, S. and Jacobs, N.J. (1964) Incidence of *Salmonella* in the hog colon as affected by handling practices prior to slaughter. *Journal of the American Veterinary and Medical Association.* **145:** 139-140.

Harbers, A.H.M., Elbers, A.R.W., Geelen, A.J., Rambags, P.G.M. and Snijders, J.M.A. (1992a) Preselection of finishing pigs on the farm as an aid for meat inspection. *Veterinary Quarterly.* **14:** 46-50.

Harbers, T.H.M., Smeets, J.F.M., Faber, J.A.J., Snijders, J.M.A. and van Logtestijn, J.G. (1992b) A comparative study into procedures for postmortem inspection for finishing pigs. *Journal of Food Protection.* **55:** 620-626.

Harvey, R.W.S., Price, T.H. and Morgan, T.H. (1977) *Salmonella* surveillance with reference to pigs - Cardiff abattoir, 1968-1975. *Journal of Hygiene, Cambridge.* **78:** 439-447.

Hathaway, S.C., Pullen, M.M. and McKenzie, A.I. (1988) A model for risk assessment of organoleptic postmortem inspection procedures for meat and poultry. *Journal of the American Veterinary and Medical Association.* **192:** 960-966.

Hathaway, S.C. and McKenzie, A.I. (1991) Postmortem inspection programs; separating science and tradition. *Journal of Food Protection.* **54:** 471-475.

Hathaway, S.C. (1993) Risk analysis and meat hygiene. Scientific and Technical Review. L'Office International des Epizooties, Paris. **12:** (4) 1265-1290.

Hill, J.R. and Jones, J.E.T. (1984) An investigation of the causes and of the financial loss of rejection of pig carcases and viscera unfit for human consumption. Studies at seven abattoirs. *British Veterinary Journal.* **140:** 558-569.

Hindmarsh, W.L. (1971) Historical Records of the Veterinary Profession in Australia. *Australian Veterinary Journal.* **47:** 510-516.

Holst, S. (1993) The occurrence of *Salmonella* in the caecum of Danish slaughter pigs. *Dansk Veterinartidsskrift.* **76:** 645-646.

Humbert, F., Proux, K., Bohnert, M. and F. (1997) Looking for a reliable method to follow the *Salmonella* status of finishing pigs. In; Proceedings of the Second International Symposium on Epidemiology and Control of *Salmonella* in Pork. Copenhagen, Denmark, August 20-22, 1997, pp 129-131.

Isaacson, R.E., Wiegel, R.M., Firkins, L.D. and Bahnson, P. (1999a) The effect of feed withdrawal on the shedding of *Salmonella typhimurium* by swine. In; Proceedings of the Third International Symposium on the Epidemiology and Control of *Salmonella* in Pork. Washington DC, USA, August 5-7, 1999, pp 296-298.

Isaacson, R.E., Firkins, L.D., Wiegel, R.M., Zuckermann, F.A. and DiPietro, J.A. (1999b) Effect of transportation and feed withdrawal on shedding of *Salmonella typhimurium* among experimentally infected pigs. *American Journal of Veterinary Research.* **60:** 1155-1158.

Jagger, F. (1984) Towards a revolution in meat hygiene. *The Veterinary Record.* **114:** 441

Jones, J.E.T. (1980) Observations on the bacterial flora of abscesses in pigs. *British Veterinary Journal.* **136:** 343-348.

Jones, H.B. and Hobbs, B.C. (1964) *Salmonella brandenburg:* an epidemiological study. *Monthly Bulletin, Ministry of Health.* **23:** 162-177.

Kasbohrer, A., Geue, L., Conraths, F.J., Blaha, T.H., Helmuth, R. and Protz, D. (1997) Pilot study on prevalence of *Salmonella* in slaughter pigs in Germany: 1. Prevalence of *Salmonella* in swine carcases by cultural methods. In; Proceedings of the Second International Symposium on Epidemiology and Control of *Salmonella* in Pork. Copenhagen, Denmark, August 20-22, 1997, pp 225-227.

Larkin, P.J. and Hicks, M. (1967) Diagnosis and treatment of chronic *Salmonella typhimurium* infection in sows. *The Veterinary Record.* **81:** 231-234.

Lee, H.W., Veary, C.M., Ingkaninun, P. and Poomvises, P. (1993) A post slaughter investigation into the tail biting syndrome in pig carcasses from selected problem herds. In; Proceedings of the 11th International Symposium of the World Association of Veterinary Food Hygienists. Bangkok, Thailand. October 24-29, 1993, pp 128-131.

Lester, R., Carnie, J., McLennan, L., Lambert, S., Kels, H., Ferriera, C., Gregory, J., Harries, B. and Rouch, G. (1997) *Salmonella* in Victoria, 1997, the story so far. *Communicable Diseases Intelligence.* **21:** 9.

Letellier, A., Messier, S. and Quessy, S. (1997a) Prevalence of *Salmonella* in finishing swine in Canada. In; Proceedings of the Second International Symposium on Epidemiology and Control of *Salmonella* in Pork. Copenhagen, Denmark, August 20-22, 1997, pp 266-268.

Letellier, A., Messier, S. and Quessy, S. (1997b) Control of *Salmonella* in swine by use of probiotics. In; Proceedings of the Second International Symposium on Epidemiology and Control of *Salmonella* in Pork. Copenhagen, Denmark, August 20-22, 1997. pp 160-163.

Libby, J.A. (1975) Meat Hygiene. Lea and Febiger, Philadelphia.

Linton, A.H.(1979) Salmonellosis in pigs. *The British Veterinary Journal.* **135:** 109-112.

Maguire, H.C.F., Codd, A.A., Mackay, V.E., Rowe, B. and Mitchell, E. (1993) A large outbreak of human salmonellosis traced to a local pig farm. *Epidemiology and Infection.* **110:** 239-246.

McClure B.J., M'Connell, H. & W.F., Kelly, H.C.I., M'Crea, J.H., Ewing J.J., Monro, A. and Thompson, S.R. (1923) Meat and Milk Inspection in Ireland. *The Veterinary Record.* **3:** 864-865.

McCullough, N.B. and Eisele, C.W. (1951) Experimental human Salmonellosis, III. Pathogenicity of strains of *Salmonella newport, Salmonella derby,* and *Salmonella bareilly* obtained from spray-dried whole egg. *Journal of Infectious Diseases.* **89:** 209-213.

McDonagh, V.P. and Smith, H.G. (1958) The significance of the abattoir in *Salmonella* infection in Bradford. *Journal of Hygiene, Cambridge.* **56:** 271-279.

Melrose, D.R., and Gracey, J.F. (1974) The Implication of Disease in the Meat Industry. In; Meat: Proceedings of the twenty first Easter School in Agricultural Science, University of Nottingham, 1974. Editors, D.J.A. Cole and R.A. Lawrie, Butterworths, London.

Miller, L., McElvaine, M.D., McDowell, R.M. and Ahl, A.S. (1993) Developing a quantitative risk assessment process. Scientific and Technical Review. L'Office International des Epizooties, Paris. **12:** (4) 1153-1164.

Moo, D., O'Boyle, D., Mathers, W.J. and Frost, A.J. (1980) The isolation of *Salmonella* from jejunal and caecal lymph nodes of slaughtered animals. *Australian Veterinary Journal.* **56:** 181.

Morgan, I.R., Krautil, F.L. and Craven, J.A. (1987) Effect of time in lairage on caecal and carcass *Salmonella* contamination of slaughter pigs. *Epidemiology and Infection* **98:** 323-330.

Morgan, I.R., Krautil, F.L. and Craven, J.A. (1988a) Comparison of swabbing and maceration methods for recovery of bacteria from pork skin. In; Reduction of Contamination on Pig Carcases. *Department of Agriculture and Rural Affairs Research Report Series.* **57:** 9-13.

Morgan, I.R., Krautil, F.L. and Craven, J.A. (1988b) Distribution of salmonellae and other bacteria on pork sampling sites for recovery of bacteria from carcass surfaces. In; Reduction of Contamination on Pig Carcases. *Department of Agriculture and Rural Affairs Research Report Series.* **57:** 14-24.

Morgan, I.R., Krautil, F.L. and Craven, J.A. (1988c) Effect of time of sampling on *Salmonella* contamination of pork carcases. In; Reduction of Contamination on Pig Carcases. *Department of Agriculture and Rural Affairs Research Report Series.* **57:** 24-27.

Morgan, I.R., Krautil, F.L. and Craven, J.A. (1988d) Dynamics of *Salmonella* contamination of pork carcases during the slaughter process. In; Reduction of Contamination on Pig Carcases. *Department of Agriculture and Rural Affairs Research Report Series.* **57:** 27-33.

Morgan, I.R., Krautil, F.L. and Craven, J.A. (1988e) Survey of abattoir lairage faeces for the prevalence of *Salmonella.* In; Reduction of Contamination on Pig Carcases. *Department of Agriculture and Rural Affairs Research Report Series.* **57:** 33-39.

Morgan, I.R., Krautil, F.L. and Craven, J.A. (1988f) Effect of transport and lairage on the prevalence of *Salmonella* in pigs. In; Reduction of Contamination on Pig Carcases. *Department of Agriculture and Rural Affairs Research Report Series.* **57:** 45-51.

Morrow, W.E.M., Davies, P.R., See, T., Eisemann, J., Zering, K., Kihlstrom, S. and Karli, K. (1999) Prevalence of *Salmonella* spp. In the faeces on farm and ceca at slaughter for a cohort of finishing pigs. In; Proceedings of the Third International Symposium on the Epidemiology and Control of *Salmonella* in Pork. Washington DC, USA, August 5-7, 1999, pp 155-157.

Mousing, J., Jensen, P.T., Halgaard, C., Bager, F., Feld, N., Nielsen, B., Nielsen, J.P. and Bech-Nielsen, S. (1997a) Nation-wide *Salmonella* enterica surveillance and control in Danish slaughter swine herds. *Preventative Veterinary Medicine.* **29:** 247- 261.

Mousing, J., Kyrval, J., Jensen, T.K., Aalbeck, B., Buttenschon, J., Svensmark, B., and Willeberg, P. (1997b) Meat safety consequences of implementing visual post-mortem meat inspection procedures in Danish slaughter pigs. *The Veterinary Record* **140:** 472-477.

Mousing, J. and Pointon, A. (1997) Liability of meat inspection-should postmortem meat inspection be abandoned? World Congress on Food Hygiene. The Hague, August, 1997, pp 3-8.

Murray, C. J. (1994) *Salmonella* serovars and phage types in humans and animals in Australia 1987-1992. *Australian Veterinary Journal.* **71:** 78-81.

Murray, G. (1986) Antemortem and postmortem meat inspection: an Australian Inspection Service perspective. *Australian Veterinary Journal.* **63:** 211-215.

NIV Study Bible (1985) The Zondervan Corporation, Grand Rapids, Michigan, USA.

Newell, K.W. and Williams, L.P. (1971) The control of Salmonellae affecting swine and man. *Journal of the American Veterinary and Medical Association.* **158:** 89-98

Nielsen, B. and Baggesen, D.L. (1997) Update on laboratory diagnosis of subclinical *Salmonella* infections in pigs. In; Proceedings of the Second International Symposium on Epidemiology and Control of *Salmonella* in Pork. Copenhagen, Denmark, August 20-22, 1997, pp 19-31.

Nielsen, J.N., Patterson. J.A., Sutton, A., Schinckel, A., Richert, B. and Boccazi, P. (1997) The influence of growth promotant antibiotics and management system on the presence and prevalence of *Salmonella* in swine. Proceedings of the Second International Symposium on Epidemiology and Control of *Salmonella* in Pork. Copenhagen, Denmark, August 20-22, 1997, pp 167-169.

Nisbet, D.N., Anderson, R.C., Buckley, S.A., Fedorka-Cray, P.J. and Stanker, L.H. (1997) Effect of competitive exclusion on *Salmonella* shedding in swine. In; Proceedings of the Second International Symposium on Epidemiology and Control of *Salmonella* in Pork. Copenhagen, Denmark, August 20-22, 1997, pp 176-178.

Norval, J.(1966) Abscesses in pigs. *The Veterinary Record* **78:** 708-712.

Oosterom, J. and Notermans, S. (1983) Further research into the possibility of *Salmonella*-free fattening and slaughter of pigs. *Journal of Hygiene, Cambridge.* **91:** 59-69.

Pointon, A.M., Mercy, A.R., Backstrom, L. and Dial, G.D. (1992) Disease surveillance at Slaughter. In; Diseases of Swine. pp 968-987. Editors, A. D. Leman, B. E. Straw, W. L. Mengeling, S. D'Allaire and D. J. Taylor, Iowa State University Press, Ames, Iowa.

Pointon, A.M. (1997a) An empirical risk based assessment of postmortem pig meat inspection in Australia. Sub-project report from the Pig Meat Hygiene Project. Pig Research and Development Corporation. Canberra. ISBN 1876007036

Pointon, A.M. (1997b) A risk assessment of Australian Pig Meat Hygiene: overview of the approach. In; Proceedings of the 30^{th} National Convention of the Australian Institute of Food Science and Technology in association with The Singapore Institute of Food Science and Technology. Perth, Western Australia, May 4-8, 1997, pp 545-563.

Pointon, A.M., Hamilton, D., Kolega, V. and Hathaway, S. (2000) A risk assessment of organoleptic postmortem inspection procedures for pigs. *The Veterinary Record* **146:** 124-131.

Quinn, P.J., Carter, M.E., Markey, B. and Carter, G.R. (1994) Clinical Veterinary Microbiology. Wolfe Publishing, London, pp 227-232.

Rabagliati, D.S. (1931) The Practical Value of Meat Inspection. *Journal Royal Sanitary Institute, England.* **51:** 652-658.

Radan, M. (1964) A Statistical Survey of *Salmonella* Infection in Emergency-slaughtered Cattle. *Zentralblatt fur Veterinarmedizin.* **11:** 644-646.

Riley, M.G. (1970) The incidence of *Salmonella* in normal slaughtered pigs. *Australian Veterinary Journal.* **46:** 40-43.

Robinson, R.A. (1965) Antemortem inspection condemnation of young calves. *New Zealand Veterinary Journal.* **13:** 76-77.

Shotts, E.B., Martin, W.T. and Galton, M.M. (1962) Further studies on *Salmonella* in human and animal foods and in the environment of processing plants. swine. In; Proceedings of the Annual Meeting of the United States Livestock Sanitary Association, 65th. pp 309-318.

Sischo, W.M., Kephart, K., Maddox, C.M., Nesselrodt, A. and Fedon, J. (1996) The effects of feed deprivation on shedding of *Salmonella typhimurium* in swine. In; Proceedings of the First International Symposium on Ecology of *Salmonella* in Pork Production. Ames, Iowa, March 11-13, 1996, p 26.

Snijders, J.M.A. (1988) Good manufacturing practices in slaughter lines. *Fleischwirtschaft* **68:** 753-756.

Snijders, J.M.A. and Berends, B.R. (1996) A proposal for an alternative meat inspection system for fattening pigs .Factors affecting the microbial quality of meat. 1. Disease status, production methods and transportation of the live animal. In; Proceedings, The Netherlands, 23-26 October, 1995. Published by University of Bristol Press, UK, pp 141-147.

Soethout, A.E.E., van den Berg, J., Narucka, U., Nouws, J.F.M., Okma, B.D. and Peelen, J.P.J. (1981) Lesions in slaughtered animals. III. Multiple abscesses in pigs. *Tijdschr. Diergeneesk.* **106:** 806-809.

Steinbach, G. and Hartung, M. (1999) An attempt to estimate the share of human cases of Salmonellosis attributable to *Salmonella* originating from swine. *Berliner und Munchener Tierarztliche Wochenschrift.* **112:** 296-300.

Tauxe, R.V. (1991) *Salmonella:* A postmodern pathogen. *Journal of Food Protection.* **54:** 563-568.

Tay, S.C.K., Robinson, R.A. and Pullen, M.M. (1989) *Salmonella* in the mesenteric lymph nodes and cecal contents of slaughtered sows. *Journal of Food Protection.* **52:** 202-203.

Taylor, C.E., Franco, D.A. and DeNovellis, R. (1984) Major causes for condemnations of cattle and swine by USDA from 1978 to 1980. *Veterinary medicine and small animal clinician* **79:** 257-259.

Taylor, D.J., Reid, S.W.J. and Gettinby, G. (1995) Farm, antemortem inspection and abattoir inspection for bacterial zoonotic disease in pigs. Factors affecting the microbial quality of meat. 1. Disease status, production methods and transportation of the live animal. In; Proceedings of a meeting held at Conferentiecentrum Kaap Doorn, The Netherlands, 23-26 October, 1995. Published by University of Bristol Press, UK, pp 57-66.

Tuovinen, V.K., Grohn, Y.T. and Straw, B.E. (1994) Partial condemnations of swine carcasses - a descriptive study of meat inspection findings at Southwestern Finland's Cooperative Slaughterhouse. *Preventative Veterinary Medicine.* **19:** 69-84.

Turner, G.V.S. (1977) Porcine arthritis and meat hygiene in South Africa. *Journal of the South African Veterinary Association.* **49:** 40-44.

Turner, G.V., Collett, M.G., Veary, C.M. and Kruger, C. (1991) Arthritis in slaughter pigs. *Journal of the South African Veterinary Association.* **62:** 107-109.

Tran Xuan Hanh (1995) Isolation and identification of *Salmonella* species in pigs at slaughterhouses in HoChiMinh City, Vietnam. *Khoa Hoc Ky Thuat Thu Y.* **2:** 89-93.

van der Waaij, D. (1992) History of recognition and measurement of colonisation resistance of the digestive tract as an introduction to selective gastrointestinal decontamination. *Epidemiology and Infection.* **109:** 315-326.

Van der Wolf, P.J., Bongers, J.H., Elbers, A.R.W., Franssen, F.M.M.C., Hunneman, W.A., van Exsel, A.C.A. and Tielen, M.J.M. (1999) *Salmonella* infections in finishing pigs in the Netherlands: bacteriological herd prevalence, serogroup and antibiotic resistance of isolates and risk factors for infection. *Veterinary Microbiology.* **67:** 263-275

Wannemuehler, M. J. (1995) Role of cytokines in intestinal health and disease. In; Cytokines in Animal Health and Disease. pp 261-290. Editors, M. J. Myers and M. P. Mutaugh, Marcel Dekker, New York.

Walley, T. (1896) A Practical Guide to Meat Inspection. Young, J., Pentland, Edinburgh and London.

Wegener, H. C. and Baggesen, D.L. (1996) Investigation of an outbreak of human salmonellosis caused by *Salmonella enterica* ssp. *enterica* serovar infantis by use of pulsed field gel electrophoresis. *International Journal of Food Microbiology* **32:** 125-131.

Wegener, H.C. and Bager, F. (1997) Pork as a source of human *Salmonella* infection. In; Proceedings of the Second International Symposium on Epidemiology and Control of *Salmonella* in Pork. Copenhagen, Denmark, August 20-22, 1997, pp 3-8.

Widders, P.R., Coates, K.J., Bobbit, J.L., Kolega, V. and Pointon, A.M. (1997) Cultural and serological analysis of the *Salmonella* status of Australian pig production. In; Proceedings of the Second International Symposium on Epidemiology and Control of *Salmonella* in Pork. Copenhagen, Denmark, August 20-22, 1997, pp 221-224.

Wilcock B.P., and Schwartz, K.J (1992) Salmonellosis. In; Diseases of Swine. pp 570-583. Editors, A. D. Leman, B. E. Straw, W. L. Mengeling, S. D'Allaire and D. J. Taylor, Iowa State University Press, Ames, Iowa.

Willeberg, P., Wedam, J.M., Gardner, I.A., Holmes, J.C., Mousing, J., Kyrval, J., Enoe, C., Andersen, S. and Leontides, L. (1997) A comparative study of visual and traditional postmortem inspection of slaughter pigs: Estimation of sensitivity, specificity and differences in non-detection rates. In; Proceedings of the 8th International Symposium on Veterinary Epidemiology and Economics. pp 31-36.

Williams, L.P. and Newell K.W. (1967) Patterns of *Salmonella* excretion in market swine. *American Journal of Public Health and the Nation's Health.* **57:** 466-471.

Williams, L.P. and Newell K.W. (1970) *Salmonella* excretion in joy-riding pigs. *American Journal of Public Health and the Nation's Health.* **60:** 926-929.

Williams Smith, H. (1960) The effect of feeding pigs on food naturally contaminated with Salmonellae. *Journal of Hygiene, Cambridge.* **58:** 381-389.

Wolff H. G. (1953) Stress and Disease. Charles C Thomas, Springfield, Illinois, U.S.A.

Wood, R.L., Pospischil, A. and Rose, R. (1989) Distribution of persistent *Salmonella typhimurium* infection in internal organs of swine. *American Journal of Veterinary Research.* **50:** 1015-1021.

Wouda, W., Snijders, J.M.A., van den Broek, M.J.M., Gruys, E. and van Logtestijn, J.G. (1987) Endocarditis and meat inspection in pigs. 1. Clinical, pathological, and microbiological findings. *Tijdschrift voor diergeneeskunde.* **112:** 1126-1235.

Wray, C. and Sojka, W.J. (1977) Reviews of the progress of dairy science: bovine salmonellosis. *Journal of Dairy Research.* **44:** 383-425690.

Chapter 10

A Producers Guide to On-farm Antemortem Inspection of Pigs

Jackowiak, J. (2000). *A producers guide to on-farm ante-mortem inspections of pigs*. PRDC Project No: 1211. Pig Research and Development Corporation et al., South Australia.