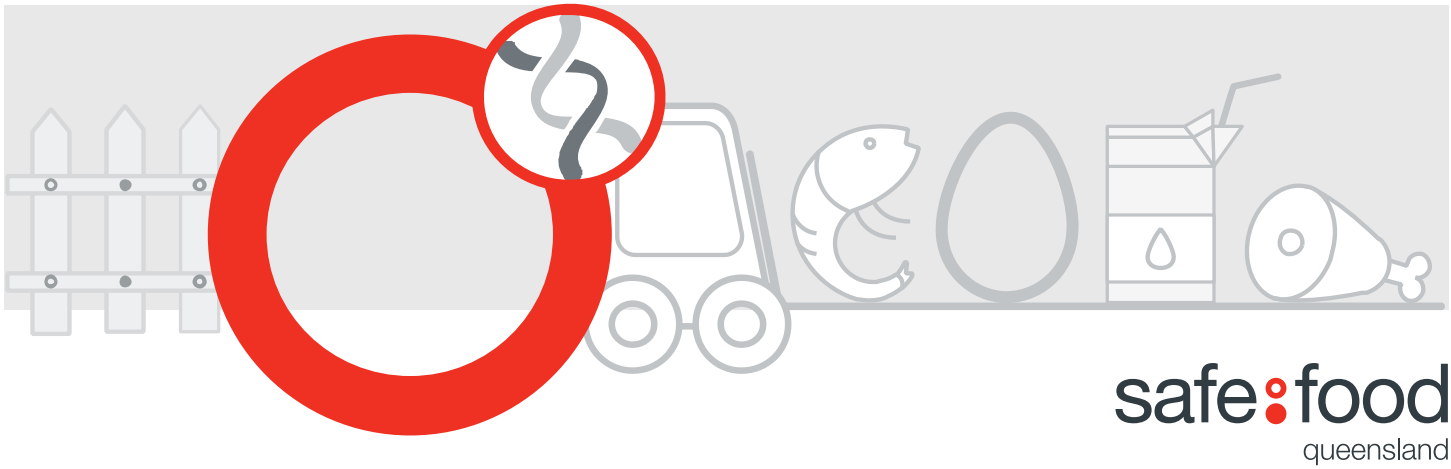
System Verification Study of Queensland Red Meat Abattoirs – 2018



safe:food queensland

About this document

This document reports the results of a system verification study of red meat abattoirs in Queensland that supply products exclusively to the Australian domestic market (referred to henceforth as “domestic red meat abattoirs”). The purpose of this study was to assess the effectiveness of the Meat Food Safety Scheme (“the meat scheme”) of the *Food Production (Safety) Regulation 2014*, as it applies to these abattoirs, and to identify opportunities to further improve compliance monitoring strategies and food safety outcomes. Principally, we collected industry census information, assessed compliance with legislative requirements and sampled carcases to inform on hygiene management. This work builds upon the achievements of similar studies performed by Safe Food Production Queensland (Safe Food) in 2004, 2007 and 2011.

Information generated from this work will assist the continued evaluation of the performance of meat food safety regulation and support Safe Food’s Statement of Strategy 2015-2020. Any enquiries about this document should be directed to Safe Food on (07) 3253 9800 or via email at info@safefood.qld.gov.au.

Acknowledgements

Safe Food would like to thank the participating accredited abattoirs for their cooperation during the study. Laboratory analyses were conducted by Symbio Laboratories.

Contents

1 Executive summary

Safe Food has the responsibility for regulating meat safety during primary production and processing in Queensland. The *Food Production (Safety) Act 2000* ("the Act") and *Regulation 2014* ("the Regulation") mandate that businesses accredited under the meat scheme must control food safety hazards and ensure that products supplied to market are safe and wholesome. By virtue of the red meat industry's well-established standards for food safety and biosecurity, the occurrence of chemical and physical contaminants in meat is infrequent. However, microbiological hazards are a very real and perpetual food safety risk for raw meat. Meat processors expend a great deal of effort to ensure that as products move along the supply chain, regulatory and consumer expectations are upheld.

The aims of this study were to:

- evaluate the effectiveness of the meat food safety scheme as it applies to domestic red meat abattoirs; and
- identify whether opportunities exist to augment mechanisms for compliance monitoring and further improve food safety management in the industry.

Safe Food set three main objectives for the study, which aligned with the core elements of the agency's Statement of Strategy 2015-2020. The objectives were to:

1. collect census information to help understand the current state of industry and gain further insights into the nature of each abattoir's food safety system;
2. assess the compliance of red meat abattoirs with the Act and Regulation; and
3. conduct a carcase hygiene survey to assist in measuring the effectiveness of each abattoir in managing microbiological hazards.

During the study, Safe Food visited 42 domestic red meat abattoirs. Most abattoirs (37/42) returned the census questionnaires. While the extent of information willing to be shared varied markedly, sufficient information was gathered via the questionnaires and compliance assessment records to construct a simplified or "baseline" model of the average food safety system. Compliance was verified in accordance with Safe Food's standard compliance framework. A total of 262 sponge swabs were collected from beef, sheep and pig carcases. All samples were analysed to estimate the number of aerobic microbes and *Escherichia coli* (*E. coli*) present per square centimetre of each sample zone.

The study generated several noteworthy findings. These were as follows:

- the majority of abattoirs are small in size, process mixed livestock species and share great similarity in terms of processes and hazard controls;
- abattoirs demonstrated a very high level of compliance with food safety legislation;
- microbiological results indicated that carcase hygiene is generally well managed; and
- there is opportunity to further improve food safety management by promoting a

uniform set of measures to verify controls and potentially establish a data-sharing initiative.

This work has assisted Safe Food to engage with Queensland red meat abattoirs to improve awareness of microbiological hazards. Further, it has provided a foundation of scientific knowledge necessary to inform ongoing regulatory discussions and policy decisions.

2 Background

Microbiological contamination is a perpetual food safety risk for businesses that slaughter livestock and process meat. There are many opportunities for carcases and meat to become contaminated and for microbes to proliferate during refrigerated storage, especially if temperature abused. These opportunities include, for example:

- as living animals are euthanised and dressed to produce carcases;
- as carcases are broken down to produce meat;
- as meat is distributed across complex and lengthy supply chains; and
- as meat is subjected to additional processing at the food service and retail levels.

While these risks are inherent to meat processing, failure to adequately control them can dramatically affect product safety and quality, and ultimately, the reputation and profitability of meat processors and other businesses who distribute their products.

If adequate control is not exercised during meat processing and handling, raw meat can easily become contaminated with human pathogenic bacteria such as *E. coli*, *Salmonella enterica, Campylobacter species*, *Staphylococcus aureus, Bacillus cereus, Clostridium perfringens* [1]. Pathogens can be inadvertently ingested by consumers at loads exceeding infectious doses if raw meat is improperly cooked or mishandled during preparation. The consequences of this can include intense gastrointestinal illness and even death in susceptible individuals. Moreover, inadequate control of meat processing and handling can result in contamination with organisms that can greatly reduce product shelf life and diminish desirable organoleptic qualities such as taste, odour, consistency and colour. Such occurrences impinge on the satisfaction of customers (i.e. retailers, restaurants, etc.) and consumers (i.e. the community), leading to product rejections, returns or complaints. These “spoilage organisms” include human pathogenic and non-pathogenic bacteria such as *Clostridium, Bacillus, Lactobacillus, Pseudomonas*, *Haemophillus*, *Escherichia*, and *Proteus* species [2, 3].

Achieving robust control over microbiological contamination in an abattoir can be a complex task. There is no ‘one size fits all’ approach because of differences in how abattoirs operate. However, there are certain practices that can be implemented in all meat processing businesses to achieve control. These fall into two categories. First, hygienic practices that minimise the occurrence of the

vertical contamination of carcases from their own hide, visceral organs, head, etc.; and horizontal contamination from other carcases, the processing environment and equipment, pests and personnel [1, 3]. Second is strict management of product temperature to minimise bacterial growth [1, 3]. It is imperative that these practices are implemented well beginning at the abattoir, as many bacterial species can rapidly proliferate as product moves downstream towards the consumer. Studying the quantities of bacteria on meat at the abattoir can inform on the effectiveness of the system to control microbiological contamination. For example, quantifying *E. coli* and aerobic microbes on meat can provide an understanding of the control of faecal contamination and exposure to other organisms, including spoilage organisms, respectively.

In Queensland, Safe Food has the responsibility for regulating meat safety during primary production and processing. The Act and Regulation mandate that businesses accredited under the meat scheme must control food safety hazards and ensure that products supplied to market are safe and wholesome. Each food safety scheme is periodically reviewed to ensure it remains a contemporary and effective regulatory tool that supports the objectives of the Act. The performance of the meat scheme, as it applies to red meat abattoirs, has been reviewed on three prior occasions by Safe Food, the last of which occurred in 2011.

Safe Food has recently begun moving food safety schemes into the digital space. This has been motivated by the ability of digital systems to assist compliance monitoring activities, facilitate surveillance for emerging risks, create further opportunities for engagement and add greater value to the regulatory process for holders of accreditation. This digital initiative is called the Central Information Monitoring System (CIMS). CIMS monitors business performance through chain by comparing routine monitoring and verification data against values representative of stable, effective systems. Data collection points are positioned at essential food safety control points and performance values are targets agreed upon through collaboration between Safe Food and industry. Moreover, CIMS alerts businesses and Safe Food when performance data falls outside of the agreed targets, allowing for systems to be corrected in near-real time.

CIMS allows industry to demonstrate that they are meeting key targets in production systems. An added benefit is that it may serve to minimise compliance costs and highlight opportunities for greater control of hazards and improved production efficiencies. A system has already been adopted by all poultry meat abattoirs in the state, dairy processors, and others are currently being developed and implemented in export accredited red meat abattoirs as well as egg producers and processors. Safe Food meets several times a year with industry consultative committee groups to discuss the performance of each industry, Queensland public health outcomes and opportunities for refining each CIMS.

3 Aims and objectives

The aims of this study were to:

- evaluate the effectiveness of the meat food safety scheme as it applies to domestic red meat abattoirs; and
- identify whether opportunities exist to augment mechanisms for compliance monitoring and further improve food safety management in the industry.

Safe Food set three main objectives for the study, which aligned with the core elements of the agency's Statement of Strategy 2015-2020. The objectives were to:

1. collect census information to help understand the current state of industry and gain further insights into the nature of each abattoir's food safety system;
2. assess the compliance of red meat abattoirs with the Act and Regulation; and
3. conduct a carcase hygiene survey to assist in measuring the effectiveness of each abattoir in managing microbiological hazards.

This work was expected to assist risk communication efforts with Queensland red meat abattoirs regarding microbiological hazards and to deliver a foundation of scientific knowledge to inform ongoing regulatory discussions and policy decisions.

4 Methods

4.1 Study participants and onsite visits

During the study, Safe Food visited all 45 domestic red meat abattoirs that were accredited with the agency during the 2018 calendar year. However, only 42 were included in this study because two abattoirs were far too remote to allow samples to be transported to the laboratory within the required time frame, and one processed only deer; a species that was not within the scope of the carcase sampling plan. In the month of March, each abattoir was contacted by phone to confirm on which day/s of the week they operate and to ascertain the average number of each species processed per week. For many abattoirs, drought was affecting access to livestock, meaning that throughput varied considerably from week to week. Each abattoir was visited once, between the months of April and September.

4.2 Industry census information

A questionnaire was developed and provided to study participants for completion and return to Safe Food. The scope of the questionnaire covered production parameters, information relating to the principles of the Hazard Analysis Critical Control Points (HACCP) concept (e.g. key controls, system monitoring and verification activities, etc.) and supporting programs (e.g. personnel training, maintenance, cleaning and sanitation, pest and waste management, document and data control, internal audit, etc.).

4.3 Compliance verification

Compliance assessments were conducted at all abattoirs in accordance with Safe Food's assessment framework. Each was assessed on their performance relating to:

- inspection and testing;
- process control;
- prerequisite programs;
- purchasing and inputs;
- product identification and traceability;
- product integrity;
- skills and knowledge; and
- sustainability.

If an abattoir failed an assessment, an audit was performed to finish evaluating their compliance with the Act and Regulation. Non-conformances were resolved by issuing a corrective action request compelling the abattoir to address the root cause and performing a subsequent audit to verify compliance had been re-established.

4.4 Carcase sampling

Carcase hygiene was assessed by collecting carcase sponge swabs during each visit. Each sample was analysed using standard plate counts (SPCs) and *E. coli* counts on Petrifilm via the AOAC 990.12 and AOAC 991.14 methods, respectively [4]. Carcases were sampled within 24 hours of stunning using sponge swabs in accordance with a modified version of the Meat Standards Committee guidelines [5].

At the time of collecting swabs, each carcase was tested with a probe thermometer to determine its surface temperature. All samples were transported to the laboratory by Safe Food officers or via overnight courier. All were received within 24 hours of collection and analysed within 24 hours of receipt at the laboratory.

Safe Food aimed to collect approximately 300 samples for microbiological analysis across all 42 abattoirs. Pigs were the predominant species being processed at the time of the preliminary phone survey, followed by sheep and cattle. Because of the inconsistency in processing observed across the industry, samples were assigned to each species and abattoir proportionate to the number processed per week. The smallest abattoirs were allocated one sample each. As a result, 131 samples were allocated to pigs, 99 to sheep and 77 to cattle. However, less samples than this were able to be collected because fewer animals than expected were being processed by some abattoirs during Safe Food's visits. A total of 263 samples were ultimately collected, including 123 pig, 72 sheep and 67 cattle samples.

All abattoirs included in the study received individual feedback reports of their results. Those whose samples had unusually high microbial counts received follow-up contact from Safe Food officers to help interpret the significance of their results. These abattoirs were asked to utilise Safe Food's "Red Meat Microbiological Risk Reduction Guide" to help review their system. This enabled each abattoir to ensure that best practices are in

place at all stages and are effective at controlling microbiological contamination as product moves through the processing chain.

To categorise abattoirs based on scale of throughput, the unit of "cattle kill equivalents" or CKEs was used. One bovine is equal to five pigs and eight sheep. Small, medium and large abattoirs were defined as those processing <15 CKEs, >15-99 CKEs, and >99 CKEs per week, respectively.

4.5 Statistical analyses

All microbiological counts were converted to log values for convenience of interpretation and graphing, as described elsewhere [6]. When microbiological counts from different study years were compared, they were reported as colony forming units per square centimetre (CFU/cm^2). As described previously [5], counts of aerobic microbes were classified as either:

- Excellent (<3.00 log^{10} CFU/cm^2);
- Good (>3.00 log^{10} CFU/cm^2);
- Acceptable (>4.00 log^{10} CFU/cm^2); or Marginal (>5.00 log^{10} CFU/cm^2).

Similarly, *E. coli* counts were classified as either:

- Excellent (<0.00 log^{10} CFU/cm^2);
- Good (>0.00 log^{10} CFU/cm^2);
- Acceptable (>1.00 log^{10} CFU/cm^2); or
- Marginal (>2.00 log^{10} CFU/cm^2).

The number of samples collected during the study was relatively small. This precluded the use of inferential statistics as the power of such analyses would have been limited. Descriptive statistics were used, including proportions and means, as well as medians, first and third quartiles, minimums and maximums (displayed as box plots).

5 Results

5.1 Abattoir dynamics

The vast majority of abattoirs (29/42) were small in size, based on weekly throughput (Figure 1). Eight were medium and seven were large.

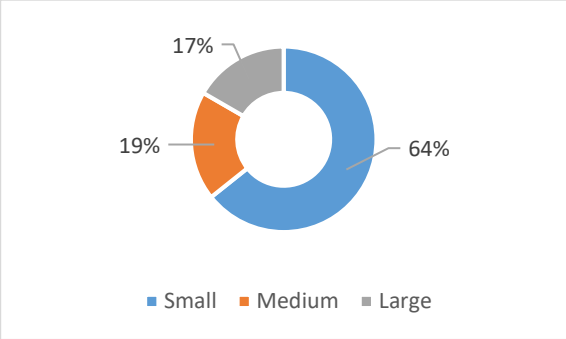


Figure 1: Size of abattoir relative to their weekly throughput.

Most (29/42) abattoirs indicated that they process a mix of cattle, sheep and pigs, while 13 indicated that they routinely process only one species (Figure 2).

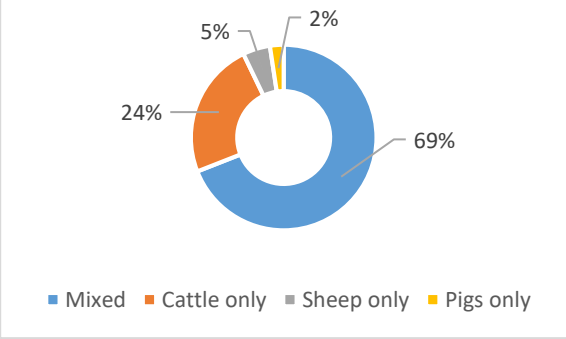


Figure 2: Proportion of abattoirs processing mixed and single species.

The industry has consolidated in recent years, with an 8.2% decrease in the number of abattoirs operating in 2018 (n=45) compared with 2011 (n=49). The number of livestock being slaughtered per week was also considerably lower in 2018 than in 2011 and 2007. While the number of pigs being slaughtered has remained consistent between 2011 and 2018, in this period the number of sheep has declined by 29.2% and cattle by 64.0% (Figure 3). The closure of just one abattoir in South East Queensland has diminished the number of cattle being processed in domestic abattoirs in the state by as much as roughly 150,000 per year.

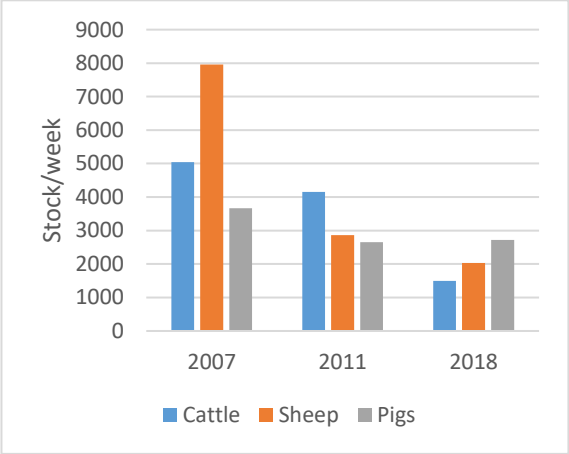


Figure 3: Number of each species processed per week in 2007, 2011 and 2018.

There was very little variation between abattoirs with regards to their processes, controls, monitoring and verification activities. Processes can generally be separated into three categories (Appendix A):

- pre-slaughter;
- slaughter and dressing; and
- chilling and storage.

Prior to slaughter, livestock were received into lairage where they were held and observed so that an antemortem disposition could be applied. Animals were slaughtered following stunning to induce unconsciousness and sticking to achieve exsanguination. Heads, hooves and hides were then removed, and carcases dressed. Carcases were eviscerated and subjected to post-mortem inspection, where dispositions were applied. At this point, carcases were reworked, if necessary, and subjected to final inspection. Antemortem, post-mortem and final inspections were conducted by certified meat safety officers. Carcases were then split into sides and quarters and washed on internal surfaces only, before being graded and weighed. Sides, quarters and other carcase parts (e.g. offal) were chilled and stored under active refrigeration. Most abattoirs used traditional carcase cradles to assist in separating hides from carcases. One used the more modern approach of a mechanical, downward hide puller. Only those abattoirs processing pigs employed decontamination steps to reduce microbiological loads on carcases (e.g. carcase scalding, singeing via gas torches). One abattoir had a fully integrated system in which they slaughter livestock, chill and bone carcases and package meat. The order in which these steps were undertaken varied little between abattoirs. However, there was some variation in the precise way in which each step was performed.

With regards to system monitoring, all abattoirs performed antemortem and post-mortem inspections, which included strict final

inspections (Figure 4). Similarly, all monitored chiller performance and carcase chilling to ensure carcases were reduced to ≤7°C surface temperature within 24 hours of stunning, as required by the relevant Australian Standard [7] under the Regulation. However, not all abattoirs had documented evidence to demonstrate their compliance.

There was variability between abattoirs in the approaches taken to verify the effectiveness of their systems. Relatively few (18/42, 42.9%) used electronic technologies to log carcase cooling data (Figure 4). Greater than half (24/42, 57.1%) conducted microbiological testing of carcases to inform on hygiene management.

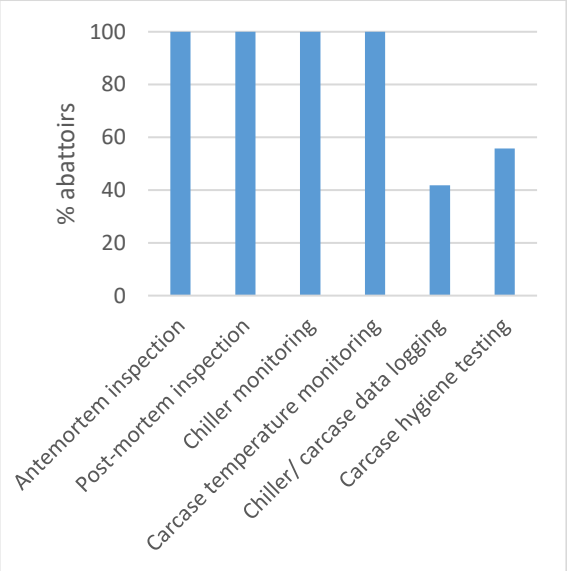


Figure 4: Proportion (%) of abattoirs undertaking system monitoring and verification activities.

5.2 Compliance with food safety legislation

All abattoirs, except one, were found to be compliant with the requirements of the Act and Regulation. One abattoir was issued a corrective action request due to a non-conformance relating to process control.

5.3 Carcase hygiene

Microbiological results suggest that the abattoirs employed robust practices to minimise microbiological contamination of carcases. Based on SPCs, 97.0% of beef, 81.9% of sheep and 59.3% of pig carcases had counts of aerobic microbes in the Excellent range (Figure 5). For sheep and pigs, greater than 90% of samples had counts that fell in the Good and Excellent ranges. Two abattoirs had one sample each that fell in the Marginal category.

Figure 5: Proportion (%) of carcases, after processing, with counts of aerobic microbes classified as either Excellent, Good, Acceptable or Marginal.

All samples carried very low counts of *E. coli*. The majority fell in the Excellent range, and the remainder, fourteen sheep samples and one pig sample, fell in the Good range (Figure 6).

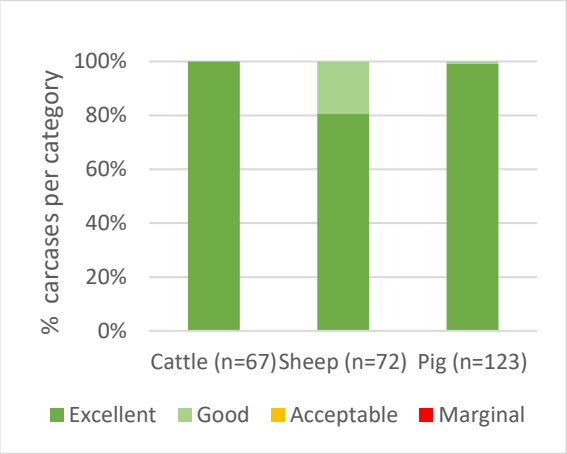


Figure 6: Proportion (%) of carcases, after processing, with counts of *E. coli* classified as either Excellent, Good, Acceptable or Marginal.

Mean and median counts of aerobes on carcases were relatively low, and virtually identical, on all three species in 2018. However, counts for cattle and pigs differed considerably between the 2007, 2011 and 2018 studies (Figure 7, Appendix B). For cattle, mean counts observed in 2018 (1.23 log^{10} CFU/cm^2) were substantially lower than those observed in 2007 (2.34 log^{10} CFU/cm^2). However, for pig carcases, mean counts observed in 2018 (2.58 log^{10} CFU/cm^2) were greater than observed in 2011 (1.93 log^{10} CFU/cm^2). For sheep, mean counts observed in 2018 (2.30 log^{10} CFU/cm^2) were similar to those in 2011 (2.42 log^{10} CFU/cm^2), but substantially lower than those in 2007 (3.24 log^{10} CFU/cm^2).

There were 17 samples, from six abattoirs, which had inordinately high (i.e. >4.00 log^{10} CFU/cm^2) aerobe counts. The maximum observed values were 4.40, 5.00 and 5.45 log^{10} CFU/cm^2 for cattle, sheep and pigs, respectively.

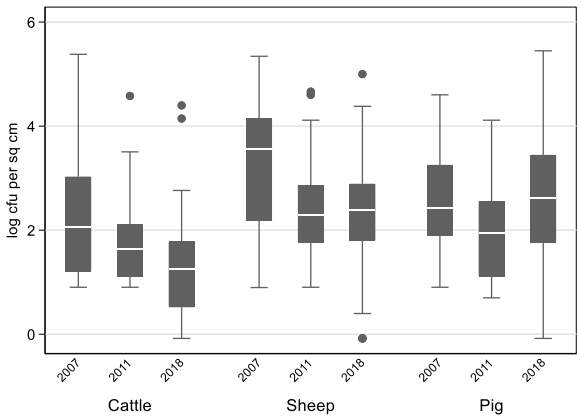


Figure 7: Variation in counts of aerobic microbes (log^{10} CFU/cm^2) detected on cattle, sheep and pig carcases (values presented as minimums, first quartiles, medians, third quartiles, maximums and outliers).

Mean and median counts of *E. coli* on carcases of all three species were exceptionally low and virtually the same (i.e. <0.00 log^{10} CFU/cm^2) for all three studies (Figure 8, Appendix C). The high frequency of occurrence of exceptionally low values skewed the dataset and complicated the visualisation of results in some instances. For example, for sheep carcases sampled in 2018 a box plot could not be generated and all counts above -1.08 log^{10} CFU/cm^2 were deemed outliers (Figure 8).

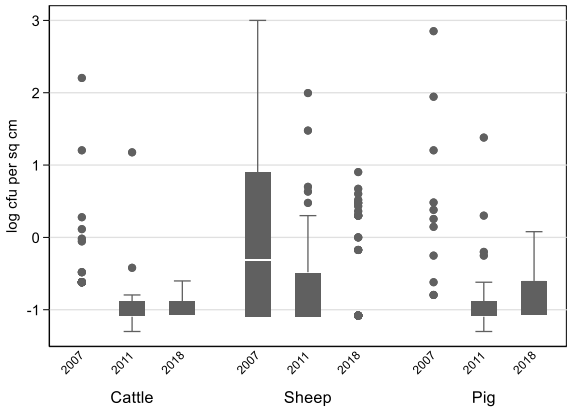


Figure 8: Variation in counts of *E. coli* (log10 CFU/cm^2) detected on cattle, sheep and pig carcases (values presented as minimums, first quartiles, medians, third quartiles, maximums and outliers).

6 Discussion and conclusion

The control of microbiological hazards within the red meat supply chain requires a multi-level approach to minimise the transmission of human pathogens into the community. Bacteria such as *Salmonella enterica*, *E. coli*, *Campylobacter* species and *Clostridium perfringens* are natural inhabitants of the gastrointestinal tracts of livestock [1, 3]. There is a well-recognised propensity for these and other human pathogens carried in and on livestock to contaminate carcases at the abattoir level. While rarely implicated in large-scale outbreaks of foodborne illness in Australia, these pathogen-commodity combinations are believed to play an important role in the epidemiology of sporadic cases [8]. Spoilage organisms are also readily introduced into the processing environment, and potentially, spread onto meat from the livestock themselves, vectors and fomites [2, 3]. Microbes can greatly diminish product shelf life and negatively affect product qualities. Microbiological contaminants represent a genuine risk for the Australian meat industry because of their potential to affect public health, industry reputation and market access. This work sought to inform on the operation of food safety controls in red meat abattoirs in Queensland. The findings obtained support several major conclusions and these are explored below.

6.1 Compliance with legislation

Overall, most abattoirs demonstrated a very high level of compliance with food safety legislation, although some may be operating at or beyond a sustainably safe capacity. This included appropriate measures to identify and control potential food safety hazards within processing systems to ensure that products intended for supply were acceptable. The rate of compliance observed in this study is supported by the very infrequent submission of complaints and formal notifications to Safe Food regarding safety and quality of raw red meat processed in Queensland.

6.2 Carcase hygiene

The microbiological findings from the study indicate that most abattoirs employ robust practices to control the microbiological contamination of carcases. This reaffirms the positive compliance outcomes observed during the study period. Data from this study suggests that carcases carried low quantities of both *E. coli* and aerobic microbes. However, there were several occasions when SPCs were exceptionally high (i.e. >4.00 $\log^{10}$ CFU/cm^2). These involved carcases of all three species from six distinct abattoirs. In most cases, these results coincided with counts on other carcases that were categorised in the Excellent range (i.e. <3.00 $\log^{10}$ CFU/cm^2). This demonstrates that there can be extreme variation in carcase hygiene outcomes within a single abattoir. It also serves as a reminder of the value of validating and routinely verifying the effectiveness of the processing system.

It is worth cautioning against complacency in the face of low *E. coli* counts. There are many factors that influence the presence and concentration of *E. coli* and other faecal-borne

pathogens and spoilage organisms in livestock. These findings highlight the importance of sustained vigilance for carcase hygiene management across all levels of operational and managerial personnel at all abattoirs.

The quantities of aerobes observed on cattle, sheep and pig carcases varied considerably. On each occasion in 2007, 2011 and 2018 cattle carcases carried the lowest quantities. Moreover, in 2018, counts on sheep and pig carcases were substantially higher than those on cattle. These observations are not unusual and are primarily attributable to the differences in the integumentary anatomy of cattle, sheep and pigs and the processes that must be carried out to prepare the respective carcases for market. Cattle have very thick hides and most of the breeds cultivated in northern Australia feature short coats. This means that hides can be removed with relatively little transference of dust and aerosols from the coat onto the carcase. This is not the case for sheep and pigs. Sheep have a hide featuring a thick woolly coat that can trap a lot of dust and moisture, especially when long [9]. Moreover, the process required to separate the hide from the carcase is often manualised and the action very forceful. This means that, when compared with cattle, there is much greater opportunity for contaminants to be transferred from the coat onto the carcase as the hide is removed. Pigs, on the other hand, have a hide that is edible and that features a sparse coat of hair, so it is retained on the carcase during processing. A series of heating and abrasive treatments, including scalding, dehairing, washing, singeing and polishing, are applied to the hide to reduce the persistence of physical and microbiological contaminants [10]. Under certain circumstances, these steps can fail to remove flora from the hide, and paradoxically, provide opportunities for the accumulation of organic matter and the transference of high levels of microbes from equipment onto carcases. A concerted effort is required to monitor these steps to ensure that practices are effective, and the processing environment is maintained to achieve the greatest level of hygiene practicable.

6.3 Carcase hygiene in context of others' findings

There is contemporaneous Australian research against which findings from this study can be compared. A study performed in domestic abattoirs in New South Wales in 2007 observed SPCs and *E. coli* at counts (log^{10} CFU/cm^2) of 2.21 and -0.61, respectively, on cattle carcases, and 2.40 and -0.06 on sheep carcases, and 2.81 and -0.23, respectively, on pig carcases [11]. A similar study performed in South Australia in 2002 reported SPCs and *E. coli* at counts (log^{10} CFU/cm^2) of 1.82 and -0.34, respectively, on cattle carcases, and 2.59 and 0.27, respectively, on sheep carcases [12]. In all cases, the results reported here in this study are marginally lower than those reported in the literature cited above. Several other Australian studies have been completed using different sampling and testing parameters to those applied here, in some cases, to allow results

to be placed into context with data generated by monitoring programs required by international trade partners, such as the United States. This complicates comparisons with the results reported here. Nevertheless, the results reported here are congruent with results published by others [6, 13, 14]. This is noteworthy as these other studies were performed in export registered abattoirs, which feature constant oversight from government veterinary inspectors and typically employ decontamination steps such as hot water rinsing, steaming and acid rinsing to reduce microbiological loads on carcases [15]; none of which occur at any domestic abattoirs in Queensland.

6.4 Food safety management systems

There was similarity in the food safety management systems between abattoirs. This extended to processes and food safety controls. However, there were marked differences in the approaches used to monitor and verify the performance of each system. All abattoirs appear to be adequately monitoring control points essential to food safety, such as antemortem and post-mortem dispositions and chiller and carcase temperatures. However, relatively few are utilising electronic monitoring of chiller and carcase temperatures and only just over half are performing carcase hygiene testing. On top of this, data is predominantly captured in a manual, analogue fashion, making it difficult to appreciate performances over time. The industry may benefit if abattoirs were to adopt a more sophisticated, standardised approach to capturing and analysing monitoring and verification data. This would allow data that is largely already collected by all abattoirs to be put to work to inform decision making.

6.5 Digital transformation and potential benefits for industry

Previous work performed by Safe Food with the poultry and egg industries has highlighted the benefits to food safety management systems by routinely gathering, recording and analysing system monitoring data at key steps along the processing chain, in addition to regularly verifying performance through scientific testing of product. Such work has helped to drive desirable behaviours, resulting in improved food safety outcomes, across all levels of personnel within these industries. Developing and implementing these systems in collaboration with Safe Food and competing businesses has helped to improve relationships and bidirectional information-sharing. It is likely that greater compliance, efficiency and food safety outcomes could be achieved by domestic red meat abattoirs if they too were willing to work in partnership with Safe Food to implement an information-sharing initiative focussing on key indicators of process control and hygiene. Such indicators could include:

- information borne out of visual carcase hygiene inspections at strategic points along the processing chain, prior to distribution;

- data from electronic loggers monitoring chiller performance and verifying carcase cooling rates; and
- records from carcase hygiene testing verifying the performance of the overall system.

For this option to alter food safety behaviours, the system would need to be developed in consultation with industry, to identify agreed targets and alerting specifications, provide meaningful feedback in an expedient way, and be of minimal impost to both industry and Safe Food.

6.6 Industry dynamics

There has been much consolidation in the Queensland red meat industry in recent years. The number of domestic abattoirs has decreased by nearly 10% since 2011 and the vast majority of livestock are now processed by just five abattoirs. Market pressures arising due to sustained dry weather in eastern Australia contributed to the recent closure of a very large, domestic abattoir in South East Queensland that formerly processed up to 150,000 cattle per year. While the resulting surplus of stock has, for the most part, been absorbed by export registered facilities, the closure has placed increased pressure on nearby domestic abattoirs and some of these may be operating at or above a sustainably safe capacity. To ensure the increased throughput of stock does not impact on food safety outcomes, these abattoirs have been advised to consider enhancing the frequency of monitoring and verification measures, increasing personnel and cross-training a greater proportion of personnel in essential roles (e.g. quality assurance, meat safety inspection, production management), expanding facilities and investing in more effective and efficient equipment.

6.7 Future work in this space

This study was robust in that it covered almost all operating domestic red meat abattoirs in the state and employed a sampling regime that accounted for the abundance of each species being processed and each abattoir's throughput at the time of commencement. It also allowed for the comparison of data collected during two other studies performed by Safe Food over the past decade. However, inferential statistical were precluded by the relatively small number of samples, and single sampling occasion, per abattoir. This limited the study's ability to account for the natural variation of each abattoir's performance within and between days and seasons. Opportunities for improving future studies might include:

- focussing the sampling plan on a smaller, representative sample of abattoirs so that greater numbers of carcases can be tested;
- expansion to capture carton meat as a way of measuring performance during deboning at abattoirs or by secondary processors;
- expanding the cohort of microbiological tests to consider the presence of other faecal indicators such as thermotolerant coliforms or Enterobacteriaceae; and

- ensuring that census questionnaires are completed onsite by Safe Food.

6.8 Conclusions

The work performed in this study provides a valuable, up-to-date foundation of knowledge regarding the operation of food safety controls in red meat abattoirs in Queensland that supply solely to the domestic market. It revealed that abattoirs demonstrate a very high level of compliance with food safety legislation and that carcase hygiene is generally well managed, but improvements could be made by promoting a uniform set of measures to verify controls and establish a data-sharing initiative. This work has assisted Safe Food to engage with Queensland red meat abattoirs to improve awareness of microbiological hazards and created information necessary to inform ongoing regulatory discussions and policy decisions to ensure public health outcomes and industry prosperity.

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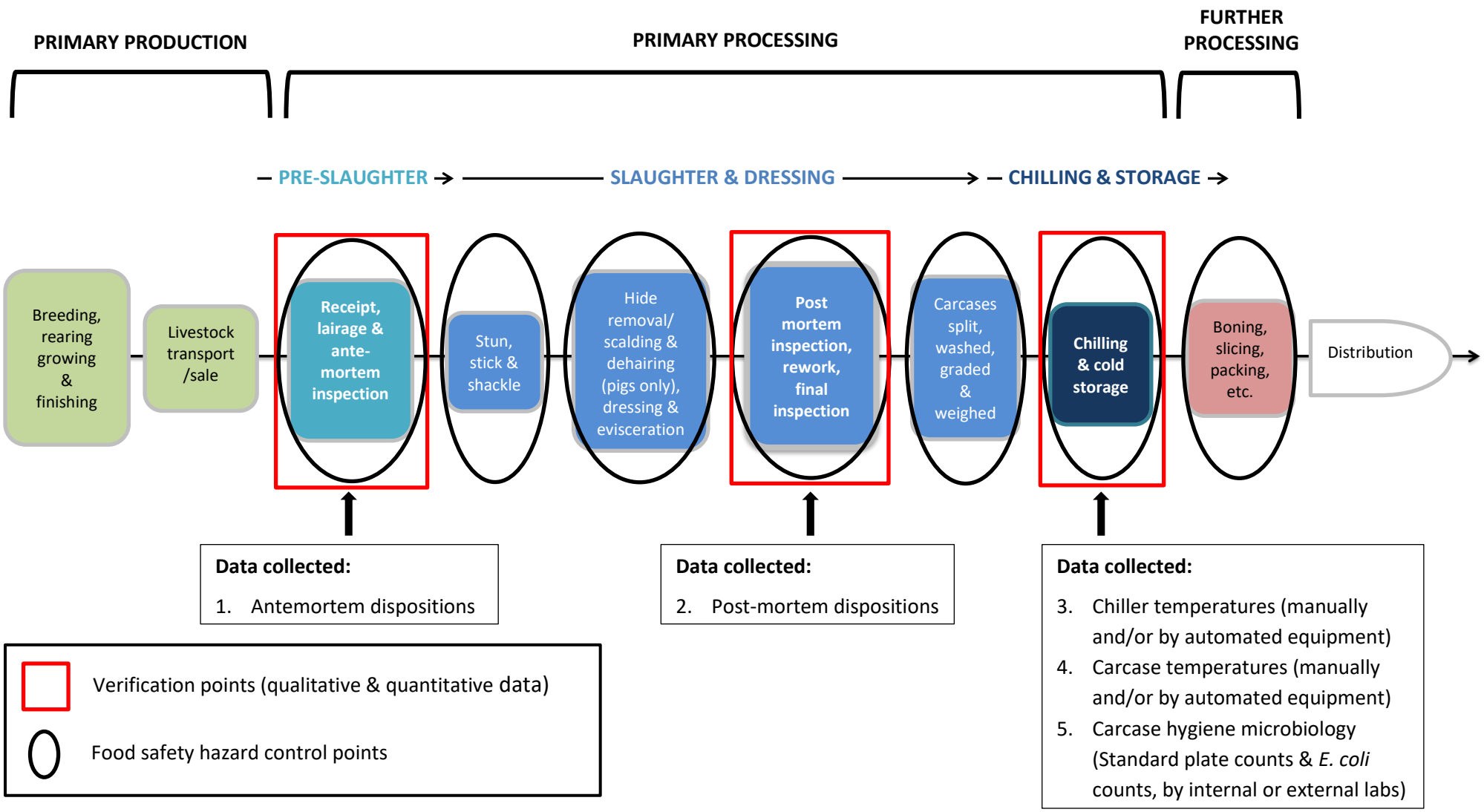
8 Appendix A: Simplified red meat supply chain (with control and verification points)



9 Appendix B: Descriptive statistics for standard plate counts (CFU/cm^2) on cattle, sheep and pig carcases sampled in 2007, 2011 and 2018

	2007			2011			2018		
	Cattle (n=84)	**Sheep (n=55)**	**Pig (n=50)**	**Cattle (n=138)**	**Sheep (n=67)**	**Pig (n=103)**	**Cattle (n=67)**	**Sheep (n=72)**	**Pig (n=123)**
Mean	2.337731692	3.242588157	2.584964163	1.700377716	2.424710203	1.933785899	1.225383499	2.30018574	2.581014371
Minimum	0.903089987	0.897627091	0.903089987	0.903089987	0.903089987	0.698970004	-0.080921908	-0.080921908	-0.080921908
Quartile 1	1.204119983	2.176091259	1.903089987	1.113943352	1.763427994	1.113943352	0.51851394	1.799340549	1.763427994
Median	2.060286966	3.556302501	2.42378633	1.641650614	2.301029996	1.944482672	1.255272505	2.380211242	2.62324929
Quartile 3	3.071578182	4.146128036	3.281886338	2.121989523	2.86332286	2.556302501	1.77815125	2.915913949	3.447158031
Maximum	5.380211242	5.342422681	4.602059991	4.579783597	4.662757832	4.113943352	4.397940009	5	5.447158031

10 Appendix C: Descriptive statistics for *E. coli* counts (CFU/cm^2) on cattle, sheep and pig carcases sampled in 2007, 2011 and 2018

	2007			2011			2018		
	Cattle (n=84)	**Sheep (n=55)**	**Pig (n=50)**	**Cattle (n=138)**	**Sheep (n=67)**	**Pig (n=103)**	**Cattle (n=67)**	**Sheep (n=72)**	**Pig (n=123)**
Mean	-0.897048911	-0.017199828	-0.759570098	-0.998892025	-0.608543428	-0.992054758	-0.962914992	-0.404846653	-0.869273116
Minimum	-1.096910013	-1.096910013	-1.096910013	-1.301029996	-1.096910013	-1.301029996	-1.080921908	-1.080921908	-1.080921908
Quartile 1	-1.096910013	-1.096910013	-1.096910013	-1.096910013	-1.096910013	-1.096910013	-1.080921908	-0.48148606	-1.080921908
Median	-1.096910013	-0.318758763	-1.096910013	-1.096910013	-0.48148606	-1.096910013	-1.080921908	-0.48148606	-1.080921908
Quartile 3	-1.096910013	0.897627091	-1.096910013	-0.886056648	-0.48148606	-0.886056648	-0.886056648	-0.48148606	-0.602059991
Maximum	2.204119983	3	2.851258349	1.176091259	1.995635195	1.380211242	-0.602059991	0.903089987	0.079181246