final report

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Pilot Risk-based evaluation of disposition judgement criteria for peri-acute pneumonia complex of lot-fed cattle

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Abstract

An unexplained increase in total carcase condemnations due to bovine respiratory disease (BRD) and associated pathology in feedlot cattle was investigated. There was uncertainty over many of the total carcase condemnations due to interpretation of the presenting gross pathology. Bacteriological examination of the main respiratory pathology, lymph nodes and muscle to determine if the carcases were septicaemic or a food safety risk (i.e. presence of *Salmonella*) was undertaken on 18 condemned carcases. The low rate of isolation of BRD agents only from respiratory abnormalities of target carcases supports the contention that they weren't septicaemic at slaughter as lymph nodes and muscle were culture negative for all carcases. Reactive lymph nodes were also found to be a poor surrogate for current active infection in these affected carcases. Interventions (i.e. stripping membranes) followed by re-inspection demonstrated most of the disputed carcase dispositions resulted in being judged as 'suitable' on reinspection. *Salmonella* was not isolated from any carcase. Although a pilot study, these results indicate that while many of these carcases have multiple chronic gross abnormalities these represent resolved infections. Partial trimming can achieve carcase suitability at no greater risk, and if considered necessary supported by a bacteriological test-and-hold arrangement conducted under government supervision, thereby minimising wastage.

Executive Summary

The problem

The carcase condemnation rate for lot-fed beef cattle processed in a southern NSW beef plant escalated atypically over the first three months of 2016 when compared to the previous two years. The main reason for total carcase condemnation was peri-acute pneumonia complex (i.e. pneumonia, pleurisy and associated abnormalities such as peritonitis and polyarthritis). There was uncertainty over some of the condemnations arising around differentiation of acute from chronic or resolving lesions, the interpretation of reactive lymph nodes, the significance of multiple abnormalities and the reliability these organoleptic assessments as indicators of septicaemia at slaughter. Anecdotal reports indicate cattle from the same feedlots processed at other plants were not being condemned at the same rate, although the prevalence of the peri-acute pneumonia resulting from Bovine Respiratory Disease (BRD) appeared to be the same. When taken together, the criteria for final disposition judgments was queried and a better understanding of the pathophysiology of the peri-acute pneumonia and its relationship to appropriate carcase disposition was sought.

Project objectives

Conduct a risk-based assessment of criteria and effect of potential interventions on carcases affected with peri-acute pneumonia complex. The key technical questions addressed were:

- **determining the relationship between the type and severity of gross pathology and microbiological status of the carcase;**
- **evaluating whether interventions were suitable for potentially condemned carcases; and**
- **determining the food safety and suitability status of affected carcases, to better inform disposition judgement.**

Approach

The target case was defined as an animal that passed antemortem inspection and that at routine post mortem inspection showed signs of peri-acute pneumonia, with or without associated abnormalities elsewhere in the carcase (e.g. peritonitis), which may warrant "*the carcase and all its carcase parts condemned*" (Schedule 3; Anon 2007).

A literature review of BRD, its pathology and associated bacterial aetiologies was conducted to support the design of the risk-based assessment.

The selection and allocation of condemned carcases to "Investigate" and "Fail" study groups followed a two-step process. Firstly, the Department of Agriculture and Water Resources Inspector and On Plant Veterinarian determined an official disposition of total carcase condemnation as part of routine inspection. Secondly, from these, the project team allocated carcases into two groups for microbiological assessment and evaluation of the effect of carcase interventions. The two groups comprised 13 "Investigate" carcases and five "Fail" carcases as follows:

- **"Investigate" carcases - 13 carcases that were typical of what had been totally condemned to date but where uncertainty remained i.e. principally resolving or chronic peri-acute pneumonia with/without gross abnormalities at multiple sites.**
- **"Fail" carcases - five carcases that were very severely affected, including signs of fever, malodour, abscessation of the carcase (i.e. grounds for condemnation not in question) i.e. a positive control group where no uncertainty remained.**

The main respiratory abnormality, prescapular lymph node and muscle tissue were cultured for the likely primary bacterial pathogens of BRD and *Salmonella* spp. to determine whether carcases were septicaemic and whether they presented a food safety risk. All carcases in both groups were subjected to partial trimming to assess whether this resulted in carcases being suitable for consumption. Data on gross abnormalities, isolation of primary pathogens and results of interventions were analysed on an individual carcase basis to determine key associations that might better inform final disposition judgment.

Key results and implications

Gross abnormalities typical of primary BRD were evident in all of the carcases assessed. The majority of these were accompanied by peritonitis and in the severe "Fail" group cases by malodour, cachexia and abscessation. The microbiology was consistent with this pathology as primary agents were isolated from 60% of five "Fail" carcases. In comparison, the pathogen positive rate of 8% of thirteen carcases was significantly lower in the "Investigate" group.

***Histophilus somni* and *Trueperella pyogenes* were isolated direct from lung lesions of "Fail" carcases. *Streptococcus uberis* was isolated by both direct and enrichment culture of the lymph node sample of one "Fail" carcase, most likely associated with footrot. *Pasteurella multocida* was isolated from the lung of one "Investigate" carcase.**

BRD agents were only isolated from ~~major~~ respiratory abnormalities and not from lymph nodes and muscle of carcases which supports the contention that these carcases were not actually septicaemic at slaughter.

Analysis on an individual carcase basis found that the positive predictive value (PPV) of a carcase being culture positive when it had reactive lymph nodes was 18%, i.e. they are a poor surrogate for current active infection in these affected carcases. Further support of this finding is that reactive lymph nodes were not significantly associated with "Investigate" or Fail" carcase groups. Consequently, reliance on reactive lymph nodes as a criterion for carcase condemnation (i.e. active systemic infection) will result in substantial and unnecessary carcase wastage. Equally, animals without reactive lymph nodes that should be condemned could be passed indicating that caution should be placed on the weight given to reactive lymph nodes.

All 18 carcases were subjected to interventions, mostly stripping of pleura and the parietal peritoneal lining, where indicated. When re-inspected the disposition of all "Fail" carcases remained unchanged, whereas all "Investigate" carcases were judged as suitable.

The finding that *Salmonella* spp. was not isolated from any site for either group further supports the interpretation these gross abnormalities and carcases do not present a food safety risk.

While the food safety risk of *Staphylococcus aureus* isolated from gross abnormalities is not attributed to foodborne illness (reviewed in Section 9.1), the isolation of *S. aureus* from carcases in this project enabled further evaluation of their significance. There was no significant difference in the *S. aureus* positive rate between the two groups and isolates were only from enrichment culture of lymph nodes which is consistent with very low numbers being present. On this basis, these *S. aureus* isolates most probably represent passing lymph node flora of lot-fed cattle.

Recommendations

It is proposed that *Peri-acute pneumonia* in Schedule 3 is either deleted and replaced by more detailed description for carcases where the disposition is uncertain, and/or that the national training material and supporting work instructions are amended in all jurisdictions, so that they reflect the research i.e. interventions for component gross abnormalities, re-inspection and test and hold under government supervision, if considered necessary.

The changes are recommended to be based on those outlined in Fig. 3. These are consistent with HACCP principles as carcases initially monitored as not meeting “Critical Limits” have interventions applied (i.e. re-work) and are followed by re-inspection to determine if they fall within “Critical Limits” i.e. suitable after partial condemnation (trimming).

It is recommended that on acceptance of this Final Report by MLA it should be submitted to the Australian Meat Regulators Group for consideration of either changing AS4696 (Anon 2007) or amending training material and jurisdictions work instructions accordingly.

Benefits and Implications

This work demonstrates the value of microbiological data to better inform the interpretation of gross abnormality observations thereby enhancing the reliability of determining carcase disposition. On the basis of the concordance of these results in identifying carcases to investigate, microbiological testing and effectiveness of interventions, it is recommended that enhanced disposition criteria be developed for “Investigate” carcases where they are held while test results can be obtained i.e. hold and test for evidence of current active infection and/or food safety hazards as undertaken in this risk-based assessment.

This approach provides a safeguard to revising the disposition to partial condemnation for up to 90% of “Investigate” carcase (i.e. disposition uncertain) that would have no greater risk when re-classified as suitable. By adopting this precautionary approach not all “Investigate” carcases will be judged as suitable. However, the approach delivers a positive risk-benefit with reduced wastage and improved social benefits (i.e. consumer

credence values such as animal life/benefit, environmental sustainability) at no greater risk.

Although only a pilot study, these results provide proof of concept for the principle that while many of these carcases have multiple chronic gross abnormalities these represent resolved infections and can be trimmed to achieve carcase suitability at no greater public health risk.

While the proposed enhanced disposition criteria for carcases are not a cure, there is no gain in enhancing production and clinical management at the feed-lot if there is no change at the abattoir to criteria used to inform disposition judgement for these uncertain cases. The cost of test and hold, while incremental when compared to full carcase value, is still sufficient to provide signals back to suppliers to apply necessary preventative and control measures; there is no encouragement given to delivery of unsuitable livestock for processing.

Further research

As 39% of the condemned carcases had not been "pulled" and treated for BRD these findings should be reviewed by consulting animal health providers in relation to determining the threshold for group therapy based on individual animal treatment rates within a lot and/or enhancement of induction processes.

The project did not record the proportion of "Investigate" versus "Fail" carcases presenting on a throughput basis. A prospective study would be required to fully quantify full benefits of the alternative arrangements i.e. to determine the true total carcase condemnation rate and the proportion that might be salvaged.

Acknowledgements

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1 Background

1.1 Purpose

This project aims to validate alternative risk-based disposition judgment and potential interventions for gross abnormalities of *AS4696 Schedule 3,3.3. Respiratory system and 3.4 Pleura* (Anon 2007) for consideration by the Australian Meat Regulators Group for (lot fed) cattle.

1.2 Significance to industry

The carcase condemnation rate for lot-fed beef cattle processed in a southern NSW beef plant escalated atypically over the first three months of 2016 when compared to the previous two years. The main reason for total carcase condemnation was peri-acute pneumonia complex (i.e. pneumonia, pleurisy and associated abnormalities such as peritonitis and polyarthritis). There was uncertainty over some of the condemnations arising around differentiation of acute from chronic or resolving lesions, the interpretation of reactive lymph nodes, the significance of multiple abnormalities and the reliability of these organoleptic assessments as indicators of septicaemia at slaughter. Anecdotal reports indicated cattle from the same feedlots processed at other plants were not being condemned at the same rate (Figs. 1, 2), although the prevalence of the peri-acute pneumonia resulting from Bovine Respiratory Disease (BRD) appeared to be the same. When taken together, industry also queried many of the final disposition judgments and sought to develop a better understanding of the pathophysiology of the peri-acute pneumonia complex (i.e. pneumonia, pleurisy and associated abnormalities such as peritonitis and polyarthritis) and its relationship to appropriate carcase dispositions.

Beef carcases, particularly feedlot derived, can be worth $1800 or more. Wagyu carcases could be worth upwards of $5000 each. The project evaluated interventions within a HACCP framework to validate more definitive disposition judgements that provide equivalent food safety and suitability.

The lot fed veterinarians informed Teys that the health of the animals being turned off this year were at least equal to, if not better than, the previous two years, over the same time period. This was supported by weight gains in the carcases that had been passed.

The raised incidence of total condemnation at this establishment provided the opportunity to obtain cases for a systematic investigation of criteria used for disposition judgment of peri-acute pneumonia judgements.

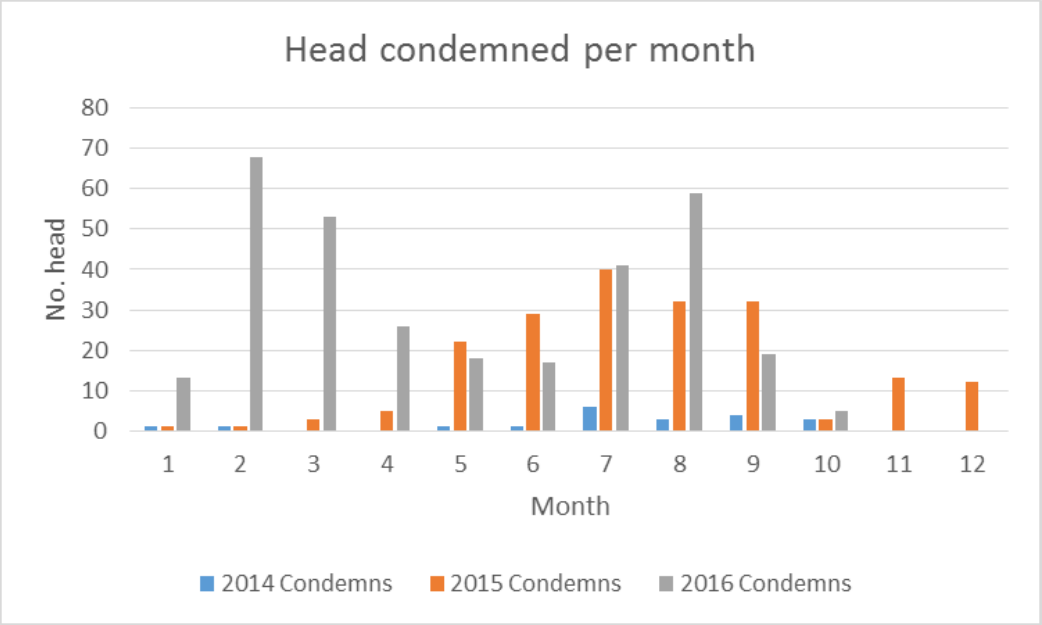

Fig 1. Number of carcases condemned on a monthly basis for 2014-2016

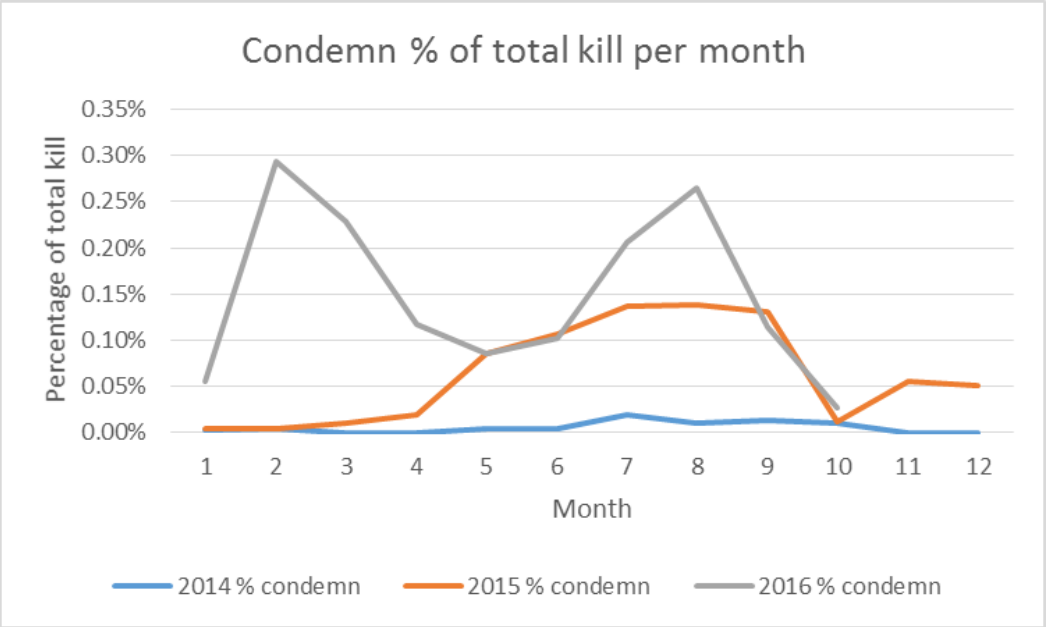

Fig 2. Total carcase condemned rate on a monthly basis for 2014-2016

The other aspect is that BRD will be having an effect on productivity (reduced growth, treatment costs) on the feedlot. There was focus on that aspect (i.e. estimating the rate of affected animals not “pulled”) with the information from this project feeding into a subsequent project on animal health surveillance along the same supply chains that will look to increase productivity by better reacting to the information on total and partial condemnation from the abattoir.

1.3 Risk-based approach

The approach undertaken is based on Codex Risk Assessment principles (Anon 1999) that underpin the Code of Hygienic Practice for Meat (Anon 2005). The Code lays the foundation for modernisation of meat safety risk management across the supply chain. This includes carcase inspection and disposition judgments having greater emphasis placed on public health risk.

The broad approach undertaken follows a systematic evaluation of risk which focuses on:

- Hazard Identification (what foodborne 'Hazards are likely to be present')
- Hazard Characterisation (severity of illness caused)
- Exposure Assessment (amount of Hazard in edible carcase tissues at the point of chilling as an indicator of risk)
- Recommending validated inspection:intervention:disposition judgment processes (disposition judgment commensurate with risk on a carcase-by-carcase basis).

Factors that determine final product status are examined as well as the effectiveness of present and alternative post-mortem inspection 'control measures' i.e. partial trimming to achieve suitability.

Results of related Australian and North American studies on BRD (Confer 2009; Hay et al 2014; 2016) and the microbiological status of lymph nodes (Cobbold 2009; MLA 2015) are utilised to provide methods and context for interpretation of results.

In summary, eighteen beef carcases condemned for respiratory related conditions (i.e. peri-acute pneumonia) were examined in detail including reasons for condemnation, treatment history and microbiological status i.e. current infection, septicaemia and *Salmonella* status of gross abnormalities, lymph nodes and edible muscle.

A literature review of Bovine Respiratory Disease Complex (BRD) in Australia is included to identify and characterise the Hazards related to the disease causative organisms. Information from the National Bovine Respiratory Disease Initiative project (Hay et al 2014, 2016) is included as appropriate (Section 9.1).

This report presents risk-based information that enables consideration of alternative arrangements for determining disposition judgments for 'Diseases and other abnormalities' of the '*Respiratory system*' and '*Pleura*' of beef carcases (Anon 2007, Schedule 3).

2 Project Objectives

2.1 Conduct a risk-based assessment of criteria and potential interventions to better inform disposition judgment of carcases affected with peri-acute pneumonia.

Technical information reviewed as background to conduct this assessment includes:

- the microbiological aetiologies of Bovine Respiratory Disease in Australia;
- pathological description of abnormalities reflecting the respiratory disease agents involved; and
- any association with foodborne hazards.

The key technical questions addressed to better inform disposition judgment were determining;

- the relationship between the type and severity of gross pathology and microbiological status of the carcase;
- whether interventions achieve suitability for potential condemned carcases; and
- the food safety status of affected carcases.

3 Methodology

3.1 Risk-based review of Bovine Respiratory Disease (BRD)

A literature review of BRD, its presentation at slaughter and current inspection/disposition outcomes within the Codex Alimentarius Commission microbiological risk assessment format (Anon 1999) is provided in Section 9.1. This provides the scientific rationale for the carcase evaluation methodology presented in Section 3.2.

3.2 Carcase evaluation

3.2.1 Selection of carcases – case definition

The definition of the case is that at routine inspection a carcase showing signs of peri-acute pneumonia, with or without associated abnormalities elsewhere in the carcase (e.g. peritonitis, fever), warranted "*the carcase and all its carcase parts condemned"* (Schedule 2; Anon 2007).

The selection and allocation of condemned carcases to "Investigate" and "Fail" study groups followed a two-step process. Firstly, the Department of Agriculture and Water Resources Inspector and On Plant Veterinarian determined an official disposition of total carcase condemnation as part of routine inspection.

Secondly, from these, the project team allocated carcases into two groups for microbiological assessment and evaluation of the effect of carcase interventions. The two groups comprised 13 "Investigate" carcases and five "Fail" carcases as follows:

- **"Investigate" carcases - 13 carcases that were typical of what had been totally condemned to date but where uncertainty remained i.e. principally resolving or chronic peri-acute pneumonia with/without gross abnormalities at multiple sites.**

- **"Fail" carcases - five carcases that were very severe, including signs of fever, malodour, abscessation of the carcase (i.e. grounds for condemnation not in question).** These were selected to provide a "positive control" group i.e. most likely to be septicaemic and having active, systemic pathology from which BRD-associated bacteria were most likely to be isolated from carcase abnormalities and systemically.

Carcases were selected on a convenience basis among those totally condemned at routine official post-mortem inspection. Consequently, they do not represent the proportional rates of "Investigate" and "Fail" carcases processed.

Carcases were selected independently of feedlot source.

The individual health history, including antibiotic treatment or not, was unknown to the inspectors or the study team at the time of official inspection and allocation into the two study groups.

3.2.2 Clinical indicators

The clinical history of cases was not used as a determinant in the selection of carcases evaluated. This was obtained once the carcase had been identified at inspection as meeting either study group definition for evaluation. Data subsequently obtained focused on whether the animal had been “pulled” and treated for respiratory BRD and whether participating feedlots routinely vaccinate for BRD at induction.

3.2.3 Pathology recording

Components of all pathology were entered on the carcase record sheet (Section 9.1). The emphasis here was to capture accurate descriptions to enable assessments as being localised/systemic and acute/chronic. This was deemed to be more informative for determining disposition judgments than the over-arching pathology ‘diagnosis’ i.e. peri-acute pneumonia.

Other pathology not immediately associated with BRD was also recorded. This required a full carcase examination on the retain rail.

All carcases were fully re-inspected for abnormalities by an experienced inspector or On Plant Veterinarian (OPV) on the retain rail after trimming to record the result of the intervention(s).

Reasons for condemnation were copied from the official records of the OPV (Table 2).

3.2.4 Revised inspection, effectiveness of interventions and disposition

The revised inspection:intervention:disposition judgment process on affected carcases in the retain area is outlined in Fig. 3. This revised inspection process follows HACCP principles. Carcases not meeting Critical Limits (i.e. no visual gross abnormalities) were subjected to interventions (re-worked) and then re-inspected to ensure carcases were within Critical Limits i.e. suitable or not.

All carcases identified for total condemnation were worked-up in this manner on the retain rail. The interventions comprised stripping of the pleura, followed by resection of affected ribs if needed. The parietal peritoneum was similarly stripped to remove signs of localised abnormalities, if appropriate.

Sequential photographs to record this process for each carcase consisted of:

- the carcase as a whole
- the main thoracic pathology
- any non-thoracic pathology e.g. peritonitis
- the affected (rib) area after stripping of the pleura and/or parietal peritoneum (after intervention 1 Fig. 3)
- the affected (rib) area after resection of ribs if required (hyperaemic after pleura removed (after intervention 2 Fig. 2)
- abdominal cavity after peritoneum stripped.

This enabled an assessment of the effectiveness of each intervention in achieving the visual Critical Limit i.e. grossly classified as suitable.

3.2.5 Microbiology

Samples

Three samples were collected from each affected carcase including:

- The main respiratory lesion e.g. adhered lung lobe, abscess, or swab of free pus, sero-fibrinous exudate from each carcases i.e. one sample of main gross abnormality.
- One lymph node (pre-scapular), uncut where possible, from each affected carcase along with surrounding fat.
- Flexor muscle on foreleg (5cm^3).

These were immediately chilled to 4°C and transported to the lab for culture as soon as practical.

All samples were coded with an individual carcase ID.

The rationale for sampling the prescapular lymph node is to pick up active septicaemia in a peripheral lymph node, as opposed to culturing a lymph node associated with organs (e.g. gastrointestinal tract) that drain sites that are otherwise healthy but contaminated with foodborne hazards (e.g. Salmonella).

Sample preparation and bacteriological culture

All gross abnormality, lymph node and muscle samples were cultured (and identified) for *Mannheimia haemolytica, Pasteurella multocida, Histophilus somni*, *Staphylococcus aureus, Streptococcus zooepidemicus* and *Salmonella* spp. Standard aerobic cultures utilised for these organisms were Chocolate, Columbia Sheep Blood, MacConkey and Columbia-CNA agars (all commercially prepared by MicroMedia). Lymph nodes and muscle samples were also cultured for *Salmonella*.

Lung lesion samples were surface sterilised by heat searing, then opened with a sterile scalpel, gently internally macerated and then sampled using a sterile swab (all performed inside a Class II Biosafety Cabinet). The culture plates listed above were then immediately inoculated.

Lymph nodes were cultured for ~~for~~ BRD pathogens and *Salmonella* by decontaminating nodes by immersion in boiling water for 3-5 seconds prior to emulsification for culture. Buffered peptone water (BPW) was added to weighed node samples to create approximately 1:10 (w/v) dilutions (2.5 g in 25 ml) and homogenised. Node homogenate was pre-enriched in BPW overnight and inoculated into each of tetrathionate broth, Rappaport-Vassiliadis (RV) broth, and mTSB broth. Enrichments from tetrathionate and RV broths were inoculated onto xylose lysine desoxycholate (XLD) and brilliant green agar plates. Following overnight culture, suspect *Salmonella* colonies from each plate were subjected to standard biochemical testing

(lysine, urease, triple sugar iron agar) for *Salmonella* confirmation. *Salmonella* isolates were stored for possible serotyping.

Muscle samples were prepared by heat searing to decontaminated surfaces. The outer surfaces were removed aseptically and a 2.5 g sample resected (all performed inside a Class II Biosafety Cabinet), placed into 25 ml of BPW and homogenised. Overnight incubated homogenate was then used at a 1:10 to inoculate tetrathionate broth, Rappaport-Vassiliadis (RV) broth and mTSB broth. Enrichments from tetrathionate and RV broths were then inoculated onto xylose lysine desoxycholate (XLD) and brilliant green agar plates for *Salmonella* investigation.

Salmonella culture was performed on both lymph node and muscle biopsy enrichments. Enrichment broths showing evidence of growth were plated for isolation of BRD or other possible primary pathogens.

3.2.6 Statistical methods

Analysis of the relationship between carcase groups with (1) reactive lymph nodes, (2) culture positive for a primary pathogen; and (3) culture of *Staphylococcus aureus* was performed by exact unconditional logistic regression, treating each group total as fixed by the study design (Lydersen at al 2009).

Analysis of the relationship between reactive lymph nodes and culture positive for a primary pathogen was performed by exact conditional logistic regression reporting mid-P values; stratifying on carcase (matched pairs analysis) and again mid-P values were reported.

All analyses were performed using Stata V14.2.

3.2.7 Pathophysiology of Bovine Respiratory Disease

The continuum of clinical signs, gross abnormalities and microbiology of BRD from acute infection through to localisation of the pathology leading towards resolution with or without sequelae has been developed for this project to provide a wider set of criteria for making disposition judgments for this condition (Table 7).

The time period for each stage will vary considerably from animal to animal and will be further influenced by the effectiveness of treatments.

The microbiological stages provide a framework for interpretation of bacteriological results obtained in this investigation.

Carcases at slaughter are predominantly at the resolving or chronic stage. The framework is intended to better define the number of carcases where there is uncertainty with regards to final disposition judgment.

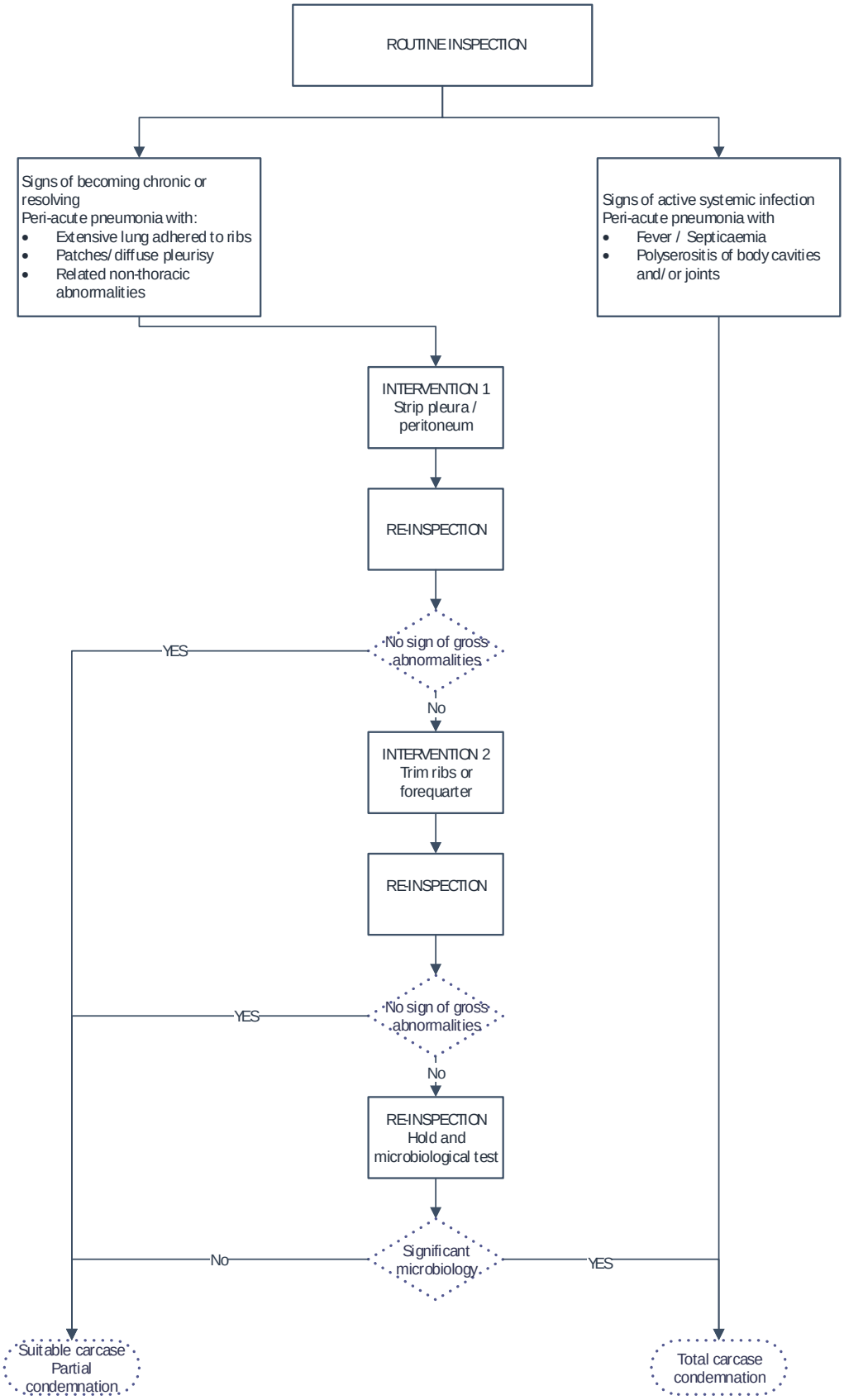

Fig 3. 'Peri-acute Pneumonia' Decision Tree: Revised Inspection/Disposition

4 Results

4.1 Carcase investigation results

4.1.1 Carcase sources and treatment history

Eighteen totally condemned carcases were sourced from four feedlots (eight from feedlot 1, six from feedlot 2 and two each from feedlots 3 and 4). All feedlots had cases in each project group.

All of the study feedlots maintain a routine vaccination program for incoming livestock to protect against *Mannheimia haemolytica* and infectious rhinotracheitis virus infection.

Of the 18 officially condemned carcases, 39% had not been “pulled” or treated with antibiotics (Table 1).

4.1.2 Gross abnormalities of carcases investigated

“Investigate” group carcases had gross abnormalities consistent with peri-acute pneumonia complex, typified by fibrous adhesions of the lung to ribs that resulted in torn lung remaining attached to ribs as a result of removing thoracic organs (Section 9.3). The extent of these varied from patches to diffuse adhesions, occurring either unilaterally or bilaterally (predominantly). Other co-existing gross abnormalities observed in order of declining prevalence included peritonitis, pericarditis and fever with the former more likely than not. Polyarthritis was not recorded in any of the carcases investigated.

“Fail” group carcases typically had a similar range of gross abnormalities to those of “Investigate” group carcases (Section 9.3); however, these had systemic abnormalities consistent with unresolved infection e.g. fever, multiple abscesses, acute peritonitis, jaundice and malodour (Tables 2).

None of the “Investigate” group carcases were condemned due to cachexia, however, cachexia was recorded for one of the “Fail” carcases as one of the reasons for total condemnation of that carcase by the OPV.

Reactive lymph nodes were not significantly associated with “Investigate” or Fail” carcase groups (p=0.21; OR=3.1; 95% CI 0.34, 35.7). In the “Fail” group, 40% did not have reactive lymph nodes recorded as part of the reason for total carcase condemnation (Tables 2, 3). The OPV recorded reactive lymph node among reasons for total condemnation in 61% of 18 carcases condemned at official inspection.

The proportional rates of carcases classified as “Investigate” and “Fail” among all routine stock slaughtered was not recorded.

4.1.3 Microbiology of lesions, lymph nodes and muscle

Histophilus somni and *Trueperella pyogenes* were isolated direct from lung lesions of “Fail” carcases. *Streptococcus uberis* was isolated by both direct and enrichment culture of the

lymph node sample of one “Fail” carcase. *Pasteurella multocida* was isolated from the lung of one “Investigate” carcase.

The primary pathogen isolation rate was significantly lower in the “Investigate” carcase group compared to the “Fail” group (p = 0.023; OR: 0.07, 95% CI 0.002, 0.96) (Table 4). The primary pathogen isolation rate for the “Investigate” carcases group compared to the “Fail” group was 8% and 60%, respectively.

Primary BRD pathogens and *Salmonella* were not isolated from any lymph nodes or muscle samples from either the “Investigate” or “Fail” carcase groups (Tables 1, 2).

There was no significant difference in the isolation rate of *Staphylococcus aureus* between the two carcase groups (p=0.79; OR 1.7, 95% CI 0.15, 54.4) (Table 5). *S. aureus* was only isolated from enrichment cultures of pre-scapular lymph nodes (Table 2).

Salmonella spp. was not isolated from any site (lymph node or muscle) from any of the 18 totally condemned carcases (Table 2). While many of the lymph node enrichments showed evidence of growth none of the muscle BPW enrichments showed any evidence of growth (no turbidity after enrichment).

4.1.4 Comparison of reactive lymph nodes with isolation of primary pathogens

Individual carcases were significantly less likely to be primary pathogen positive than reactive lymph node positive (p=0.039; OR = 0.22, 95% CI 0.03, 0.93) (Table 6).

The positive predictive value of a carcase being culture positive for a primary pathogen when it had reactive lymph nodes was 18%.

4.1.5 Effect of interventions on initially condemned carcases

All of the “Investigate” carcases were classified by re-inspection (Fig. 3) as suitable after stripping of the pleura and the parietal peritoneum, where needed (Table 1).

None of the carcases originally classified as “Fail” were considered suitable after partial trimming (Tables 1, 7).

4.2 Risk-based disposition judgment of carcases

4.2.1 Relationship with initial official disposition judgment

Assessment of the 13 “Investigate” carcases using the infection continuum framework (Table 7) resulted in:

- one carcase (C5) where total condemnation was supported by presence of signs of active infection even though stripping of membranes was judged effective

- two carcases (A2, C6) remaining uncertain after effective stripping of membranes due to remaining BRD infection and possibly remaining polyserositis (conservative determination), respectively, and
- 10 carcases judged as suitable after partial trim interventions.

For the 5 carcases classified as “Fail” this disposition was supported by results obtained.

Table 1. Effect of interventions on 18 carcases totally condemned by official inspection due to peri-acute pneumonia and related gross abnormalities

Carcase group classified by industry	n	Effect of intervention(s)		Treatment status[3]		Reactive Lymph Nodes[4]		Bacterial pathogen[5]		*Staphylococcus aureus*[6]		Carcase *Salmonella* spp[7]		Verified Risk-based disposition[8]	
		Suitable	Condemn	Treated	Nil	+ve	-ve	+ve	-ve	+ve	-ve	+ve	-ve	Suitable	Condemn
"Investigate" carcases[1]	13	13	0	8 (62%)	5 (38%)	9 (69%)	4 (31%)	1 (8%)	12 (92%)	4 (31%)	9 (69%)	0	13	12	1
"Fail" carcases[2]	5	0	5	3 (60%)	2 (40%)	2 (40%)	3 (60%)	3 (60%)	2 (40%)	1 (20%)	4 (80%)	0	5	0	5

[1] Totally condemned carcases where disposition investigated i.e. Typical of peri-acute pneumonia +/- related gross abnormalities
[2] Totally condemned carcases where disposition not investigated i.e. Severe extension of gross abnormalities and signs of active infection
[3] Treated with antibiotics as a result of being "pulled" due to ill health
[4] Reactive lymph nodes recorded by OPV as part of reason for total carcase condemnation
[5] Isolation of a recognised primary bacterial pathogen of cattle from any sample site (excluding *S. aureus*)
[6] Detection of *S. aureus* in enrichment media of pre-scapular lymph node
[7] *Salmonella* spp. culture result for all sites/carcase i.e. thoracic lesion, LN and muscle of each carcase
[8] Revised risk-based disposition taking effect of interventions and microbiological evidence into account

Table 2. Results of risk-based assessment on an individual carcase basis for 18 totally condemned carcases

Feedlot/ animal ID	Feedlot health treatments	Main pathology	OPV Reason for condemnation	Rework 1 (Pass/Fail)[1]	Rework 2 (Pass/Fail)[1]	Microbiology		
						Main respiratory abnormality	Prescap lymph node	Meat
"Investigate" carcase group								
A1	Nil	Pleurisy/Peritonitis	Peritonitis (esp left side rumen & left abdominal wall) pleurisy, carcase lymph nodes inflamed.	Pass	N/A	No growth (5 days)	Direct: No growth (5 days); Enrich: Heavy mixed growth including coliform, *Staphylococcus* sp. (coagulase neg.) and Streptococcus sp. (α-haemolytic); no BRD pathogens; no *Salmonella* isolated.	No growth (5 days); no *Salmonella* isolated
A2	Multiple treats. Draxxin for BRD (14/5) Trisoprim for scours (16-17/5) Engemycin for BRD (29-31/5) Depocillin for lameness/injury (14-16/6)	Pleurisy/Peritonitis	Peritonitis (rumen, spleen, left abdominal wall) mild enteritis, septic pneumonia, pericarditis, lymph node involvement.	Pass	N/A	Moderate pure growth ***Pasteurella multocida***	No growth (5 days) for Direct; Enrich moderate growth mixed *Staphylococcus* sp. (coagulase negative) No bacterial pathogens for BRD; no *Salmonella* isolated.	No growth (5 days); no *Salmonella* isolated
A3	Multiple treats. Micotil 6/6 & Accent 10-12/7 for BRD.	Pleurisy/Peritonitis	Peritonitis (rumen, left abdominal wall) pneumonia, generalised fibrinous pleurisy, lymph nodes inflamed.	Pass	N/A	No growth (5 days)	No growth (5 days) for Direct; Enrich light mixed growth inc. ***Staphylococcus aureus***; no *Salmonella* isolated.	No growth (5 days); no *Salmonella* isolated
A4	Multiple treats. Micotil 19/5 & Engemycin 2-4/6 for BRD	Pleurisy/Peritonitis	Peritonitis (rumen, left abdomen up to kidneys, right cranial abdomen & diaphragm) pleurisy, lymph nodes inflamed.	Pass	N/A	No growth (5 days)	No growth (5 days) for Direct; Enrich heavy mixed growth of *Bacillus* sp. and ***Staphylococcus aureus***; no *Salmonella* isolated	No growth (5 days); no *Salmonella* isolated

Feedlot/ animal ID	Feedlot health treatments	Main pathology	OPV Reason for condemnation	Rework 1 (Pass/Fail)[1]	Rework 2 (Pass/Fail)[1]	Microbiology		
						Main respiratory abnormality	Prescap lymph node	Meat
B1	Nil	Pleurisy/Peritonitis	Peritonitis (rumen, abomasum, spleen, liver, left abdominal wall and part of right abdominal wall, pneumonia, pleurisy, lymph-nodes hyperaemic & reactive.	Fever in RHS; resect ribs	Pass	No growth (4 days)	No growth (4 days) for Direct; Enrich heavy pure growth coliforms. No bacterial pathogens for BRD; no *Salmonella* isolated.	No growth (4 days); no *Salmonella* isolated
C1	Nil	Pleurisy/Peritonitis	Peritonitis, fever	Pass	N/A	No growth (5 days)	Direct: No growth (5 days) Enrich: Moderate mixed growth including predominant *Streptococcus* sp. (α-haemolytic); no BRD pathogens isolated; no *Salmonella* isolated	No growth (5 days); no *Salmonella* isolated
C2	Treated for BRD - Excede (early June @ high DOF)	Pleurisy/Peritonitis	Peritonitis, fever, enlarged lymph nodes	Pass	N/A	No growth (5 days)	Direct: No growth (5 days) Enrich: Heavy pure growth *Streptococcus* sp. (α-haemolytic); no BRD pathogens isolated; no *Salmonella* isolated	No growth (5 days); no *Salmonella* isolated
C3	Nil	Pleurisy/Peritonitis/Fever	Peritonitis, pleurisy, fever, carcase lymph node involvement.	Pass	N/A	No growth (5 days)	Direct: No growth (5 days); Enrich: Heavy mixed growth including coliform and *Streptococcus* sp. (α-haemolytic); no BRD pathogens; no *Salmonella* isolated.	No growth (5 days); no *Salmonella* isolated
C4	Treated for BRD - Draxxin then retreated with Exceed (early May)	Pneumonia	Septic pneumonia, multiple abscesses, carcase lymph node involvement.	Pass	N/A	No growth (5 days)	No growth (5 days) for Direct or Enrich; no *Salmonella* isolated	No growth (5 days); no *Salmonella* isolated

Feedlot/ animal ID	Feedlot health treatments	Main pathology	OPV Reason for condemnation	Rework 1 (Pass/Fail)[1]	Rework 2 (Pass/Fail)[1]	Microbiology		
						Main respiratory abnormality	Prescap lymph node	Meat
C5	Treated once for Respiratory - Draxxin (mid-June)	Pleurisy/Pleural abscess/Fever	Extensive amount of seropurulent exudate (100L+), generalised peritonitis, exudative pericarditis, cachexic.	Pass	N/A	No growth (5 days)	Direct scant pure growth *Streptococcus* sp. (non-haemolytic); Enrich heavy mixed growth *Streptococcus* sp. (non-haemolytic) & ***Staphylococcus aureus***; no *Salmonella* isolated	No growth (5 days); no *Salmonella* isolated
C6	Treated once for Respiratory - Draxxin (mid-June)	Pleurisy/Peritonitis	Extensive peritonitis, exudative pericarditis, haemorrhagic enteritis, reactive lymph nodes.	Pass	N/A	No growth (5 days)	No growth (5 days) for Direct; Enrich light pure growth ***Staphylococcus aureus***; no *Salmonella* isolated	No growth (5 days); no *Salmonella* isolated
D1	Treated for Respiratory - Draxxin (4/5/16) no other treatments.	Pleurisy/Peritonitis	Peritonitis & pleurisy	Pass	N/A	No growth (5 days)	No growth (5 days) for Direct or Enrich; no *Salmonella* isolated	No growth (5 days); no *Salmonella* isolated
A5	Nil	Pleurisy/Peritonitis	Pleurisy & peritonitis	Pass	N/A	No growth (5 days)	No growth (5 days) for Direct or Enrich; no *Salmonella* isolated	No growth (5 days); no Salmonella isolated
"Fail" carcase group								
A6	Treated once for Respiratory - Draxxin	Pleurisy/Peritonitis	Septic pneumonia, acute peritonitis, fever	Fail (acute peritonitis)	N/A	No growth (5 days)	No growth (5 days) for Direct; Enrich heavy mixed growth of *Bacillus* sp. and *Streptococcus* sp. (α-haemolytic) ; no bacterial pathogens of BRD isolated; no *Salmonella* isolated	No growth (5 days); no *Salmonella* isolated

Feedlot/ animal ID	Feedlot health treatments	Main pathology	OPV Reason for condemnation	Rework 1 (Pass/Fail)[1]	Rework 2 (Pass/Fail)[1]	Microbiology		
						Main respiratory abnormality	Prescap lymph node	Meat
B2	Treated twice for BRD - Draxxin (12/06/16) & Excede (18/06/16)	Pleurisy/Peritonitis	Multiple pulmonary abscesses, generalised peritonitis, pleurisy, enteritis, splenomegaly (= +LN), malodour	Fail (acute peritonitis)	N/A	No growth (5 days)	Direct: scant pure growth **Streptococcus uberi**s; Enrich: heavy mixed growth *Streptococcus uberis* & *Staphylococcus* sp. (coagulase negative); no *Salmonella* isolated.	No growth (5 days); no *Salmonella* isolated
C7	Nil	Acute Peritonitis/pleurisy	Fever, peritonitis, pericarditis, enlarged lymph nodes	Fail (acute peritonitis)	N/A	No growth (5 days)	No growth (5 days) for Direct; Enrich heavy predominant growth of ***Staphylococcus aureus***; no *Salmonella* isolated	No growth (5 days); no *Salmonella* isolated
C8	Treated twice for BRD - Draxxin & Excede end of May.	Multiple Abscesses	Multiple pulmonary abscesses, cachexia, purulent pericarditis	Fail (multiple abscess & jaundice)	N/A	Light pure growth ***Histophilus somni*** (abscess tissue sampled)	No growth (5 days) for Direct; Enrich heavy mixed growth of 3 organisms no BRD pathogens isolated; no *Salmonella* isolated.	No growth (5 days); no *Salmonella* isolated
D2	Nil	Pleurisy/Peritonitis	Peritonitis (rumen, spleen, liver, abdomen wall, diaphragm) abscess, enteritis.	Fail (multiple abscesses)	N/A	Heavy pure growth ***Trueperella pyogenes***	No growth (5 days) for Direct; Enrich moderate pure growth *Aeromonas* sp. No bacterial pathogens for BRD; no *Salmonella* isolated.	No growth (5 days); no *Salmonella* isolated

[1] Assessment performed by project an experienced inspector

Table 3. Occurrence of reactive lymph nodes for "Investigate" and Fail" carcase groups based on individual carcases data (i.e. matched pairs)

Carcase group	Lymph node +ve	Lymph node -ve	Total
Investigate	9 (69%)	4 (31%)	13
Fail	2 (40%)	3 (60%)	5

p = 0.21; OR=3.1; 95% CI 0.34, 35.7

Table 4. Isolation of primary bacterial pathogens for "Investigate" and "Fail" carcase groups based on individual carcase data (i.e. matched pairs)

Carcase group	Primary pathogen +ve	Primary pathogen -ve	Total
Investigate	1 (8%)	12 (92%)	13
Fail	3 (60%)	2 (40%)	5

p = 0.023; OR:=0.07, 95% CI 0.002, 0.96

Table 5. Isolation of *Staphylococcus aureus* for "Investigate" and Fail" carcase groups based on individual carcase data (i.e. matched pairs)

Carcase group	*Staphylococcus aureus* +ve	*Staphylococcus aureus* -ve	Total
Investigate	4 (31%)	9 (69%)	13
Fail	1 (20%)	4 (80%)	5

p = 0.79; OR=1.7, 95% CI 0.15, 54.4

Table 6. Comparison of reactive lymph nodes with isolation of a primary pathogen based on individual carcase data (i.e. matched pairs)

Lymph node reactive	Primary pathogen +ve	Primary pathogen -ve	Total
+ve	2 (31%)	9 (69%)	11
-ve	2 (20%)	5 (80%)	7
Total	4 (22%)	14 (78%)	18

p = 0.039; OR=0.22, 95% CI 0.03, 0.93; Positive Predictive Value = 0.18

Table 7. Pathophysiology of Bovine Respiratory Disease to inform risk-based criteria for disposition judgement of carcases at slaughter

Criteria	Acute stage	Organising stage	Resolving stage	Chronic stage
Pathophysiological stage	Bacteraemia/viraemia	Bacteraemia/viraemia, Secondary pathogens localising to susceptible organs	Lesions localising	Lesions localised and then diminishing in extent over time
Time (will be very variable)	0 – 14 days	7 – 14 days	10 – 28 days	> 14 days
Ante-mortem	May be showing signs of fever Lethargy, reluctance to move, increased rate of breathing, elevated temperature.	May be showing signs of fever Lethargy, increased rate of breathing, elevated temperature. Possible muco-purulent nasal discharge. Cough, signs of discomfort on coughing	No fever. Possible muco-purulent nasal discharge. Possible cough.	Normal
Gross abnormalities	Poly-serositis with straw coloured exudate with fibrin clots in cavities. Carcase showing fever/septicaemia	Bronchopneumonia. Early fibrous adhesions between visceral and parietal serosal surfaces. Erythema of serosal surfaces. Possible purulent exudate.	Adhesions well developed. Serosal erythema mild to moderate. Exudates resolving, abscess formation. Possible arthritis.	Probable hyperaemia of serosa. Diffuse/localised pleurisy and peritonitis. Possible chronic abscess. Possible (poly) arthritis.
BRD agent present in primary lesion	Yes	Probably	Possibly	Unlikely
Septicaemic with primary BRD agent[1]	Probably	Possibly	No	No
Muscle contaminated with primary BRD agent	Possibly	No	No	No
Muscle contaminated with foodborne hazard	Possibly	Unlikely	No	No
Suitability after stripping membranes	No	No	Possibly	Most likely
Project carcases (18) in each stage		C5, A6, B2, C7, C8, D2	A2, C6	A1, A3, A4, A5, B1, C1, C2, C3, C4, D1
Project disposition judgment	Total carcase condemnation	Total carcase condemnation	Hold and Test	Pass partially trimmed

[1] Alam et al 2009

5 Discussion

5.1 Conduct a risk-based assessment of criteria and potential interventions to better inform disposition judgment of carcases affected with peri-acute pneumonia.

5.1.1 Determine the relationship between the type and severity of gross pathology and microbiological status of the carcase;

Gross abnormalities, typical of primary BRD, were evident in all carcases assessed. The majority of these were accompanied by peritonitis and, in the severe "Fail" group cases, malodour, cachexia and abscessation. The microbiology was consistent with this pathology as primary agents were isolated from 60% of "Fail" carcases (Table 1). In comparison the pathogen positive rate of 8% was significantly lower in the "Investigate" group (Table 4).

The site of isolation of these BRD agents from only respiratory abnormalities also supports the contention that these carcases are not actually septicaemic at slaughter, as lymph nodes and muscle were culture negative for all carcases. However, the isolation of *S. uberis* from the prescapular lymph node of one of the "Fail" carcases may have been due to footrot as a co-morbidity. This may have contributed to that carcase being assessed as a "Fail" reflecting its' signs of systemic infection (Table 2).

From the official condemnation certificates it is apparent that lymph node status is considered important as a surrogate for current infection and/or septicaemia in determining the final disposition judgement. This is reflected in this project where OPVs recorded reactive lymph nodes among reasons for total condemnation in 61% of 18 carcases condemned at official inspection.

Analysis on an individual carcase basis found that the positive predictive value (PPV) of a carcase being culture positive when it had reactive lymph nodes is 18% (Table 6) i.e. they are a poor surrogate for current active infection in these affected carcases. In further support of this finding is that reactive lymph nodes were not significantly associated with "Investigate" or Fail" carcase groups (Table 3). Consequently, reliance on reactive lymph nodes as a criterion for carcase condemnation (i.e. active systemic infection) will result in substantial and unnecessary carcase wastage. Equally, animals without reactive lymph that should be condemned could be passed, indicating that caution should be placed on the weight given to reactive lymph nodes. Listing Fever as a reason for total carcase condemnation for some of the "Investigate" carcases was not supported by microbiology aimed at detecting likely pathogens active as current systemic infection or localised infection remaining in the main abnormality.

Reasons for this poor result is uncertain and may be due to incomplete carcase evaluation and/or recording of reasons by the OPV, successful treatment of cases (though 40% were untreated; Table 2) or presence of other BRD viruses or pathogens such as *Mycoplasma bovis* (Confer 2009; Horwood et al 2014, Hay et al 2016), though their presence would not explain the "Fail" carcases that did not have reactive lymph nodes. This finding is, however, consistent with results of a similar study of condemned pigs that also found reactive lymph nodes were infrequently associated with totally condemned carcases (Hamilton et al 2002).

These findings add weight to observations of Murray (1986) who noted "*Assessment of active and chronic stage of infection whereby chronic lesions are no more than a historical event and should not determine the suitability of meat for human consumption*". Concordance of statistical results presented in this report justifies the description of "chronic past infection" for "Investigate" group carcases and justification to apply interventions to achieve suitability. However, a precautionary approach (i.e. hold and test carcases where disposition is uncertain) is considered further in this discussion as one of the "Investigate" carcases had a BRD agent isolated from the main respiratory abnormality (Tables 1, 2).

5.1.2 Evaluate whether potential interventions achieve suitability for condemned carcases

All 18 carcases were subjected to partial interventions, mostly stripping of pleura and the parietal peritoneal lining where indicated. When re-inspected the disposition of all "Fail" carcases remained unchanged, whereas all "Investigate" carcases were judged as suitable (Tables 1, 2). A typical photographic example of a carcase from each group before and after re-work is provided in Section 9.3.

However, as "Investigate" carcase A2 (Table 2) was culture positive for a BRD agent this total condemnation disposition was retained as a precautionary disposition judgment for that carcase (Table 1).

5.1.3 Determine the food safety status of affected carcases

The finding that *Salmonella* spp. were not isolated from any site for either group (Table 2) further supports the interpretation that these gross abnormalities and carcases do not present a food safety risk. Baseline data indicating very low *Salmonella* spp. contamination of inspected lymph nodes (Anon 2007) of normal carcases has been reported by Cobbold (2009); the evidence from this peri-acute pneumonia project suggests no worsening of that status for affected carcases (reviewed in Section 9.1).

While the food safety risk of *S. aureus* isolated from gross abnormalities is not attributed to foodborne illness (reviewed in Section 9.1), the isolation of *S. aureus* from carcases in this project enables further evaluation of their significance. There was no significant difference in the *S. aureus* positive rate between the two groups (Table 5) and isolates only from enrichment culture of lymph nodes which reflects the very low numbers being present. On this basis, these *S. aureus* isolates most probably represent passing lymph node flora of lot-fed cattle.

Of most importance is the "without scenario", that the edible muscle did not contain *Salmonella* spp., BRD primary pathogens or *S. aureus*.

5.1.4 Determine the food suitability status of affected carcases

Food suitability is a common and necessary aspect of all meat safety programs. Food safety and suitability are defined by the Codex Alimentarius Commission in the Code of Meat Hygiene (CAC 2005) as follows:

Safe for human consumption according to the following criteria:

- *has been produced by applying all food safety requirements appropriate to its intended end-use;*
- *meets risk-based performance and process criteria for specified hazards; and*
- *does not contain hazards at levels that are harmful to human health.*

Suitable for human consumption according to the following criteria:

- *has been produced under hygienic conditions as outlined in this code;*
- *is appropriate to its intended use; and*
- *meets outcome-based parameters for specified diseases or defects as established by the competent authority.*

In the Australian situation as defined in the Australian Standard for the Hygienic Production and Transportation of Meat and Meat Products for Human Consumption (AS4696:2007) safe and suitable meat is described as wholesome.

Food safety caused by pathogens was described in section 5.1.3 above. Suitability in the context of the definition of wholesome within the Australia Standards as it relates to disease and its associated pathology relates to meat being:

- free of obvious contamination: and
- free of defects that are generally recognised as objectionable to consumers.

From Schedule 3, the Ante and Post Mortem Dispositions section if the standard (Anon 2007), animals that are showing acute signs of disease which includes generalised or systemic involvement the carcase and all its parts are condemned. Where the condition has become localised the localised lesions are trimmed and condemned with the healthy parts of the carcase passed for Human consumption.

Fail group carcases A6, B2, C7, C8, D2, (Table 2) had one or more of the Bovine Respiratory Disease causative agents in the primary lesion and/or also had one or more BRD causative agents detected in a peripheral lymph node (i.e. not directly draining the lesion). This indicates that the disease was still active and systemic, and, therefore, not suitable. The disposition must be condemned. These carcases were condemned as part of the trial.

From a gross pathology point of view “Fail” group carcases typically had a similar range of gross abnormalities to those of “Investigate” group carcases (Section 9.1); however, these had additional systemic abnormalities consistent with unresolved infection e.g. fever, multiple abscesses, acute peritonitis, jaundice and malodour (Tables 2, 7).

From the assessment made of the “Investigate” group using criteria detailed in Table 7 the implementation of interventions (i.e. stripping membranes) assisted in confirming most are in the chronic the stage of infection at routine slaughter. Effective membrane stripping for carcase C5 was over-ridden by evidence of extensive infection. Carcases A2 and C5 were judged to be of uncertain disposition due to extensive abnormalities and persistent BRD infection, respectively. For ten carcases initially condemned the combined result of the intervention and microbiology supported a revised disposition of Pass with partial trim. A “Hold and Test” arrangement could become an option to better inform criteria used for the final disposition judgment to reduce “false positive total condemnations” where uncertainty persists.

Results of the risk-based evaluations enhance the information used to determine suitability and wholesomeness.

From the results obtained there is opportunity for reduced wastage arising from this condition. This should not be seen as a remedy that diminishes effort to control BRD in livestock.

5.2 Technical information reviewed as background for this assessment

A review of the Australian and international literature of BRD was undertaken to inform the design of the project and is presented in Section 9.1. Key considerations include:

- the microbiological aetiologies of Bovine Respiratory Disease in Australia;
- pathological description of abnormalities reflecting the respiratory disease agents; and
- any association with foodborne Hazards.

6 Conclusions/Recommendations

6.1 Practical implications/recommendations

The practical outcome of this work demonstrated the value of microbiological data to better inform the interpretation of gross abnormality observations thereby enhancing the reliability of determining carcase disposition. On the basis of the results presented it is recommended that enhanced disposition criteria be developed for “Investigate” carcases where they are held while testing results can be obtained i.e. test and hold arrangement conducted under government supervision, thereby minimising wastage.

This approach provides a safeguard to revising the disposition to partial condemnation for a significant proportion (i.e. 77% from these limited investigations) of “Investigate” carcases that would have no greater risk when re-classified as suitable. By adopting this precautionary approach not all “Investigate” carcases will be judged as suitable. However, the approach delivers a positive risk-benefit with reduced wastage and improved social benefits (i.e. consumer credence values such as animal life/benefit, environmental sustainability) at no greater risk. For “Fail” carcases these are reliably identified at official inspection; there is no justification to hold and test these carcases.

While only a pilot study these consistent results provide proof of concept for the principle proposed by Murray (1986) that while many of these carcases have multiple chronic gross abnormalities these represent resolved infections and can be trimmed to achieve carcase suitability at no greater risk.

While the proposed enhanced disposition criteria for carcases are not a cure, there is no gain in improving production and clinical management at the feedlot if there is no change at the abattoir on how information is used to inform disposition judgement for these uncertain cases. The cost of test and hold, while incremental, is still sufficient to provide signals back to suppliers to apply necessary preventative and control measures; there is no encouragement given to delivery of unsuitable livestock for processing.

6.2 Proposed changes

6.2.1 Delete Peri-acute pneumonia

It is proposed that either:

- The *Peri-acute pneumonia* in Schedule 3 is deleted and replaced by more detailed instructions for carcases where the disposition is uncertain that reflect the enhanced disposition criteria i.e. interventions for component gross abnormalities, re-inspection and test and hold where disposition remains uncertain, if considered necessary. Adding partial condemnation as an option will enable this alternative arrangement.; and/or
- Amend the national training material and the disposition work instructions of the various jurisdictions. That is information covering disposition instructions for carcases where the disposition is uncertain that reflect the enhanced disposition criteria i.e. interventions for component gross abnormalities, re-inspection and test and hold, if

considered necessary. Adding partial condemnation as an option will enable this alternative arrangement.

Total condemnation for carcases with signs of active systemic infection is to be retained as a final disposition option.

This provides an improved objective process for judging disposition of carcases that is more rigorous, and better understood by the ~~inspectortate~~inspectorate, processors and producers. It also enhances the role of the veterinary profession in the industry by drawing on wider professional training e.g. microbiology and risk-based principles.

It is recommended that on acceptance of this Final Report by MLA it should be submitted to the Australian Meat Regulators Group for consideration accordingly.

6.2.2 Revised work instructions

The enhanced disposition criteria are recommended to be based on those outlined in Fig. 3. These follow well understood HACCP principles as carcases initially monitored as not meeting “Critical Limits” have interventions applied (i.e. re-work) and are followed by re-inspection to determine if they fall within “Critical Limits” i.e. suitable after partial condemnation (trimming).

These findings and recommendations are consistent with those from a similar companion study of peri-acute pneumonia of pigs where similar alternative procedures and changes to AS4696 have been approved by the Australian Meat Regulators Group in February 2017.

6.3 Unanswered questions/future research

It is important to note this should be considered a pilot study due to the number of carcases assessed in detail. However, it does represent novel data, as risk-based information on beef carcases was not evident in the literature review undertaken. The number of carcases assessed was also constrained by a substantial decline in carcases totally condemned at official inspection over the study period (Figs. 1, 2); thereby reducing the pool of carcases that fitted the case definition (Section 3.2.1).

The project did not record the proportion of “Investigate” versus “Fail” carcases presenting on a throughput basis. A prospective study would be required to fully quantify full benefits of the alternative arrangements i.e. to determine the true total carcase condemnation rate and the proportion that might be salvaged.

The “project design” visit to the abattoir and feedlot anecdotal evidence suggested that many of the totally condemned carcases had not been detected clinically before slaughter. This was confirmed by the finding that 39% of “Investigate” and “Fail” carcases had not been “pulled” and treated (Table 1). This quantifies the sub-clinical component of BRD and warrants a review of these data by consulting animal health providers in relation to determining the threshold for group therapy based on individual animal treatment rates within a lot and/or enhancement of induction processes.

7 Key Messages

Key messages to the inspectorate, producers and processors include:

- A substantial proportion of totally condemned carcases might be salvaged with no added risk to the safety and suitability of the carcase after additional testing i.e. hold and test.
- Reduced wastage and better social outcomes can be achieved.
- The project has validated broader criteria to determine the final carcase disposition.
- A substantial proportion of animals with BRD are not “pulled” and treated and can still be totally condemned.
- There is no reason to decrease the intensity of preventative and control measures on-farm – market signals will continue to foster implementation of preventative programs that minimise the incidence of BRD.
- Risk-based assessments should be used to improve the accuracy of carcase disposition.
- Validate enhanced disposition criteria and related work instructions to meat inspection professionals and should be submitted to the Australian Meat Regulators Group to consider accordingly.

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9 Appendix

9.1 Risk-based review of Bovine Respiratory Disease (BRD)

This section provides a literature review of BRD, its presentation at slaughter and current inspection/disposition outcomes within a Codex Alimentarius Commission microbiological risk assessment format (Anon 1999). By doing so it is intended to provide the scientific justification for the carcase evaluation methodology presented in Section 3.2.

9.1.1 Hazard Identification

Hazards likely to occur for red meat species include *Salmonella* spp. and pathogenic *E. coli* Sumner et al (2005). This has not changed in recent years (MLA V.RBP.0020 Part 2: Appendix 1). Pathogenic *E. coli* are not reported as causing systemic infections resulting in gross abnormalities in cattle years (MLA V.RBP.0020 Part 2: Appendix 4 and 5).

In a specific review that considered the source(s) of *Staphylococcus aureus* for meat, EFSA (2009) stated '*several reports suggest that S. aureus may become established as part of the endemic flora of food handlers, with subsequent contamination of carcases and meat. Vanderlinde et al (1999) used microrestriction analysis of the DNA of coagulase positive staphylococci isolated from beef mince and from workers hands and concluded the primary source of contamination was the hands of people working in the slaughterhouse. Desmarchelier et al (1999) reported increased levels of staphylococci carcase contamination within 72hrs of chilling and these authors suggest that workers' hands were the primary source of contamination for carcases. Based on genotyping Schlegelova (2004) also concluded that the animals were not the source of contaminating strains*'.

Similar conclusions are drawn in major Australian reviews of foodborne outbreaks (Food Science Australia & Minter Ellison Consulting 2002; Sumner et al 2005) in which foodborne illness resulting from *S. aureus* intoxication result largely from either undercooking or post-cooking recontamination by food handlers in conjunction with temperature abuse enabling toxin build-up. This observation is supported by EFSA (2013) in its review of foodborne Hazards of significance in meat inspection.

Implication for this study

As a result of these EU assessments, S. aureus is not considered important in a food safety context in judging the effectiveness of post-mortem inspection for beef carcases in this study. S. aureus is included in carcase evaluations as a potential secondary infection capable of causing pyogenic lesions.

9.1.2 Hazard Characterisation

For the purposes of this review, Codex risk rating criteria are used for rating the severity of public health foodborne infection consequences (ICMSF 2002).

The criteria used include:

1A Severe hazard for general population: life threatening or substantial chronic sequelae or long duration

1B Severe for restricted populations: life threatening

C Serious, incapacitating but not life threatening; sequelae infrequent; moderate duration

D Moderate, not usually life threatening; no sequelae; normally short duration; symptoms are self-limiting; can be severe discomfort.

A description of symptoms and sequelae resulting from foodborne ingestion of these Hazards may be found in ICMSF (2002).

The severity of the Hazard identified as likely to be associated with beef, is summarised in Table 9.1.

Table 9.1: Public health rating of identified Hazards of beef (Source MLA V.RBP.0020, Part 2: Appendix1).

Hazard	Severity	Risk Group[1]
***Salmonella* spp.**	C Serious 1B Severe	General population <5 yrs/elderly
Pathogenic *E. coli* (incl. O157:H7)	1B Severe	Children

9.1.3 Exposure Assessment

BRD in Live Animals

Many viruses, including bovine herpesvirus-1 (BHV-1), bovine respiratory syncytial virus (BRSV), parainfluenzavirus-3 (PI3), bovine viral diarrhea virus and combinations of these are associated with Bovine Respiratory Disease (BRD) in lot fed cattle in Australia (Hay et al 2016).

In addition, several bacteria (Table 9.2) are associated with severe bacterial pneumonia frequently seen in in lot fed cattle (shipping fever). These include *Mannheimia haemolytica, Pasteurella multocida, Histophilus somni, Trueperella pyogenes* and *Mycoplasma bovis* (Confer 2009; Horwood *et al* 2014).

All of these bacteria are ubiquitous in the cattle population as commensals in the nasopharynx and following stress or viral infection, can proliferate and be inhaled into the lungs. Each has its own cadre of known virulence factors such as adhesions, toxins and enzymes that enhance its ability to colonise, cause tissue destruction and incite an intense inflammatory response (Confer 2009).

Most of these agents appear to be insufficient, singly, to produce BRD except under contrived laboratory conditions. Under field conditions, infection with multiple organisms, particularly in association with ‘stress’ (e.g., weaning, transportation and/or inclement weather) appears to be associated with BRD more frequently than any one of these factors (organisms) by themselves (Martin et al 1988).

Similar work was conducted to investigate risk factors for bovine respiratory disease (BRD) in cattle in Australian feedlots. Hay et al (2014) reported '*Mixing, group size and timing of the animal's move to the feedlot were important predictors of BRD. Animals not mixed with cattle from other farms prior to 12 days before induction and then exposed to a high level of mixing (>= 4 groups of animals mixed) had the highest risk of developing BRD (OR 3.7) compared to animals mixed at least 4 weeks before induction with less than 4 groups forming the cohort.*

Animals in groups formed at least 13 days before induction comprising 100 or more (OR 0.5) or 50-99 (OR 0.8) were at reduced risk compared to those in groups of less than 50 cattle.

Animals moved to the vicinity of the feedlot at least 27 days before induction were at reduced risk (OR 0.4) compared to cattle undergoing short-haul transportation (<6 h) to the feedlot within a day of induction, while those experiencing longer transportation durations (6 h or more) within a day of induction were at slightly increased risk (OR 1.2). Knowledge of these risk factors could potentially be used to inform management decisions to reduce the risk of BRD in feedlot cattle' and thereby further losses due to partial or total carcase condemnation.

In describing associations between exposure to virus and bovine respiratory disease in Australia, Hay et al (2016) report that seroconversion after 35-60 days of induction increased risk of BRD which progressively increased with multiple virus exposures.

Implication for this study

The primary bacterial pathogens of BRD are considered to be the most likely causes of septicaemia in affected carcases.

Due to the bacterial agents causing fibrotic/necrotising/purulent pathology as 'peri-acute pneumonia', the main gross respiratory pathology will be sampled to examine the likely bacterial agent(s) in each carcase.

A peripheral lymph node and muscle tissue will be cultured to check for septicaemia.

The bacteriology panel investigated will be comprised of: Mannheimia haemolytica, Pasteurella multocida, Histophilus somni, Staphylococcus aureus and Streptococcus zooepidemicus.

Association of Foodborne Hazards with Live Animals and Carcases

There is a developing hypothesis in the United States of America (USA) that *Salmonella* found in ground beef does not only come from faecal contamination of the external meat surface, but from lymph nodes that are found within beef primals and trim that are used to produce ground beef. It is estimated that approximately 26 nodes are located adjacent to muscle that may be specifically included in ground beef and at least six of these are recommended for removal to exclude their presence in ground beef e.g. superficial cervical, axillary, subiliac, popliteal, coxalis and iliofemoralis (MLA 2015).

Gragg et al (2013), suggest that higher rates of carriage are associated with warmer climates and that there is a correlation between *Salmonella* prevalence on cattle hides, in the cattle environments and in the peripheral lymph nodes. They concluded that the infection is likely to

be transdermal via abrasions or biting insects with passage of *Salmonella* to the peripheral nodes via afferent lymphatic vessels.

In Australian studies, Samuel et al (1979) commonly isolated *Salmonella* from mesenteric lymph nodes associated with the intestines of Australian cattle. However, this data is not considered relevant due to these animals being without feed for four days; conditions that favour preferential growth of intestinal *Salmonella*; the mechanisms for which are reviewed by Pointon et al (2012). Pre-slaughter management of lot fed cattle (i.e. prolonged feed curfew) does not predispose to the findings of Samuel et al (1979). Also mesenteric lymph nodes are not included in trim and subsequent products.

However, carriage of *Salmonella* in deep tissue Lymph Nodes (dtLNs) of primal cuts has been demonstrated in the US by Arthur et al (2008). Also, as might be predicted from the earlier Australian studies, '*Lymph nodes from cull cattle carcasses had a higher prevalence of Salmonella than did those from fed cattle carcasses. Lymph nodes from the flanks of cow and bull carcasses had the highest prevalence at 3.86%, whereas lymph nodes from the chuck region of fed cattle carcasses had the lowest prevalence at 0.35%'.* To add uncertainty, Gragg et al (2013) demonstrated higher rates of *Salmonella* contamination from dtLN of lot fed animals over cull cows.

Such findings have led other authors (Alam et al 2009) to investigate whether faecal shedding of *Salmonella* in commercial feedlot cattle treated with antimicrobials for BRD was associated with an increase in incidence risks for health outcomes that are frequently monitored in feedlot production systems. '*In commercial feedlots, the most common cause of morbidity, mortality, and antimicrobial therapy is bovine respiratory disease complex (BRDC). The overall disease incidence in feedlots, primarily due to BRDC, tends to peak early in the feeding period, and evidence suggests that the fecal prevalence of Salmonella may peak then as well. The diagnosis and therapy for BRDC is often based on clinical observations with limited diagnostics. Potential relationships between Salmonella and BRDC have not been documented. Depending on a variety of pathogen, host, and environmental factors, Salmonella may cause subclinical infections or primary disease, predispose animals to other diseases, or result in fecal shedding or salmonellosis as sequela to other diseases. We hypothesized that the Salmonella status of cattle in commercial feedlots may affect the clinically and economically important disease outcomes that are often associated with BRDC*'.

The study demonstrated *'Crude re-pull, re-treatment and case fatality risks were higher for cattle that were Salmonella-positive versus negative at initial treatment, but not statistically different on multivariable analysis. However, case fatality risk was higher for cattle shedding Group B Salmonella than for cattle shedding other serogroups*' (Alam et al 2009).

In response to these deep tissue Lymph Node findings, Meat and Livestock Australia has commissioned studies to provide background information about location of the peripheral lymph nodes in the bovine carcase, and establish the likelihood of the nodes being incorporated into primal cuts or trim (Cobbold 2009; MLA 2015). The initial study of Cobbold (2009) of routinely inspected lymph nodes of the head of 534 cattle found '*STEC and E. coli O157:H7 were identified among node pools, although Salmonella was not*.' MLA (2015) has commissioned further work to determine the prevalence of *Salmonella* in the nine lymph nodes (Pre-pectoral, Pre-sternal, Ischiatic and including the six recommended by MLA (2015) (Axillary, Prescapular, Deep inguinal, Popliteal, Coxalis and Subiliac) that have been

highlighted as of higher risk of containing *Salmonella* and with the potential of being included into beef trim.

In comparable work on risk assessment of disposition judgments of pig carcases affected by pyaemia in Denmark (Kruse et al 2015; Baekbo et al 2015), that until now have been totally deboned, emphasis was placed on microbiological assessment of edible tissues (i.e. meat) for the presence of foodborne Hazards. Carcases classified as pyaemic typically have multiple abnormalities of embolic pneumonia and osteomyelitis. From these two Danish risk assessments it is recommended that de-boning is no longer required as long as affected carcases are subjected to thorough inspection of predilection sites when railed out. It is expected that this will most likely result in a much higher probability of finding abscesses than at routine inspection; any missed abscesses will be found at routine deboning where routine hygiene interventions would be employed if contamination eventuates.

The approach to assessing the disposition of carcases with pyaemia highlights important principles for this review of disposition judgement for peri-acute pneumonia of cattle. It illustrates how microbiology should be used to:

- determine if the carcase is septicaemic, especially with the primary or secondary agents of the abnormality of interest, and
- determine the food safety status of edible tissue e.g. muscle cuts of the affected carcase.

This information can then inform the significance of grossly observed abnormalities. For example, carcases with multiple, chronic, localised abnormalities might be railed off and traditionally inspected with localised lesions being partially trimmed rather than the carcase totally condemned; a principle promoted by Murray (1986); "*assessment of active and chronic stage of infection whereby chronic lesions are no more than a historical event and should not determine the suitability of meat for human consumption*".

It is accepted that active septicaemic cases warrant total carcase condemnation, in which case the carcase may be emaciated and meat quality affected. However, where abnormalities are localised and/or chronic, the disposition judgment should be based on an evaluation of risk to better inform disposition i.e. determine Hazard levels in edible tissue as an indicator of risk (Kruse et al., 2015: Baekbo et al., 2015).

It is, therefore, recommended that microbiological studies to detect Hazards in tissue destined for consumption be considered to provide an objective method for validation of the appropriate disposition judgments of carcases affected with these 'reasons' for total condemnation.

Implication for this study

Salmonella spp. is the foodborne Hazard most likely to occur in affected carcases.

To evaluate whether carcases are septicaemic and to determine their food safety status (i.e. Salmonella contamination) peripheral lymph nodes (pre-scapular) and muscle tissue will be examined for the presence of Salmonella spp. with the "bacto panel" for Bovine Respiratory Disease.

Abnormalities in Carcases

Gross pathology cause by bacterial infections associated with BRD is provided in Table 9.2.

In reality, the signs most likely encompass a spectrum of abnormalities from uncomplicated to secondarily infected. As such, the pathology record sheet (Appendix 9.2) provides a spectrum of pathology types rather than a specific overriding pathological description. This allows greater scrutiny of the abnormalities (i.e. acute/chronic, localised/systemic, related pathology etc.) which inform disposition judgment.

Table 9.2. Gross pathology caused by primary and secondary infectious agents of BRD (Confer 2009)

Bacteria	Typical Pathology
Mannheimia haemolytica	Cranio-ventral fibrinous to fibrino-purulent pleuropneumonia
Pasteurella multocida	Bronchopneumonia with various descriptive modifiers including acute fibrino-suppurative, subacute to chronic fibrino-purulent, fibrinous to fibrino-purulent, suppurative and fibrino-necrotizing. The presence of fibrinous to fibrino-purulent pleuritis, distended interlobular septa with edema or fibrin
Histophilus somni	Numerous pathological processes including pneumonia, septicemia, myocarditis, abortion, thrombotic meningo-encephalomyelitis and synovitis.
Trueperella pyogenes	Associated with chronic abscessing pneumonia
Mycoplasma bovis	Cranio-ventral caseo-necrotic bronchopneumonia that may have abscesses, bronchiectasis and sequestration. Arthritis may accompany respiratory disease.

Implication for this study

Pathology 'components' of BRD/peri-acute pneumonia most likely to occur are listed in the data record sheet in Section 9.2. Provision is made for recording other pathology, related and unrelated, found in affected carcases.

Current Inspection Controls

'Peri-acute pneumonia' and morphological descriptions of components of the condition are provided in Schedule 3 of the Australian Standard 4606 (Anon 2007) and presented in Table 9.3.

Table 9.3: Pathology descriptions related to BRD included in AS 4696 Schedule 3 (Anon 2007).

Schedule 3	
3.3 Respiratory System	
Bronchitis	Affected lung condemned
Multiple pulmonary abscesses	Carcase and all its parts condemned
Periacute* pneumonia – severe purulent bronchopneumonia, gangrene of the lungs or necrotic pneumonia	Carcase and all its parts condemned
Pneumonia or bronchopneumonia	Affected lungs condemned
Sinusitis	Affected head condemned
3.4 Pleura	
Adhesions and patches of fibrinous tissue	Affected serous membranes stripped and affected parts condemned
Diffuse serofibrinous, suppurative or gangrenous pleurisy	Carcase and all its parts condemned

Implication for this study

A more relevant and comprehensive list of gross pathology is provided in Section 9.2 to enable acute/chronic, localised/systemic determinations in this assessment.

9.1.4 Bibliography

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9.2 Carcase record sheet and protocol

Kill Date:		**Operators:**	
Carcase ID:			

Photo 1a/b – whole carcase (outside L & R)			**(show condition of carcase)**	
Photo 2a/b – inside carcase (main respiratory lesion)			**(both L & R sides)**	
Record Lesions/Abnormalities[1] present		**Yes[2]**	**Comments[3]**	**Sampled[4]**
Official reason for total condemnation				
	Fevered carcase (Septicaemic)			
	Cachexia			
	Pleural Fibrin tags			
	Pleural Fibrous adhesions, patches or diffuse			
	Pleural erythema, haemorrhagic, patches diffuse			
	Lungs adhered to ribs, patches or diffuse			
	Pleural abscess, walled off, lung adhered to rib			
	Diffuse, serofibrinous			
	Diffuse suppurative pleurisy - free pus in cavity			
	Gangrenous pleurisy			
	Multiple pulmonary abscesses, walled off			
	Pneumonias • Cranio-ventral bronchopneumonia • severe, purulent bronchopneumonia • necrotic pneumonia			
	Necrotic lung, not walled off, purulent			
	Peritonitis			
	Pericarditis			
	Polyarthritis			
	Synovitis			
	Myocarditis			
	Reactive lymph nodes			
	Other pathology			
Collect Samples				
	Muscle – flexor muscle on foreleg (5cm^3)[5]			**Yes[5]**
	Pre-scapular lymph node[5]			**Yes[5]**
	Main respiratory lesion[5]			**Yes[5]**
Photo 3a/b – Lungs & offal				
INTERVENTION 1 – strip pleura				
	Photo 4a/b – repeat photo 2 post intervention 1			
	Re-inspect			**Pass/Fail**
INTERVENTION 2 – resect ribs (if required)				
	Photo 5a/b – repeat photo 3 post intervention 2			
	Re-inspect			**Pass/Fail**

[1] Describe all carcase pathology; note line for other that is not listed

[2] Record Yes for each type of lesion when present i.e. a carcase may have 1 or more entries

[3] Including unilateral or bilateral according to lesion site to be recorded under Comments

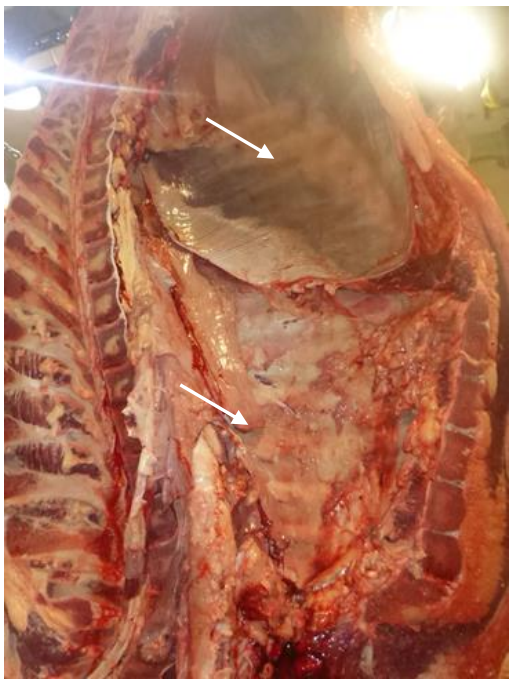
[4] Main pathology site/tissue (1) to be sampled on affected carcases i.e. total 3 samples total/carcase (*Salm., M. haemolytica, H. somni, P. multocida, A. pyogenes, S. aureus, S. zooepidemicus*)

[5] Routinely sampled on all carcases

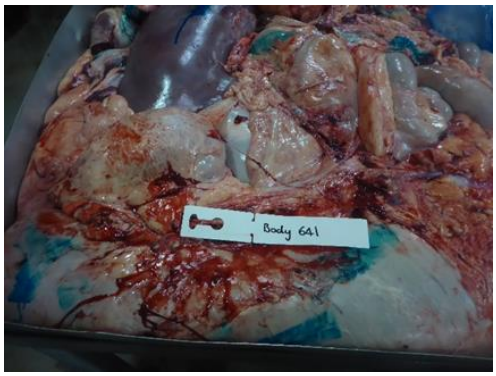
9.3 Photographic record: Carcase abnormalities and effect of interventions

Carcase C2 (“Investigate” example)

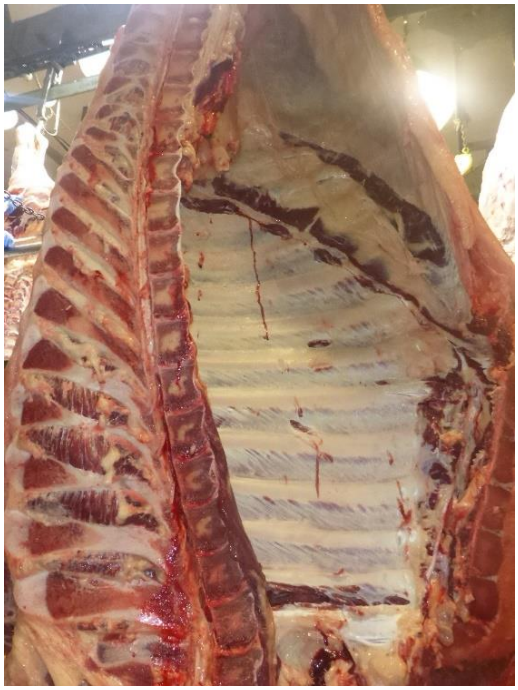
Carcase in prime condition



Pleuritis and peritonitis

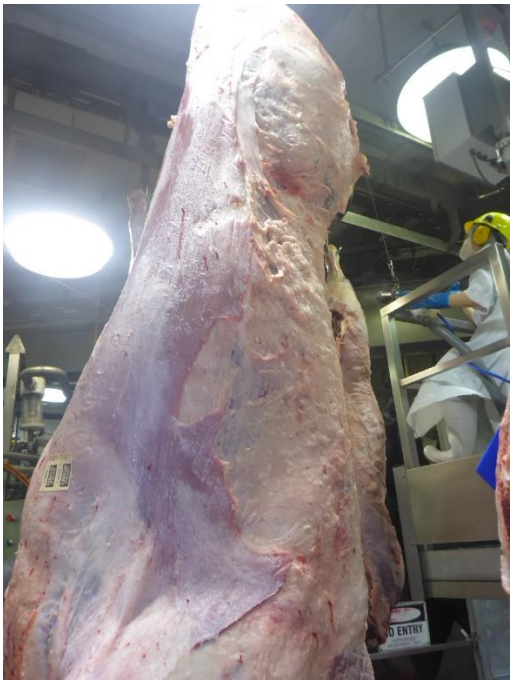


Peritonitis of mesentery

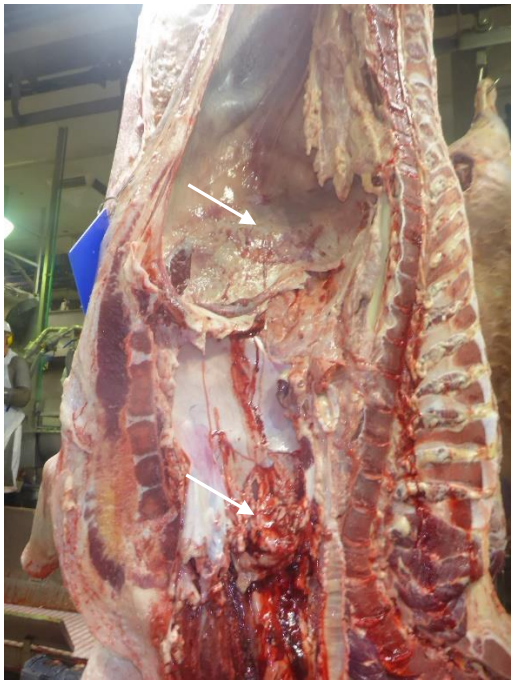


No gross abnormalities after stripping of pleural and peritoneal membranes

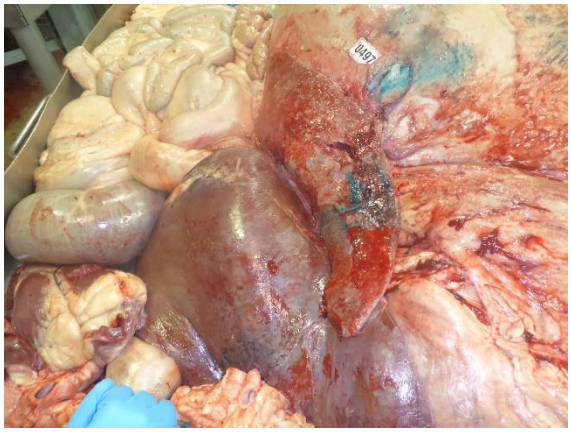
Carcase B2 (“Fail” example)



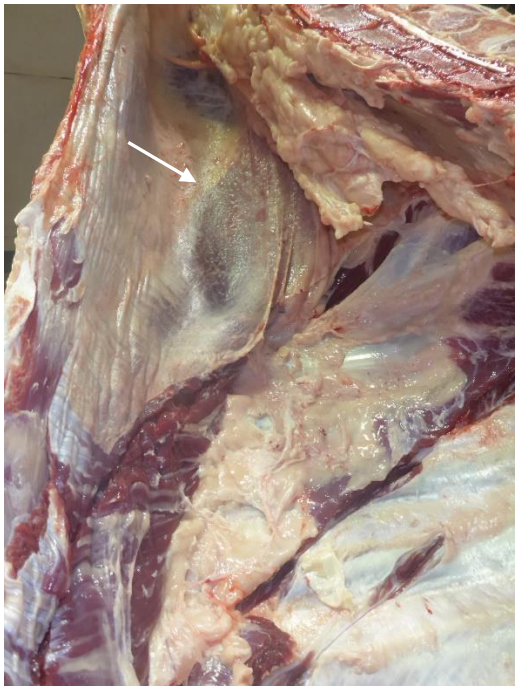
Carcase in prime condition



Pleuritis and peritonitis



Peritonitis of mesentery



Gross abnormalities after stripping of

Pleural and peritoneal membranes