final report

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Pilot Risk-Based Evaluation of Disposition Judgement Criteria used for Lot Fed Cattle Totally Condemned for Polyarthritis

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Abstract

This project investigated and proposes alternative risk-based disposition judgment criteria for the gross abnormality "Arthritis in cattle" (AS4696 Schedule 3, 3.11) for consideration by the Australian Meat Regulators Group. This investigation was enabled by a substantially higher rate carcase condemnation of lot fed cattle for polyarthritis at the project abattoir than recorded nationally. Due to a rapid, unseasonal decline in cases totally condemned due to polyarthritis the investigation failed to achieve its primary aim. That decline was not indicated by a persistent decline in the associated rate of cattle treated for Bovine Respiratory Disease, that is a precursor for development of arthritis at this feedlot, or any decline in number of cases of arthritis detected at post-mortem inspection over the seven-month study when compared with the previous year. Only *Mycoplasma bovis* was isolated from affected joints. While the investigation failed to address the stated aims, observations made indicate that changes to Schedule 3 for "Arthritis" should provide for differentiation of gross abnormalities reflecting stages of disease (i.e. chronic and acute). This would enable appropriate interventions such as trimming multiple chronic abnormalities, or total condemnation if there are signs of septicaemia or cachexia, consistent with other gross abnormalities in Schedule 3.

Executive summary

This project investigated and proposes alternative risk-based disposition judgment criteria for the gross abnormality "Arthritis in cattle" (AS4696 Schedule 3, 3.11) for consideration by the Australian Meat Regulators Group.

The carcase condemnation rate of lot fed steer/heifer cattle at Riverina Beef JBS over 2016 was substantially above the rate recorded nationally. The clinical epidemiology underlying the presentation of these cattle for slaughter was that cases of polyarthritis develop as sequalae to a poor response to two individual animal treatments with antibiotics for Bovine Respiratory Disease (BRD).

Anecdotal opinion is that one joint affected requires a disposition of partial trim, while two joints affected indicates systemic involvement necessitating total condemnation, which is applied at this establishment. The term systemic involvement is a key determinant of the final disposition used by inspectors; this is taken from DAWR 'Post Mortem Decision Notes' for government inspectors as a guide to applying AS4696. The term systemic involvement is open to interpretation.

The approach taken in this investigation is based on Codex Risk Assessment principles that underpin the Codex Alimentarius Code of Hygienic Practice for Meat. The approach undertaken follows a systematic evaluation of risk which focuses on:

- Hazard Identification (which foodborne Hazards are likely to be present)
- Hazard Characterisation (severity of illness caused)
- Exposure Assessment (microbiological status of the carcase)
  - the presence of foodborne hazards (i.e. *Salmonella* spp.) in edible carcase tissues at the point of chilling as an indicator of risk
  - bacterial cause(s) of arthritis and whether carcases are septicaemic with those or other agents
  - whether remaining infection is localised and active/resolving /chronic (to inform wholesomeness criteria).

Up to thirty beef carcases totally condemned, primarily for polyarthritis, were to be examined in detail including recording all gross abnormalities. This represents the case definition for admission to the cohort being assessed. Due to a very low number of cases being totally condemned for polyarthritis from March to May 2017, the peak season for cases, the case definition was expanded to include cases boned for arthritis. It was apparent that the primary aim of the project: *to assess disposition criteria for condemnation*, might not be met. The change enabled an investigation of infective causes of arthritis as a useful outcome.

The bacteria most likely be associated with arthritis in cattle include *Trueperella pyogenes, Erysipelothrix rhusiopathiae, Histophilus somni, Mycoplasma bovis, Pasteurella multocida, Staphylococcus aureus, Streptococcus zooepidemicus, Streptococcus uberis* and *Mycoplasma bovis*. None of these likely infectious agents pose a foodborne risk. *Salmonella* spp. are also considered in this investigation as a potential cause of septicaemia as a sequalae in bovine respiratory disease (BRD) and polyarthritis affected cattle and/or as sub-clinical contamination of edible tissues due to bacteraemia; the latter to inform food safety status of affected carcases.

The rates of treatment for BRD were similar for 2016 and 2017, both being considerably less that that recorded in 2015 in which a major peak in cases was recorded in autumn. The total number of carcases totally condemned due to polyarthritis between March and September 2016 was 66, compared to 21 for the same months of the project in 2017. This represented a highly significant ($p<0.00001$) decrease in total condemnation rate from 0.18% to 0.06%. The rate of carcases being boned for arthritis and

then passed as wholesome was not significantly different between March and September in 2016 and 2017. The proportion of carcases boned for arthritis dramatically increased in the first month of the project, March 2017, when compared to the rate of total carcase condemnation for polyarthritis.

Erysipelothrix rhusiopathiae, Pasteurella multocida, Mannheimia haemolytica, Haemophilus somni, Trueperella (Arcanobacterium) pyogenes, Staphylococcus aureus, Streptococcus equi, Streptococcus zooepidemicus and *α-haemolytic Streptococcus sp.* was not isolated from arthritic joints, lymph nodes or meat samples. *Mycoplasma* spp. was isolated from eight of eleven arthritic joints. Seven of eight isolates were identified as *Mycoplasma bovis*. No lymph nodes or meat samples tested positive for *Salmonella* spp..

Due to a rapid, unseasonal decline in cases totally condemned due to polyarthritis, the investigation failed to achieve its primary aim of conducting a risk-based investigation of criteria used for judging disposition of carcases with polyarthritis. This was not accompanied by a persistent decline in the associated rate of cattle treated for BRD that is a precursor for development of arthritis at this feedlot.

As a result, the case definition was expanded to include cases of arthritis (carcases with arthritis in one joint and boned under supervision) in order to undertake a wider investigation of the cause(s) of arthritis in this feedlot.

Microbiological examination failed to demonstrate that any of the carcases were septicaemic or had foodborne hazards isolated from edible tissues, however, this finding carries limited weight due to the low numbers meeting the original case definition.

The results of this investigation are consistent with previous reports identifying *M. bovis* as a cause of arthritis. Most cases of polyarthritis at this feedlot develop as sequalae to a poor response to two individual animal treatments with antibiotics for BRD.

While the project failed to achieve its primary aim due to a lack of carcases meeting the case definition, the comprehensive clinical and post-mortem inspection data on the same cohort of stock highlights inconsistency in determining carcase disposition of cattle with (poly)arthritis at this abattoir.

Firstly, it is beyond biological explanation that the rate of animals boned for arthritis (one joint affected) should increase so disproportionately in March 2017. Admittedly, this may have been an effect of initiating the trial. However, based on these data, it is most probable that some of the carcases boned for arthritis in March 2017 had more than one joint affected.

Secondly, the rate of 'boned for arthritis' in 2017 was the same as in 2016 over the same months of the 7-month trial period, while the rate of total condemnation for polyarthritis was significantly reduced over the term of the investigation.

The likelihood that cases of polyarthritis were boned and not totally condemned raises a lack of definition around the term 'systemic involvement' in determining carcase disposition. Admittedly, more than one joint affected indicates a previous systemic infection i.e. systemic involvement. However, it is suggested that, presence of multiple chronic gross abnormalities should be managed as advised by Murray (1986) who promoted the following principle: *Differentiation of active and chronic phase of infectious disease whereby chronic lesions are no more than a historical event and should not determine the suitability of meat for human consumption.*

The observations made indicate that changes to Schedule 3 for “Arthritis” should provide for differentiation of gross abnormalities reflecting stages of disease (i.e. chronic and acute). This would enable appropriate interventions such as trimming multiple chronic lesions, or total condemnation if there are signs of septicaemia or cachexia. This approach is used for other gross abnormalities in Schedule 3, though inconsistently.

The reasons for raised rates of total carcase condemnation should be investigated as they may arise from a variety of causes including emergence of new disease syndromes and/or imprecise disposition criteria that should both be subjected to risk-based assessment to minimise wastage.

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1 Background

1.1 Overarching aims

This project investigated and proposes revised risk-based disposition judgment criteria for the gross abnormality "Arthritis in cattle" (AS4696 Schedule 3, 3.11) for consideration by the Australian Meat Regulators Group.

The key outputs provide better information on which to determine final disposition judgments of carcases with polyarthritis.

1.2 The problem

The carcase condemnation rate of lot fed steer/heifer cattle at Riverina Beef JBS over 2016 is substantially above the rate recorded nationally (Pointon et al 2016 V.RBP.0020 MS 3.0); polyarthritis 0.44/10,000, septicaemia 0.45/10,000 carcases and boned due to arthritis. The rates recorded for Riverina Beef over 2016 were:

- 84 condemns for polyarthritis (more than one joint affected) = 6.0 /10,000 carcases
- 145 boned under supervision for arthritis = 10.4 /10,000 carcases
- 134 condemns for septicaemia = 9.6 /10,000 carcases

It is uncertain whether carcases condemned for septicaemia had polyarthritis as a co-morbidity or whether these represent a separate disease cohort. The plant throughput is around 140,000 head per year.

Anecdotal opinion is that one joint affected requires a disposition of partial trim, while two joints affected indicates *systemic involvement* necessitating total condemnation, which is applied at this establishment. The term *systemic involvement* is a key determinant of the final disposition used by inspectors; which is taken from DAWR 'Post Mortem Decision Notes' for government inspectors as a guide to applying AS4696 (DAFF 2010). The term *systemic involvement* is open to interpretation.

The project aimed to evaluate systemic involvement of terms of active/current systemic infection (proof of septicaemia and food safety status) or whether these carcases have multiple chronic/resolving abnormalities that can be trimmed. This is consistent with observations by Murray (1986) in Australia 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.
- Recognition and or removal of lesions of limited or no public health significance should be regarded as a commercial concern for processing companies.

The approach suggested by Murray (1986) is followed in part at this establishment where carcases with one affected joint are boned under supervision. The results of the project better inform whether boning in this context is justified and/or whether this partial trim disposition can be extended to carcases with more than one affected joint.

Project planning discussions with the consultant veterinarian for this feedlot, provided useful insights into the clinical epidemiology underlying the presentation of these cattle for slaughter. Most cases of polyarthritis develop as sequalae to a poor response to two individual animal treatments with antibiotics for Bovine Respiratory Disease (BRD); time to pull for BRD is shown in Fig. 1 for Riverina

Beef feedlot. The monthly incidence of Musculoskeletal death loss as % total on feed in Fig. 2 indicates Feb-May as a risk period which informs the timing of sampling for this project.

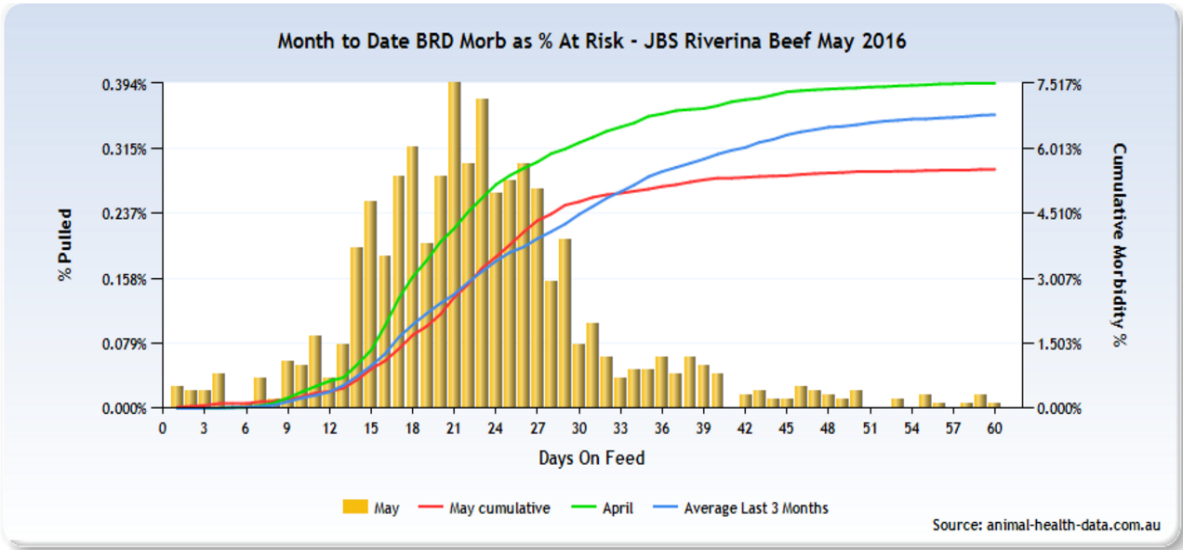

Fig. 1. BRD (first pull) morbidity curves; frequency histogram by days on feed at pull and cumulative for months indicated and benchmarked against rest of AHD database for cattle type (Source: Batterham and Bowler 2017 pers. comm.)

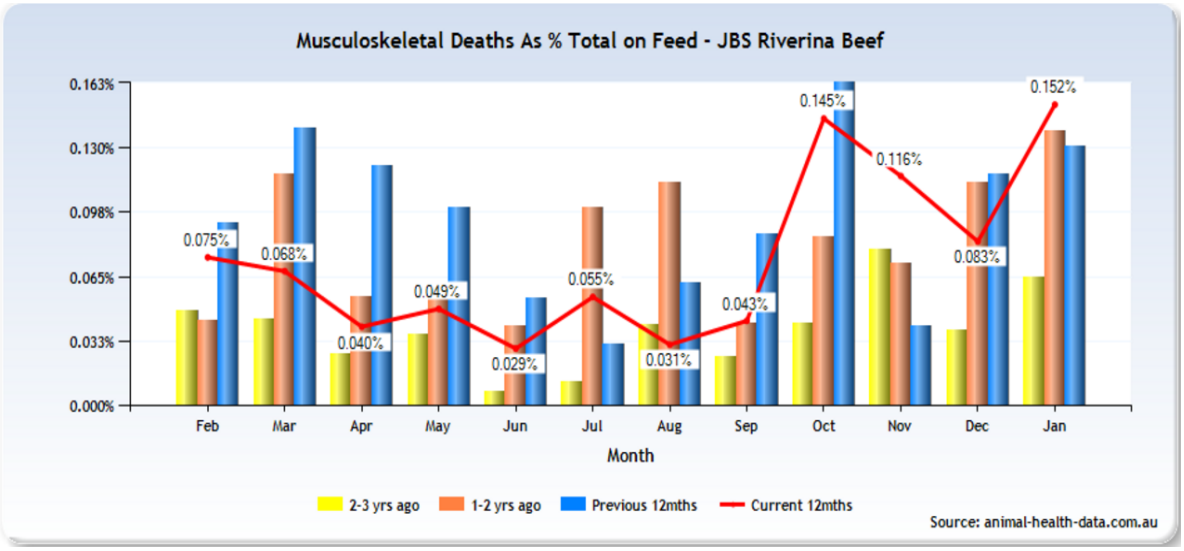

Fig. 2. Musculoskeletal death loss as % total on feed; benchmarking within Riverina Beef for previous years and against rest of AHD database. Musculoskeletal includes causes includes injury, downer, leg fracture, septic arthritis. (Source: Batterham and Bowler 2017 pers. comm.)

The association between BRD and polyarthritis is supported by isolation of bacterial agents capable of causing both conditions in a similar study of BRD in feed lot cattle in the same region in 2016 (P.PIP.0527). This informs the microbiology panel applied for this project.

Due to the debilitated health status of these affected animals it is likely that less virulent infectious agents such as *Mycoplasma bovis* may also be causing some of these persistent joint infections (Horwood et al 2014). This disease is reported in feedlot cattle (Radostits 1988) to be characterised clinically by a progressively worsening fibrinous synovitis and arthritis involving usually the large joints

such as stifle, carpal, and elbow. The disease does not respond to antibiotic therapy and appears to be associated with the occurrence of respiratory tract disease in affected animals several weeks previous to the onset of lameness. Most animals with obviously swollen joints and severe lameness due to this infection develop secondary complications associated with prolonged recumbency. They also lose considerable body weight because they are reluctant to walk to the feed and water supplies on a regular basis. It is possible that *M. bovis* is associated with acute undifferentiated respiratory tract disease in feedlot cattle and that subsequently the *M. bovis* spreads from the lung hematogenously to the synovial membranes, causing a severe fibrinous synovitis.

In view of the clinical information, this investigation into the cause(s) of arthritis has included a panel used for BRD plus some additional bacterial pathogens that cause infectious arthritis in cattle. The bacteria most likely be associated with arthritis in cattle include *Trueperella pyogenes, Erysipelothrix rhusiopathiae, Histophilus somni, Mycoplasma bovis, Pasteurella multocida, Staphylococcus aureus, Streptococcus zooepidemicus, Streptococcus uberis* and *Mycoplasma bovis* (Pointon et al 2016 V.RBP.0020 MS 3.0).

None of these likely infectious agents pose a foodborne risk.

Salmonella spp. are also considered in this investigation as a potential cause of septicaemia as a sequalae in BRD and polyarthritis affected cattle and/or as sub-clinical contamination of edible tissues due to bacteraemia; the latter to inform food safety status of affected carcases (Appendix 9.1).

1.3 AS4696 Schedule 3 - Arthritis

In AS4696 Schedule 3, 3.11 the disposition for Arthritis is described as:

- Acute infectious – Carcase and all its parts condemned
- Non-infectious, chronic with no systemic effects – Affected part condemned

There is no mention of polyarthritis. The Australian Standard does not actually elaborate on what systemic signs will present in acute cases, however, anecdotal evidence indicates more than one joint alone warrants a judgment of systemic involvement by inspectors (DAFF 2010). The standard does not describe a determination of carcase disposition for chronic gross abnormalities at multiple sites. Previous related risk-based work has demonstrated that lot-fed carcases with multiple chronic abnormalities resulting from BRD are most unlikely to be septicaemic or present a food safety risk (Pointon et al 2017). On this basis, a risk-based assessment of criteria used for disposition judgment of polyarthritis carcases is proposed.

This project complements Project No. V.RBP.0020 Review of the Post-mortem Inspection and Disposition Schedules of the Australian Standard 4696.

2 Project objectives

Conduct an objective, transparent, risk-based assessment of carcase disposition criteria used for cattle with polyarthritis by:

- Determining the epidemiology of how the condition develops pre-slaughter to inform carcase assessments
  - Includes relevant disease incidence data for 2016/2017
- Conducting detailed examination of carcases to characterise the gross abnormalities occurring that are contributing to total carcase condemnation disposition.

- Conducting microbiological investigation of:
  - Carcases to determine if they are actively septicaemic with the likely causes of polyarthritis and associated infections
  - Affected joints for infectious arthritic agents to assess active/chronic/resolving
  - Carcases (edible meat and lymph node) to determine if they are contaminated by foodborne agents (i.e. *Salmonella* spp.) i.e. edible following trimming of gross abnormalities
- Provide the report and underlying data to support MLA Project V.RBP.0020 - Review of the Post-mortem Inspection and Disposition Schedules of the Australian Standard 4696.

3 Methodology

3.1 Risk-based approach

The approach taken based is on Codex Risk Assessment principles (CAC 1999) that underpin the Codex Alimentarius Code of Hygienic Practice for Meat (CAC 2005).

The 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 (microbiological status of the carcase)
  - the presence of foodborne hazards (i.e. *Salmonella* spp.) in edible carcase tissues at the point of chilling as an indicator of risk
  - bacterial cause(s) of arthritis and whether carcases are septicaemic with those or other agents
  - whether remaining infection is localised and active/resolving /chronic (to inform suitability criteria).

Recommended disposition judgment criteria (disposition judgment commensurate with risk on a carcase-by-carcase basis) and appropriate interventions based on risk.

3.2 Case definition and number of carcases investigated

Up to thirty beef carcases totally condemned primarily for polyarthritis were to be examined in detail including recording all gross abnormalities. This represents the case definition for admission to the cohort being assessed.

Due to a very low number of cases being totally condemned for polyarthritis from March to May 2017, the peak season for cases (Figs. 3, 4 and 5), the case definition was expanded to include cases boned for arthritis. It was apparent the primary aim of the project, to assess disposition criteria for condemnation, might not be met. The change enabled an investigation of infective causes of arthritis as a useful outcome.

All project participants, including meat inspectors, were requested not to alter any current practice because of the commissioning of this project. The results of the project were kept from all direct participants except the Quality Assurance manager during the project to protect against deviation from usual practices that could bias the assessment.

The project was scheduled to be conducted over autumn when the peak incidence of cases is predicted (Figs. 3, 4 and 5).

To improve the probability of accessing carcases condemned for polyarthritis, feedlot staff identified groups of animals with multiple joints affected. These were submitted as a lot at the end of a shift to make sampling easier.

Results were to be reviewed with JBS and their consultant veterinarian when 20 cases had been assessed to decide on additional cases (up to 30 carcases) or refining microbiological investigations to obtain better data on agents 'commonly' isolated from cases.

3.3 Carcase data recorded

Gross abnormality record sheets were developed in consultation with government inspection personnel to standardise the recording of carcase descriptors of cases and all gross abnormalities observed (Appendix 9.2).

The body condition of cases was scored (DAFF Qld 2017).

All on-floor sampling and recording was conducted by JBS project staff to avoid any additional duties arising for inspectors.

3.4 Microbiology

The joint and systemic bacterial pathogens list for investigation included *Mycoplasma bovis, Erysipelothrix rhusiopathiae, Pasteurella multocida, Mannheimia haemolytica, Haemophilus somni, Trueperella (Arcanobacterium) pyogenes, Staphylococcus aureus, Streptococcus equi*, *Streptococcus zooepidemicus* and *α-haemolytic Streptococcus sp.*.

3.4.1 Samples

Three samples were collected from each affected carcase including:

- The main arthritic lesion (unopened)
- 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 or bacteraemia in a peripheral lymph node, as opposed to culturing a lymph node associated with organs that drain sites that are otherwise healthy but contaminated with foodborne hazards (e.g. local draining of *Salmonella* from the gastrointestinal tract).

3.4.2 Sample preparation and bacteriological culture

All gross abnormality, lymph node and muscle samples were cultured (and identified) for *Erysipelothrix rhusiopathiae, Pasteurella multocida, Mannheimia haemolytica, Haemophilus somni,*

Trueperella (Arcanobacterium) pyogenes, Staphylococcus aureus, Streptococcus equi, Streptococcus zooepidemicus and *α-haemolytic Streptococcus sp.* 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*.

Mycoplasma was cultured using direct and broth using *Mycoplasma* Broth Base (CM0403) Oxoid, *Mycoplasma* Selective Supplement G (SR0059C) Oxoid and Urea/*Mycoplasma* prepared plates (PP2174) Thermo Scientific (also Australian Oxoid supplier).

Mycoplasma isolates were typed using real-time PCR methods as described by Rosetti et al (2010) for *M. bovis* and *M*. bovine group 7.

Lymph nodes were cultured for arthritis 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 to be 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 primary arthritis pathogens.

3.4.3 Statistical methods

Analysis of differences in rates of total condemnation for Polyarthritis and Boned for Arthritis between March-September 2016 and 2017 were calculated by Chi-square analysis.

4 Results

4.1 Hazard Identification

While *Salmonella* spp. was identified as the foodborne hazard most likely to occur (Appendix 9.1), none of the carcases had evidence of septicaemia or contamination of edible tissues with *Salmonella* spp. (Table 4).

4.2 Hazard Characterisation

For the purposes of this review, published 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 1.

Table 1. Public health rating of identified Hazards of beef (Source MLA V.RBP.0020, Part 2: Appendix 1).

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

4.3 Exposure Assessment

4.3.1 Clinical disease patterns in source feedlot

The rate of treatments for bovine respiratory disease were similar for 2016 and 2017, both being considerably less that recorded in 2015 (Fig. 3). The autumn peak of cases in 2015 was not repeated in subsequent years (Fig. 3).

4.3.2 Total carcase condemnation rates

The total number of carcases totally condemned due to polyarthritis between March and September 2016 was 66, compared to 21 for the same months of the project in 2017 (Tables 2 and 3). This represented a highly significant ($p<0.00001$) decrease in total condemnation rate from 0.18% to 0.06% (Table 3).

The rate of carcases being boned for arthritis and then passed as wholesome was not significantly different between March and September in 2016 and 2017 (Table 3).

The proportion of carcases boned for arthritis dramatically increased in the first month of the project, March 2017, when compared to the rate of total carcase condemnation for polyarthritis (Figs. 4 and 5).

A similar peak of carcases boned for arthritis was recorded in October 2016, when the number slaughtered was relatively low. The potential effect of low slaughter numbers was more apparent in

July 2017 when the number of carcases condemned was similar to adjacent months, leading to increased rates for all three reasons for condemnation: polyarthritis, septic pneumonia and boned for arthritis (Fig. 5).

4.3.3 Microbiology

Erysipelothrix rhusiopathiae, Pasteurella multocida, Mannheimia haemolytica, Haemophilus somni, Trueperella (Arcanobacterium) pyogenes, Staphylococcus aureus, Streptococcus equi, Streptococcus zooepidemicus and *α-haemolytic Streptococcus sp.* was not isolated from arthritic joints, lymph nodes or meat samples (Table 4).

Mycoplasma spp. was isolated from eight of eleven arthritic joints (Table 4; Fig. 6). Seven of these were identified as *Mycoplasma bovis*, with one remaining unidentified.

No lymph nodes or meat samples tested positive for *Salmonella* spp. (Table 4).

4.3.4 Carcase condition score

All four carcases totally condemned had body scores of two (carcases 405, 566, 570 and 583). Of seven carcases boned for arthritis and passed after trimming as wholesome, three had body scores of two (Table 4).

Table 2. Monthly total carcase condemnation numbers for polyarthritis, boned for arthritis and septicaemia in 2016 and 2017. (Project data in red text)

Month	Polyarthritis		Arthritis Boned		Septicaemia		Total Slaughtered	
	2016	2017	2016	2017	2016	2017	2016	2017
Jan	4	5	7	15	12	9	5339	4040
Feb	21	1	16	21	27	13	8783	5257
March	23	2	11	35	30	6	7008	5762
April	8	1	13	7	23	4	6453	4103
May	2	1	11	12	15	7	4449	5287
June	7	7	7	7	13	12	4072	5856
July	12	5	1	9	7	12	6403	2305
Aug	10	5	15	4	9	16	5247	6448
Sept	4	0	7	2	4	7	2923	5382
Oct	2		11		1		1762	
Nov	3		12		10		4758	
Dec	1		5		5		2397	

Table 3. Rates of total carcase condemnation for polyarthritis and boned for arthritis over March – September in 2016 and 2017.

Disposition	2016	2017
Polyarthritis total condemnation/Total	66/36555	21/35143
%	**0.18%**	**0.06%** [1]
Boned for Arthritis/Total	65/36555	76/35143
%	**0.18%**	**0.22%**[2]

[1] Rate of total carcase condemnation significantly less in 2017 ($p<0.0001$: OR=0.33: 95%CI 0.19-0.55)

[2] Not significantly different

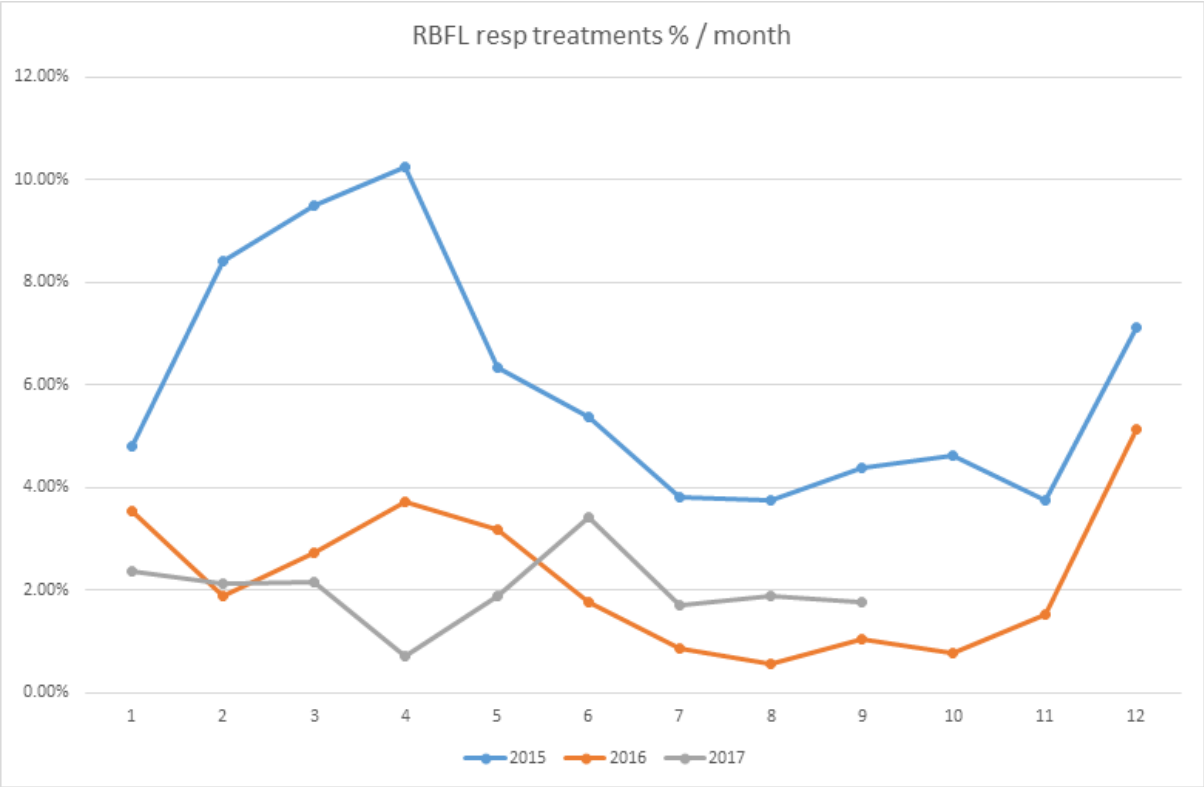

Fig. 3. Rate of respiratory treatments/month

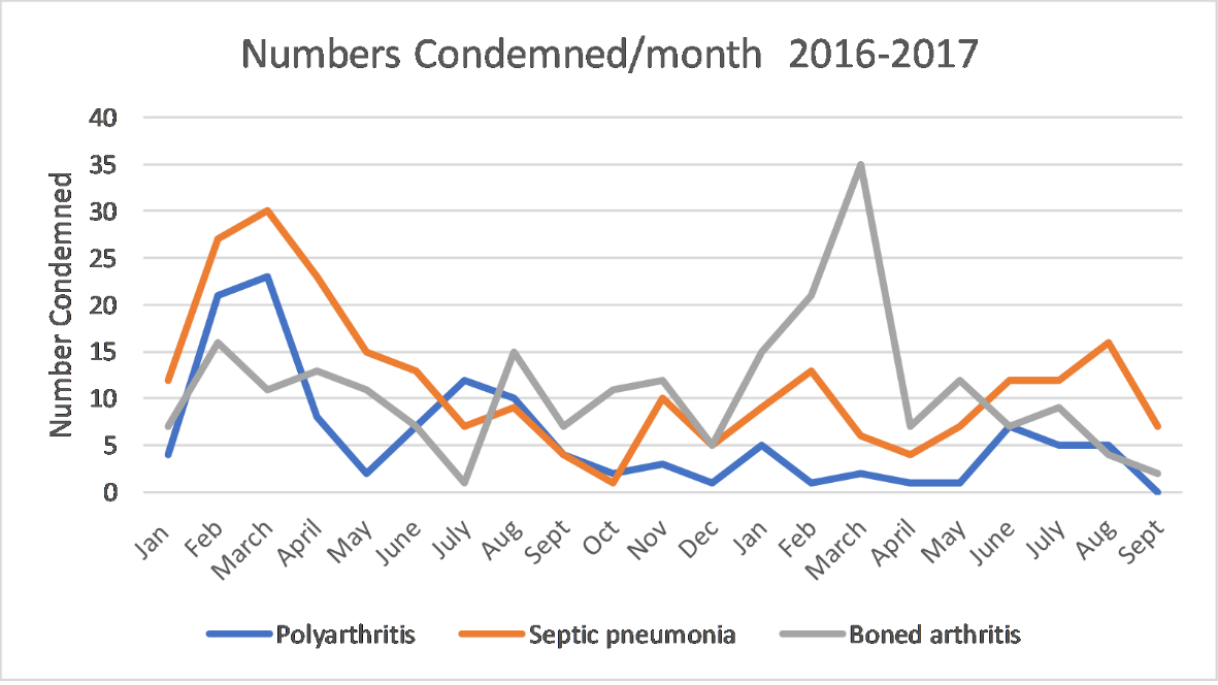

Fig. 4. Number of total carcase condemnations by month

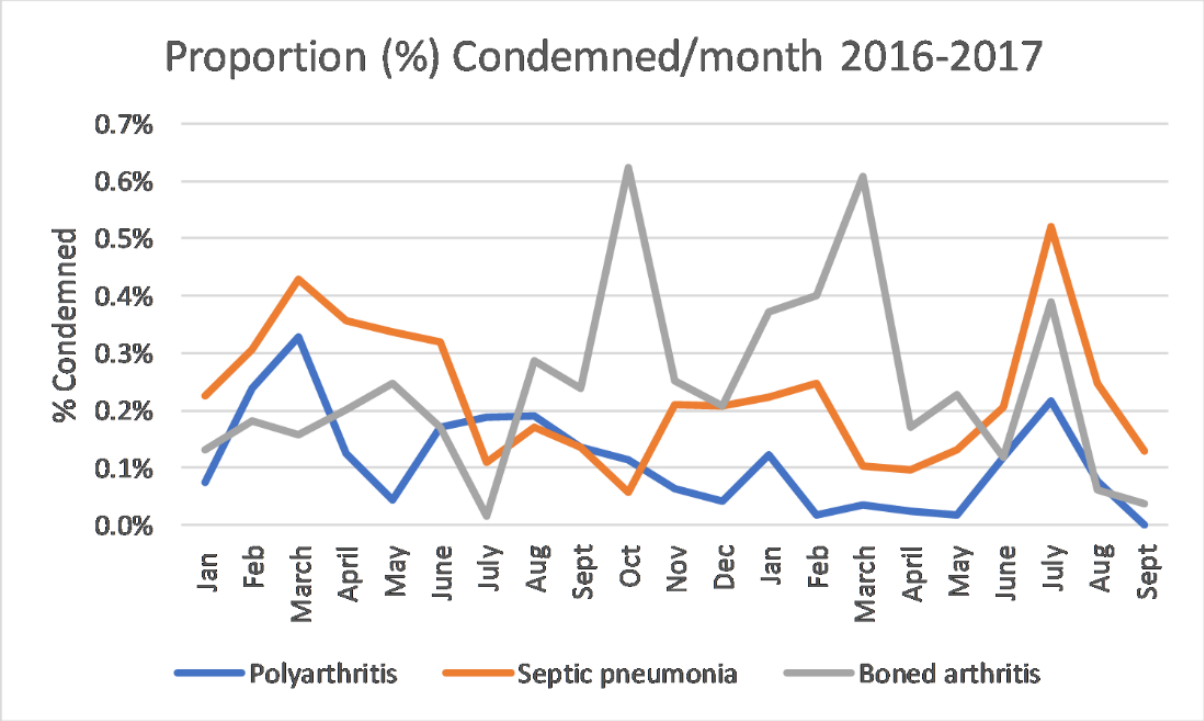

Fig. 5. Rate of total carcase condemnation by month

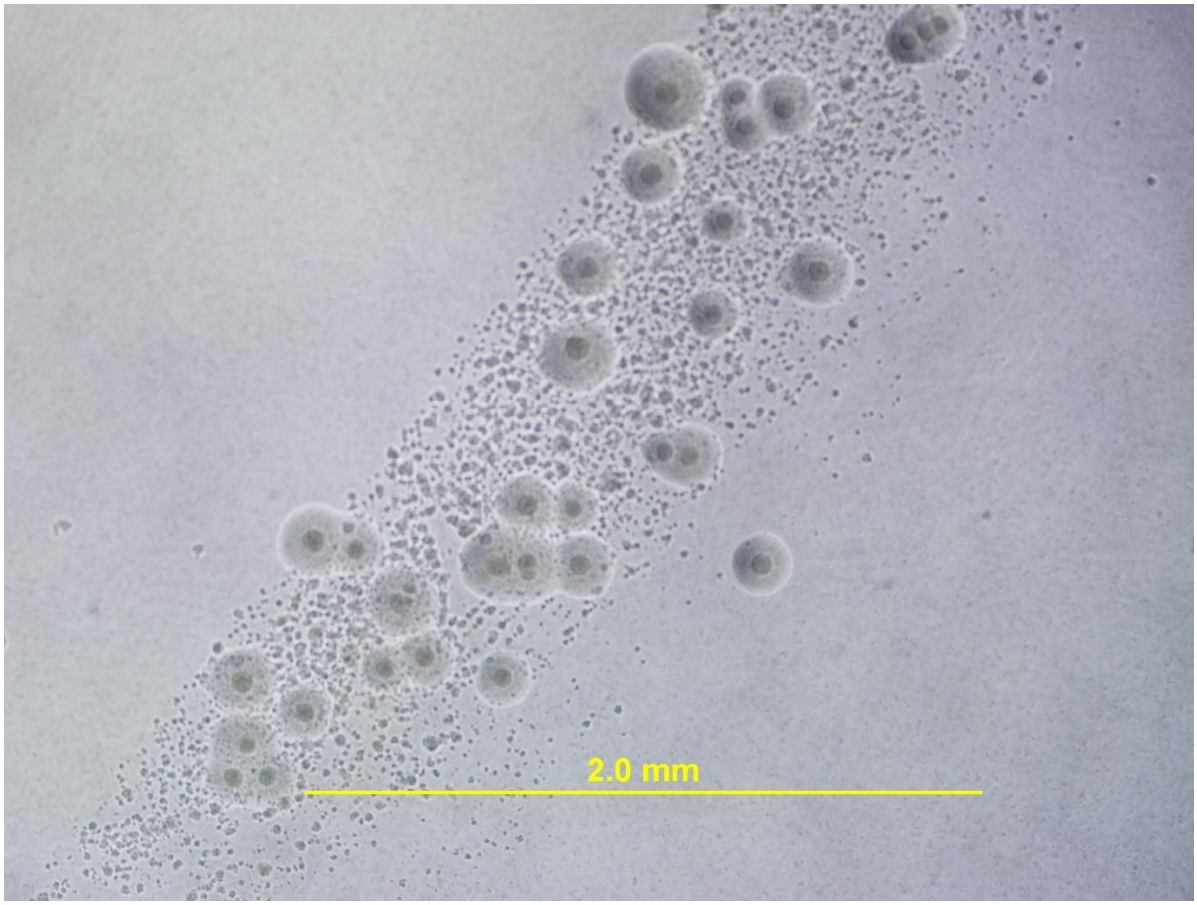

Fig. 6. *Mycoplasma* colonies inoculated from enrichment broth from a case of arthritis.

Table 4. Description and microbiology of carcases with arthritis (Red text highlights positive culture for arthritis agent)

Carcase No.	Main pathology	Reason for condemnation	Body Score	Sample joint fluid description	Meat - aerobic culture	Prescap LN – aerobic culture	Joint - aerobic culture	Joint - Mycoplasma
405	Polyarthritis - fibrous with creamy exudate, 3 joints affected, no other pathology.	Polyarthritis	2	Blood tinged, viscous, cloudy, >30mls, Gram Stain +++ WBCs, no bacteria seen	Aerobic culture - No growth after 5 days incubation. *Salmonella* - neg.	Direct Aerobic culture - No growth after 5 days incubation. BPW ENRICHMENT LN - Heavy mixed growth of *Staphylococcus* sp. (coagulase negative) *Salmonella* - neg.	No growth after 5 days incubation.	**Positive** from direct and enrichment culture.
566	Polyarthritis - fibrous with creamy exudate, 3 joints affected, no other pathology.	Polyarthritis	2	Heavily blood stained, viscous, cloudy, >30mls, Gram Stain +++ WBCs, no bacteria seen	Aerobic culture - No growth after 5 days incubation. *Salmonella* - neg.	Direct Aerobic culture - No growth after 5 days incubation. BPW ENRICHMENT LN - Heavy mixed growth of *Staphylococcus* sp. (coagulase negative) *Salmonella* - neg.	No growth after 5 days incubation.	**Positive** from direct and enrichment culture.
570	Polyarthritis - soft and serous fluid in 2 joints	Polyarthritis	2	Blood tinged, viscous, cloudy, >30mls, Gram Stain +++ WBCs, no bacteria seen	Aerobic culture - No growth after 5 days incubation. *Salmonella* - neg.	Direct - No growth after 5 days incubation BPW Enrichment - No growth after 5 days incubation. *Salmonella* neg	No growth after 5 days incubation.	**Positive** from both primary and enrichment culture
583	Polyarthritis - abscess, and 3 joints soft with serous fluid	Polyarthritis	2	Blood tinged, viscous, cloudy, >50mls, Gram Stain +++ WBCs, no bacteria seen	Aerobic culture - No growth after 5 days incubation. *Salmonella* - neg.	Direct - No growth after 5 days incubation BPW Enrichment - No growth after 5 days incubation. *Salmonella* neg	No growth after 5 days incubation.	**Positive** from both primary and enrichment culture
551	Arthritis - soft joint with serous fluid	Trimmed Passed	3	Blood tinged, viscous, cloudy, >500mls, Gram Stain +++ WBCs, no bacteria seen	Aerobic culture - No growth after 5 days incubation. *Salmonella* - neg.	Direct Aerobic culture - No growth after 5 days incubation. BPW ENRICHMENT LN - No growth after 5 days incubation. *Salmonella* - neg.	No growth after 5 days incubation.	No Mycoplasma sp. isolated from either direct or enrichment culture.
565	Arthritis - soft joint with serous fluid	Trimmed Passed	3	Blood tinged, viscous, cloudy, >500mls, Gram Stain +++ WBCs, no bacteria seen	Aerobic culture - No growth after 5 days incubation. *Salmonella* - neg.	Direct - No growth after 5 days incubation BRW - Light pure growth of *Staphylococcus* sp. (coagulase negative) No joint or systemic bacterial pathogens isolated *Salmonella* neg	No growth after 5 days incubation.	No Mycoplasma sp. isolated from either direct or enrichment culture.

Carcase No.	Main pathology	Reason for condemnation	Body Score	Sample joint fluid description	Meat - aerobic culture	Prescap LN – aerobic culture	Joint - aerobic culture	Joint - Mycoplasma
564	Arthritis - soft joint with serous fluid	Trimmed Passed	2	Blood tinged, viscous, cloudy, >200mls, Gram Stain +++ WBCs, no bacteria seen	Aerobic culture - No growth after 5 days incubation. *Salmonella* - neg.	Direct - No growth after 5 days incubation BPW Moderate pure growth of an *Aeromonas* sp. No joint or systemic bacterial pathogens *Salmonella* neg	No growth after 5 days incubation.	No Mycoplasma sp. isolated from either direct or enrichment culture.
606	Arthritis - soft joint with serous fluid	Trimmed Passed	3	Blood tinged, viscous, cloudy, >30mls, Gram Stain +++ WBCs, no bacteria seen	Aerobic culture - No growth after 5 days incubation. *Salmonella* - neg.	Direct - No growth after 5 days incubation BWP enrichment - No growth after 5 days incubation. No joint or systemic bacterial pathogens *Salmonella* neg	No growth after 5 days incubation.	**Positive** from both direct and enrichment culture
546	Arthritis - soft joint with serous fluid	Trimmed Passed	3	Blood tinged, viscous, cloudy, >120mls, Gram Stain +++ WBCs, no bacteria seen	Aerobic culture - No growth after 5 days incubation. *Salmonella* - neg	Direct Aerobic culture - No growth after 5 days incubation. BPW ENRICHMENT LN - Heavy mixed growth of *Staphylococcus* sp. (coagulase negative) No joint or systemic bacterial pathogens *Salmonella* neg	No growth after 5 days incubation.	**Positive** from both primary and enrichment culture
348	Arthritis - soft joint with serous fluid	Trimmed Passed	2	Blood tinged, viscous, cloudy, >30mls, Gram Stain +++ WBCs, no bacteria seen	Aerobic culture - No growth after 5 days incubation. *Salmonella* - neg.	Direct Aerobic culture - No growth after 5 days incubation. BPW ENRICHMENT LN - Heavy predominant growth of *Aeromonas* sp. No joint or systemic bacterial pathogens isolated after 5 days incubation *Salmonella* neg	No growth after 5 days incubation.	**Positive** from both primary and enrichment culture
571	Arthritis - soft joint with serous fluid, Abscess	Trimmed Passed	2	Blood tinged Viscous cloudy >120mls, Gram Stain +++WBC's no bacteria seen	Aerobic culture - No growth after 5 days incubation. *Salmonella* - neg.	Direct - No growth after 5 days incubation BRW - Heavy mixed growth of *Staphylococcus* sp. (coagulase negative) No joint or systemic bacterial pathogens *Salmonella* neg	No growth after 5 days incubation.	**Positive** from both primary and enrichment culture

5 Discussion

Objective: Conduct an objective, transparent, risk-based assessment of carcase disposition criteria used for cattle with polyarthritis.

5.1 Assessment of disposition criteria

Due to a rapid, unseasonal decline in cases totally condemned due to polyarthritis the investigation failed to achieve its primary aim of conducting a risk-based investigation of criteria used for judging disposition of carcases with polyarthritis. This was not indicated by a persistent decline in the associated rate of cattle treated for BRD that is a precursor for development of arthritis at this feedlot (Fig. 3), or any decline in number of cases of arthritis detected at post-mortem inspection over the seven-month investigation (Table 3).

Over the duration of the project (March to September 2017) there was a significantly lower rate of total carcase condemnation (0.06% versus 0.18%; $p<0.0001$) than for the same period the previous year (Table 3). By comparison, over the same period, the rate of carcases boned for arthritis was unchanged. This variability may have occurred as an effect of initiating the project, as in the first month of the project, March 2017, there is a marked increased rate of carcases boned due to arthritis and a marked decrease in those totally condemned due to polyarthritis (Table 2). Examination of the rate of cattle with clinical BRD requiring treatment at that time in 2016 and 2017 indicates this is highly unlikely to account for changes in disposition judgement rates of this magnitude (Fig.3).

This lower rate of total carcase condemnation is a major contributing factor in the project failing to obtain sufficient carcases that fit the case definition. As a result, the case definition was expanded to include cases of arthritis (carcases with arthritis in one joint and boned under supervision) in order to undertake a wider investigation of the cause of arthritis in this feedlot.

Microbiological examination failed to demonstrate that any of the carcases were septicaemic or had foodborne hazards in edible tissues, however, this finding carries limited weight due to the low numbers meeting the original case definition of totally condemned due to polyarthritis.

5.2 Cause of arthritis

The clinical syndrome is consistent with that reported for feedlot cattle in that cases of arthritis occur with peaks of bovine respiratory disease either as a sequalae of BRD or due to common primary agents (Radostits 1988; Horwood et al 2014). Haines et al (2001) found *Mycoplasma bovis* in over 80% of cases investigated, including in 45% of joints and 71% of lungs tested. *Mycoplasma bovis* and bovine viral diarrhoea virus (BVDV) were the most common pathogens persisting in the tissues of animals that had failed to respond to antibiotic therapy.

The results of this investigation are consistent with these previous reports, with *M. bovis* being the only arthritic agent isolated from affected joints; however, this current investigation did not include an examination of the role of BVDV. Most cases of polyarthritis at this feedlot develop as sequalae to a poor response to two individual animal treatments with antibiotics for BRD, according to a consultant feedlot veterinarian.

5.3 What worked/What didn't

The project was enabled by a relatively high rate of total carcase condemnations that should have resulted in sufficient cases to be investigated to obtain a reliable assessment of carcase disposition criteria. Unfortunately, insufficient cases meeting the strict case definition were identified for investigation. Efforts to target likely carcases also failed to deliver the required cases.

That this variability occurred serves to highlight that procedures to determine carcase disposition are imprecise; however, efforts should be implemented to reduce this variability and resulting waste.

6 Conclusions/recommendations

6.1 Inconsistency in carcase disposition judgements

While the project failed to achieve its primary aim due to a lack of carcases meeting the case definition, the comprehensive clinical and post-mortem inspection data on the same cohort of stock highlights inconsistency in determining carcase disposition of cattle with (poly)arthritis at this abattoir.

Firstly, it is beyond biological explanation that the rate of animals boned for arthritis (one joint affected) should increase so disproportionately in March 2017. Admittedly, this may have been an effect of initiating the trial. However, based on these data, it is most probable that some of the carcases boned for arthritis in March 2017 had more than one joint affected (Table 2, Figure 4).

Secondly, the rate of 'boned for arthritis' in 2017 was the same as in 2016 over the same months of the 7-month trial period, while the rate of total condemnation for polyarthritis was significantly reduced over the term of the investigation (Tables 2 and 3).

The likelihood that cases of polyarthritis were boned and not totally condemned raises a lack of definition around the term 'systemic involvement' in determining carcase disposition. However, the presence of multiple chronic gross abnormalities should be managed as suggested by Murray (1986) who promoted the following principle: *Differentiation of active and chronic phase of infectious disease whereby chronic lesions are no more than a historical event and should not determine the suitability of meat for human consumption.*

A similar failure in judging carcase disposition of cattle with peri-acute pneumonia for a lack of clarity around 'systemic involvement' (Pointon et al 2017) points to a need to review Schedule 3 and associated training material for meat inspectors. Approaches to this are outlined by Pointon et al (2017).

6.2 Proposed alternative procedure for equivalence determination

The observations made indicate that changes to Schedule 3 for "Arthritis" should provide for differentiation of gross abnormalities reflecting stages of disease (i.e. chronic and acute). This then enables appropriate interventions such as trimming multiple chronic lesions or total condemnation if there are signs of septicaemia or cachexia. This approach is used for other gross abnormalities in Schedule 3, though inconsistently.

The report should be made available to the Department of Agriculture and Water Resources for consideration. If changes are approved by AMRG, changes the Post-Mortem Decision Notes DAFF (2010) should be made accordingly.

6.3 Interventions for *Mycoplasma* arthritis in feedlot cattle

It is beyond the remit of this project to advise on interventions. However, it is worth noting that this feedlot appears to have a persistent and widespread population of *M. bovis* that requires specific interventions by therapy, vaccination etc. Isolates have been stored to enable further investigations as needed.

These investigations should be discussed between JBS and their animal health consultant.

7 Key messages

This report should be submitted to the Australian Meat Regulators Group to consider expanding disposition options for "Arthritis" in Schedule 3 (Anon., 2007) to better reflect stages of disease (as detailed in section 6.2).

Reasons for raised rates of total carcase condemnation should be investigated as they may arise from a variety of causes including emergence of new disease syndromes and/or imprecise disposition criteria, that should both be subjected to risk-based assessment to minimise unnecessary wastage.

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9 Appendix

9.1 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 2017).

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 2017). 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 (2017) 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 (2017) (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. In addition to culture for arthritis-associated bacteria.

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9.2 JBS Riverina Beef Carcase record sheet – slaughter-floor recording

Kill Date:		**Inspector:**	
Carcase ID:			

Photo 1a/b – whole carcase (outside L & R)			**(to show condition of carcase)**	
Photo 2a/b – main swollen joints				
Record Lesions/Abnormalities[1] present		**Yes/No[2]**	**Comments[3]**	**Sampled[4]**
	Body condition score			
	Polyarthritis			
	Number of joints affected			
	Location of affected joints – list all (LHS+RHS)			
	Describe joints – soft, fibrous, exudate, fistula			
	Describe fluid - ??serous, cloudy, bloody, creamy, clotted			
	Septicaemia (Petechial haemorrhages)			
	Fever (reddened carcase)			
	Cachexia/emaciation			
	Pneumonia (mild/moderate/severe)[3]			
	Pleurisy (mild/moderate/severe)[3]			
	Peritonitis			
	Abscessation liver (number)			
	Pericarditis (Serous, Purulent)			
	Splenomegaly			
	Malodour			
	Other pathology – list all			
	Reactive lymph nodes – list affected nodes			
Collect Samples				
	Muscle – flexor muscle on foreleg (5cm^3)		**Label bags with carcase ID, pack in separate sample bags, chill and hold <5°C, send on ice to lab**	**Yes[4]**
	Pre-scapular lymph node			**Yes[4]**
	Main arthritic joint - unopened			**Yes[4]**
Photo – arthritis pathology				
	Photos of joint, fluid and other pathology			
	Other significant abnormality (s) of the carcase			

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

[2] Record Yes/No for each type of lesion when present i.e. a carcase may have 1 or more entries. Record No to indicate this was specifically checked.

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

[4] Routinely sampled on all carcases