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Experiment 2 - Economic Impact of Bovine Respiratory Disease

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Abstract

Bovine Respiratory Disease (BRD) is the single biggest health issue faced by the feedlot industry, causing significant economic losses. The aim of the current project was to quantify the economic impact of Bovine Respiratory Disease (BRD) to the Australian feedlot industry. The project was undertaken at a commercial feedlot in Southern NSW, Australia, and consisted of records of steers from two separate feedlot trials (Trial 1: started in February, n=898; Trial 2: started in June, n=1,314). Animals were followed from induction to slaughter and had veterinary treatment records collected during the feeding phase and lung lesions indicative of BRD collected at slaughter.

Trial 1 showed a BRD incidence rate of 16% based on both visual signs and clinical symptoms with a further 7% of animals showing only clinical signs but not visual signs of BRD, and 2.3% of mortalities with previous history of BRD treatment at the feedlot. Of all animals that showed both visual and clinical signs, the proportion of inducted animals receiving 1, 2 and 3 BRD treatments was 16.3, 3.0 and 3.5%, respectively. Mortality rate for Trial 1 was 2.56% with 91% of these deaths attributed to BRD upon necropsies. The average total financial loss for each animal dead due to BRD was 1,691 $/hd including BRD treatment cost of $63.7/hd on average (up to $123.3 /hd). The average cost at induction of BRD vaccinations was $5.67/hd inducted, and the average BRD treatment costs at the hospital was $35.2 per animal treated (i.e. $3.52 for each of every 100 inducted animals and each 10% of BRD incidence). This results in a total cost of BRD of 9.3 $/hd inducted plus 16.9 $/hd inducted for each 10% of BRD incidence and each 1% of mortality due to BRD, respectively. In addition, carcasses of BRD case animals were 12.4 kg lighter and $80.8 cheaper resulting in a lower net profit of 112.6 $/hd compared to animals never treated for BRD. Therefore, each 10% of BRD incidence reduced net returns by $1,126 for every 100 animals inducted plus a loss of $16.91 per animal inducted for each 1% of BRD mortality rate).

On a 'dead and rejects in' basis, the difference in net profit between BRD controls and BRD cases was 329 $/hd with the mortality rates observed in the present study (net profit of 167.4 ± 12.5 vs. -161.5 ± 25.1 for controls and BRD cases, respectively). However, marked differences also existed between animals treated 1, 2 and 3+ times for BRD with hospital treatment costs increasing to 88.8 $/hd treated, carcass weight decreasing by 40 kg/hd and net return decreasing by 383 $/hd in animals treated 3+ times compared to animals never treated for BRD on dead and reject out basis. Animals that showed pleurisy score of 3 at slaughter showed higher BRD treatment cost (16.3 $/hd), lower carcass weight (20 kg/hd) and value (135 $/hd), and lower net financial return (137 $/hd) compared to animals with lower pleurisy scores. A similar finding was reported for animals with severe compared to normal or moderate lung lesions at slaughter. Animals that were classified to have experienced clinical, subclinical and resolved BRD showed lower carcass weight compared to healthy animals (by 18 kg/hd). Clinical BRD animals showed lowest, subclinical medium, and resolved and healthy animals highest carcass value. However, net return was lowest for clinical cases, medium for subclinical and resolved BRD animals, and greatest for healthy animals. Control and subclinical BRD animals showed lower BRD treatment cost compared to resolved and clinical.

Trial 2 showed a BRD incidence rate of 9.6% of all inducted animals with both visual and clinical signs. Mortality rate was 0.53% with 57% of these confirmed to have died due to BRD. The low incidence of BRD in Trial 2 may prevent a robust analysis however some of the trends were similar to Trial 1. Net loss for each animal dying from BRD was $1,762, with average BRD treatment cost of 36 $/hd. The proportion of animals treated 1, 2 and 3+ times for BRD was 7.2, 1.2 and 1.2%, respectively. As the number of BRD treatments increased from 0 to 3+, ADG decreased from 1.98 to 1.41 kg/d, carcass weight from 366 to 329 kg/hd, veterinary costs increased from 0.6 to 100.3 $/hd, and net returns decreased from 299 to 15 $/hd. Pleurisy score or lung lesions had no impact on costs of veterinary treatments, carcass weight or value, or net return. Animals considered to have experienced clinical or resolved BRD showed lower ADG, lighter and cheaper carcasses (by 25 kg/hd

and 140 $/hd), and lower net return (by 80 $/hd) compared to those considered with subclinical BRD or healthy. The severity of BRD has significant impacts on performance and economic outcomes, reducing carcass value and net returns per animal.

Executive summary

Bovine Respiratory Disease (BRD) is the most significant disease affecting the Australian cattle feedlot industry. BRD is reported as the cause of 60-70% of all illness and mortality in Australian feedlots and is estimated to cost the industry in excess of $40 million per year, both in reduced animal performance and increased costs associated with disease treatment (Sackkett et al., 2006). This project aimed to determine the true economic impact of BRD by quantifying every known cost factor associated with BRD, including individual animal treatment records, lung abnormalities at slaughter to discern between clinical and subclinical disease, labour costs and the costs associated with decreased production, among others. The project addressed two main objectives;

1. Determine the effect of the number of BRD antimicrobial treatments and lung abnormalities at slaughter (disease severity) on carcase characteristics of Australian feedlot cattle and,
2. Compare the subclinical cost of BRD (BRD not detected by human observation but evident in lung lesions at slaughter) to the cost of clinical BRD (BRD diagnosed by human observation and clinical measures, as well as lung abnormalities present at slaughter)

The project used BRD treatment records and lung data of animals from two independent trials (Trial 1: n=898, Trial 2: n=1,314) at one southern Australian feedlot in 2017. Trial 1 was a case-control trial, where for the first 150 animals that became sick with BRD, a visually healthy animal was also pulled from the same pen as the visually sick animal each day. Trial 2 involved 6 pens of steers, only pulled visually sick animals and used a different treatment protocol. All animals were followed from induction into the feedlot to slaughter at an average of 116 days on feed (DOF). Animals were monitored daily for visual signs of BRD throughout the feeding phase by feedlot pen riders. Any animals exhibiting visual signs of BRD were removed from their pens and taken for further inspection at the feedlot's hospital. Inspection at the hospital included measurement of rectal temperature and lung sounds via lung auscultation. Animals were then treated based on these clinical symptoms according to the treatment protocols of the respective trials. All treatment records and associated costs were obtained. All dead animals were autopsied by feedlot personnel trained in necropsies by the feedlot's veterinarian, with reason of death recorded and a necropsy report obtained. At slaughter, animals had their lungs examined and scored for lung consolidation and pleurisy by personnel trained prior to the commencement of the trials. All carcases were graded at 24 hours of slaughter to obtain MSA marbling, Aus-Meat Marbling, eye muscle area (EMA), total hot dressed weight, and MSA Index. Additional data collected for the purposes of economic analysis included treatment cost and close out reports for individual trial lots as well as feed allocation and feed consumption reports.

Data was analysed using mixed-effects linear mixed models to determine the effect of different BRD diagnoses and number of BRD treatments on performance, production cost and carcass characteristics (initial weight, DMI, ADG, exit weight, carcase weight, MSA Marbling, MSA Index, purchase cost, processing cost, treatment costs, feed cost, yardage cost, total value, and net returns). For the case-control BRD diagnosis based on both visual signs and clinical symptoms, a third category of animals classified as 'hospital cases' was included in analysis. These animals were initially pulled as visually healthy but upon examination at the hospital shed displayed either elevated rectal temperature or abnormal lung sounds and so were treated for BRD. For the lung diagnosis, animals were categorised into normal, moderate and severe based on their percentage of lung consolidation and pleurisy score. As no differences were found between normal and moderate animals, these two categories were combined, and only severe animals were considered in the clinical BRD diagnosis definition explained below. For the clinical BRD diagnosis definition, five categories were used in analysis; clinical, subclinical, resolved, hospital case and healthy animals. The clinical animals were those that displayed both visual signs and clinical symptoms and had severe lung lesions at

slaughter. The subclinical animals were those that did not display visual signs of BRD and were not pulled by the feedlot pen riders but displayed severe lung lesions at slaughter. The resolved animals were those that were pulled and treated for BRD based on visual signs and clinical symptoms but displayed either normal or moderate lungs at slaughter. The hospital case animals were the same as those described above for the case-control BRD diagnosis, initially pulled as visually healthy but with clinical symptoms of BRD, regardless of their lung status at slaughter. Fixed effects were included in the models for lot number and breed. Initial weight as a covariate was included in the models for any variables related to initial weight. Main effects were considered significant at $P < 0.05$.

For trial 1, compared to control animals, steers that were BRD cases (based on visual signs and high rectal temperature or lung auscultation scores) were 7.78 kg/hd lighter at induction, had 12.42 kg/hd lower carcass weights and a net return of 112.58 $/hd less ($P < 0.05$; dead and rejects out basis). With dead and rejects included, case animals had a net return of 328.91 $/hd less than control animals. The number of BRD treatments an animal received also had a large influence on animal performance and economic return, with animals treated for BRD two and three or more times exhibiting lower growth rates, carcase weights, marbling and net returns compared to animals never treated and treated once for BRD ($P<0.05$). Net return was greatest for animals never treated (183 ± 6.0 $/hd) and lowest for animals treated three or more times (-201 ± 36.6 $/hd; $P<0.05$), which amounts to a difference in profitability of $384 (dead and rejects out). With dead and rejects included, animals treated three or more times for BRD showed 930 $/hd lower net return compared to animals that were never treated for BRD.

Animals with a pleurisy score 3 had 18.79 kg lighter carcases at slaughter and returned on average $136.80 less than those with a score of 0 ($P < 0.001$). Animals with severe lung lesions at slaughter had carcases that were 14.31 kg lighter, had average daily gains 0.26 g/day less, higher BRD treatment costs, lower carcass value, and lower net return of $91.50 per head compared to animals with normal lungs ($P<0.001$). Animals with clinical BRD had 24 kg lighter carcases at slaughter and gained 0.42 g/day less and had a net return of $213.94 less than healthy animals ($P<0.05$). Carcase value was lowest for animals with clinical BRD and greatest for animals that were pulled as visually healthy but exhibited clinical symptoms at the hospital ('Hospital Case') ($P<0.05$). Net return was lowest for clinical, then animals with resolved BRD, subclinical BRD, and greatest for hospital case animals ($P<0.05$). Subclinical BRD cases showed carcasses with 100 $/hd higher value and yielded 147 $/hd higher net returns compared to clinical BRD cases ($P<0.05$).

Results in trial 2 were similar to trial 1 for the effects of the number of BRD treatments on performance, carcass traits and economic returns. However, lung lesions diagnosis and pleurisy score had no significant effects on performance, carcass traits and economic returns. This lack of an effect of lung lesions resulted in subclinical animals performing similarly to healthy animals and above clinical and resolved BRD cases. The reasons for these results are unclear.

The results from the present project demonstrated that performance, carcass traits and economic outcomes declined as the number of BRD treatments and the severity of lung abnormalities increased. Animals with subclinical BRD also had reduced carcase value at slaughter and reduced net returns compared to healthy animals in trial 1 but not in trial 2. These results help to gain a greater understanding of the economic cost of BRD to the Australian feedlot industry and can aid in identifying areas to address in order to reduce its impact on commercial feedlots. The data produced in this study could also be a useful tool for feedlot business management decisions such as health and profit driven marketing strategies related to BRD (e.g. pre-conditioning, vaccination, disease detection).

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1 Background

Bovine Respiratory disease is the largest health issue faced by the feedlot industry, resulting in significant economic losses as well as welfare concerns. The disease is estimated to cost the industry over $40 million per year primarily due to decreased carcase value and treatment costs (Sackkett et al., 2006). BRD is prevalent in feedlots due to the stress factors that young cattle face preceding and upon entering the feedlot finishing phase, such as transportation, commingling of unfamiliar animals and diet changes (Cusack, McMeniman & Lean, 2003). These stressors result in compromised animal immunity, making them susceptible to viral and bacterial pathogen infection (Snowder et al., 2006). While there have been numerous studies undertaken on the economic costs of BRD to the North American feedlot industry, to date there has been limited research on the economic cost of BRD to the Australian feedlot industry. Research in the United States has demonstrated that lung abnormalities decrease carcase weight and quality characteristics such as marbling, and that up to 50% of cattle with lung abnormalities at slaughter exhibit no clinical signs (these animals are deemed subclinical BRD cases) (White & Renter, 2009). It has also been demonstrated that overall carcase value decreases as treatments for BRD increase (Schneider et al., 2009). An Australian study by Sackkett et al. (2006), while providing useful baseline figures for the overall cost of BRD, was largely based on expert opinion and modelling rather than scientific methodology with measurements taken on an individual animal level.

This project aimed to quantify the economic cost of BRD to the Australian feedlot industry through analysis of BRD treatment records and lung abnormalities at slaughter. This can provide a clearer picture of the economic cost of BRD in feedlots to allow the Australian feedlot industry more informed decisions to manage BRD.

2 Project objectives

1. Determine the effect of the number of BRD antimicrobial treatments and lung abnormalities at slaughter on carcase characteristics of Australian feedlot cattle

3 Methodology

The present project addressed the above objective through two main analyses:

1. To compare the 'subclinical cost' of BRD (BRD not detected by human observation but evident by lung abnormalities at slaughter) to BRD diagnosed through visual signs, clinical symptoms and lung abnormalities ('clinical' BRD)
2. To determine the economic impact of severity of disease (number of BRD treatments and severity of lung abnormalities on animal performance and carcase characteristics)

3.1 Location and animals

Two trials were conducted at a single feedlot in Southern Australia.

Experiment 1 consisted of feedlot treatment records and carcass and lung data of animals from a case-control trial (n=898) using 4 pens. Steers were inducted into the feedlot between 28th of February 2017 to 15th of March 2017.

Experiment 2 was performed at the same feedlot (n=1,314) with a different BRD treatment protocol and did not include control animals (i.e. only visually sick animals were pulled). Steers were inducted into the feedlot between 12th of April 2017 and 9th August 2017.

All animals were steers of mixed breed, sourced from multiple private vendors and saleyards (Figures 1-3). Data for animal source was not available for animals from Trial 2.

Upon induction into the feedlot, all animals were administered the standard feedlot induction treatments which included a hormonal growth implant (Revalor S, Coopers Animal Health, NSW, Australia), a vaccination against *Manhaemia haemolytica* (Bovilis MH, Coopers Animal Health, NSW, Australia), a vaccination against Infectious Bovine Rhinotracheitis (IBR) (Rhinogard, Zoetis Animal Health, New Jersey, USA), a clostridial vaccine (Tasvax 5 in 1, Coopers Animal Health, NSW, Australia) and an antiparasitic injection (Bomectin, Bayer, Leverkusen, Germany). All animals were given a feedlot ear tag with a unique visual ID number. Live weight, breed type and number of permanent teeth was obtained for all animals at induction. After the completion of each induction day, animals were sent to production pens according to the assigned lot number.

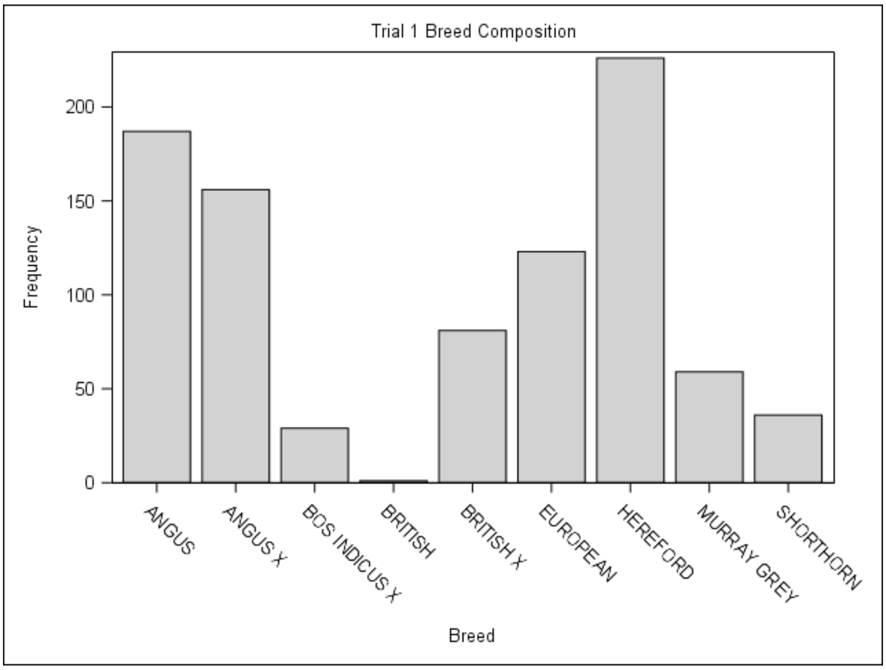

Figure 1. Breed composition of animals from Trial 1.

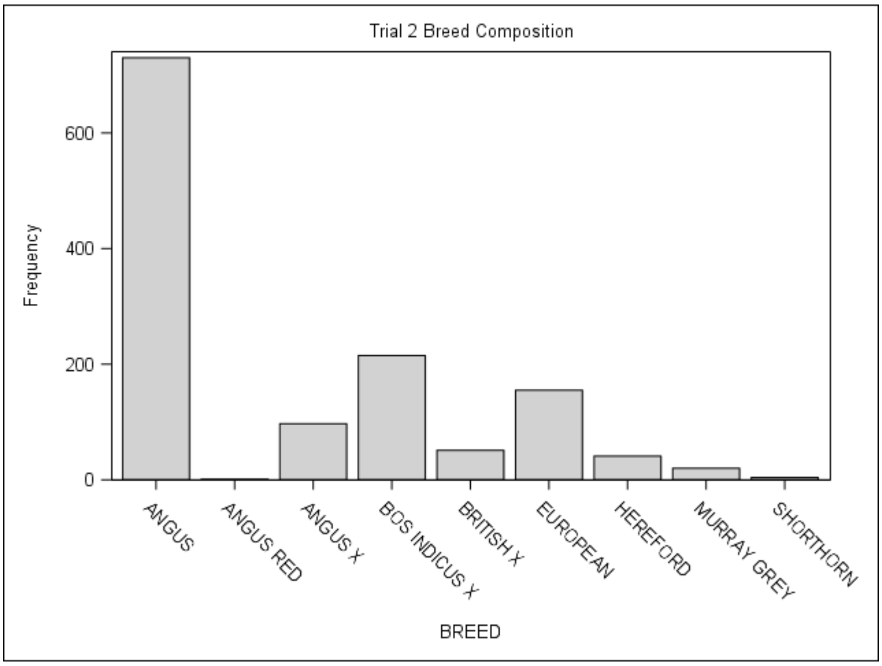

Figure 2. Breed composition of animals from Trial 2.

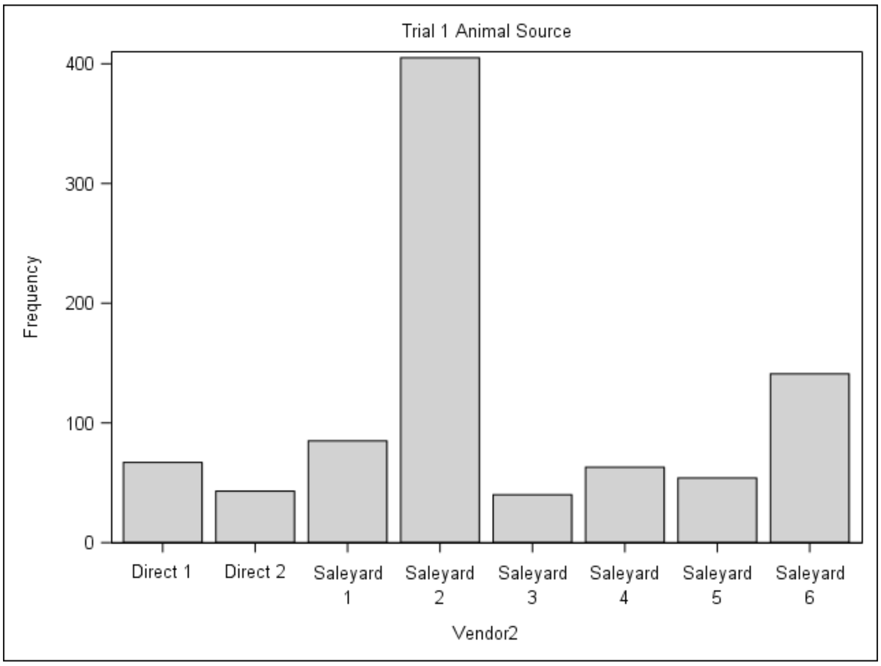

Figure 3. Animal source for Trial 1.

3.2 Diets and feeding

Animals were fed to allow for ad-libitum feed consumption. Animals were transitioned through 3 starter rations to a steam-flaked barley-based finisher diet over an 18-day period. Animals remained on this ration until slaughter unless they were sent to hospital pens for disease treatment in which case they received a high roughage (lucerne and barley hay) steam-flaked barley starter diet.

3.3 BRD treatment data collection

Following induction, animals were monitored in their pens for visual signs of BRD by trained feedlot pen riders once daily in the AM at approximately 6 to 10 AM. Any animals exhibiting visual signs of BRD (nasal and ocular discharge, cough, lethargy, depression, laboured breathing and depleted rumen fill; (McGuirk, 2008) were pulled from their pens and taken to the feedlot hospital shed for clinical measurements and treatment if required. For trial 1, a visually healthy animal was pulled for every visually sick animal until 300 animals in total were obtained for clinical measures in the same way, from which point only visually sick animals were pulled. Date, time, visual ID, RFID, pen and weight were recorded for each animal at the hospital shed. Rectal temperatures were recorded using a GLA M750 rectal thermometer (GLA Agricultural Electronics, California, USA). Lung auscultation scores were recorded using a Whisper computer assisted lung auscultation system (Geissler Corporation, Plymouth, USA).

Animals diagnosed with BRD (using rectal temperature and lung auscultation score) were treated according to the feedlot's veterinary treatment protocol with all treatments recorded. Animals from Trial 1 were treated according to the feedlot protocol in Tables 1 and 3, with lung auscultation score and rectal temperature collected only at first treatment for BRD and on control animals. Any animals pulled a second or third time for BRD did not have lung auscultation score or rectal temperature collected and were therefore treated regardless of clinical symptoms.

Animals in Trial 2 were treated according to the treatment protocol outlined in Tables 2 and 3. Animals that were pulled a third time for BRD in this trial received Nuflor and Meloxicam and were then sent to the chronic hospital pen with no further antimicrobial treatment permitted. These animals later returned to their production pens once recovered and were slaughtered with the main cohort if they were deemed salvable and had cleared any chemical withholding period/export slaughter interval. Any animals pulled on suspicion of Infectious Bovine Rhinotracheitis (IBR) from either Trial 1 or Trial 2 were treated with penicillin and dexadresson for the first treatment of IBR, followed by two more doses of penicillin over the subsequent two days. If the animal was still sick or pulled again for IBR following the first course of penicillin, animals were treated with a second course of penicillin, consisting of three doses each three days apart. These IBR animals were considered as BRD affected in the analysis.

Table 1. Feedlot treatment protocol for first treatment of Bovine Respiratory Disease in Trial 1

Lung auscultation score and rectal temperature	Treatment
Lung score 1 & rectal temperature <40°C	No treatment
Lung score 1 & rectal temperature ≥40°C	Tilmicosin (Micotil, Elanco Animal Health)
Lung score ≥2, regardless of rectal temperature	Tulathromycin (Draxxin, Zoetis Animal Health)

Table 2. Feedlot treatment protocol for the first treatment of Bovine Respiratory Disease in Trial 2

Lung score and rectal temperature	Treatment
Lung score 1 & rectal temperature < 40 °C	No treatment
Lung score 1 & rectal temperature ≥ 40 °C or Lung score ≥2 regardless of temperature	Tulathromycin (Draxxin, Zoetis Animal Health)

Table 3. Feedlot treatment protocol for second and third treatment of Bovine Respiratory Disease for Trial 1 and Trial 2.

Second treatment	Third treatment	Animals 60-90 DOF*†	Animals >90 DOF†
Oxytetreacycline, (Engemycin, Coopers Animal Health)‡	Florfenicol‡ (Nuflor, Merck Animal Health) and Meloxicam (Meloxicam20m Ilium)	Ceftiofur (Excede, Zoetis)	Ceftiofur (Accent, Zamira)‡

*DOF=Days on Feed
† Due to slaughter withholding periods, regardless of what number of BRD treatment the animal is receiving
‡ 2 doses, 2 days apart. NB for the second course of the third BRD treatment, only Nuflor is administered

3.3.1 Visual-clinical BRD definition

Trial 1 was a case-control experimental design which involved pulling a visually healthy animal for every animal pulled with visual signs of BRD until 150 sick animals and 150 healthy animals were obtained. Following this number of animals being reached, only sick animals were pulled from their pens. Animals pulled as visually healthy controls that displayed high rectal temperature or high lung auscultation score, or both, upon examination at the hospital shed were then treated as per the routine treatment protocol of the feedlot. Therefore, a BRD 'hospital case' definition accounted for these animals pulled as visually healthy but showing clinical symptoms of BRD. The classification of animals as either BRD cases, controls or hospital cases based on visual signs and clinical symptoms at the hospital is outlined in Table 4.

Table 4. Classification of animals into the visual-clinical BRD definition based on visual signs and clinical symptoms of BRD.

Visual signs and clinical symptoms	BRD Control	BRD Case	BRD Hospital case
Visual signs of BRD*	No visual signs of BRD in the pen	Visual signs of BRD in the pen	No visual signs of BRD in the pen
Clinical symptoms (elevated rectal temperature and/or abnormal lung sounds)†	No clinical symptoms of BRD at the hospital shed	Clinical symptoms of BRD at the hospital shed	Clinical symptoms of BRD at the hospital shed

*Visual signs of BRD included any of the following; nasal or ocular discharge, lethargy, depression, anorexia, cough or abnormal head carriage

†Rectal temperature threshold for BRD was 40°C. Lung auscultation threshold for BRD was a score ≥2 for lung score

3.3.2 Number of BRD treatments

Animals were categorised into either never treated for BRD, treated once, treated twice or treated three or more times. For this part of analysis, the hospital case animals described above were excluded from the analysis as these animals were not considered normal cases of BRD due to their lack of visual signs of BRD in the pen and them being pulled as healthy control animals.

3.4 Necropsies

Necropsies were performed on any trial animal that died during the experiment by trained feedlot personnel, with date and reason of death recorded and a necropsy report obtained (Sullivan & O'Brien, 2016). Body removal costs were estimated based on the time required to dispose 30 random bodies undertaken throughout the trial period. The time taken averaged 30 minutes per mortality for one person with an estimated hourly rate of $35/hr and $42.50/mortality for machinery and fuel costs, totalling $60 per BRD mortality.

3.5 Slaughter and lung scoring

All trial animals were followed through to slaughter at between 112 and 122 days on feed. Just after the knocking box, a person recorded body number and feedlot visual ID of all trial animals. All lungs were examined on the offal table by the same two people who were trained prior to the commencement of the trial. Lungs were examined for consolidation, pleurisy and abscesses. Lung consolidation was recorded using the lung scoring method explained by (Theurer et al., 2013), where the consolidation on each lobe was summed to form a total percentage of lung consolidation. Pleurisy was recorded using a scoring system of 0 to 3 outlined in Table 5 (Sullivan, 2017).

Table 5. Pleurisy scoring system for lungs at the abattoir

Pleurisy Score	Description
0	No pleurisy or pleuritic tags evident on the lungs
1	Tags between lobes or small pleuritic tags on the lung surface
2	Significant pleuritic tags on the lung surface or small pieces of lung adhered to the thoracic wall or significant tags on the lung margins (fringing) or between lobes that could not be broken apart by the inspector
3	All the lung adhered to the thoracic wall with no lung present on the offal table for scoring

Presence of lung abscess was recorded as either yes or no. No consolidation score was recorded for animals with a pleurisy score of 3 due to the lungs being adhered to the thoracic wall and unable to be scored. Lung lesions were categorized as normal, moderate or severe based on the consolidation and pleurisy scores (Table 6). Animals that died at the feedlot were not included in this lung score definition.

Table 6. Lung scores categorization table for the lung lesion definition (N=Normal, M=Moderate, S=Severe).

	Pleurisy			
Consolidation	**0**	**1**	**2**	**3**
0-1%	N	N	M	S
2-9%	N	M	M	S
10-55%	M	M	S	S
No Score			M	S

Grading occurred on all carcases at approximately 24 hours after slaughter and data was collected and recorded by the plants data recording system using a combination of the Ausmeat (AUS-MEAT Australia; (AUS-MEAT, 2005)) and Meat Standards Australia grading systems (MSA; (Polkinghorne et al., 2008)). Data collected at slaughter included kill date, body number, sex, dentition, butt shape, fat depth (P8), fat colour, meat colour, MSA boning group, hump height, tropical breed content, MSA marbling, Ausmeat Marbling, Ossification, EMA pH, Rib Fat, EMA, total hot standard carcase weight, left and right-side bruising, left and right-side weight, and MSA Index. This data was also collected for an MSA un-grade (except the MSA Index which is an indicator of eating quality).

3.5.1 Clinical, subclinical, hospital case, resolved and healthy BRD definition

Animals were considered to be 'clinical' cases of BRD if they were pulled from their pens due visual signs of BRD, displayed clinical symptoms (high temperature or lung auscultation, or both) and had severe lung lesions. Animals were considered 'subclinical' cases of BRD if they were never treated for BRD at the feedlot but showed severe lung lesions at slaughter. Animals were considered 'healthy' for BRD if they were never treated for BRD and showed normal or moderate lungs at slaughter. Animals were considered 'resolved' cases if they were pulled and treated for BRD based on visual signs and clinical symptoms but displayed either normal or moderate lungs at slaughter. Animals that were pulled as visually healthy in trial 1 (no visual signs of BRD), that were then treated for BRD due to displaying clinical symptoms (elevated temperature or lung auscultation score) were classified as hospital cases as in the BRD case-control definition described above.

3.6 Performance outcomes

Performance and economic data for analysis included average daily gain (ADG), dry matter intake (DMI), carcase weight, total value and net return per animal. Performance outcome and cost variables and formulas are presented below in Table 7. Trial 1 and 2 contained similar data collected at the feedlot and used for the calculations. However, Trial 2 dataset contained less information compared to Trial 1. Therefore, Trial 2 assumed a purchase price of $3.20 /kg of BW at induction, an induction cost of $13.53 /head, a transport cost of $13 /head from place of purchase to feedlot, transport cost of $13/head for transport from feedlot to abattoir, a yardage cost of $1.07 /hd/day, and a feed cost of $0.27 /kg of DM. Information for Trial 2 is presented in MLA final report for Project B.FLT.0242 because we used the animals from the control treatment of that experiment.

Table 7. Performance and cost outcome variables, descriptions and formulas for animals.

Variable	Descriptions	Formula
Induction weight, kg	Individual animal weight at feedlot entry	
DMI, kg	Individual Dry Matter Intake	(Weight days x total feed delivered)/pen weight days*
Exit weight, kg	Weight at feedlot exit	
ADG, kg/d	Average daily gain	(Exit weight – induction weight)/DOF
Carcass weight, kg	Total hot carcass weight at slaughter	
MSA Marble	MSA marbling score (range 100-1190)	
MSA Index	Eating quality potential of carcass (range 30-80)	
Purchase Cost, $/kg	Direct cost of purchase per animal based on $/kg	Feedlot records for trial 1. Assumed $3.2/kg LW for trial 2
Processing cost	Cost of individual animal processing at induction	Labour cost + treatment cost + visual ID and NLIS ID tag cost
BRD Treatment Cost	Individual drug cost for animals treated for BRD + BRD vaccination cost at induction	
Feed Cost, $/hd	Average feed cost for delivered feed per head to cattle slaughtered ($270/ton DM)	
Total hospital treatment cost $/hd	Sum of all costs incurred for animal treatment at the hospital shed independent of type of disease	
Yardage Cost, $/hd	Yardage costs per animal per day (includes feedlot overheads)	Total DOF x Yardage per day (~$1.05/day)
Body removal cost†	Average cost of body removal per animal	

Total Value, $/hd Net Return per Animal, $/hd	estimated at $60/mortality Individual value of carcasses obtained at the plant according to the grid	Time spent on each task and labour units Total value at slaughter – purchase price – processing cost - feed cost – veterinary treatment cost – yardage cost – freight out – freight in – buyer commission – levy – miscellaneous costs

* Weight days = average weight of animal x total DOF. Pen weight days=∑DOF of all animals in pen x ∑average weight of all animals in pen
†Body removal cost was calculated using an average time of 30 minutes per dead at a labour rate of $35/hr plus fuel and machinery costs of $42.50/hr.
Included: Hay cost upon arrival and before induction, direct fed microbial (DFM) cost and other miscellaneous costs

3.7 Statistical analysis

Data was analysed using the statistical software package SAS (SAS Institute, NC, USA). Mixed-effects linear mixed-effects models were used to determine the effect of different BRD diagnoses methods and the number of BRD treatments on performance, production costs and carcass characteristics (initial weight, DMI, ADG, exit weight, carcase weight, MSA Marbling, MSA Index, purchase cost, processing cost, treatment costs, feed cost, yardage cost, total value, and net returns). Honker animals (difficult breathing) were considered as BRD for the purpose of analysis. Fixed effects were included in the models for BRD diagnoses method or number of BRD treatments, breed; and lot number as a random effect. Initial weight was included as a covariate in the models when significant because initial weight was different (e.g. carcass weight was affected by induction weight). Main effects were considered significant at $P \leq 0.05$ and tendencies discussed at $0.05 < P \leq 0.10$. Where data did not follow a normal distribution, it was transformed prior to analysis using either square or log transformation to obtain p-values with the mean and standard error values obtained from the untransformed data.

4 Results

4.1 Results Trial 1

4.1.1 Animals and Induction (Trial 1)

Basic statistics are shown below for data captured at induction in Trial 1 (Table 8). Steers were purchased at an average of $3.19/kg of live weight but ranged from $2.70-$3.50/kg (data not shown). Induction weight was highly variable but followed a normal distribution, with most animals between 400-500 kg at induction into the feedlot.

Table 8. Basic statistics for Trial 1 at induction into the feedlot.

Variable	N	Minimum	Mean	Maximum	Std Dev
Pay Weight, kg/hd	898	282	438	581	50.0
Off Truck Weight, kg/hd	898	280	426	563	50.0
Induction Weight, kg/hd	898	276	432	576	51.0
Purchase Cost, $/hd	898	895	1,397	1,837	159.0
Freight-in Cost, $/hd	898	0.00	14.38	27.39	9.140

There were 870 animals slaughtered which had lung and carcase data collected. Table 9 gives an overview of the number of animals inducted, dead, rejected and slaughtered for the four pens in Trial 1. The three animals rejected for slaughter were deemed unfit to travel and be slaughtered with the main cohort due to chronic lameness and were sent for pet food. No carcass or lung data was collected for these animals. Out of the two animals retained at the feedlot, one was still within the withholding period due to veterinary treatment so could not be slaughtered for human consumption and the other could not be sent with the main cohort to slaughter due to illness. These animals were retained at the feedlot until they were able to exit for slaughter. No lung data was collected for these animals.

Table 9. Summary of the number of animals inducted, dead, rejected for slaughter, retained at feedlot and slaughtered for the metabolomics trial 1 lots.

Lot Number	Inducted	Dead	Rejected for slaughter	Retained at feedlot	Slaughtered
1	300	2	1	0	297
2	266	12	2	0	252
3	91	4	0	0	87
4	241	5	0	2	234
Total	898	23	3	2	870

4.1.2 BRD Treatment Records (Trial 1)

A total of 391 treatments were made at the hospital shed (Table 10). It should be noted that the same animal could appear in multiple rows and any animals treated for BRD a second and third time are included in the first BRD treatment total. The BRD treatment rate was high, with 25.6% of the 898 trial animals treated for BRD, compared to only 6.1% treated for lameness conditions. There were 230 animals treated for BRD a first time, 58 treated for BRD a second time and 31 treated for BRD a third time. The total cost of BRD treatments (first, second and third treatments) was $7854.62, with most of the cost associated with the initial BRD treatment. The total cost of lame treatments was $686.77. Lot 3 had the highest proportion of treatments (76%), followed by lot 2 (62%), lot 1 (31%), with lot 4 having the lowest proportion of treatments (26%). Some bullers may sometimes not be treated at the hospital shed as they are removed and from their home pen and passed through the hospital pens for one week.

Table 10. Number of treatments in each trial lot treated at the hospital for BRD, lameness, bulling and pink eye and total costs of treatments at the hospital for Trial 1. *

		Lot Number				
		1 N=300	**2 N=266**	**3 N=91**	**4 N=241**	**Total N=898**
1st BRD	Nro. Treatments	55	99	44	32	230
	Cost, $/pen	$1296.14	$2377.85	$1068.41	$791.59	$5533.99
	Cost, $/hd treated	$23.57	$24.02	$24.28	$24.74	$24.06
	Cost, $/hd inducted	$4.32	$8.94	$11.74	$3.28	$6.16
2nd BRD	Nro. Treatments	9	24	14	11	58
	Cost, $/pen	$79.99	$291.83	$166.65	$131.10	$669.57
	Cost, $/hd treated	$8.89	$12.16	$11.90	$11.92	$11.54
	Cost, $/hd inducted	$0.27	$1.10	$1.83	$0.54	$0.75
3rd BRD	Nro. Treatments	5	14	7	5	31
	Cost, $/pen	$256.35	$788.46	$365.96	$240.29	$1651.06
	Cost, $/hd treated	$51.27	$56.32	$52.28	$48.06	$53.26
	Cost, $/hd inducted	$0.85	$2.96	$4.02	$1.00	$1.84
Lame	Nro. Treatments	15	24	4	12	55
	Cost, $/pen	$183.79	$311.61	$42.11	$149.26	$686.77
	Cost, $/hd treated	$12.25	$12.98	$10.53	$12.44	$12.49
	Cost, $/hd inducted	$0.61	$1.17	$0.46	$0.62	$0.76
Bullers	Treatments	8	5	0	2	15
	Cost, $/pen	$31.77	$0	$0	$6.21	$37.98
	Cost, $/hd treated	$3.97	-	-	$3.11	$2.53
	Cost, $/hd inducted	$0.11	-	-	$0.03	$0.04
Pink eye	Nro. Treatments	1	0	0	1	2
	Cost, $/pen	$2.06	$0	$0	$2.06	$4.12
	Cost, $/hd treated	$2.06	-	-	$2.06	$2.06
	Cost, $/hd inducted	$0.01	$0.00	$0.00	$0.01	$0.00
Total number of treatments		93	166	69	63	391
Total cost of treatments, $/pen		$1850.10	$3769.75	$1643.13	$1320.51	$8583.49
Treatment cost ($/total head treated)		$19.89	$22.71	$23.81	$20.96	$21.95
Treatment cost ($/total head inducted)		$6.17	$14.17	$18.06	$5.48	$9.56

*BRD treatments include all treatments done including animals with visual signs and clinical signs, or only clinical signs. Dead animals are also included if treated.

4.1.3 Mortalities due to BRD (Trial 1)

There were 23 mortalities in Trial 1 (2.6% mortality rate), with 78% (18) attributed to BRD and the remaining deaths due to bloat, injury/abscess, enterotoxaemia and septicaemia (Figure 5). A downer refers to an animal that is unable to get up in the pen and it was euthanised. Despite the reason of death being recorded as BRD for only 18 of the 23 mortalities, there was only two animals out of the remaining five animals that was either never treated for BRD or had no signs of BRD recorded at the time of necropsy. The three animals that were treated for BRD before death but cause of death was not recorded as BRD died from either bloat, enterotoxaemia, broken leg or being a downer.

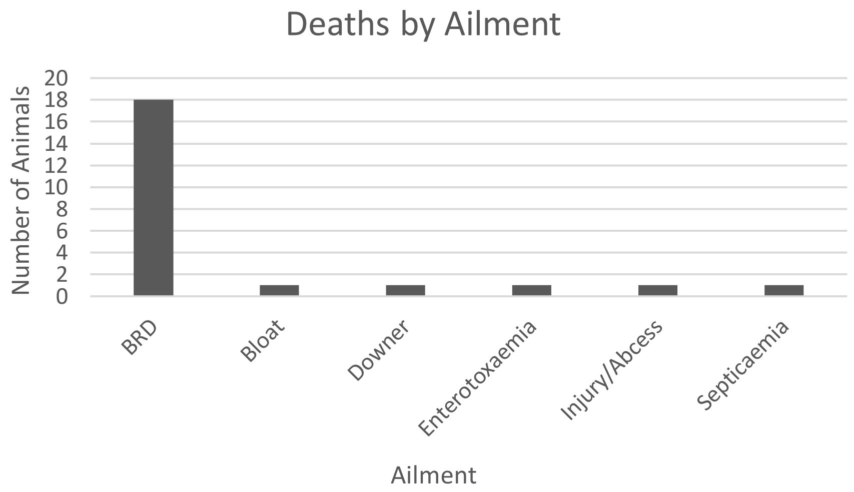

Figure 5. Number of mortalities attributed to BRD, bloat, downer, enterotoxaemia, injury/abscess and septicaemia in Trial 1. Deaths attributed to BRD were recorded as 18 however 21 animals were treated for BRD before death.

The frequency of animals that had 0, 1 and 2 BRD treatments before death is displayed in the histogram below (Figure 6). There were two animals that had no treatment for BRD, 20 animals that had 1 treatment and one animal that was treated for BRD twice before death.

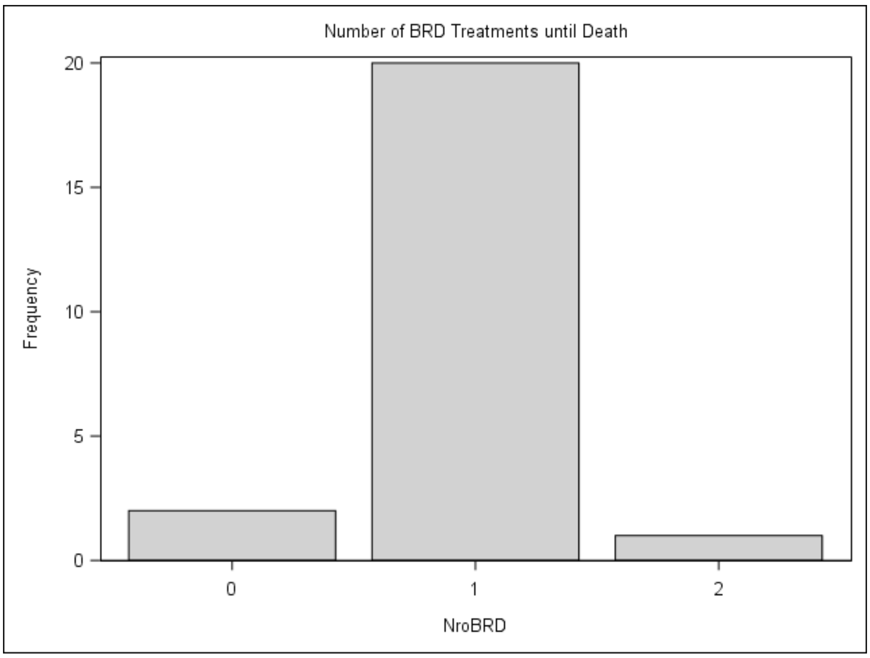

Figure 6. Histogram of number of BRD treatments of the trial 1 mortalities.

Descriptive statistics for the mortalities from Trial 1 is shown in Table 11. The average days on feed at death was 42 DOF, with the first mortality occurring at 14 DOF. On average, the 23 animals that died lost an average of 1.10 kg/day from induction until day of death. The average net loss per animal for all 23 animals (not just those that were BRD) was -1690.59 $/hd, while the average net loss per animal for animals that died from BRD only was -1690.99 $/hd, totalling $35,510.79.

Table 11. Summary statistics for performance and cost variables for the 23 mortalities from Trial 1.

Variable	N	Minimum	Mean	Maximum	Std Dev
Days on feed at death	23	14.00	42.78	97.00	22.59
Induction Weight, kg/hd	23	328.00	431.65	492.00	46.53
Pay Weight, kg/hd	23	340.00	441.57	510.00	48.72
Purchase Value, $/hd	23	1,064.88	1,399.30	1,627.11	142.78
Total DMI, kg/hd	23	116.03	361.09	727.90	177.39
ADG to first pull, kg/day	23	-10.00	-1.10	2.91	3.33
Induction processing costs, $/hd*	23	12.97	12.97	12.97	0
BRD hospital treatment costs, $/hd	21	16.18	63.53	117.67	36.61
Total BRD treatment costs, $/hd†	23	5.67	63.67	123.34	39.41
Lame hospital treatment costs, $/hd	5	9.45	13.12	23.78	6.00
Buller hospital treatment costs, $/hd	1	21.00	21.00	21.00	0
Transport cost, $/hd	23	0	14.10	27.38	9.33
Feed cost, $/hd	23	31.32	97.49	196.53	47.90
Yardage cost, $/hd	23	14.21	44.95	101.97	23.70
Direct cost to death, $/hd‡	23	1,133.75	1,630.59	1,929.98	172.64
Body removal costs, $/hd§	23	60.00	60.00	60.00	0
Net loss death ‖	23	-1393.75	-1690.59	-1989.98	172.64
Net loss death BRD only	21	-1393.75	-1690.99	-1989.98	180.90

*Induction processing cost includes cost of BRD vaccinations valued at $5.67/animal
†Total BRD treatment costs include vaccination for BRD at induction and BRD antimicrobial treatments upon pulling
‡Direct cost to death includes purchase cost, induction processing costs, hospital treatment costs, transport costs, feed costs and yardage costs
§Body removal cost was calculated using an average time of 30 minutes per dead at a labour rate of $35/hr plus fuel and machinery costs of $25/hr.
‖ Net loss was calculated as the sum of direct costs to death and body removal costs

4.1.4 Animal slaughter and lung data (Trial 1)

Basic statistics for the carcase data collected at the abattoir are shown below (Table 12). Carcase value showed large variability, with $1,476 difference between the highest and lowest value carcases. Hot standard carcase weight was also highly variable, with a difference of 281 kg between the heaviest and lightest carcases.

Table 12. Summary statistics for carcase data of the 870 animals slaughtered in trial 1.

Variable	N	Minimum	Mean	Maximum	Std Dev
Dentition	870	0	1.28	6	1.35
Fat Depth, mm	870	2	17.10	40	5.36
Fat Colour Score	870	0	0.90	5	0.45
MSA Boning Group	851	2	6.38	12	1.65
Hump Height, cm	870	0	71.83	135	19.88
Tropical Breed Content	870	0	75.61	110	51.02
MSA Marble*	869	130	351.7	640	75.98
Ausmeat Marble	870	0	1.17	4	0.68
Ossification score	870	110	177.57	230	18.80
pH	870	5.20	5.51	6.34	0.086
Rib Fat, mm	870	0	8.56	25	3.49
Eye Muscle Area, cm^2	869	55	85.1	124	13.0
Carcass Weight, kg/carcass	870	228	351.36	509	44.51
Total Value, $/hd	870	1,094	2,059	2,570	253.3
Left Bruise score	870	0	0.03	3	0.29
Left Weight, kg	870	106	174.98	253	22.31
Left Price, $/kg	870	4.8	5.86	6.13	0.26
Left Value, $	870	540	1025.18	1284.24	127.02
Right Bruise score	870	0	0.03	3	0.30
Right Weight, kg	870	115.5	176.38	256	22.27
Right Price, $/kg	870	4.8	5.86	6.13	0.26
Right Value, $	870	554.4	1033.39	1292.8	126.68
MSA Index†	851‡	47.67	54.69	60.84	1.97

*MSA=Meat Standards Australia

† Only 851 animals had an MSA Index assigned due to 19 animals not meeting MSA specifications (MSA ungrade)

There were 790 animals with a lung consolidation score recorded at slaughter. This was due to 80 animals being assigned a score 3 for pleurisy, with all the lungs remaining in the chest cavity and therefore a consolidation score could not be assigned for these animals. A histogram of the number of animals in each of the lung consolidation percentage categories shows a logarithmic distribution with a low number of animals exhibiting a high proportion of the lungs affected (Figure 7). Most animals (85.70%) had less than 10% lung consolidation and only two animals had 50% lung consolidation.

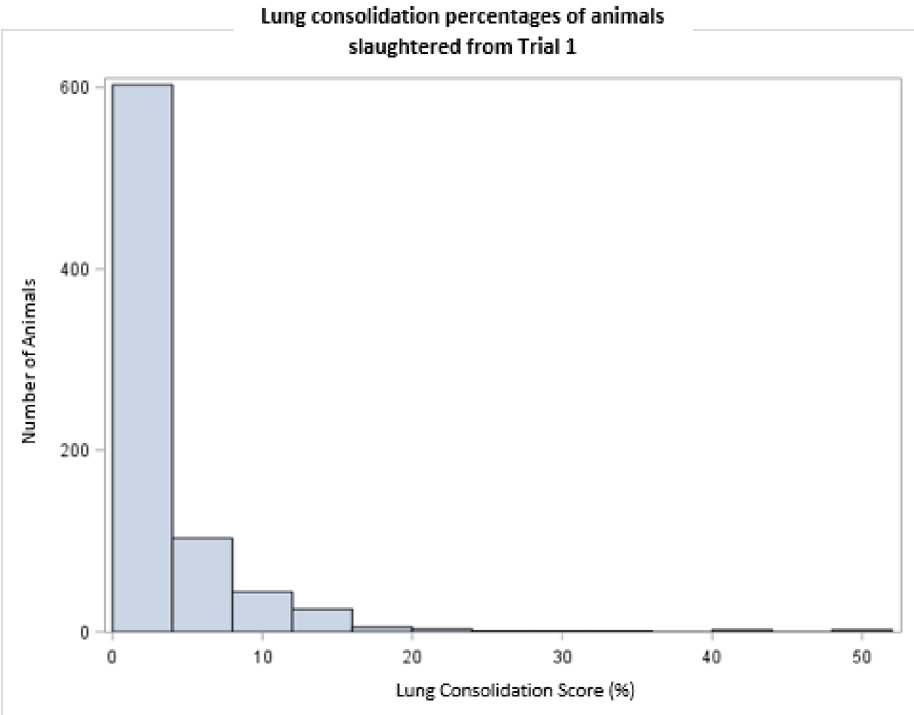

Figure 7. Lung consolidation scores for Trial 1.

4.1.5 Effects of BRD on animal performance and economic outcomes (Trial 1)

4.1.5.1 Effect of visual-clinical BRD status on animal performance and economic outcomes

Table 13 displays the animal performance and economic outcomes of BRD cases, controls and hospital case animals as defined by visual signs and clinical symptoms on a DEADS AND REJECTS OUT basis, with the 23 mortalities and 3 chronic lame rejects deleted from analysis. Most animals (76%) were classified as controls according to this definition, with 16.6% of animals classified as cases and 7% classified as hospital cases. BRD cases had lower ADG, DMI, exit weight, carcass weight and marbling score compared to both control and hospital case animals ($P < 0.05$). In addition, BRD cases showed higher BRD treatment costs, and as a result of this and lower carcass value, the net return was lower compared to control and Hospital cases ($P < 0.05$). Interestingly, Hospital cases showed greater ADG and exit weight ($P < 0.05$) compared to control animals however their net returns were similar ($P > 0.10$). Feed costs were greater for control animals than case animals ($P<0.001$).

Table 13. Performance and economic outcomes for BRD case, control and hospital case animals according to the visual-clinical BRD definition on a DEADS AND REJECTS OUT basis in Trial 1.

	Visual-Clinical BRD Status			
Variable	Control	Case	Hospital case§	*P* value
N	664	145	63	ChiSq=<0.001
In-weight, kg/hd*	428.23 ± 5.96	420.45 ± 6.82	437.53 ± 8.49	0.07
Exit weight, kg/hd*†	636.86 ± 5.32^{a}	611.48 ± 6.12^{b}	653.56 ± 7.61^{c}	<0.001
DMI, kg DM/hd‡	1211.42 ± 6.02^{a}	1142.51 ± 11.41^{b}	1238.42 ± 17.28^{a}	<0.001
ADG, kg/d*‡	1.81 ± 0.05^{a}	1.55 ± 0.06^{b}	1.94 ± 0.07^{c}	<0.001
Carcass weight, kg/carcass*†	349.01 ± 2.95^{a}	336.59 ± 3.39^{b}	357.72 ± 4.21^{a}	<0.001
MSA marble score*†	348.69 ± 7.99^{a}	323.89 ± 9.15^{b}	346.43 ± 11.43^{ab}	0.0023
MSA Index*†	54.31 ± 0.21	54.15 ± 0.24	54.13 ± 0.30	0.54
Purchase price, $/hd*	1373.51 ± 18.52	1369.01 ± 21.22	1406.98 ± 26.41	0.23
Processing cost, $/hd	7.30 ± 0	7.30 ± 0	7.30 ± 0	1
BRD treatment cost, $/hd#	5.67 ± 0 ^{a}	40.88 ± 0.86^{b}	28.86 ± 1.31^{c}	<0.001
Lame treatment cost, $/hd	11.46 ± 0.714	10.84 ± 0.976	6.93 ± 3.780	0.47
Transport, $/hd‡	25.11 ± 0.36^{ab}	26.84 ± 0.68^{a}	23.37 ± 1.02^{b}	0.01
Feed cost, $/hd‡	327.08 ± 1.62^{a}	308.48 ± 3.08^{b}	334.37 ± 4.67^{a}	<0.001
Yardage cost, $/hd‡	117.88 ± 2.41	117.88 ± 2.41	117.88 ± 2.41	1
Total value at slaughter, $/hd*†‡	2042.61 ± 19.88^{a}	1961.86 ± 22.34^{b}	2084.70 ± 27.89^{a}	<0.001
Net return, $/hd	182.86 ± 6.08^{a}	70.28 ± 13.32^{b}	198.10 ± 19.54^{a}	<0.001

*model included breed as a fixed effect (P < 0.05)
†model included induction weight as a covariate (P < 0.05)
‡model included Lot/pen number as a fixed effect (P < 0.05)
§ Animals pulled as visually healthy but subsequently treated at the hospital shed based on clinical symptoms of elevated rectal temperature or lung auscultation score
‖MSA=Meat Standards Australia
Includes induction cost for BRD vaccinations of 5.67 $/hd. Data was log transformed to obtain mean and standard error values due to non-normality.

Table 14 displays animal performance and economic outcomes of BRD cases, controls and hospital case animals as defined by visual signs and clinical symptoms on a DEADS AND REJECTS IN basis, with the 23 mortalities and 3 chronic lame reject animals included in analysis. There were 669 controls, 165 cases and 64 hospital cases according to this BRD definition. Including the dead animals in analysis exacerbated the difference between case and control animals. Case animals had lower induction weights, exit weights, DMI, ADG, carcase weight and marbling score (P < 0.001). No differences were observed between controls and hospital cases (P > 0.05) except for exit weight and BRD treatment cost (P < 0.001). Case animals had higher BRD treatment costs (38.8 $/hd) and a lower value (-312.8 $/hd) and net return (-328.9 $/hd) at slaughter compared to control animals (P < 0.001). Total value at slaughter was highest for hospital cases (despite these animals having BRD treatment costs) (P < 0.001).

Table 14. Performance and economic outcomes for case, control and hospital case animals based on the visual-clinical BRD definition on a DEADS AND REJECTS IN basis in Trial 1.

	Visual-Clinical BRD Status			
Variable	Control	Case	Hospital case§	*P* value
N	669	165	64	ChiSq=<0.001
In-weight, kg/hd*	427.85 ± 5.91	422.17 ± 6.63	436.57 ± 8.40	0.13
Exit weight, kg/hd*†	636.94 ± 5.31^{a}	611.41 ± 6.11^{b}	653.52 ± 7.61^{c}	<0.001
DMI, kg DM/hd‡#	1204.49 ± 8.24^{a}	1052.95 ± 14.83^{b}	1226.70 ± 23.82^{a}	<0.001
ADG, kg/d*‡	1.81 ± 0.05^{a}	1.55 ± 0.06^{b}	1.94 ± 0.07^{a}	<0.001
carcass weight, kg/carcass*†	349.09 ± 2.94^{a}	336.52 ± 3.38^{b}	356.63 ± 4.21^{a}	<0.001
MSA marble score*†	348.41 ± 8.08^{a}	324.32 ± 9.26^{b}	346.44 ± 11.57^{ab}	0.0007
MSA Index*†	54.31 ± 0.21	54.16 ± 0.24	54.13 ± 0.30	0.55
Purchase price, $/hd*	1372.72 ± 18.49	1369.58 ± 20.75	1404.35 ± 26.28	0.27
Processing cost, $/hd	7.30 ± 0	7.30 ± 0	7.30 ± 0	1
BRD treatment cost, $/hd**	5.67 ± 0.0 ^{a}	44.60 ± 0.95^{b}	28.75 ± 1.53^{c}	<0.001
Lame treatment cost, $/hd	12.80 ± 0.81	10.79 ± 1.08	8.53 ± 3.23	0.20
Transport, $/hd‡	25.11 ± 0.36^{ab}	25.30 ± 0.65^{a}	23.27 ± 1.04^{b}	0.21
Feed cost, $/hd‡#	325.21 ± 2.22^{a}	284.30 ± 4.01^{b}	331.21 ± 6.43^{a}	<0.001
Yardage cost, $/hd‡	117.88 ± 2.41	117.88 ± 2.41	117.88 ± 2.41	1
Total value at slaughter, $/hd†‡#	2057.84 ± 15.97^{a}	1745.05 ± 28.77^{b}	2095.63 ± 46.12^{a}	<0.001
Net return, $/hd	167.39 ± 12.46^{a}	-161.52 ± 25.09^{b}	171.72 ± 40.28^{a}	<0.001

*model included breed as a fixed effect (P < 0.05)
†model included induction weight as a covariate (P < 0.05)
‡model included Lot/pen number as a fixed effect (P < 0.05)
§Hospital case refers to animals that were pulled as visually healthy but were subsequently treated at the hospital based on clinical symptoms of elevated rectal temperature or lung auscultation score
||MSA=Meat Standards Australia
#Data was transformed using squared root to obtain p-value due to non-normality
** Includes 5.67 $/hd of BRD vaccinations at induction. Data was log transformed to obtain p-value due to non-normality

4.1.5.2 Effect of number of BRD treatments on animal performance and economic outcomes

Table 15 shows the performance outcomes based on the number of BRD treatments an animal received on a DEADS AND REJECTS OUT basis, with the 23 mortalities, 3 chronic lame rejects and hospital case animals deleted from analysis. Most animals (82%) were never treated for BRD, with 13% treated once, 3% treated twice and 2% treated three or more times. Animals treated for BRD 2 and 3+ times showed lower growth rate, exit weight, carcass weight and marbling compared to animals never treated and treated once for BRD (P < 0.001). ADG was greater for animals treated twice compared to animals treated 3+ times for BRD (P <0.001). Cost of BRD treatments increased with the number of treatments (P < 0.001) whereas animal value and net return decreased with the number of treatments (P < 0.001) showing a difference of $384.97 in net return between animals not treated for BRD and treated 3 or more times. No significant differences were found for in-weight, MSA Index, purchase price, processing cost, lame treatment cost, transport cost or yardage cost (P > 0.05).

Table 15. Performance and economic outcomes according to the number of treatments for Bovine Respiratory Disease defined as animals having both visual and clinical signs on a DEADS AND REJECTS OUT basis. Animals treated as a result of showing clinical signs, but not visual signs were not considered in the analysis in Trial 1.

	Number of BRD Treatments				
Variable	0	1	2	3 +	*P* value
N	663	101	26	19	Chi=<0.001
In-weight, kg/hd*	427.98 ± 5.996	420.29 ± 7.328	418.12 ± 11.432	413.20 ± 12.899	0.26
Exit weight, kg/hd*†	633.54 ± 5.142^{a}	623.95 ± 6.301^{a}	580.77 ± 9.803^{b}	559.48 ± 11.320^{b}	<0.001
DMI, kg DM/hd‡	1212.87 ± 6.060^{a}	1164.31 ± 13.846^{b}	1121.84 ± 26.440^{bc}	1055.64 ± 30.953^{c}	<0.001
ADG, kg/d*‡	1.79 ± 0.048^{a}	1.69 ± 0.058^{a}	1.30 ± 0.089^{b}	1.10 ± 0.102^{b}	<0.001
carcass weight, kg/carcass*†	347.44 ± 2.816^{a}	343.38 ± 3.450^{a}	320.29 ± 5.368^{b}	307.85 ± 6.198^{b}	<0.001
MSA§ marble score*†	347.68 ± 8.110^{a}	331.86 ± 9.917^{ab}	304.07 ± 15.460^{b}	299.73 ± 17.451^{b}	<0.001
MSA§ Index*†	54.30 ± 0.213	54.33 ± 0.261	53.38 ± 0.418	54.14 ± 0.479	0.10
Purchase price, $/hd*‡	1403.76 ± 18.726	1376.54 ± 22.415	1370.98 ± 34.622	1342.53 ± 39.118	0.12
Processing cost, $/hd	7.30 ± 0	7.30 ± 0	7.30 ± 0	7.30 ± 0	1
BRD treatment cost, $/hd	5.67 ± 0.0	25.32 ± 1.125^{a}	37.40 ± 2.173^{b}	88.83 ± 2.612^{c}	<0.001
Lame treatment cost, $/hd	11.91 ± 0.804	10.75 ± 1.442	10.83 ± 1.935	11.70 ± 3.867	0.73
Transport cost, $/hd‡	25.09 ± 0.360	26.59 ± 0.823	26.32 ± 1.57	29.08 ± 1.840	0.07
Feed cost, $/hd‡	327.58 ± 1.627^{a}	314.79 ± 3.648^{b}	302.88 ± 7.127^{bc}	285.05 ± 8.343^{c}	<0.001
Yardage cost, $/hd‡	117.88 ± 0	117.88 ± 2.1	117.88 ± 4.102	117.88 ± 4.802	1
Total value at slaughter, $/hd*†	2035.29 ± 18.888^{a}	2023.90 + 22.970^{a}	1883.19 ± 36.579^{b}	1740.54 ± 41.600^{c}	<0.001
Net return, $/hd	182.86 ± 6.044^{a}	118.07 ± 15.438^{b}	-6.34 ± 31.030^{c}	-202.11 ± 36.569^{d}	<0.001

*model included breed as a fixed effect (P < 0.05)

†model included induction weight as a covariate (P < 0.05)

‡model included Lot/pen number as a fixed effect (P < 0.05)

§MSA=Meat Standards Australia

Table 16 reports performance outcomes based on the number of BRD treatments an animal received on a DEADS AND REJECTS IN basis, with the 23 mortalities and 3 chronic lame rejects included in analysis. Similar to the case-control BRD diagnosis, including the dead animals in the analysis exacerbated the differences between number of BRD treatments an animal received. Animals treated for BRD 2 and 3+ times showed lower growth rate, exit weight, carcass weight and marbling compared to animals never treated and treated once for BRD ($P < 0.001$). Cost of BRD treatments increased whereas carcass value and net return decreased ($P < 0.001$) with the number of BRD treatments. There was a much larger difference between animals not treated for BRD and treated 3+ in animal value ($953.66) and net return ($929.48) with inclusion of the mortalities. No significant differences were found for in-weight, MSA Index, purchase price, processing cost, lame treatment cost, transport cost or yardage cost ($P > 0.05$).

4.1.5.3 Effect of pleurisy score on animal performance and economic outcomes

Table 17 reports the animal performance and economic outcomes associated with increased severity of pleurisy on a DEADS AND REJECTS OUT basis, with the 23 mortalities and 5 animals rejected for slaughter excluded from analysis. There were only 11% of animals with no evidence of pleurisy, with most animals being either a score 1 (26%) or score 2 (42%), with 11% of animals being assigned a score 3 for pleurisy, indicating severe adhesion to the thoracic cavity. For most of the variables there was no significant difference between animals with pleurisy scores of 0, 1 and 2 ($P > 0.05$). Animals with a pleurisy score 3 at slaughter were lighter at exit, showed lower DMI, grew slower, had lower marbling score, and had lighter carcasses compared to animals with a score of 0, 1 or 2 ($P < 0.001$). Animals with a pleurisy score 3 had 18.79 kg lighter carcases at slaughter compared to those with a 0 score ($P < 0.001$). Score 3 animals had greater BRD treatment costs, lower total carcass value at slaughter, and returned on average $136.80, $146.07 and $129.46 less than animals with a score 0, 1 and 2, respectively ($P<0.001$).

Table 16. Performance and economic outcomes according to the number of treatments for Bovine Respiratory Disease on a DEADS AND REJECTS IN basis in Trial 1.

	Number of BRD Treatments				
Variable	0	1	2	3 +	*P* value
N	669	107	30	29	Chi=<0.001
In-weight kg/hd*	428.02 ± 5.98	419.99 ± 7.17	421.84 ± 10.93	417.34 ± 10.78	0.31
Exit weight, kg/hd*†	633.43 ± 5.14[a]	624.68 ± 6.25[a]	580.59 ± 9.80[b]	559.39 ± 11.32[b]	<0.001
DMI, kg DM/d‡ıı	1207.25 ± 8.11[a]	1120.00 ± 17.80[b]	1033.11 ± 33.92[b]	834.66 ± 33.37[c]	<0.001
ADG, kg/d*	1.79 ± 0.05[a]	1.70 ± 0.06[a]	1.30 ± 0.09[b]	1.10 ± 0.10[b]	<0.001
carcass weight, kg/hd*†	347.36 ± 2.82[a]	343.94 ± 3.42[a]	320.16 ± 5.37[b]	307.77 ± 6.20[b]	<0.001
MSA§ Marble, %*†	347.75 ± 8.09[a]	331.32 ± 9.82[ab]	304.17 ± 15.43[b]	299.86 ± 17.42[b]	<0.001
MSA§ Index*†	54.30 ± 0.21	54.33 ± 0.26	53.38 ± 0.42	54.14 ± 0.48	0.10
Purchase price, $/hd*	1404.10 ± 18.70	1372.88 ± 21.97	1380.60 ± 33.18	1349.35 ± 32.78	0.08
Processing cost, $/hd	7.30 ± 0	7.30 ± 0	7.30 ± 0	7.30 ± 0	1
BRD treatment cost, $/hd#	5.67 ± 0.19[a]	31.26 ± 0.49[b]	43.14 ± 0.97[c]	95.07 ± 0.95[d]	<0.001
Lame treatment cost, $/hd	12.80 ± 0.83	10.75 ± 1.49	10.83 ± 2.10	10.87 ± 2.71	0.56
Transport cost, $/hd	25.09 ± 0.37	25.87 ± 0.80	24.79 ± 1.56	23.80 ± 1.51	0.64
Feed cost, $/hdıı	325.96 ± 2.19[a]	302.40 ± 4.81[b]	278.94 ± 9.16[b]	225.36 ± 9.01[c]	<0.001
Yardage cost, $/hd	117.88 ± 0	117.88 ± 2.1	117.88 ± 4.102	117.88 ± 4.802	1
Total value at slaughter, $/hd†ıı	2053.11 ± 13.32[a]	1926.91 + 33.31[b]	1698.58 ± 63.92[c]	1099.45 ± 62.91[d]	<0.001
Net return, $/hdıı	166.74 ± 11.60[a]	24.05 ± 28.99[b]	-198.11 ± 55.68[c]	-762.74 ± 54.74[d]	<0.001

*model included breed as a fixed effect (P < 0.05)
†model included induction weight as a covariate (P < 0.05)
§MSA=Meat Standards Australia
ııData was square transformed to obtain mean and standard error values
#Data was log transformed to obtain p-value due to non-normality

Table 17. Performance and economic outcomes according to pleurisy score on a DEADS AND REJECTS OUT basis in Trial 1.

	Pleurisy Score				
Variable	0	1	2	3	*P* value
N	95	315	367	93	Chi=<0.001
In-weight, kg/hd*	415.08 ± 7.48[b]	428.09 ± 6.30[ab]	431.57 ± 6.07[a]	416.25 ± 7.64[b]	0.0051
Exit weight, kg/hd*†	623.53 ± 6.78[a]	637.57 ± 5.69[a]	633.92 ± 5.49[a]	598.89 ± 6.94[b]	<0.001
DMI, kg DM/hd‡	1188.66 ± 14.66[a]	1214.29 ± 8.26[a]	1213.32 ± 7.43[a]	1132.02 ± 14.10[b]	<0.001
ADG, kg/day*‡	1.74 ± 0.06[a]	1.80 ± 0.05[a]	1.78 ± 0.05[a]	1.44 ± 0.06[b]	<0.001
carcass weight, kg/carcass*†‡	347.39 ± 3.78[a]	349.87 ± 3.13[a]	347.74 ± 3.01[a]	328.60 ± 3.76[b]	<0.001
MSA§ marble score*†	337.58 ± 10.00[a]	351.82 ± 8.41[a]	344.24 ± 8.09[a]	311.36 ± 10.23[b]	0.0002
MSA§ Index*	53.84 ± 0.27[b]	54.46 ± 0.23[a]	54.27 ± 0.22[ab]	53.86 ± 0.28[b]	0.0038
Purchase price, $/hd‡	1394.50 ± 16.54[ab]	1416.41 ± 9.32[ab]	1421.68 ± 8.39[a]	1370.40 ± 15.99[b]	0.02
Processing cost, $/hd	7.30 ± 0	7.30 ± 0	7.30 ± 0	7.30 ± 0	1
BRD treatment cost, $/hd ‖	10.92 ± 1.68[a]	11.19 ± 0.92[a]	12.04 ± 0.86[a]	27.66 ± 1.70[b]	<0.001
Lame treatment cost, $/hd	10.22 ± 1.887	10.15 ± 1.047	12.38 ± 0.974	11.66 ± 1.193	0.43
Transport cost, $/hd‡	25.39 ± 0.87	24.84 ± 0.49	25.24 ± 0.44	26.65 ± 0.84	0.32
Feed cost, $/hd‡	320.94 ± 3.96[a]	327.86 ± 2.22[a]	327.60 ± 2.00[a]	305.65 ± 3.81[b]	<0.001
Yardage cost, $/hd‡	117.88 ± 2.59	117.88 ± 1.46	117.88 ± 1.31	117.88 ± 2.49	1
Total value at slaughter, $/hd*†‡	2042.12 ± 24.94[a]	2050.90 + 20.59[a]	2032.33 ± 19.85[a]	1906.48 ± 24.80[b]	<0.001
Net return, $/hd	177.90 ± 16.54[a]	187.17 ± 8.98[a]	170.56 ± 8.35[a]	41.10 ± 16.81[b]	<0.001

*model included breed as a fixed effect (P < 0.05)
†model included induction weight as a covariate (P < 0.05)
‡model included Lot/pen number as a fixed effect (P < 0.05)
§ MSA=Meat Standards Australia
‖Data was log transformed to obtain p-value due to non-normality

4.1.5.4 Effect of BRD lung lesion score on animal performance and economic outcomes

The number of treatments associated with each lung lesion score category is displayed below (Table 18). Lung lesions (moderate or severe) occurred in 65% (432 out of the 662 animals) of the animals that were never treated for BRD. For animals treated once for BRD, 71.4% had moderate or severe lesions present. For animals treated twice for BRD, 88.9% had lesions present and for animals treated three or more times, 85% had lesions evident at slaughter. Out of the 282 animals that had no lesions present, 18.4% were treated for BRD.

Table 18. Contingency table for the number of animals treated 0, 1, 2 or 3+ times for BRD and the observed lesions of the respiratory system at the abattoir. Hospital cases, dead and rejected animals not included in Trial 1.

	Lung Lesion Score			
Number of BRD Treatments	**Normal**	**Moderate**	**Severe**	**Total**
None	230	359	73	662
1	46	78	37	161
2	3	11	13	27
3 or more	3	2	15	20
Total	282	450	138	870

Table 19 details animal performance and economic outcomes based on the lung lesion definition of BRD on a DEADS AND REJECTS OUT basis. According to the lung lesion definition, 32.4% of all 870 animals were classified as normal, 51.7% were classified as moderate and 15.9% were classified as severe. Animals with severe lung lesions showed lower ADG, DMI, exit weight, carcass weight, carcass value and marble score compared to animals with normal lungs or moderate lung lesions ($P < 0.05$). In addition, animals with severe lung lesions showed greater BRD treatment cost and lower net returns per animal ($P < 0.05$). No differences were found between normal and moderate animals for any of the variables except for purchase price which was higher in animals with moderate compared to those with normal lung lesions ($P < 0.05$). Animals with severe lung lesions had lower value at slaughter and resulted in a net return of $91.50 less compared to those with normal lungs ($P < 0.001$). No significant differences were found between normal, moderate and severe animals for induction weight, MSA index, processing cost, lame treatment cost, transport cost and yardage cost ($P > 0.05$).

Table 19. Performance and economic outcomes according to lung lesion definition on a DEADS AND REJECTS OUT basis in Trial 1.

	Lung Lesions			
Variable	Normal	Moderate	Severe	*P* value
N	282	450	138	Chi=<0.001
In-weight, kg/hd*	422.06 ± 6.35	430.63 ± 6.04	422.80 ± 7.09	0.05
Exit weight, kg/hd*†	632.84 ± 5.57^{a}	636.61 ± 5.29^{a}	603.79 ± 6.22^{b}	<0.001
DMI, kg DM/hd‡	1198.08 ± 8.77^{a}	1218.39 ± 6.84^{a}	1154.22 ± 11.56^{b}	<0.001
ADG, kg/d*‡	1.76 ± 0.05^{a}	1.81 ± 0.05^{a}	1.50 ± 0.06^{b}	<0.001
Carcass weight, kg/carcass*†	347.16 ± 3.11^{a}	349.48 ± 2.95^{a}	332.85 ± 3.47^{b}	<0.001
MSA§ marble score, %*†	341.67 ± 8.42^{a}	350.74 ± 8.00^{a}	313.25 ± 9.42^{b}	<0.001
MSA§ Index*†	54.15 ± 0.23	54.35 ± 0.21	54.00 ± 0.25	0.09
Purchase price, $/hd*	1352.03 ± 19.67^{a}	1388.19 ± 18.73^{b}	1368.30 ± 21.97^{ab}	0.009
Processing cost, $/hd	7.30 ± 0	7.30 ± 0	7.30 ± 0	1
BRD treatment cost, $/hd ‖	10.91 ± 0.98^{a}	11.27 ± 0.77^{a}	24.68 ± 1.40^{b}	<0.001
Lame treatment cost, $/hd	10.90 ± 1.093	10.71 ± 0.946	12.35 ± 1.012	0.46
Transport, $/hd‡	25.47 ± 0.52	24.79 ± 0.41	26.41 ± 0.69	0.11
Feed cost, $/hd‡	323.48 ± 2.37^{a}	328.97 ± 1.85^{a}	311.64 ± 3.12^{b}	<0.001
Yardage cost, $hd‡	117.88 ± 1.54	117.89 ± 1.21	117.88 ± 2.04	1
Total value at slaughter, $/animal*†‡	2041.73 ± 20.94^{a}	2045.30 ± 19.79^{a}	1936.25 ± 22.96^{b}	<0.001
Net return, $/animal	181.34 ± 7.42^{a}	180.34 ± 7.42^{a}	89.84 ± 13.71^{b}	<0.001

*model included breed as a fixed effect (P < 0.05)
†model included induction weight as a covariate (P < 0.05)
‡model included Lot/pen number as a fixed effect (P < 0.05)
§MSA=Meat Standards Australia
‖Data was log transformed to obtain p-value due to non-normality

4.1.5.5 Effect of clinical versus subclinical BRD on animal performance and economic outcomes

Table 20 details the performance and economic outcomes based on whether an animal was classified as clinical, subclinical, hospital case, resolved or healthy for BRD on a DEADS AND REJECTS OUT basis. Healthy and hospital case animals were the best performers showing greater ADG, DMI, exit weight, carcass weight and net return compared to clinical, subclinical and resolved cases ($P < 0.05$). There were no differences between healthy and hospital case animals except for a higher BRD treatment cost in hospital cases compared to healthy animals ($P < 0.05$). Similarly, subclinical and resolved BRD cases did not show statistical differences ($P > 0.10$), except for the higher cost for BRD treatments of the latter ($P < 0.05$; Table 20). Both subclinical and resolved BRD cases performed better than animals with clinical BRD but worse than healthy and early treated animals ($P > 0.05$). Clinical cases showed the highest BRD treatment cost and lowest carcass value and net returns compared to all groups ($P < 0.05$). No significant differences were found for induction weight, MSA Index, purchase price, processing cost, lame treatment cost or yardage cost ($P > 0.05$).

Table 20. Performance and economic outcomes for animals with clinical, subclinical, resolved and early treatment for BRD on a DEADS AND REJECTS OUT basis in Trial 1.

Variable	Clinical	Subclinical	Resolved	Hospital case	Healthy	*P* value
N	58	73	89	63	587	Chi=<0.001
In-weight, kg/hd*	416 ± 8.65	425 ± 8.13	424 ± 7.45	437 ± 8.48	428 ± 5.98	0.18
Exit weight, kg/hd*†	593 ± 7.72^{c}	611 ± 7.17^{bc}	620 ± 6.59^{b}	652 ± 7.51^{a}	639 ± 5.28^{a}	<0.001
DMI, kg DM/hd‡	1,116 ± 17.68^{b}	1,170 ± 15.77^{b}	1,160 ± 14.45^{b}	1,239 ± 17.14^{a}	1,219 ± 6.37^{a}	<0.001
ADG, kg/day*‡	1.41 ± 0.07^{c}	1.57 ± 0.07^{bc}	1.64 ± 0.06^{b}	1.94 ± 0.07^{a}	1.83 ± 0.05^{a}	<0.001
Carcass weight, kg/carcass*†‡	328 ± 4.53^{b}	336 ± 4.22^{b}	339 ± 3.90^{b}	356 ± 4.48^{a}	352 ± 3.23^{a}	<0.001
MSA§ marble score*†	299 ± 11.47^{c}	326 ± 10.88^{bc}	340 ± 9.95^{ab}	344 ± 11.26^{ab}	349 ± 7.92^{a}	<0.001
MSA§ Index*†	54 ± 0.31	54 ± 0.29	54 ± 0.27	54 ± 0.30	54 ± 0.21	0.19
Purchase price, $/hd*	1,346 ± 27.02	1,364 ± 25.26	1,375 ± 23.17	1,406 ± 26.35	1,374 ± 18.60	0.29
Processing cost, $/hd	7.30 ± 0	7.30 ± 0	7.30 ± 0	7.30 ± 0	7.30 ± 0	1
BRD treatment cost, $/hd	44.47 ± 1.14^{a}	5.67 ± 1.00^{d}	35.18 ± 0.92^{b}	27.78 ± 1.09^{c}	5.67 ± 0.35^{d}	<0.001
Lame treatment cost, $/hd	11.25 ± 1.86	14.11 ± 1.31	10.96 ± 1.38	6.93 ± 4.15	10.92 ± 0.98	0.25
Transport cost, $/hd‡	29.00 ± 7.38^{a}	28.05 ± 6.98^{ab}	28.59 ± 6.68^{a}	24.99 ± 7.27^{b}	26.73 ± 4.43^{ab}	0.02
Feed cost, $/hd‡ǁ	301.28 ± 4.77^{b}	315.90 ± 4.26^{b}	313.20 ± 3.90^{b}	334.53 ± 4.63^{a}	329.14 ± 1.72^{a}	<0.001
Yardage cost, $/hd‡	117.88 ± 3.13	117.88 ± 2.79	117.88 ± 2.63	117.88 ± 3.03	117.88 ± 1.13	1
Total value at slaughter, $/hd*†‡	1,876 ± 27.94^{d}	1,976 ± 26.13^{c}	2,005 ± 24.18^{bc}	2,080 ± 27.34^{a}	2,049 ± 19.68^{ab}	<0.001
Net return, $/hd	-24.72 ± 21.06^{d}	122.07 ± 18.45^{bc}	98.58 ± 17.20^{c}	198.10 ± 19.86^{ab}	189.22 ± 6.52^{a}	<0.001

*model included breed as a fixed effect (P < 0.05)
†model included induction weight as a covariate (P < 0.05)
‡model included Lot/pen number as a fixed effect (P < 0.05)
§MSA=Meat Standards Australia
ǁData was square transformed to obtain p-values due to non-normality

4.2 Results Trial 2

Results for Trial 2 were presented in final report of project B.FLT.0242 and described in the present report. A brief summary for the mortalities is followed by results for each BRD diagnosis method, i.e. number of BRD treatments, pleurisy scores, lung lesions and clinical-subclinical BRD.

4.2.1 Summary statistics (Trial 2)

A summary of those variables measured at the pen level is presented in table 21. The number of animals per pen was very homogeneous ranging from 215 to 223. Animals showed an average final shrunk body weight of 663 kg/hd, grew at a rate of 2 kg/d, consumed 11.5 kg DM/hd/d, had a feed to gain ratio of 5.8 kg of feed per kg of BW gained, and showed a 55.4% shrunk dressing percentage on shrunk BW basis.

Table 21. Summary statistics for variables measured at the pen level in Trial 2.

Variable	N	Minimum	Mean	Maximum	Std Dev
Animals, #/lot	6	215.0	219.0	223.0	2.5
Carcasses, #/lot	6	208.0	212.7	219.0	3.5
Final full BW, kg/d	6	661.2	690.5	722.2	21.3
Final shrunk BW, kg/hd	6	634.8	662.9	693.3	20.4
Fasted weight gain, kg/d	6	1.9	2.2	2.5	0.2
Shrunk weight gain, kg/d	6	1.7	2.0	2.2	0.2
Lot Dry matter Intake, kg/d	6	10.5	11.5	12.6	0.7
Pen DMI, % BW	6	1.9	2.1	2.2	0.1
Full feed to gain, kg/kg	6	4.9	5.2	5.5	0.2
Shrunk feed to gain, kg/kg	6	5.5	5.8	6.2	0.2
Full dressing percentage, % BW	6	52.7	53.2	53.7	0.4
Shrunk dressing percentage, %	6	54.9	55.4	56.0	0.4

Table 22 presents the summary statistics for those variables measured on an individual animal basis. Out of 1,314 animals inducted, 3.6% did not have a weight taken after 50 days on feed (N = 1,279) due to mortalities and animals being held in the hospital and chronic pen system, and another 3 animals did not go to slaughter (retained) resulting in final weight for 1,276 animals. Animals grew at an average rate of 2 kg/d, resulting in a total weight gained of 228.5 kg and a feed DM intake of 1,292 kg of feed DM throughout the feeding period (Table 22). Animals with very low feed intake or ADG were dead or with chronic health issues which were taken out of the trial and did not go to slaughter.

Table 22. Summary statistics for performance variables measured or estimated at individual animal level in Trial 2.

Variable	N	Minimum	Mean	Maximum	Std Dev
Induction weight, kg/hd	1,314	292.0	434.5	552.0	42.1
Body weight @ 50 DoF, kg/hd	1,279	344.0	553.2	696.0	52.9
Days on feed till slaughter	1,276	112.0	114.6	122.0	2.8
Exit body weight, kg/hd	1,276	450.9	662.8	852.6	62.2
Total Gain, kg/hd	1,276	7.2	228.5	415.5	48.8
ADG, kg/d	1,276	0.1	2.0	3.6	0.4
Feeding Period Avg Weight, kg/hd	1,314	319.0	545.6	674.0	50.3
Dry Matter Intake, kg/hd	1,314	37.4	1,292.5	1,700.7	217.9

Summary statistics for Trial 2 are shown in Table 23. It is important to highlight that numbers may not add up compared to other table for many reasons including missing observations or doubling of information. For example, there were 123 animals treated for the first time for BRD but rectal temperature was collected for 118 animals only. From these, 29 animals were treated for a second time for BRD however some animals could also have been treated due to being honkers. Honkers were considered as a BRD treatment to analyse the effect of the number of BRD treatments on performance and economics of the present study. On another example, lung consolidation data had 1,214 but pleurisy on 1,276 which is the number of animals slaughtered. The remainder of the animals (1,276 – 1,214 = 62) were animals with the lungs stuck to the thoracic cavity or to the rumen, or not allowed to be scored by the abattoir due to being condemned. On average, animals were treated at 24.9, 36.9 and 38.6 DoF for the first, second and third BRD treatment (Table 23). Lung consolidation ranged between 0 and 50% of the lungs with an average of 4.5%, with pleurisy score ranging from 0 to 3 and averaging 1.5 (Table 23).

Summary statistics for other health records are shown in Table 24. These included animals treated for lameness on the hoofs, lameness high in the legs, bullers, pizzle, bloat and polioencephalomacia. The same animal was treated up to 4 times for lameness at an average of 43.7 DoF and 515 kg/hd however the most frequent treatment other than BRD was for lame high at an average of 27.2 DoF and 450 kg/hd. Buller steer syndrome was the third most frequent cause of pulling after BRD and lameness at 1.1% of all animals.

Carcass data collected at the abattoir was possible for 1,276 animals (Table 25) due to 7 animals dead and 31 animals retained in the feedlot for slaughter due to being in chronic pens or within the withholding period of veterinary treatments. The summary statistics indicated an average carcass weight of 367 kg/hd, 17.1 mm of fat depth at the P8 site, 8.7 mm of fat depth at the rib site, MSA marbling score of 383 units, and received a price of 6 $/kg CWT (Table 25).

Table 23. Summary statistics for health records regarding Bovine Respiratory Disease in feedlot cattle of Trial 2.

Variable	N	Minimum	Mean	Maximum	Std Dev
BRD treatments, #/hd	1,314	0.0	0.1	3.0	0.5
First BRD treatment					
Days on Feed	123	3.0	24.9	92.0	18.6
Body weight, kg/hd	122	268.0	455.0	608.0	68.8
Rectal temperature, °C	118	37.6	39.5	41.2	0.8
Whisper score	118	1.0	2.2	4.0	0.6
Second BRD treatment					
Days on Feed	29	7.0	36.9	92.0	20.8
Body weight, kg/hd	28	280.0	468.4	624.0	83.1
Rectal temperature, °C	21	37.6	38.8	40.1	0.8
Whisper score	21	1.0	2.0	3.0	0.6
Third BRD treatment					
Days on Feed	14	11.0	38.6	62.0	16.2
Body weight, kg/hd	14	270.0	450.8	545.0	69.7
Rectal temperature, °C	1	39.3	39.3	39.3	.
Whisper score	1	1.0	1.0	1.0	.
First Honker treatment					
Days on Feed	6	20.0	31.7	49.0	9.5
Body weight, kg/hd	6	410.0	493.0	594.0	62.2
Rectal temperature, °C	2	39.9	40.4	40.8	0.6
Whisper score	1	1.0	1.0	1.0	.
Second Honker treatment					
Days on Feed	4	32.0	38.3	52.0	9.3
Body weight, kg/hd	4	432.0	484.5	550.0	56.1
Abattoir data					
Lung consolidation, %	1,214	0.0	4.5	50.0	6.5
Chest Pleurisy Score	1,275	0.0	1.3	3.0	0.6
Left Pleurisy score	1,276	0.0	0.6	3.0	1.0
Right Pleurisy score	1,276	0.0	0.5	3.0	1.0
Final Pleurisy score	1,276	0.0	1.5	3.0	0.7

Table 24. Summary statistics of health records other than Bovine Respiratory Disease in feedlot cattle of Trial 2.

Variable	N	Minimum	Mean	Maximum	Std Dev
Lame treatments, #/hd	1,314	0.0	0.0	4.0	0.3
First lame days on feed	19	5.0	43.7	88.0	26.0
First lame body weight, kg/hd	20	378.0	515.4	638.0	65.0
Second lame days on feed	4	15.0	27.3	36.0	10.1
Second lame body weight, kg/hd	4	452.0	483.0	528.0	36.0
First lame high days on feed	24	2.0	27.2	64.0	18.5
First lame high body weight, kg/hd	24	288.0	449.7	604.0	70.7
Second lame high days on feed	12	6.0	24.5	43.0	12.1
Second lame high body weight, kg/hd	13	340.0	425.7	526.0	47.2
Buller treatments, #/hd	1,314	0.0	0.0	2.0	0.2
First buller days on feed	15	2.0	18.7	105.0	27.1
First buller body weight, kg/hd	15	324.0	455.2	548.0	66.8
Second buller days on feed	5	6.0	9.0	13.0	2.7
Second buller days on feed	5	384.0	435.2	536.0	58.7
Pizzle treatments, #/hd	1,314	0.0	0.0	2.0	0.1
First pizzle days on feed	3	7.0	25.7	57.0	27.3
First pizzle body weight	3	404.0	427.3	474.0	40.4
Second pizzle days on feed	2	10.0	13.0	16.0	4.2
Second pizzle body weight	2	404.0	408.0	412.0	5.7
Bloat days on feed	3	8.0	54.7	78.0	40.4
Bloat body weight, kg/hd	2	532.0	596.0	660.0	90.5
Polioencephalomacia, days on feed	1	85.0	85.0	85.0	.
Polioencephalomacia body weight, kg/hd	1	500.0	500.0	500.0	.

Table 25. Summary statistics for carcass measurements at the abattoir in Trial 2.

Variable	**N**	**Minimum**	**Mean**	**Maximum**	**Std Dev**
Dentition, # permanent teeth	1,276	0.0	1.2	6.0	1.3
Hot Standard Carcass Weight, kg/carcass	1,276	248.0	367.0	469.0	34.1
P8 fat, mm	1,276	1.0	17.1	35.0	5.3
Fat colour	1,276	0.0	0.7	3.0	0.5
Hump height	1,276	40.0	76.6	160.0	16.5
MSA marbling score	1,276	140.0	383.4	670.0	76.3
Aus-Meat marbling score	1,276	0.0	1.4	4.0	0.7
Ossification score	1,276	110.0	183.9	500.0	16.7
Meat pH	1,276	5.3	5.5	6.3	0.1
Rib fat, mm	1,276	1.0	8.7	30.0	3.5
Eye muscle area, cm2	1,276	56.0	86.0	120.0	11.1
Left Bruising score	1,276	0.0	0.0	4.0	0.3
Left carcass weight, kg/half carcass	1,276	123.5	182.0	232.5	16.9
Left value, $/left carcass	1,276	638.8	1098.4	1,332.2	105.1
Right bruising score	1,276	0.0	0.0	4.0	0.3
Right weight, kg/half carcass	1,276	123.5	185.0	236.5	17.3
Right value, $/half carcass	1,276	659.0	1116.0	1,361.0	106.6
Price, $/kg CWT	1,276	5.0	6.0	6.4	0.3
MSA Index	1,266	43.8	55.1	60.1	2.1

Table 26 presents summary statistics for the economic variables for all animals inducted (N = 1,314) except for those animals that died. Net return was on average 297 $/hd on 'deaths and reject out' basis but this ranged from a loss of 400 to a gain of 1,015 $/hd. On a 'deaths and reject in' basis, net return was reduced by approximately 55 $/hd (net return = 242 $/hd) per head inducted with the mortality and disease rates observed in this trial. Average carcass value decreased by approximately 64 $/hd on a dead and rejects in compared to out basis which indicates that the economic loss is mainly driven by the lack of saleable carcass rather than by the cost of veterinary treatments. The largest cost for production was due to the cost of purchasing the animals (1,390 $/hd), followed by feed cost (349 $/hd) and yardage cost (120 $/hd). Total cost of veterinary treatments was 4.8 $/hd on average but ranged from 0 to 140 $/hd (Table 26).

Table 26. Summary statistics for economic variables of feedlot cattle in Trial 2.

Variable	N	Minimum	Mean	Maximum	Std Dev
Purchase Cost, $/hd	1,314	934.4	1,390.3	1,766.4	134.7
Induction Cost, $/hd (with BRD)	1,314	13.5	13.5	13.5	0.0
Induction BRD cost, $/hd	1,314	5.7	5.7	5.7	0.0
Body Removal Cost, $/hd	1,314	0.0	0.3	60.0	4.4
Transport Cost, $/hd	1,314	13.0	25.6	26.0	2.2
Yardage cost, $/hd/d	1,314	1.1	1.1	1.1	0.0
Total DoF, #/hd	1,314	4.0	112.3	122.0	14.6
Yardage cost, $/hd	1,314	4.3	120.2	130.5	15.6
Levy, $/hd	1,314	0.0	4.9	5.0	0.8
Feed Cost, $/hd	1,314	10.1	349.0	459.2	58.8
Total Hospital Cost, $/hd	1,314	0.0	4.8	139.8	15.5
BRD treatment cost, $/hd					
Carcass value, $/hd	1,276	1,297.9	2,214.4	2,680.4	211.0
Carcass value dead and rejects in, $/hd	1,314	0.0	2,150.3	2,680.4	425.5
Net Return, $/hd	1,276	-439.9	296.8	1,015.0	171.2
Net Return Dead's and rejects in, $/hd	1,314	-2040.7	241.7	1,015.0	362.8

4.2.2 Mortalities (Trial 2)

In trial 2, there were only 7 deaths out of 1,314 animals inducted (0.53%) with only 4 out of 7 for which the cause of death was confirmed to be BRD upon necropsy. Another animal was considered a downer but has previously been treated for BRD. Animals died at an average of 36.1 DoF, after consuming 461 kg of feed DM, receiving hospital treatments for $36.1 /hd, and originating a total loss of $1,784 /hd on average (Table 27).

Table 27. Summary statistics for performance and cost variables for mortalities in Trial 2.

Variable	N	Minimum	Mean	Maximum	Std Dev
Days on feed at death	7	12	36.14	99	30.55
Induction Weight, kg/hd	7	392	463.4	514.0	45.1
Purchase Value, $/hd	7	1,254	1,483	1,645	144.4
Total DMI, kg/hd	7	120.4	460.9	1,068.0	379.2
ADG to last pull, kg/day	4	-14.67	-3.76	0.89	7.30
Induction processing costs, $/hd*	7	13.53	13.53	13.53	0
Total BRD treatment costs, $/hd†	4	23.8	46.8	89.5	29.2
Total Hospital treatment costs, $/hd	7	0	36.10	89.52	32.86
Transport cost, $/hd	7	13	13	13	0
Feed cost, $/hd	7	32.52	124.44	288.37	102.38
Yardage cost, $/hd	7	12.8	53.7	105.9	41.4
Net loss death, $/hd ıı	7	-2,041	-1,784	-1,439	180
Net loss death BRD only, $/hd	4	-2041	-1,762	-1439	249

*Induction processing cost includes cost of BRD vaccinations valued at $5.67/animal

ıı Net loss was calculated as the sum of direct costs to death and body removal costs

4.2.3 Effects of BRD on animal performance and economic outcomes Trial 2

All results regarding performance and economic variables for trial 2 are presented as both uncorrected and corrected values for the covariate induction body weight to the reader can see the difference between both. This covariate was not used for MSA marbling score, MSA index and EMA to reduce the size of the tables and because it did not affect the results.

4.2.3.1 Effect of number of BRD treatments on animal performance and economic outcomes

A total of 9.6% of all animals were treated for BRD and the number of animals treated 2 or 3+ times for BRD was only 16 (Table 28) which could reduce the robustness of the analysis. Animals that received 1 treatment for BRD had lower induction weight compared to those not treated for BRD (P < 0.05) but no significant differences were found for animals treated 2 or more times. Average daily gain and carcass weight decreased with the number of BRD treatments (P < 0.001; Table 28). Carcass weight corrected for induction weight decreased by 12, 17 and 37 kg/hd for animals with 1, 2 and 3+ BRD treatments compared to healthy animals which did not receive BRD treatments. However, uncorrected carcass weight decreased by 22, 24 and 43 kg/hd 1, 2 and 3+ BRD treatments compared to healthy controls (P < 0.05; Table 28). A similar finding was reported for carcass value with a decrease of 117, 162 and 258 $/hd for the uncorrected carcass value for 1, 2 and 3+ BRD treatments, respectively, compared to untreated animals (Table 28).

The MSA marble scores and EMA were lower for animals receiving 1 BRD treatment compared to animals that did not receive any BRD treatments (P < 0.05; Table 28). The MSA index was lower for animals that received 2 BRD treatments compared to the untreated animals and those receiving 1 BRD treatment (P < 0.05). However, price received was not affected by the number of BRD treatments (P = 0.41).

Feed intake (DMI) and feed costs decreased (P < 0.05) whereas the treatment costs at the hospital shed increased with the number of BRD treatments (P < 0.05; Table 28). Net return decreased with the number of BRD treatments for both dead in and out estimations (P < 0.001) however dead-in calculations showed much sharper reduction of net returns because of the large influence of mortalities on a relatively low number of animals with 2 or 3+ BRD treatments.

4.2.3.2 Effect of pleurisy score on animal performance and economic outcomes

Over half of the steers received a lung pleurisy score of 1 and 38.6% received pleurisy score of 2 with only 4.6% and 5.6% of all animals received a pleurisy score of 0 and 3, respectively (Table 29). Induction weight and weight at 50 DoF were not affected by pleurisy score (P > 0.05). However, ADG was greater in animals with pleurisy score of 2 compared to animals with pleurisy score of 3 (P < 0.05) whereas pleurisy score of 0 and 1 showed similar ADG than all scores (P > 0.05). A similar trend was found for carcass weight and value however these differences did not reach statistical significance (P > 0.05; Table 29). MSA index were lower in steers with pleurisy score of 0 compared to those with score of 1 and 2 (P < 0.05) with no differences between pleurisy scores for EMA and price received (P > 0.05). No significant differences between pleurisy scores were found for hospital cost, feed cost and net return (P > 0.05; Table 29).

4.2.3.3 Effect of lung lesions on animal performance and economic outcomes

Table 30 details the effect of lung lesions at slaughter on animal performance and carcass traits. No differences between animals with normal, moderate and severe lung lesions were observed for induction weight, weight at 50 days, ADG, carcass weight, carcass value, MSA marble scores and EMA (P > 0.10). However, animals with moderate lung lesions had greater MSA index than animals with normal lungs (P < 0.001; Table 30). No differences between lung lesions groups were observed on hospital costs, feed costs or net returns (P > 0.05).

4.2.3.4 Effect of clinical and subclinical BRD on animal performance and economic outcomes

The effect of BRD status classified as clinical, subclinical, resolved and healthy on performance and carcass traits are reported in Table 31. Of all steers, 20.7% were considered to have experienced some form of BRD prior to slaughter with sub-clinical BRD being the most prevalent at 12.4% and clinical BRD the least prevalent (1.6%). Steers which did not show any signs of BRD at the feedlot or slaughter (healthy) and those with sub-clinical BRD showed greater induction weights, DMI, ADG, carcass weight, carcass value and MSA marbling than steers with resolved (P < 0.10) and clinical BRD (P < 0.10; Table 31).

Feed costs were lower and costs at the hospital shed were higher for clinical and resolved BRD cases (P < 0.05) compared to subclinical and healthy animals which led to higher net returns of the latter two groups (P < 0.05; Table 31).

Table 28. Performance and carcass traits of feedlot cattle according to the number of treatments for Bovine Respiratory Disease (Trial 2)

	Number of BRD treatments				P-value	
	0	1	2	3+	Nro. BRD	Breed
Number of animals	1,188	94	16	16	-	-
Dead animals, #	2	1	2	2	-	-
% of animals	90.4	7.2	1.2	1.2	-	-
Induction weight, kg/hd	432 ± 7.4 a	414 ± 8.3 b	412 ± 12.2 ab	432 ± 12.2 ab	<.0001	<.0001
Corrected Weight at 50 days, kg/hd [A]	554 ± 6.1 a	527 ± 7.3 b	522 ± 11.8 b	504 ± 13.9 b	<.0001	<.0001
Weight at 50 days, kg/hd	552 ± 7.9 a	509 ±9.3 b	511 ± 15.1 b	484 ± 17.8 b	<.0001	<.0001
ADG, kg/d	1.98 ± 0.085 a	1.82 ± 0.094 b	1.72 ± 0.139 abc	1.41 ± 0.160 c	<.0001	<.0001
DMI, kg/hd	1312 ± 32.6 a	1240 ± 34.3 b	1246 ± 44.0 ab	1199 ± 48.7 b	<.0001	
Corrected carcass weight, kg/hd [A]	366 ± 5.2 a	354 ± 5.8 b	349 ± 8.7 abc	329 ± 10.0 c	<.0001	<.0001
Carcass weight, kg/hd	365 ± 4.8 a	343 ± 5.8 b	341 ± 10.1 b	322 ± 11.8 b	<.0001	<.0001
MSA marble score	387 ± 10.5 a	357 ± 12.8 b	366 ± 22.7 ab	367 ± 26.8 ab	0.0017	<.0001
Eye Muscle Area, cm^2	84.9 ± 1.97 a	81.1 ± 2.27 b	85.3 ± 3.65 ab	79.0 ± 4.24 ab	0.0088	0.0001
MSA index	54.6 ± 0.64 a	54.5 ± 0.91 a	49.6 ± 1.63 b	54.4 ± 1.92 ab	0.0075	<.0001
Carcass value, $/hd	2202 ± 40.2 a	2085 ± 44.6 b	2040 ± 66.4 b	1944 ± 76.2 b	<.0001	<.0001
Hospital Cost, $/hd	0.58 ± 0.628 d	35.36 ± 0.795 c	47.49 ± 1.425 b	100.33 ± 1.421 a	<.0001	0.8183
Feed cost, $/hd	354.2 ± 8.80 a	334.8 ± 9.27 b	336.3 ± 11.88 ab	323.7 ± 13.15 b	<.0001	<.0001
Net return Dead out, $/hd	299.3 ± 36.81 a	233.5 ± 40.17 b	151.1 ± 57.40 bc	15.25 ± 65.27 c	<.0001	<.0001
Net return Dead in, $/hd	287.3 ± 51.22 a	96.3 ± 60.95 b	-278.0 ± 96.59 c	-846.4 ± 96.40 d	<.0001	<.0001
Price, $/kg cwt	6.04 ± 0.031	6.07 ± 0.040	5.96 ± 0.076	6.04 ± 0.090	0.407	<.0001

[A] Induction weight used as covariate to correct least square means.

[a, b, c] Means without a common superscript differ (P < 0.05).

Table 29. Effect of lungs pleurisy scores at slaughter on performance and carcass traits of feedlot steers (Trial 2).

	Pleurisy score				P-value	
	0	1	2	3	Pleurisy	Breed
Number of animals	59	653	493	71	-	-
Proportion of animals	4.62	51.18	38.64	5.56	-	-
Induction weight, kg/hd	421 ± 8.9	429 ± 7.3	433 ± 7.4	432 ± 8.6	0.121	<0.0001
Corrected Weight 50 days, kg/hd [A]	550 ± 7.8	551 ± 6.0	554 ± 6.1	549 ± 7.4	0.681	0.0016
Weight 50 days, kg/hd	539 ± 10.0	547 ± 7.7	552 ± 7.8	548 ± 9.6	0.001	<0.0001
Corrected ADG, kg/d [A]	1.96 + 0.096 ab	1.95 + 0.082 ab	2.00 + 0.082 a	1.87 + 0.093 b	0.0227	<0.0001
ADG, kg/d	1.97 ± 0.098 ab	1.95 ± 0.083 ab	2.00 ± 0.084 a	1.87 ± 0.094 b	0.028	<.0001
Corrected carcass weight, kg/hd [A]	363.0 ± 5.86	364.19 ± 5.04	366.8 ± 5.09	358.7 ± 5.67	0.055	<0.0001
Carcass weight, kg/hd	357.9 ± 6.27	361.2 ± 4.75 B	366.5 ± 4.84	358.0 ± 5.95	0.010	<0.0001
Carcass value, $/hd	2143 ± 47.6	2183 ± 40.8	2211 ± 41.2	2175 ± 46.1	0.016	<0.0001
MSA marble score	357 ± 14.1 b	385 ± 10.6 a	387 ± 10.9 a	388 ± 13.3 ab	0.026	<0.0001
EMA, cm2	84.1 ± 2.42	84.7 ± 2.00	84.6 ± 2.02	82.5 ± 2.34	0.414	0.0005
MSA index	54.0 ± 0.36 b	54.8 ± 0.27 a	55.0 ± 0.27 a	54.8 ± 0.34 ab	0.002	<0.0001
Price, $/kg cwt	5.99 ± 0.045	6.05 ± 0.032	6.04 ± 0.032	6.08 ± 0.042	0.187	<0.0001
Feed Cost, $/hd	1281.1 ± 34.14	1295.8 ± 31.32	1310.5 ± 31.40	1288.4 ± 33.39	0.040	<0.0001
DMI, kg DM/hd	1245.4 ± 19.2 ab	1266 ± 10.9 b	1288 ± 11.3 a	1250 ± 17.3 ab	0.002	<0.0001
Hospital Cost, $/hd	5.03 ± 2.436	2.82 ± 1.796	4.329 ± 1.836	5.348 ± 2.304	0.105	0.031
Net return, $/hd	277.6 ± 40.72	289.1 ± 37.55	299.3 ± 37.84	268.6 ± 41.58	0.351	<0.0001

[A] Induction weight used as covariate to correct least square means.

[a, b, c] Means without a common superscript differ (P < 0.05).

Table 30. Effect of lung lesions at slaughter as an indicator of Bovine Respiratory Disease on performance and carcass traits of feedlot steers (Trial 2)

	Lung lesions			P-value	
	Normal	Moderate	Severe	Lung lesions	Breed
Number of animals	351	747	178	-	-
Proportion of animals	27.51	58.54	13.95	-	-
Induction weight, kg/hd	429 ± 7.4	430 ± 7.3	435 ± 7.7	0.182	<.0001
Corrected Weight 50 days, kg/hd [A]	548 ± 6.2	554 ± 5.9	551 ± 6.5	0.071	0.0027
Weight 50 days, kg/hd	544 ± 8.0	550 ± 7.7	551 ± 8.4	0.167	<.0001
Corrected ADG, kg/d [A]	1.93 + 0.084	1.98 + 0.082	1.93 + 0.086	0.062	<.0001
ADG, kg/d	1.94 ± 0.085	1.99 ± 0.084	1.93 ± 0.088	0.053	<.0001
Corrected carcass weight, kg/hd [A]	363 ± 5.3	366 ± 5.1	363 ± 5.4	0.065	<.0001
Carcass weight, kg/hd	360 ± 5.0	364 ± 4.8	363 ± 5.2	0.233	<.0001
MSA marble score	377 ± 11.0	387 ± 10.6	388 ± 11.6	0.111	<.0001
EMA, cm2	84.5 ± 2.04	84.7 ± 1.98	84.2 ± 2.12	0.856	0.0004
MSA index	54.5 ± 0.28 b	55.0 ± 0.26 a	54.9 ± 0.29 ab	0.001	<.0001
Carcass value, $/hd	2,178 ± 41.7	2,196 ± 40.9	2,198 ± 42.9	0.342	<.0001
Price, $/kg cwt	6.04 ± 0.032	6.05 ± 0.036	6.05 ± 0.036	0.8008	<.0001
Hospital Cost, $/hd	3.25 ± 1.874	3.35 ± 1.794	5.01 ± 1.991	0.051	0.607
DMI, kg/hd	1,299 ± 32.9	1,307 ± 32.6	1,314 ± 33.3	0.326	<.0001
Feed Cost, $/hd	350.8 ± 8.87	352.9 ± 8.79	354.7 ± 9.00	0.326	<.0001
Net Return, $/hd	284.0 ± 38.10	298.2 ± 37.50	278.6 ± 38.99	0.184	<.0001

[A] Induction weight used as covariate to correct least square means.

[a, b, c] Means without a common superscript differ ($P < 0.05$).

Table 31. Effect of Bovine Respiratory Disease status on performance and carcass traits in feedlot cattle (Trial 2). [A]

	BRD status				P-value	
	Clinical	Sub-Clinical	Resolved	Healthy	BRD status	Breed
Number of animals	20	158	86	1,012	-	-
Animals, %	1.6	12.4	6.7	79.3	-	-
Induction weight, kg/hd	411 ± 11.3 bc	438 ± 7.85 a	413 ± 8.33 c	431 ± 7.3 ab	<.0001	<.0001
Corrected Weight 50 days, kg/hd [B]	538 ±10.3 ab	552 ± 6.6 a	524 ± 7.2 b	555 ± 6.0 a	<.0001	<.0001
Weight 50 days, kg/hd	520 ± 13.2 b	555 ± 8.6 a	507 ± 9.3 b	552 ± 7.8 a	<.0001	<.0001
ADG, kg/d	1.75 ± 0.120 bc	1.95 ± 0.089 ab	1.78 ± 0.094 c	1.99 ± 0.085 a	<.0001	<.0001
DMI, kg DM/hd	1,230 ± 39.8 b	1,324 ± 33.5 a	1,240 ± 34.3 b	1,310 ± 32.6 a	<.0001	<.0001
Corrected carcass weight, kg/hd [B]	350.4 ± 7.45 bc	364.6 ± 5.44 ab	352.0 ± 5.72 c	366.4 ± 5.12 a	<.0001	<.0001
Carcass weight, kg/hd	339.0 ± 8.38 b	366.3 ± 5.36 a	341.6 ± 5.80 b	364.5 ± 4.84 a	<.0001	<.0001
Carcass value, $/hd	2,063 ± 57.5 b	2,214 ±42.7 a	2,071 ± 44.7 b	2,200 ± 40.4 a	<.0001	<.0001
MSA marble score	357.6 ± 18.8 b	391.9 ± 11.7 a	359.4 ± 12.8 b	386.1 ± 10.5 a	0.0013	<.0001
EMA, cm2	79.2 ± 3.09 a	84.8 ± 2.13 ab	82.0 ± 2.27 ab	84.8 ± 1.98 b	0.014	0.0001
MSA index	54.0 ± 0.48 ab	55.0 ± 0.30 a	54.4 ± 0.33 b	54.9 ± 0.26 a	0.0043	<.0001
Feed Cost, $/hd	332.1 ± 10.74 b	357.4 ± 9.04 a	334.7 ± 9.26 b	353.7 ± 8.80 a	<.0001	<.0001
Price, $/kg	6.06 ± 0.062	6.05 ± 0.036	6.03 ± 0.040	6.04 ± 0.031	0.9236	0.1604
Hospital Cost, $/hd	43.8 ± 1.58 a	0.30 ± 0.93 c	39.8 ± 1.02 b	0.37 ± 0.80 c	<.0001	0.9969
Net Return, $/hd	200.2 ± 50.48 bc	298.2 ± 38.10 a	221.0 ± 41.23 c	283.0 ± 39.71 ab	<.0001	<.0001

[A] Clinical: animals with clinical signs of BRD and treated at the feedlot, and showing severe lung lesions at slaughter. Sub-Clinical: animals not detected with clinical signs of BRD and not treated at the feedlot but showing severe lung lesions at slaughter. Resolved: animals detected with clinical signs of BRD and treated at the feedlot but showing lung lesions at slaughter. Healthy: animals not detected with clinical signs of BRD and not treated at the feedlot, and not showing lung lesions at slaughter.

[B] Induction weight used as covariate to correct least square means.

[a, b, c] Means without a common superscript differ ($P < 0.05$).

5 Discussion

Trial 1

The incidence of BRD in feedlots varies widely and is dependent on numerous environmental and animal factors (Snowder et al., 2006). A Canadian study found that 21% of calves were treated for BRD in the first 28 days following feedlot entry, while in an Australian study, 19% out of 209 animals developed BRD (Cusack, 2004; Macartney, Bateman & Ribble, 2003). The moderate BRD incidence rate of 26% out of 898 animals (based on treatment for BRD or not) in trial 1 could be due to several factors including the use of high-risk saleyard cattle as well as the fact the trial occurred in autumn. Previous research has found that cattle that are sourced from multiple vendors or saleyards and those that are inducted in summer and autumn are at highest risk of contracting BRD (Hay et al., 2016; Sanderson, Dargatz & Wagner, 2008). The majority (82%) of all veterinary treatments in the current study were attributed to BRD, confirming it is the largest health issue faced by the feedlot sector. Lameness was the second biggest cause of morbidity in the study. These findings are consistent with previous studies where the percentage of morbidity attributed to BRD was estimated at 67-87%, with lameness being the second largest cause of morbidity at around 4% (Baptista et al., 2017; Edwards, 1996). The moderate BRD morbidity rate was reflected in high treatment costs, with an average cost/head treated for an initial BRD treatment of $24.06, compared to lameness at $12.47/head. There was a 25% BRD relapse rate, with 58 of the 230 animals initially treated for BRD requiring a second treatment. This high relapse rate and the fact around half of these relapse animals then required a third BRD treatment highlights potential for improvement in BRD detection, diagnosis and treatment protocols. Lot 3 had the highest rate of veterinary treatments which could be attributed to breed differences between the pens or to the fact that the pen was comprised of only saleyard cattle, however lot 4 was also comprised of all saleyard cattle and had the lowest proportion of veterinary treatments, suggesting that animal source did not have an effect on the morbidity rate of the individual pens.

The trial 1 mortality rate was 2.6%, which is moderate compared to Trial 2 and other studies that have reported mortality rates between 0.18% and 0.64% (Baptista et al., 2017; Edwards, 1996; Vogel & Parrott, 1994). Similar to the morbidity rate, the moderate mortality rate seen in the current study is probably due to the high disease risk cattle selected for the study. Although the reason of death was recorded as BRD for 18 of the 23 mortalities in trial 1, there were only two animals that were either never treated for BRD or had no signs of BRD recorded at the time of necropsy, meaning 91% of mortalities were attributed to BRD in some form. This figure is also higher than other reports on the proportion of deaths attributed to BRD, which have found anywhere between 44-69% of mortalities in feedlots are due to BRD related illnesses (Baptista et al., 2017; Gagea et al., 2006; Vogel & Parrott, 1994). Interestingly, most animals that died from BRD only received one treatment, indicating that either these animals were not picked up early enough and treatment was too late or that treatment was ineffectual depending on the pathogen involved. Despite the higher incidence of morbidity early in the feeding period, mortalities in this trial occurred throughout the feeding period. Usually most BRD related deaths occur early in the feeding period in North America and Brazil (Baptista et al., 2017), with those occurring later attributed to various other ailments including lameness. As most of the mortalities in the current trial were attributed to BRD, the cause of death did not change with days on feed and this relationship could not be examined. The net loss for BRD mortalities was substantial and averaged $39.54/head across all animals in trial 1. This figure is much higher than a previous estimate of $1.43/head for Brazil (Baptista et al., 2017), and is most likely a result of the moderate mortality rate seen in the current study.

In trial 1, 25.5% of all animals were treated for BRD and this proportion was composed of 16.1% of animals with both visual and clinical signs, 7.0% with only clinical signs (rectal temperature and lung auscultation), and 2.3% of dead animals treated for BRD before dead. Dependent on the inclusion of the dead animals or not, the BRD incidence based on the visual-clinical definition was between 16 and 18%, which is more in line with previous estimates of BRD incidence in feedlots (Cusack, 2004; Faber et al., 1999; Macartney, Bateman & Ribble, 2003). Significant differences were found between case and control animals for most of the performance and economic outcomes, with control animals performing better and having higher carcass value and net returns than BRD case animals. Although some research has suggested that animals that are lighter at entry to the feedlot are more likely to become sick, initial weights between case and control animals did not differ in trial 1 (Martin et al., 1989; Sanderson, Dargatz & Wagner, 2008). The reduced ADGs and carcase weights of the BRD affected animals compared to the healthy animals found in the current study are similar to previously reported figures (Gardner et al., 1999; Rezac et al., 2014; Schneider et al., 2009). Average daily gains in animals treated for BRD have been found to be 0.05-0.25 kg/day less than animals that were never treated for BRD (Gardner et al., 1999; Schneider et al., 2009). These figures are consistent with the reduction of 0.26 kg/day in cases versus controls found in the present study. This reduction in ADG in the BRD affected animals resulted in 12.42 kg lighter carcase weights in these BRD case animals, which is slightly higher than other reports of reduced carcase weights in BRD animals when compared to healthy animals (Gardner et al., 1999; Schneider et al., 2009). However, it is important to highlight that marked differences between studies exist including breed, body weight, slaughter weight, and DoF at time of treatment, amongst others due to being different production systems with different endpoints. In the present study, MSA marble score was also 26% lower in the BRD case animals compared to the controls which is consistent with other reports of decreased marbling and carcase quality attributes associated with treatment for BRD (Gardner et al., 1999; Schneider et al., 2009). Feed costs were higher for the control animals due to their higher feed intake, however the methodology used in the current study did not account for a sick animal consuming less feed as a proportion of BW than a healthy animal. When the dead and rejects were included in analysis, the net loss of case animals totalled $-26,565 or 30 $/hd inducted, which is a substantial loss of income and represents approximately 20-30% of profit. On a 'dead and rejects in' basis, the difference in net profit between BRD control and BRD cases was 329 $/hd with the mortality rates observed in the present study (net profit of 167.4 ± 12.5 vs. -161.5 ± 25.1 for controls and BRD cases, respectively). However, these losses depend on BRD incidence rate and mortality rate, and therefore apply to the present study only. Other values presented herein can be used more broadly. For example, the average total financial loss for each animal dead due to BRD was 1,691 $/hd including a purchase cost of 1,399 $/hd and BRD treatment cost of 63.7 $/hd on average (up to $123.3 /hd). For every 1% BRD mortality rate, this equates to 16.9 $/hd inducted for every 100 animals inducted.

Similarly, the costs for BRD treatments for every 100 animals inducted can be calculated as follows:

1) Induction BRD vaccination cost: 5.67 $/hd inducted
2) Average BRD treatment costs: 35.2 $/hd treated
    a. 1% BRD incidence: 0.35 $/hd inducted
    b. 10% BRD incidence: 3.52 $/hd inducted
3) Total cost of BRD:
    a. @ 1% BRD incidence: 6.02 $/hd inducted
    b. 10% BRD incidence: 9.29 $/hd inducted
4) Production losses:
    a. Carcass weight: 12.4 kg/carcass

    b. Carcass value: 80.8 $/carcass
    c. Each 1% BRD incidence: 0.81 $/hd inducted
    d. Each 10% BRD incidence: 8.80 $/hd inducted

5) Total BRD losses:
    a. Each 1% BRD incidence rate: 6.83 $/hd inducted
    b. Each 10% BRD incidence rate: 18.09 $/hd inducted
6) Net returns losses
    a. Losses per head treated: 112.6 $/hd treated
    b. Net return @ each 1% BRD: 1,26 $/hd inducted
    c. Net return @ each 10% BRD: 11,3 $/hd inducted
7) Cost of BRD mortalities @ 1% rate: 16.9 $/hd inducted

The information above indicates that losses due to BRD for every 100 animals inducted were approximately 18.1 $/hd inducted at 10% BRD incidence plus 16.9 $/hd inducted for every 1% BRD mortality rate, totalling 35 $/hd inducted. However, it is important to pinpoint that the cost of pen riders has not been considered in the present study because of the argument that pen riders are also going to be needed despite BRD is completely abolished.

Interestingly, hospital case animals, or those which did not display visual signs of BRD in the pens but had elevated rectal temperature or lung auscultation score and were consequently treated for BRD, had $15.24 higher net returns than the true control animals despite the additional hospital treatment costs for these animals. These animals also had higher ADG and heavier exit weights compared to control animals. The increased performance of these hospital case animals could be due to several reasons. It could be suggested that these animals received treatment early in the disease process before visual signs appeared and this preventative, or early interventional antimicrobial treatment allowed them to perform better than the true control animals by limiting disease progression and preventing the animal partitioning energy resources into an immune response. An acute phase fever response is typical of the early stages of BRD pathogen infection, with clinical symptoms often appearing later in the disease process by which time treatment can become ineffectual (Cusack, McMeniman & Lean, 2003; Schaefer et al., 2007). These results could support the known benefits of preventative antimicrobial metaphylaxis on animal performance and economic return (Galyean, Gunter & Malcolm-Callis, 1995; Schumann, Janzen & McKinnon, 1991). It could also be argued that rectal temperature and lung auscultation alone are not reliable indicators of BRD infection and that these animals were not true BRD cases despite receiving treatment for the disease.

Most animals were never treated for BRD, with only 13% treated once, 3% treated twice and 2% treated three or more times, with hospital cases and dead animals excluded from analysis. The hospital case animals were excluded for analysis of effects of the number of BRD treatments on performance and economic outcomes as these animals should not have received treatment under routine visual diagnosis by the pen riders and were not reflective of a normal BRD first treatment situation based on visual BRD signs followed by the presence of clinical symptoms. Most of the performance traits decreased as the number of BRD treatments increased, which is consistent with the findings of previous studies (Brooks et al., 2011; Gardner et al., 1999; Schneider et al., 2009). Reductions in appetite and hence feed intake, a decreased feed efficiency or extra energy loss associated with disease severity is likely to be the reason for the decline in ADG and carcase weight as the number of BRD treatments increased (van der Mei & van den Ingh, 1987). Animals receiving only one BRD treatment showed similar performance to those which did not receive any treatment for BRD, which could suggest that animals treated once were either mild cases of BRD and performance was not overtly affected by the disease, or that these animals were potentially misclassified as sick based on the apparent low sensitivity and specificity of clinical symptoms (White & Renter, 2009).

As the number of BRD treatments increased, total value at slaughter and net returns decreased which has been reported previously (Brooks et al., 2011; Cernicchiaro et al., 2013; Schneider et al., 2009). Schneider et al. (2009) reported a reduction in total value at slaughter of $23.23, $30.15 and $54.01 USD for animals treated once, twice and three or more times compared to animals that were never treated, which is a lesser reduction in value at slaughter than was found in our study, where total value at slaughter decreased by $11.39, $152.10 and $294.75 AUD when comparing cattle never treated with cattle treated once, twice or three or more times, respectively. Similar to results of other studies, net returns in the present study also significantly decreased as the number of BRD treatments increased (Brooks et al., 2011; Cernicchiaro et al., 2013; Schneider et al., 2009). However the differences in net return associated with number of BRD treatments found in the present study are much greater than in previous studies, where returns have estimated to be $74.39-$90.50 less in animals treated three or more times compared to animals that were never treated for BRD (Brooks et al., 2011; Cernicchiaro et al., 2013). Differences in animal value and net returns between the current study and previous estimates is most likely related to cattle prices, exchange rates, as well as carcass weight and quality attributes at slaughter such as marbling. Additionally, the net returns in the Schneider et al. (2009) study are underestimations as they do not account for cost of treatments, labour and death loss. Therefore, caution should be taken when comparing studies based on carcass value and net return. The decline in performance associated with increased number of BRD treatments is indicative of the effects of disease severity on performance and inclusion of the dead and reject animals in analysis exacerbated these differences, resulting in much lower overall animal value and net returns. For animals treated three or more times, the net return was $929.48 less compared to animals that were never treated for BRD with the inclusion of dead and rejected animals in analysis, whereas a difference of only $384.97 was found with dead and rejects excluded from analysis.

Lung lesions (moderate or severe) were found in 65.3% of cattle that were never treated for BRD, and in animals with lesions, 73.5% had never been treated, indicating either that visual observation missed a large number of animals suffering from BRD, that these animals had subclinical BRD or that the lesions observed developed prior to feedlot entry (Schneider et al., 2009). This figure is similar to another study that found that out of all animals with lesions present, 69.5% had never been treated for BRD (Thompson, Stone & Schultheiss, 2006). Lesions were present in 71.4% of animals treated once for BRD, 88.9% of animals treated twice and 85% of animals treated three or more times, suggesting that the accuracy of using lung lesions as a diagnosis method increased as the severity of disease increased. In animals that were treated for BRD, 75% had lesions evident at slaughter, which is similar to the 74% found in the Schneider et al. (2009) study. In animals without lesions, 18.4% were treated for BRD, potentially indicating that treatment may have prevented lung damage, or that these animals were false positives for BRD (Schneider et al., 2009).

Most of the carcase data were within normal ranges for grain finished cattle. The mean MSA Index was below the average index of 57.59 for the 2016-17 period, while the mean MSA marble score was within the expected range for cattle on feed administered HGPs (MLA, 2017). There was some (>0) degree of either lung consolidation or pleurisy present at slaughter in 92% of the 870 animals with lung data recorded, however 36% of these displayed minimal lung damage (<5% lung of the lung consolidated or ≤ 1 pleurisy score). The percentage of animals with some extent of lung damage is higher than in other studies (Gardner et al., 1999; Rezac et al., 2014; Wittum et al., 1996), and is probably attributed to the lung scoring method used. Animals with a pleurisy score of 3 exhibited the lowest performance, carcass value and net returns at slaughter. The fact that animals with pleurisy score of 3 had significantly higher BRD treatment costs than animals with a 0, 1 or 2 pleurisy score confirms the relationship between BRD and pleurisy (Nicholas, Ayling & Stipkovits, 2002). This is also supported by the fact that over half (51%) score 3 pleurisy animals were treated for BRD compared to a smaller proportion (21%) of animals with a < 3 pleurisy score being treated. In addition to their lower growth rates, the trimming of contaminated carcases of the pleurisy score 3 animals could have contributed to their lower carcase weights. The fact that there were no differences between animals with a score of 1 or 2 suggests that using a simpler 2 level scoring system of either no pleurisy or severe pleurisy (score 3) would be sufficient. This is a significant finding because assigning animals either a 0 or score 3 for pleurisy at the abattoir is practical and quick to perform (either lungs adhered to the thoracic wall or not). This data could then be used to provide valuable health feedback data for producers on the impacts of BRD at slaughter and the effects of BRD management practices in the backgrounding phase.

Combining pleurisy and lung consolidation to produce the overall lung lesion definition produced similar results to pleurisy alone. Animals categorised as having severe lung lesions at slaughter showed decreased performance, carcass value and net returns, and greater BRD treatment costs compared to normal and moderate animals, however no differences were found between normal and moderate animals. However, the difference between animals with pleurisy score of 3 and lower pleurisy scores was greater than the difference between animals with severe and normal or moderate lung lesions. This could suggest that pleurisy score is a better indicator of BRD episodes than the classification of lung lesions based on both pleurisy and lung consolidation. Moreover, attaining pleurisy scores is a more practical method of assessing lung damage at the abattoirs than lung consolidation percentages. However, it is important to point out that not all BRD cases result in pleurisy because other factors are involved in the evolution of the disease including type of pathogen, and type, timing and effectiveness of veterinary treatments, amongst others. A reduction in performance and carcase weight of animals with severe lung lesions has been described previously (Schneider et al., 2009; Wittum et al., 1996). Wittum et al. (1996) reported a 0.076 kg/day reduction in ADG in animals with lung lesions compared to animals with no lesions, which is a smaller difference than reported in the present study of 0.26 and 0.30 kg/day for severe and pleurisy score 3 animals, respectively. Similar to other studies (Gardner et al., 1999; Schneider et al., 2009), lung score severity also had an effect on carcase weight and marbling, with this decreased performance of animals with severe lung lesions resulting in lower carcase value at slaughter and net returns compared to animals with normal and moderate lungs. While there is substantial evidence supporting the negative effects of lung lesions on animal performance and carcase traits such as ADG, marbling and carcase weight, no peer reviewed literature could be found on the effect of lung lesions on actual monetary animal value or net return figures.

Out of the 870 animals with both treatment records and slaughter data available, 6.7% were clinical cases of BRD, 8.4% were subclinical cases, 7.2% were treated for BRD based on clinical symptoms but displayed no visual signs of the disease (hospital cases), 10.2% had visual and clinical signs but low lung damage at slaughter (termed 'resolved') and 67.5% were deemed healthy. Previous estimations of the incidence of clinical and subclinical BRD in feedlots has varied widely (Schneider et al., 2009; Thompson, Stone & Schultheiss, 2006). Thompson, Stone & Schultheiss (2006) reported that out of 2036 animals, subclinical BRD occurred in 29.7% and clinical BRD in 22.6% of animals. The much lower incidences of clinical and subclinical BRD we reported is due to only including animals with severe lesions for the clinical and subclinical diagnosis (rather than also including the moderate animals). The decision to include only severe animals in the clinical and subclinical diagnosis definition was made based on the fact few differences were found between normal and moderate animals in the lung lesion case definition. The fact there were more subclinical cases of BRD than clinical cases suggests that more than half of the animals infected with BRD went undetected in the present study. This is suggestive of the potential complexities of BRD diagnosis based on only visual and clinical observations and raises the question as to whether further efforts are required to reduce subclinical cases by improving BRD detection methods (Leruste et al., 2012; White & Renter, 2009). It is important to note however, that the experimental design of the present study did not allow for differentiation between animals that developed lesions prior to feedlot entry and those that were exposed to BRD and developed lesions after entering the feedlot. Therefore, these 'subclinical BRD' animals could fall into this category and caution should be exercised with these results. The resolved BRD cases are also difficult to interpret as they could either be false positives for BRD or effectively treated animals that consequently did not develop lung lesions because the antimicrobial treatments were effective. Schneider et al. (2009) reported that 26% of the treated animals in their study did not have lung lesions present at slaughter and attributed this to interventional treatment preventing further lung damage.

Healthy animals and hospital case animals displayed the greatest performance and economic returns compared to animals that were either resolved for BRD, subclinical or clinical BRD cases, with the latter showing the lowest performance of all groups. The reduced performance of the clinical animals when compared to the resolved or subclinical animals suggest that the clinical cases did not recover from BRD and this is reflected in the high treatment costs of these animals. No differences in performance or animal value were found between animals with resolved and subclinical BRD. This could be due to several explanations. Either the resolved animals were false positives for BRD, subclinical cases developed and resolved the BRD infection prior to feedlot entry but evidence of lung damage was still apparent at slaughter, or that the treatment of resolved cases was largely ineffectual when compared to animals with subclinical BRD, or a combination of these. However, the fact that the resolved cases performed worse than the healthy animals suggests that these animals were not false positives. Clinical cases in the present study had 0.16 kg lower ADG than subclinical cases, although this difference was not significant. The lower ADG in clinical versus subclinical animals is consistent with a previous study, where ADG decreased by 0.13 kg in clinical versus subclinical animals (Thompson, Stone & Schultheiss, 2006). The reductions in performance of the clinical and subclinical animals is most likely attributed to reduced feed intake and the accelerated protein and energy metabolism associated with the febrile response that is typical of BRD (Sowell et al., 1999). Clinical cases produced carcases that were 24 kg lighter than healthy animals, while subclinical animals produced carcases that were 16 kg lighter. Marbling was also significantly less in clinical and subclinical animals compared to healthy animals, which has been seen previously (Schneider et al., 2009). The reduction in performance and carcase weight and quality attributes associated with clinical and subclinical BRD contributed to these animals having lower value at slaughter and is indicative of the substantial losses associated with both clinical and subclinical disease.

Trial 2

Animals in trial 2 experienced a 4-fold lower mortality and BRD incidence rate compared to Trial 1 likely due to the former being performed at a season typically of lower incidence (winter) compared trial 1 (late summer). Average DoF, weight, and direct cost to death of mortalities were similar in both trials however Trial 1 had greater BRD treatment cost of dead animals due to the different veterinary treatment protocols used in both trials which were more expensive in trial 1. Trial 1 also experienced higher proportion of clinical BRD (6.7 vs 1.6%) and resolved BRD (10.2 vs 6.7%), and lower of subclinical BRD (8.4 vs 12.4%) compared to trial 2 despite the fact both trials used the same definitions for these groupings.

Trial 2 reported similar trends to Trial 1 on performance, carcass traits and economic outcomes with increasing number of BRD treatments however the extent of the impact varied. For example, similar reductions on ADG and carcass weight were observed in trial 1 (0.69 kg/d and 40 kg/carcass) and trial 2 (0.57 kg/d and 37 kg/carcass). However, net return decreased from 183 to -202 $/hd in trial 1, and from 299 to 15 $/hd in trial 2 between animals with 0 and 3+ BRD treatments. In addition, the clear decreasing trend in carcass quality attributes observed in trial 1 was not observed in trial 2 such as EMA, and MSA index and marbling independently of whether induction weight was used as covariate or not (data not shown). These differences are due to various factors including cost structure of cattle and grain, veterinary products, and price received according to the grid prices at a particular time of the year. The price of cattle, transport, feed and induction processing costs were similar in both trials with the main difference of costs being assumed constant in trial 2 and measured in on each animal for trial 1. Therefore, estimations of net return in trial 1 are more accurate compared to trial 2. Economic losses for each animal dead and hospital costs were also similar amongst trials and it is estimated that under the conditions of the present trial every dead animal would need to be covered with the profit of 6 to 8 healthy animals. However, it is important to note that these values largely depend on the market conditions of inputs and beef prices.

In contrast to the similar results between trials for the number of BRD treatments, pleurisy scores and lung lesions at slaughter seemed to be good indicators of BRD and predictors of the economic impact of BRD in feedlot cattle of trial 1, particularly for animals with pleurisy score of 3. However, lesions at slaughter were not a good indicator of BRD for animals in trial 2 where subtle or no effects on ADG, carcass weight and net returns were observed. The reasons for such differences amongst trials are unknown considering that the same people scored animals in both trials and similar levels or incidences of lung lesions were observed between trials. The lower incidence of BRD in Trial 2 could have reduced the robustness of the results in addition to potential differences between trials in the type of pathogens involved, source of the animals, and pre-vaccination programs before arrival to the feedlot all of which factors were not assessed in the present study. The lack of effects of lung lesions at slaughter were reflected on the results reported on the effects of clinical and subclinical BRD on animal performance and economic outcomes. For example, the lowest performance and returns were observed for clinical and resolved BRD cases which consisted of animals treated for BRD at the feedlot. However, subclinical BRD cases which consisted of animals not treated for BRD at the feedlot but showed lung lesions at slaughter performed similarly to healthy animals.

6 Conclusions/recommendations

The results of this study indicate that BRD morbidity and mortality have significant impacts on performance and carcase traits and that substantial economic losses occur as a result of decreased performance, and carcase quality, and increased BRD treatment costs. The study demonstrated that animals suffering from clinical BRD, chronic BRD (3+ treatments) and those with severe pleurisy and lung lesion scores had significantly lower performance and economic returns when compared with animals that suffered less severe BRD or no BRD. To date there are also no published data on the incidences of subclinical BRD in Australian feedlots and this study provided valuable insight into the rate of subclinical BRD and its effects on animal performance and economic return. Results presented herein allow quantifying the performance and costs of BRD related to the treatment costs associated with BRD and the reduced animal performance and carcase value.

Data presented in this report can be used to assess the economic impact of BRD in feedlot cattle and this information could be useful for business management decisions such as health-driven marketing strategies for feeder cattle (e.g. preconditioning and vaccinations, and beef quality) and investment to reduce the impact of the disease on feedlot profitability. To further validate these results and ensure their application to lot feeders across the industry, future work should include analysis of records from multiple feedlots throughout Australia in order to gain a more comprehensive picture of the costs of BRD to the whole Australian feedlot industry under different health management strategies. The project's findings will allow producers tangible quantification of the extent to which BRD impacts performance and economic returns.

7 Key messages

- ✓ BRD is the largest health issue faced by the feedlot sector and the severity of the disease has significant implications on animal performance, value and economic returns
- ✓ The incidence of BRD was 16.6% in late summer (Trial 1) and 9.6% (Trial 2) in autumn and winter
- ✓ BRD mortalities were approximately 80% of all mortalities and between 2% (Trial 1) and 0.3% (Trial 2) of all animals inducted
- ✓ The majority (~70%) of animals are treated once for BRD
- ✓ A proportion of visually healthy animals show high rectal temperature or lung auscultation
- ✓ Animals treated for BRD 3+ showed carcass 40 kg lighter in both trials and returned $384.97 less in Trial 1 and $284 in Trial 2 compared to healthy animals on a dead out basis.
- ✓ Severe lung lesions were observed in 16% (trial 1) and 6% (trial 2) of the animals slaughtered
- ✓ Pleurisy score of 3 (lungs adhered to thoracic wall) was observed in 10.7% and 5.6% of animals for trial 1 and 2, respectively
- ✓ In trial 1, animals with severe lung lesions or pleurisy score of 3 yielded carcases that were 14.31 kg and 18.79 kg less, respectively, compared to animals with normal lungs at slaughter. Net returns were also decreased by $91 per head for these animals
- ✓ In trial 1, animals with pleurisy score of 3 returned $137 less than the other score on average
- ✓ In trial 2, lung lesions and pleurisy score had no significant effects on carcass trials or net returns
- ✓ Subclinical BRD incidence was between 8.4 and 12.4% in Trial 1 and 2, respectively
- ✓ Animals with clinical BRD (treated for BRD and with severe lung lesions at slaughter) displayed the lowest performance followed by subclinical BRD (not treated for BRD but with severe lung lesions), 'resolved' BRD (treated for BRD but no severe lung lesions) and healthy animals displaying the greatest performance and net returns.
- ✓ There were minimal differences in performance between clinical and subclinical animals, however clinical animals had lower value at slaughter and net returns were $127 per head lower than subclinical BRD cases

8 Bibliography

Aus-Meat 2005, 'Handbook of Australian Meat', Aus-Meat, Brisbane, Australia.

Baptista, AL, Rezende, AL, Fonseca, PD, Massi, RP, Nogueira, GM, Magalhaes, LQ, Headley, SA, Menezes, GL, Alfieri, AA & Saut, JPE 2017, 'Bovine respiratory disease complex associated mortality and morbidity rates in feedlot cattle from southeastern Brazil', *JOURNAL OF INFECTION IN DEVELOPING COUNTRIES,* vol. 11, no. 10, pp. 791-799.

Brooks, KR, Raper, KC, Ward, CE, Holland, BP, Krehbiel, CR & Step, DL 2011, 'Economic effects of bovine respiratory disease on feedlot cattle during backgrounding and finishing phases 1: 1', *Professional Animal Scientist,* vol. 27, no. 3, pp. 195.

Cernicchiaro, N, White, BJ, Renter, DG & Babcock, AH 2013, 'Evaluation of economic and performance outcomes associated with the number of treatments after an initial diagnosis of bovine respiratory disease in commercial feeder cattle', *American Journal of Veterinary Research,* vol. 74, no. 2, pp. 300-309.

Cusack, PMV 2004, 'Effect of mass medication with antibiotics at feedlot entry on the health and growth rate of cattle destined for the Australian domestic market', *Australian Veterinary Journal,* vol. 82, no. 3, pp. 154-156.

Cusack, PMV, Mcmeniman, N & Lean, IJ 2003, 'The medicine and epidemiology of bovine respiratory disease in feedlots', *Australian Veterinary Journal,* vol. 81, no. 8, pp. 480-487.

Edwards, AJ 1996, 'Respiratory diseases of feedlot cattle in the central USA', *Bovine Practioner,* vol. 30, pp. 5-7.

Faber, R, Hartwig, N, Busby, WD & Bredahld, R 1999, 'The costs and predictive factors of Bovine Respiratory Disease in standardized steer tests', *1999 Beef Research Report*, Iowa State University, Iowa.

Gagea, MI, Bateman, KG, Van Dreumel, T, Mcewen, BJ, Carman, S, Archambault, M, Shanahan, RA & Caswell, JL 2006, 'Diseases and pathogens associated with mortality in Ontario beef feedlots', *Journal of Veterinary Diagnostic Investigation,* vol. 18, no. 1, pp. 18-28.

Galyean, ML, Gunter, SA & Malcolm-Callis, KF 1995, 'Effects of arrival medicationwith tilmicosin phosphate on health and performance of newly received beefcattle', *Journal of animal science,* vol. 73, pp. 1219-1226.

Gardner, BA, Dolezal, HG, Bryant, LK, Owens, FN & Smith, RA 1999, 'Health of finishing steers: effects on performance, carcass traits, and meat tenderness', *Journal of Animal Science,* vol. 77, no. 12, pp. 3168.

Hay, KE, Morton, JM, Mahony, TJ, Clements, ACA & Barnes, TS 2016, 'Associations between animal characteristic and environmental risk factors and bovine respiratory disease in Australian feedlot cattle', *Preventive Veterinary Medicine,* vol. 125, pp. 66-74.

Leruste, H, Brscic, M, Ruis-Heutinck, LFM, Visser, EK, Wolthuis-Fillerup, M, Bokkers, EaM, Stockhofe-Zurwieden, N, Cozzi, G, Gottardo, F, Lensink, BJ & Reenen, VCG 2012, 'The relationship between clinical signs of respiratory system disorders and lung lesions at slaughter in veal calves', *Preventive Veterinary Medicine,* vol. 105, no. 1-2, pp. 93-100.

Macartney, JE, Bateman, KG & Ribble, CS 2003, 'Health performance of feeder calves sold at conventional auctions versus special auctions of vaccinated or conditioned calves in Ontario', *Journal of the American Veterinary Medical Association,* vol. 223, no. 5, pp. 677-683.

Martin, SW, Bateman, KG, Shewen, PE, Rosendal, S & Bohac, JE 1989, 'The frequency, distribution and effects of antibodies, to seven putative respiratory pathogens, on respiratory disease and weight gain in feedlot calves in Ontario', *Canadian journal of veterinary research = Revue canadienne de recherche veterinaire,* vol. 53, no. 3, pp. 355-362.

Mcguirk, SM 2008, 'Disease Management of Dairy Calves and Heifers', *Veterinary Clinics of North America: Food Animal Practice,* vol. 24, no. 1, pp. 139-153.

Mla 2017, 'Meat Standards Australia Annual Outcomes Report 2016-2017', Meat & Livestock Australia.

Nicholas, RaJ, Ayling, RD & Stipkovits, LP 2002, 'An experimental vaccine for calf pneumonia caused by Mycoplasma bovis: clinical, cultural, serological and pathological findings', *Vaccine,* vol. 20, no. 29, pp. 3569-3575.

Polkinghorne, R, Watson, R, Thompson, JM & Pethick, DW 2008, 'Current usage and future development of the Meat Standards Australia (MSA) grading system', *Australian Journal of Experimental Agriculture,* vol. 48, no. 11, pp. 1459-1464.

Rezac, DJ, Thomson, DU, Bartle, SJ, Osterstock, JB, Prouty, FL & Reinhardt, CD 2014, 'Prevalence, severity, and relationships of lung lesions, liver abnormalities, and rumen health scores measured at slaughter in beef cattle', *JOURNAL OF ANIMAL SCIENCE,* vol. 92, no. 6, pp. 2595-2602.

Sackkett, D, Holmes, P, Abbott, K, Jephcott, S & Barber, M 2006, 'Assessing the economic cost of endemic disease on the profitability of Australian beef cattle and sheep producers', *AHW.087*, Meat and Livestock Australia, Sydney, NSW, Australia.

Sanderson, MW, Dargatz, DA & Wagner, BA 2008, 'Risk factors for initial respiratory disease in United States' feedlots based on producer-collected daily morbidity counts', *Canadian Veterinary Journal,* vol. 49, no. 4, pp. 373-378.

Schaefer, AL, Cook, NJ, Church, JS, Basarab, J, Perry, B, Miller, C & Tong, AKW 2007, 'The use of infrared thermography as an early indicator of bovine respiratory disease complex in calves', *Research in Veterinary Science,* vol. 83, no. 3, pp. 376-384.

Schneider, MJ, Tait, RG, Jr., Busby, WD & Reecy, JM 2009, 'An evaluation of bovine respiratory disease complex in feedlot cattle: Impact on performance and carcass traits using treatment records and lung lesion scores', *Journal of Animal Science,* vol. 87, no. 5, pp. 1821-1827.

Schumann, FJ, Janzen, ED & Mckinnon, JJ 1991, 'Prophylactic medication of feedlot calves with tilmicosin', *Veterinary Record,* vol. 128, pp. 278-280.

Snowder, GD, Van Vleck, LD, Cundiff, LV & Bennett, GL 2006, 'Bovine respiratory disease in feedlot cattle: Environmental, genetic, and economic factors', *Journal of Animal Science,* vol. 84, no. 8, pp. 1999.

Sowell, BF, Branine, ME, Bowman, JG, Hubbert, ME, Sherwood, HE & Quimby, W 1999, 'Feeding and watering behavior of healthy and morbid steers in a commercial feedlot', *Journal of Animal Science,* vol. 77, no. 5, pp. 1105-1112.

Sullivan, KF 2017, 'Pleurisy Scoring System', Bell Veterinary Services.

Sullivan, KF & O'brien, C 2016, *Practical bovine autopsy technique: a practical guide for autopsy and sample collection in cattle*, Austasia Animal Products and Bell Veterinary Services, Forbes, NSW.

Theurer, ME, Anderson, DE, White, BJ, Miesner, MD, Mosier, DA, Coetzee, JF, Lakritz, J & Amrine, DE 2013, 'Effect of Mannheimia haemolytica pneumonia on behavior and physiologic responses of calves during high ambient environmental temperatures', *Journal of animal science,* vol. 91, no. 8, pp. 3917-3929.

Thompson, PN, Stone, A & Schultheiss, WA 2006, 'Use of treatment records and lung lesion scoring to estimate the effect of respiratory disease on growth during early and late finishing periods in South African feedlot cattle', *Journal of Animal Science,* vol. 84, no. 2, pp. 488.

Van Der Mei, J & Van Den Ingh, TS 1987, 'Lung and pleural lesions of veal calves at slaughter and their relationship with carcass weight', *The Veterinary quarterly,* vol. 9, no. 3, pp. 203.

Vogel, GJ & Parrott, C 1994, 'Mortality survey in feedyards - The incidence of death from digetstive, respiratory, and other causes in feedyards on the Great-Plains', *COMPENDIUM ON CONTINUING EDUCATION FOR THE PRACTICING VETERINARIAN,* vol. 16, no. 2, pp. 227-227.

White, BJ & Renter, DG 2009, 'Bayesian estimation of the performance of using clinical observations and harvest lung lesions for diagnosing bovine respiratory disease in post-weaned beef calves', *Journal of Veterinary Diagnostic Investigation,* vol. 21, no. 4, pp. 446-453.

Wittum, TE, Woollen, NE, Perino, LJ & Littledike, ET 1996, 'Relationships among treatment for respiratory tract disease, pulmonary lesions evident at slaughter, and rate of weight gain in feedlot cattle', *Journal of the American Veterinary Medical Association,* vol. 209, no. 4, pp. 814-818.